CHALMERS
UNIVERSITY OF TECHNOLOGY

DESIGN GUIDELINES: STUDY SOLUTIONS FOR CHILDREN

Ergonomic aspects of study solutions for 5-14-year-old children

Bachelor's thesis within Industrial Design Engineering

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Gothenburg
Ann Forsman Sjöberg

ABSTRACT

Studying is an essential activity throughout the majority of children's life. The studying does not only involve the working environment at schools but also the child's workplace at home. This degree project is made in collaboration with The Department of Children's IKEA and aims to elicit user-related aspects to consider in the design of study solutions in home context for 5-14-year-old children.

The data collection involved a literature study and user research. The literature study included physical, psychological and emotional aspects, such as children's cognitive and physical development, recommendations regarding biomechanics, view- and lighting conditions, the use of anthropometric measurements when developing products for children and equations that can be used to ensure matching sizes between a desk- and chair-solution were considered. The user study consisted of observations and workshops with students and interviews with teachers and families in the Gothenburg region. The result is presented as design guidelines and recommendations that have been visualized by a concept including a desk and chair. The concept was evaluated by interviews, and lo-fi prototypes with three children and one educator specialized in children with special needs.

The design guidelines are represented in four categories; *Facilitate everyday life*, *Strive for a healthy workplace*, *Growing with the child* and, *The child in charge*. In this study it is concluded that encouragement of positive postural behaviors, flexibility in positions and posture, proper lighting and storage, and solutions for cables and digital devices are of importance. Educing positive emotions and the creation of a solution that match each stage of the child's development and remain attractive throughout the childhood were other aspects covered in the formulated design guidelines. The design guidelines can be used as a starting point for further development of study solutions for children within the target group.

Keywords: Product development, Children, Studying, Design Guidelines, Ergonomic

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GLOSSARY

Design recommendations (DR)

A summary of the main conclusions of the design implications in each section from the theory and user-insight chapter. The design recommendations create the foundation of the design guidelines.

Design guidelines (DG)

Consisted in this project of several design recommendations clustered together and envisioned under one of the main themes; *Facilitate everyday life*, *Strive for a healthy workplace*, *Growing with the child* or *The child in charge*. The design recommendations are further described and abstracted into useful design implications in the design guidelines.

Study Solution

The term was used in this project to define the subject explored in the research question. Study solution refers to a set of furniture used when children are studying at home and includes a desk/worktop-solution, chair/sitting-solution, and the lighting.

ABBREVITATIONS

UCD	User-centered design
D4CR	Design for children's right
LCA	Life cycle analysis
ESW	Eco-Design strategy Wheel
ZPD	Zone of proximal development
EF	Executive functions

1. INTRODUCTION

The introduction gives an understanding of the background, purpose, and aim of this project. The research questions used are presented in this chapter, as well as limitations for the project and the structure of the report.

1.1 Background

Studying is commonly regarded as a significant activity for enhancing children's development and future. Several authors (Gouvali & Boudolos, 2006; Panagiotopoulou, Christoulas, Papanckolaou, Mandroukas, 2004; Parcells, Stommel, Hubbard, 1999) state that bad posture habits due to poorly designed school furniture may impact the child's growth process. In the meantime, never have children been more engaged in sedentary behaviors than today (WHO, 2016). Ergonomic study solutions developed for children, flexible and suitable for small space living, are therefore essential.

IKEA is committed to develop products that support children's development and growth most healthily while studying. The child perspective is at the center in all stages of the product development process. Children are involved in several ways, for example by home visits, IKEA Kid's panel and IKEA Kid's lab where their needs, thoughts, and wishes are enhanced.

The department Children's IKEA is expanding the range of study solutions for children and is, therefore, composing a strategy describing their vision and developing guidelines. To be able to understand what these study solutions could look like, IKEA is starting a research project involving experts in the area of study solutions, from pre-schools, schools, and research organizations. This project contributes to IKEA's research project by investigating different needs and ergonomic requirements for study solutions for children between 5-14 years of age.

1.2 Purpose, aim and research question

The purpose of the project is to investigate the ergonomic and emotional aspects of children's development and user needs in order to create guidelines for the development of study solutions for children at home.

The project aims to create ergonomic guidelines for children and a conceptual solution reflecting these guidelines.

The research question is:

What user-related aspects should be considered in the design of study solutions for children between 5-14 years of age?

1.3 Delimitations

The user-studies was executed in schools and homes in the Gothenburg region due to temporal and locational limitations. This project does not consider cultural and national differences regarding physical, psychological and emotional varieties, neither sociocultural and gender disparities.

Furthermore, the theory chapter included both theories and published peer-reviewed scientific research; no discrimination has been made between these different types of sources.

Children with special needs have been taken into consideration, to create an inclusive solution, but without a more profound analysis of different diagnoses.

The purpose of the final concept is to visualize one potential solution based on the generated guidelines. The concept should be seen as a first model that need further development and evaluation. The exact dimensions, material and technical specifications are not fully developed within this project.

1.4 Structure of the report

After the introduction, chapter two presents the methods used in this project followed by a benchmark analysis in chapter three. The theory chapter, chapter four, includes theories, that within its field can be seen as fundamental, as well as published peer-reviewed research. The chapter is divided into three parts; a general section regarding product development and its implications followed by theories on children's cognitive development and research concerning the physical development of children and ergonomic requirements on a study solution. The main results from the user study are presented in chapter five, user insights, with the same categorizing as the theory chapter. Each section in the theory- and user insight chapter are summarized by one or more design recommendation that have been clustered together into four general guidelines in chapter six. The idea generation, selection, and development of the final concept and its evaluation are presented in chapter seven. Chapter seven follows by a discussion of the fulfillment of the aim, considerations made for the guidelines, concept and process and methods used and a reflection about sustainable aspects. The main conclusions drawn from the project are presented at the end of the report, in chapter nine.

2. METHOD

The project is divided into four phases; pre-study, user-study, data analysis, idea and concept development, and evaluation. Each phase and the methods used are described in the sections below.

2.1 The process

An overview of the process of the project can be seen in figure 2.1 The process is divided into four parts; prestudy, user-study, idea and concept development and, evaluation. The methods used are presented in the upper part of the figure and the output/result at the bottom.

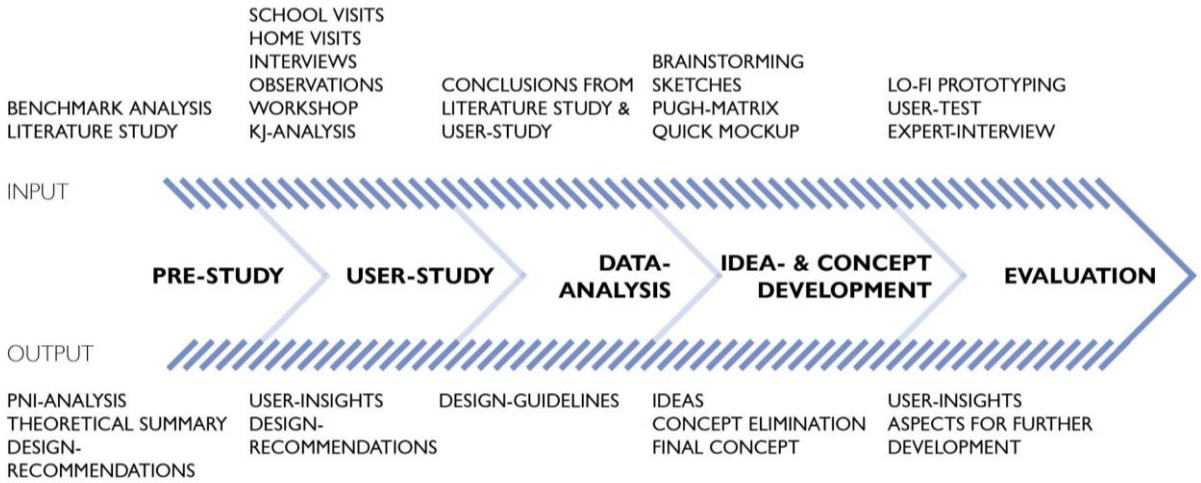


Figure 2.1 Overview of the process used in this degree project

2.2 Pre-study

The pre-study consisted of a data collection including a literature study and a benchmark analysis. The aim with the pre-study was to get an understanding of the current market and relevant insights to consider when designing a workplace for children.

2.2.1 Benchmark analysis

Different ergonomic study solutions for children were investigated to find common and competing features. The focus of the benchmark was on desks and chairs from different continents as an attempt to get a global understanding of the market. Some of the leading companies on ergonomic furniture for children were included. The most interesting desk and chair solutions were specified and evaluated by a PNI-analysis (Österlin, 2010). A PNI-analysis describe the intuitive positive, negative and interesting aspects of the solution to achieve an understanding of selling points and user request.

2.2.2 Literature study

The literature study involved both theories and published peer-reviewed scientific research without discernment. The physical aspects consist of a brief review of children's physical development, biomechanical aspects such as reaching zones and visual fields, recommendations regarding lighting, anthropometric measurements and definitions for matching sizes of desks- and chairs for children. When available,

sources considering children in the relevant age group have been used, but some recommendations are based on adults with the assumption that they are generalizable on children. For the psychological and emotional aspects fundamental learning and development theories were used, as they are more general than the physical factors because less research could be found applying these theories into product development practice. The literature study aimed to identify relevant differences between children and adults and the shifting needs throughout the age span included in the project.

2.3 User-studies

The user studies include school visits and home visits with a combination of observations and interviews. A creative workshop with third-grade students was executed to get a deeper insight into children's visions and thoughts of their study space at home. Each step of the user studies is described below.

2.3.1 School visits

A request for executing observation and interviews was sent to different schools in the Gothenburg region. Two different schools were selected, one Montessori school and one school based on the Monroe model in order to get different pedagogical perspectives on children's learning environment. Both schools have classes with students from preschool to ninth grade.

To include a wide age span, the observation was conducted during a lesson with a group of four- and five-grade students and one lesson with seventh- and ninth-grade students. To the students, the observation study was communicated at the beginning of the lecture. The choice of seating, place, and task was documented and summarized in an observation guide (Appendix 1-3), by notes and quick sketches of the classrooms set up. Photos also documented the environment. During the observation six of the students were asked questions about their choice of study-place and their preferences. Since the observation was conducted during a lecture, only the students who could be approached without disturbing were chosen. The questions asked the four- and five grade students were conducted spontaneously as a short unstructured interview to get a deeper understanding of their choice of study-place as well as thoughts about their study environment. Their answers were noted while interviewing them. The seventh- and nine grade students were asked to fill in a short survey (Appendix 4) with a following unstructured interview in the same manner as for the younger students.

Semi-structured interviews with teachers followed both observations. At the Montessori school four teachers were interviewed, whereas two of them, both from first to ninth grade, were interviewed together. The other two were interviewed separately, one teacher in first to third grade, the other in fourth to sixth grade. One

teacher for children in seventh to ninth grade was interviewed at the Monroe school. The interviews were conducted in a semi-structured manner with predetermined questions (Appendix 6). A semi-structured interview allows additional questions and new directions, which makes the conversation more dynamic and open for unforeseen perspectives (Martin & Hanington, 2012). Five interviews were held in total, with teachers from primary school up to secondary school. The interviews were recorded and transcribed.

2.3.2 Home visits

Home visits were conducted within the Gothenburg region in order to see how people live and experience their everyday environment. The families were recruited by posting information in groups on Facebook and other social media. The post (Appendix 7) included information about the project and a short description of the execution of the home visits and contact information. A non-random selection of the families having children in appropriate age was used. Five families with children between 6 months to 14 years old were visited. The observation and interview focused on the children in the target group, in the age between 5 to 14 years old.

Each home visit took about one hour and included observations at the places the children used for studying and questions about both the current study places and thoughts and wishes for future study solutions. The observation guide and interview guide are presented in Appendix 8. The children decided if they wanted to join the interview, listen or contribute. In two visits both parents were presented together with the child, in one interview only the children were included and in the other two the main focus was on the children and the parents added their perspective when needed. During the interview, the children were able to show how they use their furniture and measurements of the chair and table were taken, as well as photos of the current setting.

2.3.3 Workshop

A creative workshop was held to find out the children's thoughts and wishes for a study solution. A third-grade class was contacted, and the workshop took place in their classroom with two smaller groups of ten children at each session.

Each workshop lasted one hour and twenty minutes, included two parts and started with an introduction, including a presentation of the project and aim of the workshop. The first part was a questionnaire (Appendix 4) with questions about the children's preferred body position, desirable emotions, and conditioning in the environment while studying and if they preferred studying alone, with a parent, a friend, sibling or someone else. The last questions linked further to the interactive part of the workshop, the children were asked which color and material they preferred for a piece of furniture they would use while studying. The color was free of choice and sixteen different materials could be chosen such as wood, marble, concrete, bamboo fiber, plastic,

textile, etc. Before the second part a short presentation was held, explaining commonly used tools when working with visualizing ideas and directions in product development. Two different kinds of mood boards and different kind of sketches were shown in order to give the children a mental model of how their work could be presented. The children were then asked to either sketch or make their own mood board by images and pictures collected from different magazines. During their work the children were asked questions about their thoughts to get a deeper understanding of what they found attractive in a study place or not. All the material from the workshop was collected afterwards.

2.4 Data analysis

The results from the user-study were categorized and analyzed with a KJ-analysis which build the starting point for the creation of the guidelines. A KJ-analysis is a useful method for large amounts of data since it gives an overall picture of the collected data and enables the results to be arranged and analyzed in different categories (Martin & Hanington, 2012; Magnusson, Rassmus-Gröhn, Tollmar, & Deaner, 2009).

The first part of the KJ-analysis resulted in thirteen groups: homework, computers and other digital aids, lighting, sound- and noise, body positions, the study solution, desk, chair, inclusive design, emotions, concentration and distractions, age-differences and surrounding environment, which further were reduced into nine categories; defining the context, general physical aspects, desk, chair, lighting, surrounding environment, age-differences, improve and maintain attention and emotional aspects.

Each category, both in the theory chapter (marked with a T next to the number) and the user-insight chapter (marked with a U next to the number), was summarized with one or more design recommendations and coded with a falling number. All recommendations were then clustered into the four groups that constituted the formulated design guidelines; Facilitate everyday life, Strive for a healthy workplace, Growing with the child and, The child in charge. At the end of each guideline are the connected recommendations specified to enable the reader to track the result.

2.5 Idea generation and concept development

Brainstorming is a commonly used method for idea generation. Product development and idea generation is an iterative process, and different ideas are integrated into the final concept to achieve a result as good as possible (Magnusson, et al., 2009).

The first step of the idea generation was a brainstorming activity with participants with different competencies, a teacher-student, a design engineer and a social worker and medical student. The ideas were generated during a brainstorming session with

different topics under a time limit. The participants had their own paper and pen. Each session lasted for about three minutes and afterward all ideas were presented to each other to inspire and share ideas. The topics of the idea generation sessions focused on different solutions that enable studying while lying, sitting on the floor, sitting on a chair or similar, standing and at last a solution that enables all mentioned above. Worktop, chair, and light were investigated during the brainstorming. At the end of the idea generation activity, some of the mood boards and sketches made by the third-grade students during the earlier workshop (Appendix 9) were used as an inspiration. All sketches were collected, and the most interesting concepts were further developed by general design methodology through iteratively exploring, refining and combining ideas.

The best ideas were evaluated with a modified Pugh-matrix (Johannesson, Persson & Pettersson, 2013) with criterion derived from the guidelines, by selecting the aspects that could be evaluated at an early stage of the development. Each criterion was defined as mandatory or desirable, depending on its ergonomic importance. The mandatory criterion was, for the chair; adjustable in sizes, lumbar and spine support and compatible with a desk, and for the desk; allowing standing and sitting on a chair, adjustable in height and allow enough workspace. No reference solution was used, each criterion was instead evaluated whether it passed the criteria or not. The ideas that passed all mandatory criteria were then compared to each other. The solution with most criteria meet was used for further development.

To set approximate measurements for the concept DINED anthropometric database (2018) was used. The database includes data from fifteen studies, three of the studies including children within the age range, two Dutch studies and one study made on Chilean children. The study with the most measurement was the Dutch study (1993). The study included children from age 2 to 12, for this project was age 5 and 12 used, to get the lowest and highest anthropometrical values. The Dutch growth study (2002) included all ages in the target group, but with limited data, stature was the only measurement that could be used for the project. The Chilean study (2012) covered almost every age, from 6-years-old to 18, for the study was the upper age set to fourteen. The Chilean study included more measurements than the growth study, but without full coverage. As an attempt to include as many potential users as possible, the lowest percentile was set to 0.01 (for 5- and 6-year-olds) and the highest percentile to 99.9 (for 12- and 14-year-olds). A table of the used measurements is presented in Appendix 10.

2.6 Evaluation of final concept

The final concept was evaluated and refined by end-users, three non-randomly selected children within the age range, and an educator specialized on children with different needs working on a school in Gothenburg.

Evaluation through lo-fidelity prototyping, by sketches, storyboards or sketch-models, is a conventional method in the early stages of product development to verify result and features (Magnusson, et.al, 2009). An early evaluation supports an iterative process with changes to a lower cost (Lindstedt & Burenius, 2006; Martin & Hanington, 2012). Since the project involve an early-stage concept lo-fi prototyping were used as a method for user evaluation. The user-test with the children consisted of four parts. At first, the size of the worktop was evaluated to find out whether it was big enough to offer space for all essential equipment yet small enough to be easily handled when making adjustments in angle and height. The children were asked to grab the worktop and make one adjustment on its position, by moving it up and downward. In the second part, questions were asked about the child's views regarding the size of the desk and if it is sufficient for homework.

The third part included evaluation of the vision screen on the chair. A lo-fi, sketch model made of cardboard was fixated in a proper height to the child's chair, and the child was asked to execute a task. After the execution questions were asked about the child's experience of the screen and whether it reduced the stimulus around or not. At last sketches of the concept were showed and evaluated by defining the strengths and weaknesses of both the chair and desk as well as the two pieces combined. The first evaluation was conducted with two 11-years-old children together, and one 9-year-old child made the second evaluation.

The interview with the educator was conducted in a semi-structured manner starting with an open question about how the physical environment can be adjusted to improve learning for children with difficulties maintain attention, sitting still, reading- and writing and, understand and construe tasks. The structure of the interview and the questions are presented in Appendix 12 and 13. The starting question created a framework for the evaluation and gave topics that could be picked up during the conversation. A SWOT-analysis (Lindstedt & Burenius, 2006) was used as a tool to get both positive and negative aspects of the concept. The chair and desk were evaluated separately by showing simple sketches and describing the thoughts and features. In order to create an inclusive solution the universal design principles were used as a tool for evaluation with related questions to each principle. Each question was introduced by a quick summary describing the principle and examples of its guidelines.

2.7 Ethical considerations

Several ethical aspects have been considered since the project involves children and include commercial products. Children can experience difficulties in understanding the purpose of their participation and the aim of the project (Johnsson & Karlsson, 2013). Magnusson et.al. (2009) lists five ethical aspects to consider when involving users in the design process; treating participants with respect, make information and activities

accessible, ensure a basic level of success, testing activities and use an informed consent. Johnsson and Karlsson (2013) emphasize the need of an ethical symmetry between the executor and the participants. The symmetry can be achieved by showing humility and genuine willingness to understand the child's thoughts, experiences, and ideas. Therefore, the participants have been informed that their participation is optional and that they can interrupt or call off the interview at any time. The children have been able to choose whether they want to answer the questions or if a parent should be interviewed or both. The layup of each session involving users have been discussed with at least one other person to get feedback and adjust the fit of the target group and assure that all ethical aspects have been considered. The activities have all been executed in the user's own context, school environment or at their home, which increase the ethical symmetry (Johnsson & Karlsson, 2013).

The participants have received information about the aim of the study and a description about how the visit is going to be executed before they consent to the meeting, they were also given the same information before the interview and the observation started. All voice recordings have been done with the participants and their parent's approval. The data is anonymized and without traceability to the participants. Photos from the workshop and observations do not show the children’s faces or other identifying features to ensure anonymity and are taken with approval from the persons involved. The result reflects general conclusions, and any quotes are anonymous.

3. BENCHMARK ANALYSIS

The benchmark analysis includes different ergonomic desk- and chair solutions mainly developed for children. The designs presented below highlight different, common or particularly interesting solutions. Each design is presented by pictures, a short description, the size of the furniture and the approximate price. At last, initial positive, negative and interesting aspects based on selling points and the products features are highlighted.

ANDERSon Desk

Figure 3.1–3.2 ANDERSon Desk (Haba, n.d)

The desk ANDERSon is produced by Haba (n.d). The height of the desk is between 58 to 72 cm, and the worktop can be adjusted in five different positions. There are several accessories available to customize the desk such as a desk drawer, a hanging shelf, and a three-drawer chest on wheels. The desk is made of solid beech treated with natural oils (Little Dreamers, 2018).

Size: 132x65x105.3 cm [WxDxH]

Price: About €560

Positive

➢ Adjustable height, so the desk fits different ages and sizes

➢ Adjustable positions enable different work positions

➢ Easy and perceptible adjustment of worktop position

Negative

➢ The lower height is equal a tilted worktop

➢ The pipes on the top are only used for accessories

➢ Only one execution

Interesting

➢ Wooden spars ensure the position of the paper

➢ Scratch-resistant surface

iStudy C120E Desk

Figure 3.3-3.4 iStudy desk C120E (iStudy, 2018)

The desk iStudy C120E is produced by the Chinese company Zhangzhou Istudy Kids Commodity Co., Ltd (2018) which is specialized in ergonomic study furniture for children. This desk is developed for children between 6 to 18 years old. It comes in four colors; blue, pink, grey and wood. The tabletop has an L-shape with a fixed part to the left and a flexible section to the right. The flexible part can tilt 0-70°, in twelve levels regulated by a gas cylinder. The height can be adjusted from 550-750 mm. The surface of the tabletop is easy to clean and resistant to scratches.

Size: 120x67x55-75 cm [WxDxH]

Price: About €520

Positive

➢ A wide range of heights

➢ 12 levels of tilt degrees make the desk multifunctional

➢ Easy to adjust, children can do it by themselves

Negative

➢ The shelf takes a lot of space - not suitable for small spaces

➢ A cluttered impression

Interesting

➢ Easy adjustments of height and tilt of the desktop

➢ A lot of visual explanation to the user with a scale of height e.g.

The Edge Desk

Figure 3.5-3.7 A kneeling desk (The Edge Desk systemTM, 2018; Kickstarter, 2018)

The Edge Desk systemTM (2018), is the company behind a portable kneeling desk, The Edge Desk, which can be folded or assembled in ten seconds. The kneeling helps the user to maintain a good posture, and the thick padding on the seat and knee rests ensure a comfortable position. The seat can be adjusted in four positions, and the desktop can be adjusted in height, tilt, orientation, and distance from the user. Accessories, such as phone holder, bottle holder, and organizer cups, can be snapped to the edge. When folded, the desk can be tucked away under the bed, in the car or behind the sofa.

Size: No information, 152.4 mm thick when folded. The desktop is 50,8x76,2 cm

Price: About €352

Positive

➢ Different settings make the solution fit a variety of people

➢ A well-thought balance between desktop space and mobility

➢ Different positions at the desktop enable different tasks

Negative

➢ The desk is not developed for children, which means the sizes would probably not fit the target group

➢ May lead to some pressure on the knees and legs when sitting longer

Interesting

➢ The folding mechanism can be useful in small spaces

➢ The use of a kneeling position to create a proper sitting position.

Swoppster by Aeris

Figure 3.8-3.9 Dynamic stool (Aeris, 2018)

Swoppster is described as an active 3D-swivel stool for children. Its design is based on children's need for movement and ergonomic aspects to increase the child's ability to concentrate and do their homework. The height can be adjusted from 32 to 47.5 cm by a lever under the seat. The stool can move aside (15°), around and in a vertical direction which allow the user to keep a good position even when moving. The bottom is constructed with a stable foot ring with castors and fixed feet. The resistance in the movements can be adjusted related to the child's weight. Swoppster can be used by children with a weight between 15 to 50 kg (Aeris, 2018).

Size: 34-48 x 32-47.5 cm [⦰xH]

Price: About €250-300

Positive

➢ Different adjustment to customize the movements and measurements of the product

➢ Enable different position without losing a good posture

➢ Playful design

Negative

➢ Weight limitations of 50 kg

➢ Length limitations of 165 cm

➢ Takes some time to get used to the movement

Interesting

➢ Enable the child to concentrate by allowing movement while studying

➢ Recommended especially for kids with ADHD.

iStudy premium ergonomic chair E06

Figure 3.10-3.11The hugging chair (Kidsstudydesk, 2018)

The “hugging” dual-back system support neck, upper back, lower back, and the waist areas. According to the retailer, Kidsstudydesk (2018), the spine pressure is reduced by 50 % compared to a conventional chair. The seat is constructed with a memory foam cushion, and the seat height can be adjusted from 36 to 54 cm. The castors are equipped with a compression brake activated when the child is seated. The backrest can also be adjusted from 74 to 96 cm measured from the floor.

Seat size: 45x46.5x36-54 cm [WxDxH]
Back size: 40.5x45x74-96 cm [WxDxH]

Price: About €350

Positive	Negative	Interesting
➢ Adjustable seating height and height of the backrest.	➢ A tilted angel on the foot while using the plate as a footrest ➢ A wide seat gives a clumsy impression	➢ Memory foam for comfortable seat ➢ Backrest in two parts, “hugging” the user.

Hokki Stool

Figure 3.12-3.13 Balance pallet (Hokki, 2018)

VS, the company behind the Hokki Stool, says that the design “promotes collaboration, focus and, creativity” (Hokki, 2018). The stool is equipped with a curved, slip resistant, base, which allow controlled movements in all directions that stimulate the musculoskeletal system. The Hokki brand has four fixed sizes and two height-adjustable sizes (adjusted with a gas spring) in nine different colors, from vibrant to more natural ones. The stool is stable but still lightweight so it can be handled with ease. The base is made of scratch-resistant polypropylene with a foam seat shell, all recyclable (Hokki, 2018).

Size: 34,5x30,5-68cm [⦰Xu]

Price: About €85-95 for fixed sizes and €149-154 for adjustable sizes (Wittfitt, 2018)

Positive	Negative	Interesting
➢ Aesthetic and straightforward design that comes in different colors for individual preferences ➢Durable with scratch resistant material that can be cleaned easily	➢ No spinal support and demands an active sitting posture ➢ Limitation in its different sizes, no solution that can be adjusted to fit everyone	➢ Hokki is used both in schools, offices, and homes thanks to its flexible size and lightweight. ➢ Simple and intuitive to use. No distracting elements.

4. THEORY

The theory chapter is divided into two components starting with a theoretical framework presenting underlying theories for product development used in this project. The second component of this chapter consists of the literature study and involves theories of children's cognitive development, physical development of children, physical and ergonomic requirements and anthropometric equations.

4.1 Product development

The product development process and its methods vary from case to case, but some crucial phases are usually included in each development process. The objective of the process implicates the methods that should be used, and several methods are often combined to accomplish a good result (Osvalder, Rose & Karlsson, 2008). Luchs, Scott-Swan, and Griffin (2016) describe design thinking, a commonly used systematic and collaborative approach for identifying and creatively solve problems. The process is nonlinear with two major phases; identifying and solving the defined problem.

Luchs, Scott-Swan, and Griffin (2016) state that a common risk to be aware of when investigating user needs is the tendency to quickly translate them into technical solutions and bias them toward minor modifications of existing products. The first phase, problem identification, starts therefore by an open exploration of customer needs. The discovery mode is characterized by gaining an understanding of the user's experiences, behavior, and their context. The methods used during the discovery mode is often qualitative. The data collection iterates with data synthesis, when the meaning of the qualitative data is derived and summarized into user insights. The process can move on into the defining stage when a set of customer insights are defined. The defining stage can be translated into a distillery of customer insights into well-defined problems to solve, also called problem statements.

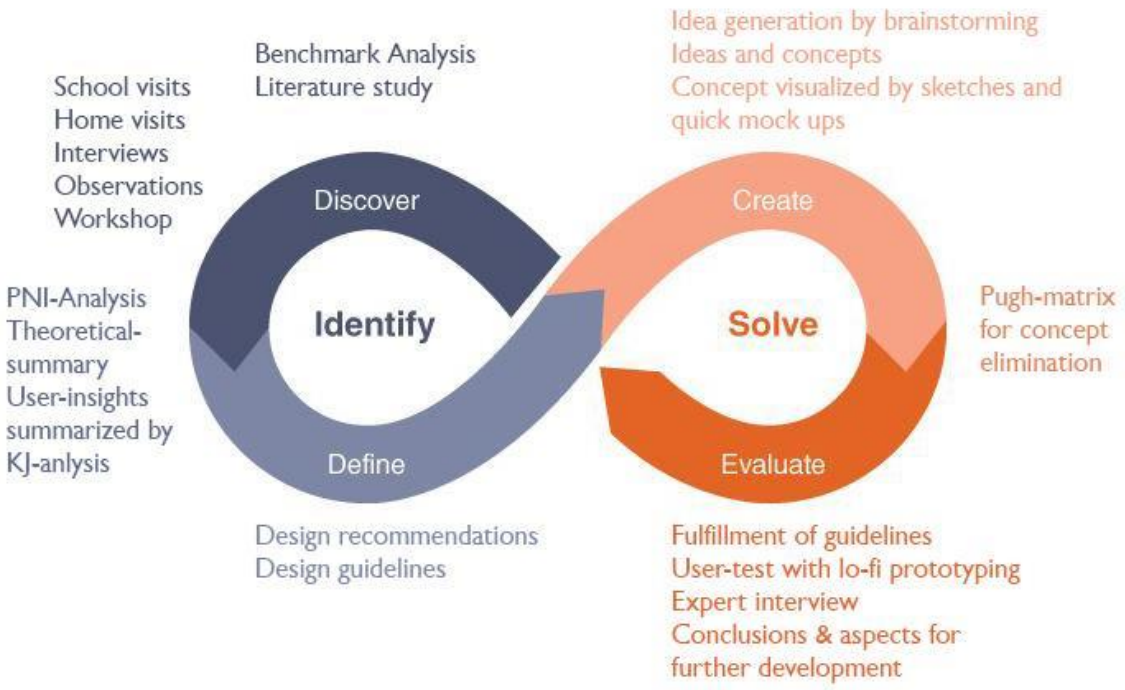


Figure 4.1 The Design Thinking Process and its connections to this project (Based on Luchs, Scott-Swan & Griffin, 2016).

When the problem statements are defined the process is moving over to the solving phase, starting with the idea creation. The aim of this phase is to develop one or more

concepts for the target market to respond to and which improvements can be made upon. The feedback from the target users is often done on quick and straightforward prototypes visualizing the product or features of the product. The first evaluation should be seen more as a learning stage rather than a validation of the design. The development process needs several iterations, of each stage, before a product is fully developed (Luchs, Scott-Swan & Griffin, 2016). Figure 4.1 shows the Design thinking process with the methods used in this project added to each mode. In this project, the theory- and user insight chapters constitute the *discover* mode in the Design thinking model. The formulated design recommendations have been clustered and distilled into design guidelines and form the *define* mode in the process. Furthermore, the *create* and *evaluate* mode are represented in the first steps of concept development including idea generation, refining, concept elimination, further refining, and a first user-evaluation. It is important to note that this project has not reached a fully developed product and needs further iterations, both in the *identifying* phase and the *solving* phase. The following sections present the design perspectives that are used in this project.

4.1.1 User-centered design

A user-centered design (UCD) approach is defined in ISO 9241-210 (2018a), and by many other researchers. UCD is commonly used to create a solution with high usability. The characteristics of a UCD-process can be summarized by; the striving for an understanding of the users, tasks and environments and the whole user experience, user involvement in each phase including user-centered evaluation for refining and push the development further and multidisciplinary teams with different skills and perspectives.

4.1.2 Product development for and with children

Johnsson and Karlsson (2013) describe different aspects to consider when executing scientific research and development with children involved. Children, as other participants engaged in research, require an ethical symmetry. The methods and situation must, therefore, be designed and adjusted by the existing circumstances. There is still an imbalance in authority that not can be overseen, the scientist should represent “another kind of adult,” neither a parent or a teacher, with genuine interest and humility to understand and listen to the child’s thoughts and experiences. The chosen methods should give the child a feeling of empowerment. The same ethical restrictions as for adults should be considered, with some extensions. The ethical considerations involve; information, consent, confidentiality, and usage. To increase the feeling of context and understanding the children should have the option to take part of the result in an inclusive manner (Johansson & Karlsson, 2013; Magnusson, et.al., 2009).

Designing for Children’s Rights (2018), a global non-profit association, have created thirteen principles (D4CR-guide) based on the United Nations Declaration of the

Rights of the Child to enhance ethical products and services with the child's best in the center. The principles requests products that everyone can use, support growth, are safe and proactive and make the child's influence matter. The product should also offer space for active play with others and relaxation. Other aspects described in the D4CR-guide concern use of personal data, commercial activities and the need to communicate in a way the child can understand. The last principle encourages the involvement of children and their parents, teachers, and experts when developing products and services for children. Both the principles and the recommendations by Johnsson and Karlsson (2013) and Magnusson, et.al. (2009) have been considered throughout the project.

4.1.3 The principles of universal design and its goals

The Principles of Universal Design is a tool for design and evaluation activities. The tool includes seven principles, or basic universal design attributes, which are further described and specified by several guidelines (Steinfeld & Maisel, 2012). The seven principles are; equitable use, flexibility in use, simple and intuitive use, perceptible information, tolerance for error, low physical effort, size and space for approach and use (Conell et al., 1997).

There are several definitions of universal design, the most common one was formulated by Mace (1985): "The design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design." Universal design can both be seen as an idealistic approach as well as a contextual process with continuous improvements for a more comfortable, healthy and friendlier life (Steinfeld & Maisel, 2012).

Steinfeld and Maisel (2012) defined eight goals of universal design. The goals are; body fit, accommodate a wide range of body sizes and abilities, comfort, awareness, understanding, wellness, social integration, personalization, and cultural appropriateness. The first two aims to create a solution that matches different body sizes and abilities comfortably. They are further linked to goal number five, wellness, and goal seven, personalization. A universal designed product should contribute to both health and wealth and reduce the risk of injury and disease. Further, Steinfeld and Maisel argue that the design should allow personalized adaptations to meet user needs and preferences. Cognitive aspects of the design are accommodated by the third and fourth goal, awareness and understanding. Relevant information should be clear and unambiguous. Goal six and eight have a higher level of abstraction, social integration, and cultural appropriateness; the design should treat all groups with dignity, respect, and reinforcement of cultural values. The Universal design principles and its goals have mainly been used in the evaluation of the project.

4.1.4 Developing products with high usability

Usability is defined as "The extent to which a product can be used by specified users to achieve specific goals with effectiveness, efficiency, and satisfaction in a specified context of use." (ISO, 2018b). Gould and Lewis (1985) listed three principles when designing for usability: early focus on the user and the task, empirical measurements and an iterative process. By evaluation early on and throughout the project early adoptions can be made, with lower costs and increased usability (Lindstedt & Burenius, 2006).

Kurosu and Kashimura (1995) distinguish apparent usability from inherent usability. However, both need to be considered when creating a product with high usability. To enhance inherent usability three strategies are in focus; the cognitive efficiency strategy, the operational efficiency strategy, and the safety strategy. These three strategies can be linked together with Jordans (1998) ten principles for the development of products with high usability, marked by parentheses in the text.

The cognitive efficiency strategy accommodates the reduction of the cognitive load (*consideration of user resources, visual clarity and, compatibility*) by e.g. making information quick and easy to read by considering glance sequence, familiarity by using well-known settings and symbols compatible with user-expectations and grouping through the laws of gestalt.

The operational efficient strategy (*consistency, prioritization of functionality and information, appropriate transfer of technology, and explicitness*) consider the sequence of the task and how to make similar tasks in a similar way, with commonly used functions centered and in a logical path with clues and guidelines for the user.

Reducing failure or mistakes is the primary purpose of *the safety strategy* (*user control, feedback, and error prevention and recovery*), this can, for example, be achieved by addressing actions, separating irreversible commands, minimizing errors and make them easy to recover.

According to Kurosu and Kashimura (1995) the apparent usability reflects the visual impression of an interface. The apparent usability combined with aesthetics, size, and the price is, according to Kurosu and Kashimura, determining whether the customer is going to buy the product or not. Furthermore, Kashimura and Kurosu argue that there is an aesthetic-usability effect, the theory that apparent usability affects the user's experience of the products performing (inherent usability). Tractinsky, Kats and Ikar (2000) showed the same correlation in their study “What is beautiful is usable”, but Tuch et al. (2012) claimed the opposite. Numerous studies have investigated the relation between beauty and usability, with different results (Hassenzahl & Monk, 2010). Whether aesthetics implicate usability, high usability implicates aesthetic, or

there is an interplay between the two factors is yet to be determined, but both apparent and inherent usability seems to be of importance when developing products.

4.1.5 Emotional design

There is no consensus in the definition of emotions (Kleinginna & Kleinginna, 1981; Holt et al., 2012). Holt et al. (2012) differentiate mood from emotion, with emotion referring to an intense and short stimulus-elicited response. Some state (e.g. Darwin, 1965; Plutchick, 1994; Ekman, 1992) that all emotions originate in a few innate and universal emotions such as sadness, anger, fear and happiness. However, there is no consensus regarding how many and which these basic emotions are. Others (e.g. Sclosberg,1954; Osgood, 1969) believe that our emotions arise from the arousal and valence dimensions. This theory is expressed in the circumplex model seen in Figure 4.2. The emotions on the right side of the picture can be seen as positive emotions. Ackerman (2018) denotes joy, gratitude, interest, pride, inspiration, confidence and happiness as some of the emotions people tend to describe as positive. Positive emotions expand our awareness of the responses we can choose from and promote creative thinking and action. Health and wellbeing, and memory are also improved by positive emotions, according to Ackerman (2018).

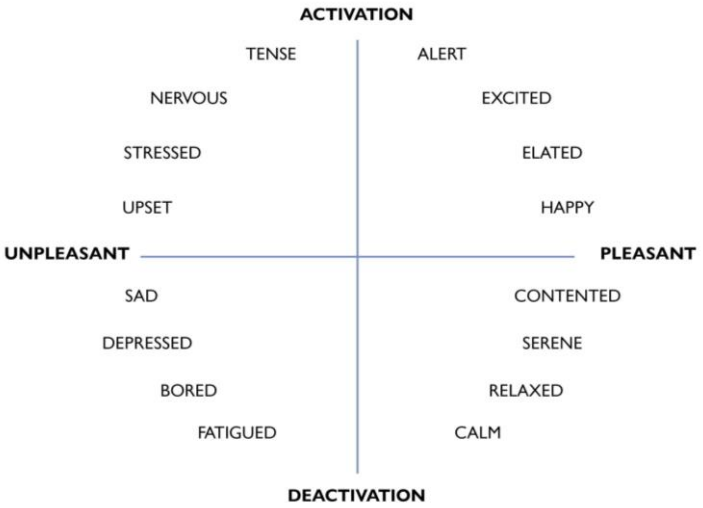


Figure 4.2 Circumplex model describing different emotions (Based on Colibazzi et al., 2010)

Emotions have also been a subject concerning design and product development. Chapman (2010) argues that solely creating products with physical durability may lead to fully functioning products, wasted on landfills. The creation of more extended user and product relations depends on the design of the product, and the design should consider both physical and emotional durability. Norman (2005) explains the underlying theories about what creates these emotional bonds by describing three different levels of brain structure; the visceral level, the behavioral level, and the reflective level. The visceral level is preprogrammed to make automatic judgments about looks, feeling and sound, which gives immediate emotional impact. The visceral level of the brain reacts to different conditions in the environment. Warm, comfortable and lit places, sweet tastes and smells, symmetrical objects, sensuous feelings, sounds, and rounded, smooth objects produce positive effects on human emotions. Sharp objects, darkness or extremely bright light and unexpected loud sounds, on the other hand, create negative ones. The context in which the product is going to be used

affect the design. Stressful situations need a more careful design since we tend to recognize the details before the bigger picture. An environment associated with positive emotions empowers the creativity, curiosity, and learning according to Norman (2005).

Furthermore, Norman (2005) states that the behavior level regulates well-learned, routine operations. It is all about the use when designing products for the behavior level; the product should consider function, understandability, usability and physical feel. To achieve good behavioral design the understanding of the performed activities and task is essential. The highest level is represented by the reflective level, such as conscious thought, learning new concepts and generalizations of the world. Reflective decisions about message, culture, and self-image affect our impressions of a product and the reflective level often determines the overall impression of it. Experiences, training, and culture influence the behavioral- and the reflective level but the visceral level seems to be about the same for all people. Our impression of a product depends on context, emotions and time, and is, therefore, a complex challenge for design. However, the design should consider these aspects regulating the visceral, behavioral and the reflective level to enhance an emotional durable product with the benefits associated with positive emotions.

DESIGN RECOMMENDATIONS:

T1: The solution should aim for inducing positive emotions, both intuitive and throughout the products life. Consider shape, physical feel and texture as well as function to induce an emotional durable design.

4.1.6 Tools and context for the creation of sustainable products

Sustainability involves ecological, social and economic factors and in June 2018 the new sustainability strategy for IKEA was launched. The strategy includes three focus areas; healthy and sustainable living, circular and climate positive and, fair and equal. Healthy and sustainable living include both resource-effective products and new innovative ways of living and changed mindsets towards a more sustainable behavior. IKEA aims to be climate positive by 2030, among other things by adopting a circular business model. Furthermore, IKEA strive for being a leader in creating a fair and equal society, by implementing and working with IWAY, IKEA's code of conduct, children's rights, and inclusive business. The extraction of raw materials (38%) and the product life at the customer's homes (23%) are estimated as the areas with major climate impact, measuring greenhouse gas footprint, for IKEA's business. According to Design Council (2002), 80% of the products environmental impact is determined at the design stage. Sustainability is an essential part of product development of today and several strategies and tools have been developed to help designers create more sustainable products. A small selection of these strategies and tools are described

below. The methods combined with IKEA's sustainability strategy creates the foundation for the sustainability discussion made later on in this project.

A conventional method for evaluating products environmental impact is is the usage of a life cycle analysis (LCA). LCA consider environmental impacts throughout a products life, see Figure 4.3, from the extraction of raw material, production of intermediate and the end product, usage, and end of life (Gröndahl & Svanström, 2010). As a tool to explore how different aspects of the product development process can be more sustainable the Eco-design Strategy Wheel (ESW) was developed by Okala (White, Pierre & Belletire, 2013). ESW is a brainstorming tool which highlights new opportunities in eco-design with different topics and examples connected to each stage of the life cycle of a product.

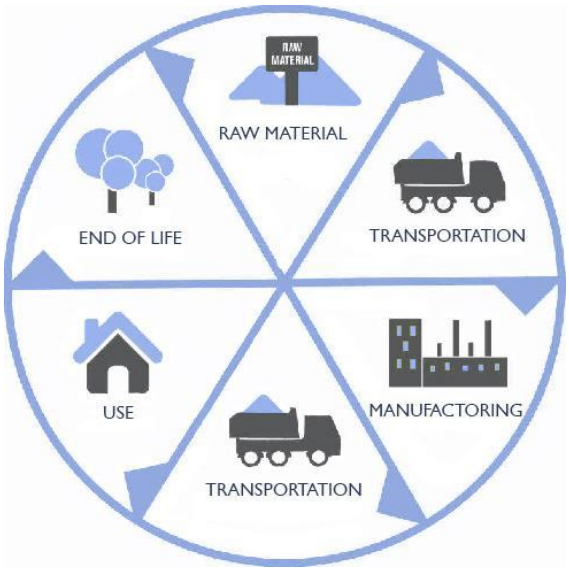


Figure 4.3 The stages of a products life used in LCA (Oyenuga & Bhamidimarri, 2017)

4.2 Children's cognitive development

The following theoretical framework of children's cognitive development and learning processes give an introduction to some of the psychological aspects of ergonomics, that need to be considered when formulating the guidelines. A complete framework would be beyond the limits of this project. Therefore, two well-known theories of children's cognitive development are presented followed by an introduction to the development of executive functions.

4.2.1 Piaget's developmental stages

Piaget (1926, 1977) describe children as natural born scientists who seek to understand the world, which depends on the creation and development of schemas[1]. Cognitive development is driven by the acquirement of new schemas combined with assimilation and accommodation of existing schemas. Piaget's describe the cognitive development of children in four stages, the sensorimotor, pre-operational, concrete operational and formal operational stage.

Piaget (1926, 1977) states that infants are in *the sensorimotor stage* from birth to about age two. Sensory experiences and physical motor interactions form their understanding of the world. Children achieve the ability to understand the concept of object permanence, the knowledge that an object continues to exist even if it's not

[1] Schemas are defined as organized patterns of thought and action in the brain.

visible, by the age of 8 months. Language is acquired after the age of 1 year, and the child can use words to represent objects, needs, and action by the end of the sensorimotor stage, as well as form simple concepts, solving problems and communicating their thoughts.

The child enters the *pre-operational stage* by age 2 and it lasts until the age of 7. Children at this stage represents the world symbolically through words and mental images, but they do not yet understand basic mental operations or rules. The stage is characterized by rapid language development and an ability to relate to time, the past and the future. Children in this phase are also able to anticipate some of the consequences of their actions and develop symbolic thinking. Their cognitive abilities still have some limitations; Children at this stage do not understand the concept of conservation[2]. The children in the per-operational stage does often show animism[3] and egocentrism[4].

The third stage, *the concrete operational stage*, occurs between the ages of 7 to 12 years old. Children at this stage can perform basic mental operations when the problems involve concrete objects and situations. They understand the concept of reversibility, are less self-centered and can easily solve conservation problems. Their ability to confront hypothetical and abstract problems are still limited.

The formal operational stage starts about age 11 and continues until adolescence. Children in this stage can think logically and systematically about both concrete and abstract problems. They can form and evaluate their hypotheses and usually enjoy hypothetical tasks.

More recent research has shown that children acquire many of the skills in Piaget's model at an earlier age than he thought (Bryant, 1974; Donaldson 1978) and that the stages are overlapping (Siegler, 1986; Karmiloff-Smith, 1992). A child does not necessarily master all the abilities in a stage before they can solve tasks at a higher stage. Piaget's stages should be seen as a simplified model, cognitive development is more complex, and all children do not follow the same developmental path. His model has nevertheless influenced the way we see children, their development and learning process, both in schools and in everyday life (Holt et al., 2012).

DESIGN RECOMMENDATIONS:

T2: The solution must consider and accommodate each developmental stage of the intended user, which means that the design must be intuitive even for a child in the pre-operational stage yet encourage the inner scientist of the child even in the formal operational stage.

[2] The principle that properties of an object such as mass, volume or quantity, stay the same even when the appearance may change
[3] The phenomenon when attributing lifelike qualities to physical objects
[4] Defined by difficulties in viewing the world from someone else's perspective

4.2.2 Socio-cultural perspective of learning

Vygotsky and Bruner state that the social context is the core of development, contrary to Piaget's more individualistic perspective (Holt et al., 2012). Vygotsky argued that the interplay between biological and sociocultural input are drivers of development, which can be visualized by the zone of proximal development (ZPD). The ZPD can be described as the difference between what a child can do independently and what the child is able to perform with assistance from adults or more advanced peers, see Figure 4.4. The ZPD concept can increase the recognition of what children are capable of understanding with help and what they soon may be able to do by themselves; two important factors to understand when one wants to push a child's cognitive development. The maximum level of ZPD are important as well since it visualize the upper limit of the child's current progress. Vygotsky also emphasized the importance of language as a tool for contextualizing the child's development. Younger children tend to talk to themselves while performing tasks as a way to structure their thoughts, and the monologues are by age internalized into an inner speech.

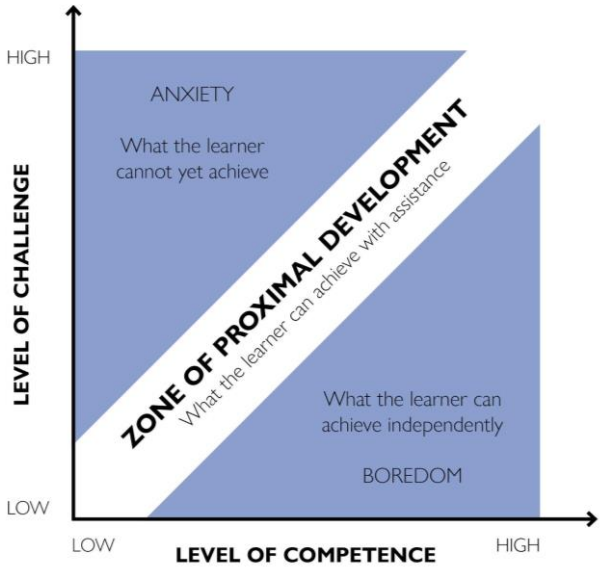


Figure 4.4 The Zone of Proximal Development-model (Based on Holt et al., 2012)

DESIGN RECOMMENDATIONS:

T3: The feeling and level of challenge and competence are linked together and enhanced by interactions and assistance from adults and friends. The solution should empower learning by challenge the child and yet make them feel competent.

T4: Language is an important tool for learning and contextualizing. The solution should accommodate the use and development of language during learning.

4.2.3 Executive functions

Vibeke and From (2016) describe executive functions (EF) as the ability of problem-solving and self-control, which is built upon subordinate skills and abilities such as attention, perception, working memory. EF is dynamic and can both improve and deteriorate as a reaction to the surrounding environment. Parents and other adults are essential as support for the child's development of these abilities. Executive domains are usually divided into three to five categories with different functions included. Anderson's, Jacob's, and Anderson's (2008) model include four areas, as shown in Figure 4.5; cognitive flexibility, goal setting, attentional control, and information processing.

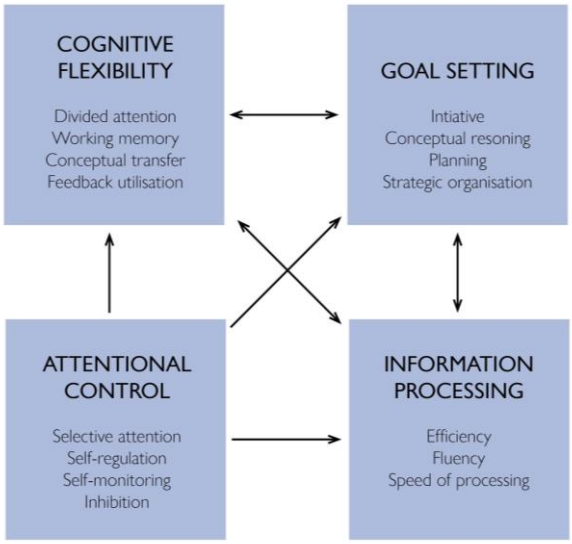


Figure 4.5 Model of the executive domains and there interactions. (Anderson, Jacobs & Anderson, 2008)

Development of executive functions

Executive functions are the last mental functions to fully mature and are not fully developed until about age 25 (Holt et al., 2012; Vibeke & From, 2016). Executive control functions are evolving at the first major developmental spurt at the age of 3 to 5 years old, self-control, selective attention and working memory are strengthened (Holt et al., 2012; Vibeke & From, 2016). A child at this age can follow simple rules, control their impulses and execute one-step tasks (Vibeke & From, 2016). Accordin to Brown and Beran (2008) does children in this age enjoy activities that improve their balance, hand-eye coordination and interactive skills. Furthermore, independence is important, but they are still relying on their parents and other adults and have a high need of feeling safe and secure (Brown & Beran, 2008).

Children are not able to reverse mental actions until the age of 7; they are therefore unable to understand the consequences of their actions and consequently often repeat the same mistakes (Brown & Beran, 2008). Memory capabilities, as well as processing speed, are continuously improved, especially between the ages of 8 and 12, called the second development spurt (Holt et al., 2012; Vibeke & From, 2016). The child's attention span and ability to inhibit impulsive responses increase with age and children at this age are more capable of systematically searching for information. Rehearsal helps children hold information in working memory and process it into long-term memory. Such strategies are more often used by older children, from 8 years and older. The ability to reflect on one's own and others' state of mind, known as metacognition, enables the child to judge their cognitive processes, regulate them and

maximize learning (Holt et al., 2012; Vibeke & From, 2016). An 8-year-old has cognitive flexibility equal to an adult. The child's working memory and attention span are improved and the child can concentrate about 20 minutes at a time. The impulse-control is almost fully developed by the age of 8 (Vibeke & From, 2016). Children between 6 to 7 years have a strong desire to perform well and do things right, are fixated on rules and rituals and are quite sensitive and emotionally vulnerable. On the other hand, many children within this age range are testing limits as an exploration strategy. Since they are not fully capable of understanding cause and effect, this exploration is sometimes associated with risks (Brown & Beran, 2008).

Middle-school children, from age 10 and older, evolve their social skills, get a better understanding of other people's perspectives and begins to see parents and authority figures as fallible human beings. Children in this age may experience different situations as embarrassing and spending time with peers become important (Brown & Beran, 2008; Vibeke & From, 2016). They are usually goal-oriented and able to take more responsibility at home. They can keep their homework in order and follow rules even when no one is watching (Vibeke & From, 2016). Teenagers develop the ability to use foresight and understand the consequences of their actions, a competence that evolves until age 25. Their communication skills are almost equal that of adults (Brown & Beran, 2008).

DESIGN RECOMMENDATIONS:

T5: The solution must consider the developmental level of the child's executive functions and should strive for enhancing that development.

T6: Cognitive development generally and executive functions specifically develop in synergy with others, parents and peers. The solution should, therefore, encourage these interactions.

4.3 Physical ergonomics

The theory section describing physical ergonomics consider; Children's physical development and differences from adults, biomechanics and reach zones, visual recommendations for work by a screen, and lighting. These sections are followed by a description of how to use anthropometric measurements when developing products for children, equations to define sizes of a chair and desk and at last a summary of trends in seating.

4.3.1 Physical development of children

Children's first growth spurt, mainly in the extremities, occurs during their first five years, followed by the second spurt for girls between age 9 to 14 and boys between

11 to 16 years of age (Norris & Smith, 2008). The growth spurt can implicate greater risk since the length of the bone does not match the bone mineral content, which makes the bone long before strong. Children's bones are growing and soft, and unlike adults their ligament is stronger than the bones. Bone fragment injuries are therefore more likely than ligament injuries (Lueder, 2003). Adaption of posture and coordination follows a growth spurt as well (Lueder, 2003). The spine is growing, and the lumbar curve is formed in early adolescence. At this stage are neck and back pain more commonly reported, especially for girls. Postural support is essential throughout the child's development, at first to promote good postural habits and later to reduce stress (Hedge & Lueder, 2008). Until puberty, the growth rate is almost the same for boys and girls, with similar lean body mass. Girls enter puberty before boys and the hormones associated changes the distribution of fat and muscles, boys' muscle mass doubles from age 10 to 17 and the gender differences become greater (Lueder & Rice, 2008a).

Coordination, fine-motor skills and strengths are three physical abilities that develop during childhood. 5-year-old's have good hand and body coordination but limited hand strength and ability to perform complex motor tasks. Many children like to test their physical strength, but they may have a limited understanding of the potential consequences of their risk-taking (Lueder & Rice, 2008a). Several authors (Gouvali & Boudolos, 2006; Panagiotopoulou, Christoulas, Papanckolaou, Mandroukas, 2004; Parcells, Stommel, Hubbard, 1999) state that bad posture habits due to poorly designed school furniture may impact the child's growth process. Ergonomic study solutions developed for children are therefore vital.

DESIGN RECOMMENDATIONS:

T7: The design should enable positive postural habits as a foundation for the future and promote a healthy physical development of the child. This is particularly important for the spine, including the lumbar curve and neck.

T8: Gender differences become more significant after puberty, resulting in the need of a greater range of sizes to match everyone within the age range.

4.3.2 Biomechanics: flexion, extension and reach

Some of the most common goals in biomechanical research are to reduce the level of effort to accommodate end-users' abilities, tolerances and preferences and increase efficiency and productivity in task performance (Steinfield & Maisel, 2012). General guidelines with biomechanical considerations involve reduction of unnecessary and potentially harmful movement, operating forces and efforts required for lifting as well as designing to maintain balance. One recommendation is that frequently used equipment should be accessible and, adjustments should be able to do without harmful positions (Pheasant, 2003). The range of motion describes the distance and

direction a joint can move to its full potential. However, too much flexion or extension cause muscles in an extreme, non-optimal position, wherein strength is limited. Static and loading or strain work positions should therefore be avoided (Hägg, Ericson & Odenrick, 2008). Reach distances are often divided into; the optimal or neutral reach zone, maximum and outer reach zone, see Figure 4.6. According to Steinfield and Maisel (2012), Hägg, Ericson and Odenrick (2008) and Pheasant (2003), too much inactivity can reduce strength and stamina, some level of movement and a varied position is therefore to prefer. However, the movement should be able to do without harmful positions such as bends and twists, especially if they are static, heavy lifting or repetitive. Furthermore, Hägg, Ericson and Odenrick state that low, static loading is often wrongly attributed, and it is hard for the user to see the connection between the loading and pain or, in the worst case, musculoskeletal injuries.

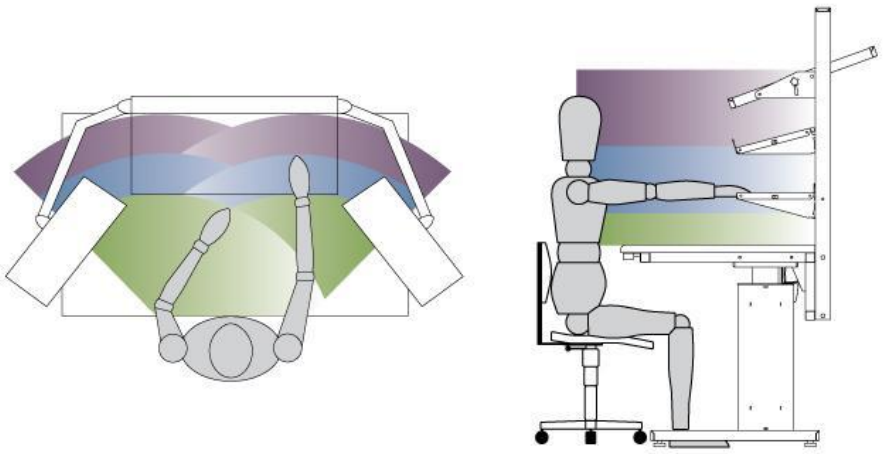


Figure 4.6 Reach zones divided into neutral, maximum and outer reach zone. (BOSTONtec, 2018)

DESIGN RECOMMENDATIONS:

T9: A majority of the tasks, especially frequent and repetitive, should be able to do with the body in a neutral position.

T10: Storage and equipment often needed should be placed accessible, and preferable in the neutral zone of reach.

T11: The design should accommodate alternative methods for applying forces to enable a wider range of users and an inclusive design.

4.3.3 Vision and homework done by a screen

The task and its visual demands regulate the position of visual displays, or other objects in the center while working. It is essential since the posture of the head and neck are profoundly influenced by the positioning (Pheasant, 2003), and adaption of

bad postures may lead to tensions and fatigue in the neck, shoulder, and back (Fostervold & Ankrum, 2008).

The visual objects should be placed in the center of the vision, with a minimized need of changes in viewing distance (Hägg, Ericson & Odenrick, 2008). Figure 4.7 shows the resting line of sight. When relaxed, our head is tilted about 10-15° downward, the preferred display zone is therefore between 0-30° below the horizontal line and defines where the center of the screen should be placed. About 45° below the horizontal line is the maximum limit for visual displays, which results in a modest neck flexion (Pheasant, 2003). The distance from the eyes also determines the visual comfort. The lens of the eye is fully relaxed when looking at far distances, more than 6 meters away, viewing closer objects needs activation of muscles regulating both accommodation and convergence (Pheasant, 2003). Fostervold and Ankrum (2008) recommend a minimum viewing distance of 650 mm, while Pheasant (2003) recommends a distance about 500 mm but preferably 740 mm. Children seem to prefer a tilted desktop (between 0-20° slope) when writing and reading in school (Agaard-Hansen & Storr-Paulson, 1995) and studies on adults have shown that a 20° slope on the desk leads to less flexion in the neck and a more upright sitting posture (Bridger, 1988; Hamaoui, Hassaïne, Watier, & Zanone, 2016). A slightly tilted desktop seems therefore to prefer.

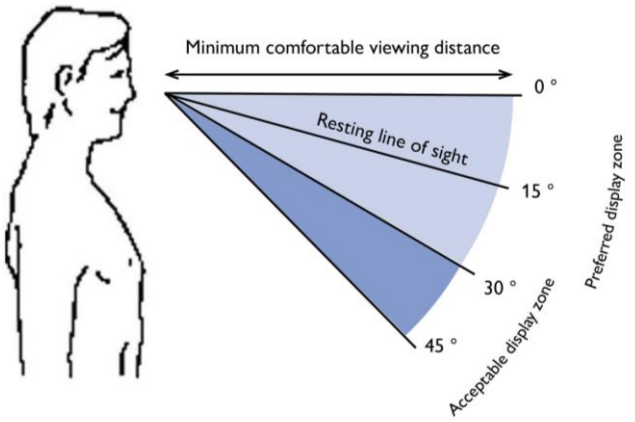


Figure 4.7 Recommended viewing angles (Based on Pheasant, 2003)

DESIGN RECOMMENDATIONS:

T12: To reduce the risk of harmful postures, the design should consider visual demands by encouraging a proper visual setting on the desk (place visual field between 0-30° below the horizontal line), including viewing distance (minimum 500 mm) and a 20° slope on the desk.

4.3.4 Recommended lighting conditions for home work

Fostervold and Ankrum (2008) argue that lighting both positively and negatively can influence children's visual development. Furthermore, proper lighting is essential for a good study environment. Inadequate lighting may be accepted by many children as long as they can see what they are doing, but poor lighting conditions strain children's vision in the same way as for adults.

Fostervold and Ankrum (2008) state that the knowledge of children's preferences for lighting is limited; many standards are therefore based on recommendations for adults. Different tasks require different levels of lighting. For office environments the lowest illuminance recommendation is 500 lux. For more precise tasks 1000 lux is considered the lowest recommended value. The luminance should be highest in the center of the field of view and then be reduced towards the peripheral field of view. A common recommendation is a 5:3:1 luminance condition (Figure 4.8) with a luminance five times higher in the internal field (i.e. the center of the visual field) than the surrounding, outer field. However, the individual differences are not to be overseen, and the lighting depends both on the surrounding environment, the individual's vision and perceptual characteristics (Hägg, Ericson & Odenrick, 2008). A common assumption is that increasing light levels would improve performance, but that seems to be wrong. If the light level is within normal limits will not simply changing illumination affect reading performance, according to Fostervold and Ankrum. The direction of the light should avoid shading of visual object and dazzle. Dazzle can be avoided by correct positioning of the light, using non-reflective materials and creating an even light at the workplace (Hägg, Ericson & Odenrick, 2008).

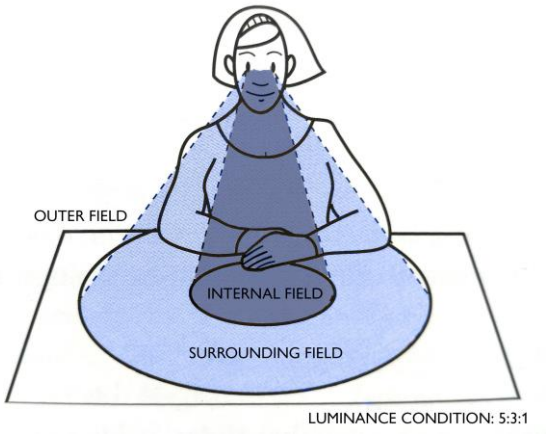


Figure 4.8 Recommended luminance conditions (Hägg, Ericson & Odenrick, 2008)

To create an inclusive environment for people with visual limitation some adjustments might be necessary. Information transfer with other senses is recommended by several authors (Hägg, Ericson & Odenrick, 2008; Steinfeld & Maisel, 2012) for example tactile information such as different structures or hardness to simplify orientation. Sound, smell and vibrations can also be used. Contrasting colors on important features can highlight key information. Hägg, Ericson and Odenrick (2008) recommend a higher luminance for people with visual limitations. Furthermore, spotlights could be used to point out particular features and avoid dazzle.

DESIGN RECOMMENDATIONS:

T13: The solution should offer proper lighting, dimmable, with an illuminance of at least 500 lux but preferable 1000 lux when reading or doing precision work.

T14: The direction of the light should be adjustable to avoid glare.

T15: Use multimodal information, haptic, visual and auditory, in order to create an inclusive and intuitive solution.

4.3.5 Anthropometric measurements for children

When designing for adults, it is common practice to design for the 5th percentile (5th%) female to the 95th percentile (95th%) male (Norris & Smith, 2008). The same approach cannot be applied when designing for children, according to Norris and Smith. Both boys and girls have a growth spurt during the first five years. For girls, the next spurt generally occurs in 9 to 14 years old and 11 to 16 years old for boys. In different stages can, therefore, the girl's measurements represent the upper percentile and vice versa. The growth-spurts entails that body sizes can vary a lot between children within the same age, it is, therefore, essential to make sure that the different data sources have used the same age-range definitions and calculations.

Ethnic and socioeconomic differences in anthropometric data cannot be overseen, and the divergence between populations increases by age. Socioeconomic conditions can also affect the anthropometric data; hence, the data should include as many populations as possible (Norris & Smith, 2008). However, it seems as the secular growth trend, i.e. the thought that Europeans and North-Americans are increasing their height about 10 mm per decade, is slowing significantly across all ages. Weight and other circumference and width dimensions have, on the other hand, increased over the past decades, therefore should the latest anthropometric data accessible be used (Norris & Smith).

The extremes should sometimes be included in the calculations, for example when there is a risk of injury. A safety tolerance should be added to the maximum- or minimum percentile to ensure the entire population is included (Norris & Smith, 2008). The anthropometric data do usually not include children with impairments, and other sources may be used to ensure an inclusive design (Norris & Smith, 2008; Steinfield & Maisel, 2012).

DESIGN RECOMMENDATIONS:

T16: Assure that the right anthropometric measurements are being used. Search for the highest and lowest value in each population, both for boys and girls.

T17: Use extreme-values when necessary, for example when there is a risk of injury.

T18: Be aware that anthropometric data usually do not include children with impairments. Use other sources when needed.

4.3.6 Equations for defining sizes of desk and chair

Pheasant (2003) states that the posture is highly dependent on the design of the chair. Sitting posture is considered more harmful for the human body than standing (Pheasant, 2003). Several studies have shown a mismatch between school furniture sizes and children's anthropometric measurements, which results in pain in the neck, upper- and lower back as well as discomfort in shoulders, wrists, knee and ankle regions. The problems increase with age, with a higher prevalence in girls (Castellucci, Arezes & Molenbroek, 2015).

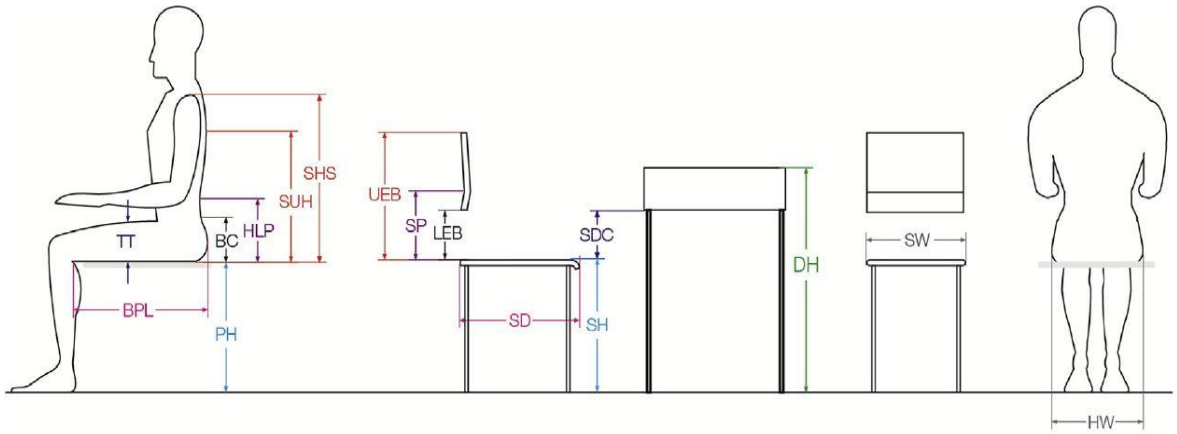


Figure 4.9 Defining measurements used in the following equations (Carneiro et al., 2017).

Stature is commonly used as the prescription measure; however, stature can imply ambiguity sizes since the anthropometric dimensions of an individual are corresponding to different percentiles. Recent studies argue that the popliteal height (PH) is a more precise measurement and should therefore be used (Castellucci, Arezes & Molenbroek, 2015; Carneiro, Gomes & Rangel, 2017). When designing a desk and chair, the seat height is recommended as the starting point. Below the recommended equations used when defining each measurement for chair and desks designed for children are presented, followed by a short explanation of critical aspects to consider. The variables used in the equations are defined in Figure 4.9.

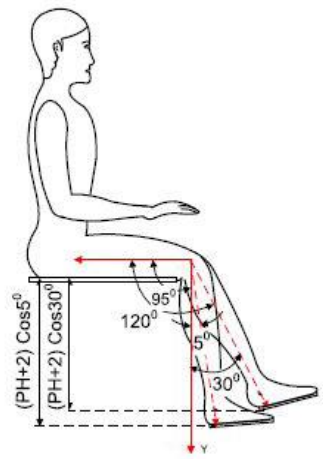


Figure 4.10 Equation for seat height (Yanto et al., 2017)

Equation 1 - Seat height (SH) $[(PH + SC)\ cos30° \leq SH \leq (PH + SC)\ cos5°]$

The seat height is recommended as the starting point for sizing the set of a desk and chair. The equation uses the popliteal height (PH) but also take the biomechanics of the knee into account, since the inferior part of the leg makes an angle related to the vertical of 5-30° (see Figure 4.10). The term SC stands for shoe correction and represent the thickness of the sole. If the user is wearing shoes while using the chair, this value should be added, otherwise SC=0. A correct posture can also be ensured if the chair has a footrest, then the height of the footrest should correspond to Equation 1 (Castellucci et al., 2015; Yanto, Chih-Wei Lu & Jun-Ming Lu, 2017; Carneiro et al., 2017). Seating with a footrest improves body stabilization, the distance of reach and decreases fidgeting (Rice & Lueder, 2008b). A tangible extension may cause discomfort since the thighs do not get enough support and lower seat height than recommended compresses the buttock region (Castellucci et al., 2015; Yanto et al., 2017).

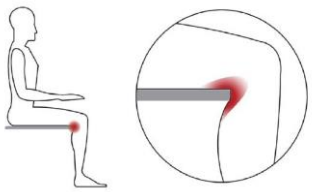


Figure 4.11 Consequences of a too deep Seat Depth (Carneiro et al., 2017)

Equation 2 - Seat Depth (SD) $[0.80\ BPL \leq SD \leq 0.95\ BPL]$

The seat depth (SD) should be lower than the buttock-popliteal length (BPL) to ensure sufficient blood circulation in legs and feet when seated with the back and lumbar spine supported by the backrest (Castellucci et al., 2015; Yanto et al., 2017). A good dimensioned seat depth enables support under the thigh so that the weight is evenly distributed and the sitting posture is perceived comfortable (Yanto et al., 2017). A plane seat surface is to prefer from a shaped one (Pheasant, 2003) and a small radius can be added in front to reduce pressure in the knee joint as shown in Figure 4.11 (Pheasant, 2003; Castellucci et al., 2015). A firm upholstery is better than a soft one, a recommendation is a deformation below 25 mm for a heavy user, with covering materials that offer proper ventilation and stability (Pheasant). Equation 2 (see Figure 4.12) should therefore be used when dimensioning the seat depth (Castellucci et al., 2015; Yanto et al., 2017; Carneiro et al., 2017).

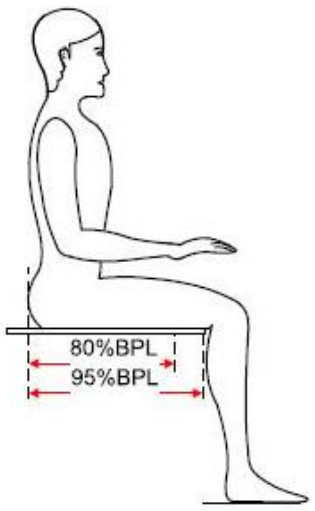


Figure 4.12 Equations for defining the seat depth (Yanto et al., 2017)

Equation 3 and 4 - Seat Width (SW) $[HW < SW]$ *or* $[1.1\ HW \leq SW \leq 1.3\ HW]$

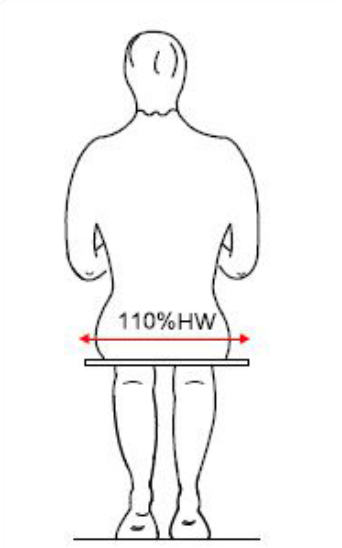


Figure 4.13 Equation for seat width (Yanto et al., 2017).

There is no upper limit on the seat width if the chair does not have an armrest. The only restriction is that the size of the seat width should be higher than the measurement of hip width (HW), which means that Equation 3 can be used (Castellucci et al., 2015). Yanto et al. (2017) suggest that the seat width should be 110 % of HW, see Figure 4.13. The seat width must be enough to support the ischial tuberosities, stability and space for lateral movements. A recommendation is to ensure that the seat width fits even the users with the largest hip breath (Yanto et al., 2017). Gouvali & Boudolos (2006) suggest an upper limit, 130 % of HW, for space economy. The upper limit can, however, be of importance if the chair is constructed with armrests since the shoulder should not be flexed more than 25° (Castellucci et al., 2015). Armrests can give some postural support and also constitute support when getting up and sitting down. The length of the armrest is restricted both by the elbow, the ulnar nerve, and the access in front. A gap of about 100 mm in the back, between the armrest and the seat, and 350 mm in the front, should be left. For a relaxed posture, the armrest should be slightly lower than sitting elbow height (Pheasant, 2003).

Equation 5 and 6 - Upper Edge of Backrest (UEB) $[SUH \geq UEB]$*or* $[0.6\ SHS \leq UEB \leq 0.8\ SHS]$

A neutral position of the lumbar spine is vital for the design of the seat, which can be achieved by a semi-reclined sitting position, well-balanced in depth and by creating an angle between the seat and backrest over 90° (Pheasant, 2003). Pheasant divides the height of the backrest into three groups; low, medium or high level, depending on how much support it offers. A low-level backrest supports the lumbar and lower thoracic region and finishes in the subscapular area which allows free movement of the arm and shoulder. The medium-level backrest offer support up to mid-thoracic level and high-level support gives full support, even for head and neck.

Irrespective of the height of the backrest a convex contour, spine-shaped, is the preferable solution for posture support. However, the contour should not be too excessive, that is probably worse than a flat backrest. Clearance for the buttocks needs to be considered, achieved by leaving a gap between the bottom of the backrest and the seat (Pheasant, 2003). Castellucci et al. (2015) state that the upper edge of the backrest should be dimensioned so that it is placed right below the subscapular or in the limit of the subscapular line (denoted as subscapular height, SUH). If the

anthropometric data does not include SUH the value of should height sitting (SHS) can be used (Castellucci et al.) or the stature (S) with the same limits as for SHS (Yanto et al., 2017).

Equation 7 - Seat to desk clearance (SDC) $[TT + 20 < SDS]$

In Equation 9, the thigh thickness (TT) has been used since it is estimated as a more accurate dimension than the knee height (K) (Carneiro et al., 2017), which sometimes is being used. 20 mm, at least, should be added to allow movement such as changing posture and standing and sitting comfortably.

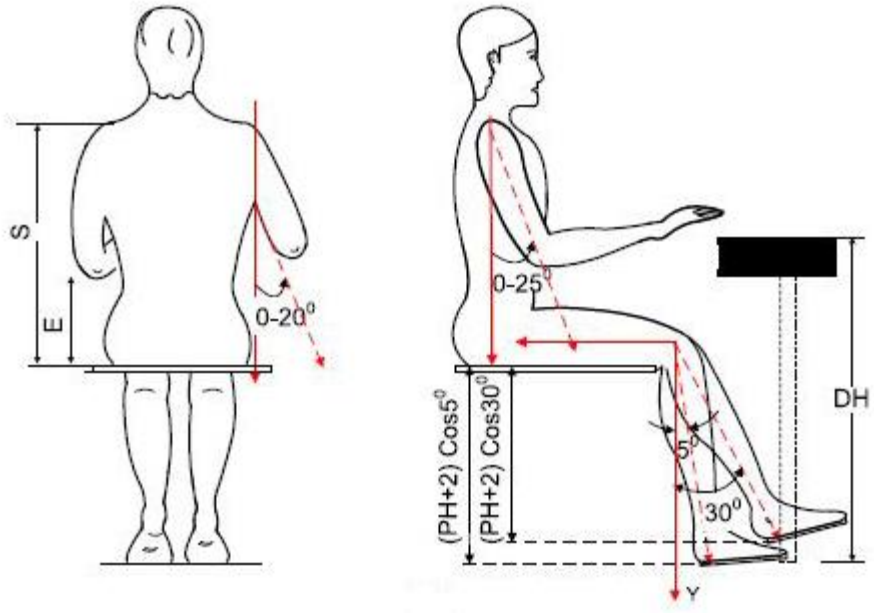


Figure 4.14 Equations for defining desk height (Yanto et al., 2017).

Equation 8 and 9 - Desk height (DH) $[SH + SDC + T]$ or

$$[E + (PH + 2)\ cos30° \leq DH \leq [(PH + 2)cos5°] + (0.8517E) + (0.1483S)]$$

A desk height that mismatches the child may result in an awkward neck and shoulder posture, a known risk factor for musculoskeletal disorders. If the desk is too high, the shoulder must be flexed and abducted more than the recommended higher limits of 25° and 20° when the elbows are supported on the desk (Yanto et al., 2017). Castellucci et al. (2015) suggest Equation 8 when defining the desk height, if the following conditions are considered; the starting point for dimensioning is the seat height (Equation 1), the seat to desk clearance are large enough (defined by Equation 7), and the table thickness (T) is a low value (they suggest 65 mm). Yanto et al. (2017) propose Equation 9 which considers the elbow rest height (E) and the recommended values of shoulder flexion [0°<<25°] and abduction [0°<<20°]. After some calculations and integration of Equation 1 the desk height can be calculated with Equation 9. There

is, however, a risk of contradictory between the DH and SDC criteria, which needs to be considered (Castellucci et al., 2015)

Different studies have proposed updated sizes for school furniture to create a better match with the children's anthropometric sizes. Carneiro et al. (2017) have suggested five universal sizes for chair and desk set adjusted for children between 6 to 10 years of age. Yanto et al. (2017) proposed four sizes to match the measurement of Indonesian children between 6 and 12 years old. Even children within the same age require different sizes since their growing spurts differ in time. There is no one-size-fits-all solution (Yanto et al., 2017). How many, and which sizes should be used for a global market for 5-14-year-old's, can not be defined without further calculations.

DESIGN RECOMMENDATIONS:

T19: The measurements of the desk and chair must match each other, and the users. This should be securely set if the proposed equations and anthropometric recommendations are used. Use the popliteal height as the prescription measurement and start with the seat height when deciding sizes for desk and chairs.

4.3.7 Trends in seating: kneeling-chair and active sitting

The kneeling chair and different active-sitting solutions have been developed as an attempt to reduce the harmful effects of passive sitting. Despite the theoretical basis for the design of kneeling and active sitting chairs, the positive effects have not yet been unambiguously proved. Brunswic (1981) showed that neither a kneeling chair nor a tilted seat resulted in a better lumbar posture compared to a horizontal seat. A study by Drury and Francher (1985) stated that the kneeling chair could be even worse than a proper office chair, since the kneeling chair may result in pressure on the shins, discomfort in knee region and no improvements in back comfort. Atherton et al. (1982) highlight the difficulties in standing up and sitting down and the fixation of movements and thus position changes as two drawbacks in the design of the kneeling chair.

Regarding active sitting, Le and Marras (2016) concluded that an active sitting design showed less muscle activation in the axial musculature, measured with surface EMG, in comparison with a traditional chair. Gregory, Dunk, and Callaghan (2006) showed that prolonged sitting on a stability ball, instead of an office chair, was associated with a minor increase of muscle activation and reduction of pelvic tilt, however, not beneficial enough to override the reported increase of discomfort and safety risks associated with sitting on an unstable surface. A systematic review by O'Sullivan, O'Keeffe, O'Sullivan, and Dankaerts (2013) included seven studies evaluating dynamic sitting. Only two studies showed a difference in trunk muscle activation, and five reported no difference. Increased discomfort, spinal shrinkage, and greater fatigue

could be seen in the two studies with a higher trunk muscle activation, probably as a result of the lack of backrest rather than the dynamic sitting component. Before implementing new sitting solutions, scientific research and evaluation should be conducted to determine the physical advantages (Gregory, Dunk & Callaghan, 2006).

DESIGN RECOMMENDATIONS:

T20: New solutions should be tested and evaluated scientifically before implementation to secure that the solution meets the desired ergonomic requirements.

5. USER INSIGHTS

The result from the user-studies is described in three parts; learning activities at home and school, physical and psychological aspects. Each section includes results from the observations and interviews at the two schools and the five visited families. The result also includes conclusions from the conducted workshop with twenty third-grade students. Design recommendations summarize the user insights at the end of each section.

5.1 Learning activities at home and school

Three out of five families lived in apartments. One family lived in a terraced house and the fifth family in a detached house. One of the families had one child, the others had two or more children. Each child included in the project, except from two siblings, had their own room. All of the children had their own dedicated workplace but a majority of the children did their homework by the dining table, accompanied by their parents.

Table 5.1 Description of the visited families and the children's study places

Family	Age	Gender	Type of home	Own room	Child's main study place
Family 1			Terraced house, 108 m^2		
Child 1.1	8 years	Girl		Yes	Dining table or sofa, both in the living room
Child 1.2	10 years	Girl		Yes	By her desk in her own room
Family 2			Apartment, 80 m^2		
Child 2.1	6 years	Boy		Yes	Did not have any homework yet. Was often sitting together by the dining table in the kitchen or by himself in his room
Family 3			House, 108 m^2		
Child 3.1	10 years	Girl		Yes	By the dining table in the kitchen, or when repetitive tasks in her own room
Child 3.2	13 years	Girl		Yes	In her own room, by her desk, in bed or sofa
Family 4			Apartment, 82 m^2		
Child 4.1	11 years	Girl		Shared with sibling	Was often starting in their own room, often distracting each other and was therefore separated so one of them ends up sitting in the kitchen or living room.
Child 4.2	11 years	Boy		Shared with sibling	
Family 5			Apartment, 100 m^2		
Child 5.1	11 mounts	Girl		Shared with child 5.2	Not included in the project
Child 5.2	4 years	Girl		Shared with child 5.1	Was sometimes using her sisters' desk for painting, playing with doll-house. Did not have any homework or school related tasks. Not included in the project.
Child 5.3	8 years	Girl		Yes	Did have reading assignments each week, often done by the dining table in their kitchen and sometimes in her own room by her desk.

The younger children, first to third grade, had a reading assignment for homework each week and occasional individual assignments, depending on the child's need for further practice. The older students, grade four up to ninth grade, did not usually get specified homework. Their assignments were often ones they haven't been able to

finish during lecture. This could be reading, math, vocables or writing assignments. The oldest students also needed time after school to practice for tests. A majority of the interviewed teachers mentioned that committed parents is an important part of the children's school results according to the teachers. Furthermore, highly educated parents correlate to better school results for their children. The main part of the assignments was therefore made in school.

"I prefer to do my homework by the dining table. It is close to mom when she is preparing dinner, so I can ask her if I have any questions."

8-year-old child

The younger children preferred to do their homework with a parent, often by the dining table or in the living room. The parent could assist, correct and support their learning or just keep them company. Some children had their own computer at school, but none of the younger children did their homework by a computer or iPad. Only the older ones, from junior high school, were allowed to take their laptop home to complete tasks. The younger children used digital devices for practicing different abilities, such as math, words and spelling through learning programs. The older children were more often doing their homework at their own room. The homework took from 15 to 30 minutes for the younger children and about 1-2 hours per day for the older children. Even the younger children could be sitting for longer periods of time when painting or crafting.

Figure 5.1-5.3 Different study places for the children.

Different digital devices, such as laptops and smartphones, could both promote learning as well as distract the children according to the teachers and parents. After reading or writing by hand, working by the computer could be relaxing for those children who get strained in eyes and hand. According to the teachers, the surrounding environment could easier be screened off while working by a computer for most children, and both phones and computers could be used for searching inspiration and information. Self-regulation was nevertheless

"I usually do my homework in my own room. It's quieter and I can close my door to not be disturbed."

10-year-old child

an obstacle for many children and the digital devices could as well distract focus from the task.

Digital devices were nonetheless an important part of the children's lives and the families mentioned a need of a hidden, yet easy to access, solution for cables and charging opportunities for gaming devices, smartphones and laptops integrated into the workplace.

DESIGN RECOMMENDATIONS:

U1: The solution must be compatible with a variety of tasks. Children's homework includes both reading, writing, calculating and repeated vocable practicing both on paper and with a laptop.

U2: A parent or friend should be able to sit by the child to encourage and help learning, this is particular important for the younger children.

U3: The solution should be compatible with digital devices, such as laptops and smartphones, with hidden yet easy to access solutions for cables and charging.

5.2 Physical aspects of study solutions at homes and schools

In this section different perspectives on the physical characteristics of study solutions are presented. The result includes both descriptions of the current solutions as well as wishes for a potential ergonomic study solution. The section is divided into five subtitles; general aspects, desk, chairs, lighting and the surrounding environment.

5.2.1 General aspects regarding a study solution

When discussing ergonomic furniture for children, height-adjustable tables were in top of mind of the interviewed parents. A solution that allows different body positions, sitting, standing and perhaps even lying, was a desirable solution according to the parents. When considering ergonomic aspects of study furniture for children the characteristics of the chair was described as more important than the desk for most parents. The match in size and model between the chair and desk was also described as an important ergonomic aspect, both from teachers and parents.

Especially the families living in smaller apartments requests a flexible solution that can expand in each direction, both length and depth. Both parents and teachers preferred a flexible solution, that could be combined in a variety of ways and enabled refurnish.

A customized, or customizable study solution, was mentioned as one example on how different user and needs could be met. A built-in possibility to change the solutions expression could also increase the attractiveness of the product over the years according to the children and parents. This was also described as a way to create a feeling of the workplace as “my own”. The possibility for the child to make adjustments by themselves and reach and explore their equipment’s and material without harmful positions or bending promoted independence. The teachers described that the study place should stimulate and inspire learning, not restrain it. Trying, and sometimes breaking things was described as a natural and important part of learning. The feeling of self-importance was described as increasing when the child was encouraged to take care of their own place in school.

Figure 5.4 Example of a classroom for first to third grade students on the Montessori school. Each item should be easy to access and the colors are sober. The carpet is often used to sit on when studying or playing games during breaks.

“They should not be afraid to try. It’s no big deal if something breaks. It’s a part of the learning to see and realise the boundaries of things”

Teacher

All families required proper storage solutions for the child. The storage helped the child keep things in order and gave a possibility to put away things when they needed a clean workspace. The storage could with advantage be put underneath the desktop and include drawers with different compartment inserts, stated by parents and children.

Figure 3.5-5.7 Different solutions for storage.

The furniture needed to be easy to clean in order to keep the furniture attractive in present and through the years. Some of the families used oilcloth to avoid scratches, paint or glue on the desktop. The families requested long-lasting, high quality material, something that could be taken care of and refine, such as wood.

DESIGN RECOMMENDATIONS:

U4: The solution should be flexible with a variety of settings and positions.

U5: The solution should encourage children's independence and learning by simple instructions for adjustments and easy access to their equipment and study-material.

U6: The solution should offer proper storage, preferable with drawers and adjustable sections for their equipment, reachable for the child.

U7: The solution must be durable, easy to clean and keep in shape, with high quality in material and construction.

5.2.2 The desk

The families requested a big workspace. Even the families with limited space wanted a solution that is both wide and deep, so that the child can spread out all their work and have a friend or parents by their side. Most of the children used their desk for other tasks than homework, such as playing, reading, scrapbooking, painting etc. Dedicated place for each item helped the child to keep the desk organized and easy to clean. Toys and other stuff were described as distracting when studying, by both children and parents, something that could be remedied with access to drawers and sections.

"I like to keep my things organized. I prefer a solution with a door or something that can hide the mess and keep me from being distracted."

10-year-old child

The size of the table was also described as a question about integrity, in terms on how close the child wanted to sit to another person. Table 5.2 describes the sizes of the children's desks, whether they find it enough and their summarized experience of the desktop size. The desk did not need to be bigger than a school bench, approximately 650x580 mm (Lekolar, n.d), for homework but other tasks required bigger space. About 600 mm depth seemed to be enough while the length often was regulated by the walls in the child's room. The interviewed families wanted the desktop to be as long as possible.

Table 5.2. Summary of the children's desktop sizes and their comment of the space

Size of desktop [mm]	Considered enough	Comment
1860x635	Yes	Got enough space for a friend or parent to sit on the side
1200x600	No	Would like a longer desktop to be able to spread out crafts
1580x400	No	Adjusted to fit the room but would like a deeper desktop if it was compatible with the room.
2000x600	Yes	Was considering a smaller desktop when purchasing but are happy that they choose the bigger one.
800x600	No	A bureau with lot of storage, the child rarely uses it for homework. Enjoy the possibility to close the bureau and liberate space.
1600x800	Yes	A lot of space, enough for the two children to sit together. But when they are moving to another apartment, with separate rooms, each child are getting their own desk, they are choosing smaller sizes.
2500x550	No	Adjusted to fit the room but would like a deeper desktop if it was compatible with the room.

Only one of the families had an electric height-adjustable desk, but the children were not aware of the function since the parent thought they would play with it. When the parents were asked about ergonomic solutions of the desk, a height-adjustable function was mentioned, both to enable different positions, preferable so the worktop could be only 20 centimeters from the floor up to a standing position, but also to fit different body sizes and enable use even when the child grow. A possibility to tilt the desktop was also requested from the families.

Both teachers and parents emphasize the importance of a durable desktop that easily can be cleaned. One family used an oilcloth to cover and protect the surface, another family had a transparent cloth that enabled papers with instructions or supportive information to be placed under. One family wanted the surface not too glossy to reduce the risk of slipping papers and reflections. Furthermore, a well-balanced surface to write on, neither too stiff nor too soft, without joints, that is easy to clean and maintain nice over the years was desired.

"The perfect worktop would be one with ten layers that can be pulled off when the surface is damaged"

Parent

DESIGN RECOMMENDATIONS:

U8: The desk should allow a variety of positions, both in height and angle of the desktop.

U9: For most homework a desktop size of 800x600 seems to be enough, but other tasks require a bigger workspace.

U10: The solution must be flexible and fit in small spaces.

U11: The features of the desk need to outweigh the risks of the children playing or misuse them.

5.2.3 The Chair

Different children preferred different chairs. Some of them liked a specific cushion with massaging points, others balance pallets and some more of a regular chair. Different sitting options was mentioned as important to meet these shifting needs according to some of the teachers. Some children were sitting with their knees hunched on the seat, some with one leg or foot hunched during observations. Many children used another chair as a footrest when possible. Multiple children also liked to work sitting or lying on the floor, especially when they had bigger material or played games with others. One

Figure 5.8-5.13 First different chairs at the children's home. Below shows sitting solutions at a school .

parent believed that the younger children not necessarily need a traditional chair or sitting solution. She described it as that they rather need to move around and sit in different positions, which can be encouraged by alternative sitting solutions.

The motoric distraction from balance stools was described as supportive for children with special needs, such as ADHD or daydreamers whose thoughts easily float away, to keep focus. Both balance stools and the opportunity to move around and change posture was considered success factors for the students at the Montessori school.

Figure 5.14-5.15 Two types of sitting-pads.

The teachers and families wanted a chair that is easy to handle for the children and that fits their body dimensions. Height adjustable with a foot-, back- and armrest was other requests for an ergonomic chair. A spin function as well as castors enable reaching, sit and, rise, something the children mentioned. Both the third-grade students and the interviewed children requested a soft and comfortable chair, preferable with padded seat and backrest. One of the children described discomfort when using the chair with sticks in the backrest, since they could pressure certain points of the back. A smooth, high, backrest, without bumps was considered more comfortable by some of the asked children. The families in smaller apartments wanted a chair that could be able to steer under the desk when it's not used.

DESIGN RECOMMENDATIONS:

U12: The solution should encourage changes in position and posture.

U13: Different padding could increase the child's focus and sitting comfort. A majority of the asked children prefer a padded, soft, seat.

U14: Motoric distraction with inbuilt balance functions could benefit focus for some children, others prefer a static furniture.

U15: The chair should give support for a good sitting posture with a comfortable seating. The backrest should be smooth without bumps. A high backrest is preferred by the asked children.

5.2.4 Lighting

The emotions of the child could be regulated by the lights, and the lights may need to adapt to match the child's emotions, according to the teachers and parents. A more sober lighting with candles created a calm environment and was frequently used as a tool for relaxation in the classrooms. Intense light, could in the same manner, awake the children and refresh their focus and energy. Both teachers, the children and their parents highlighted the fact that different tasks require different types of lighting. A proper, focused, lighting was important when reading but a soberer lighting could be more inviting and cozy. The families wished for an integrated lighting solution that could be combined with the workstation. The cables should be hidden from the workspace to reduce risk of getting harmed if accidently cutting a cable, or just visually distract the children while working at their desk.

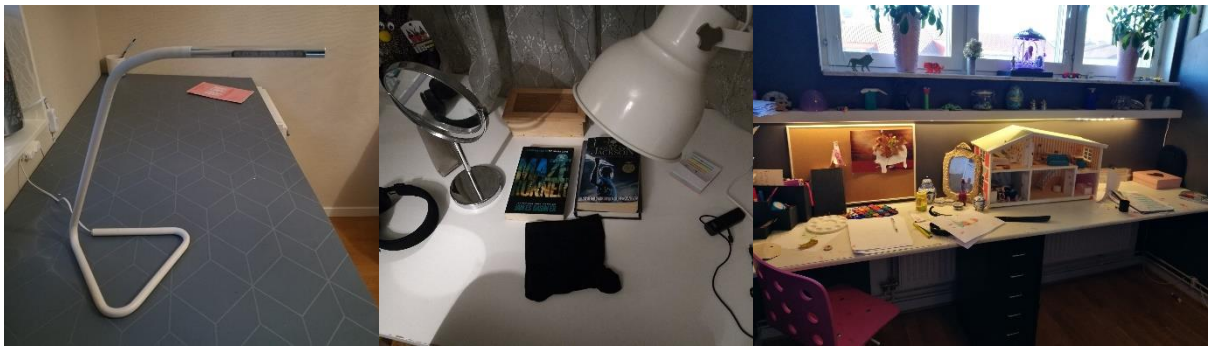


Figure 5.16-5.18 Different lighting solutions. Two directable and one dimmable, integrated into the study solution along the worktop.

DESIGN RECOMMENDATIONS:

U16: Dimmable lighting is requested by both children, parents and teachers, to adapt the lighting to different moods, or create a certain atmosphere in the room.

U17: The design must consider any cables, to minimize their visibility and reduce the risk of damage if the cable gets cut or worn.

5.2.5 Surrounding environment

The teachers described that the people around are incredibly important for the work environment. Furthermore, the teachers were talking about adults as role models that needs to behave accordingly. One teacher mentioned that the families have different prerequisites, all children doesn’t have their own room or a quiet space to do their

homework, some have a hard time finding peace in their home and others take a lot of responsibility at home and are therefore not able to do their homework at home. The study environment at home should be calm and harmonic. A stricter environment with less impressions and stimulus and neutral colors reduce distraction, according to the interviewed teachers and parents. The children wanted the surrounding environment to be light, in order and quiet with a warm, cozy and soft feeling rather than the opposite.

"Adjustments need to be done in an inclusive manner. Even high-performance children can benefit from changes made for children with special needs"

Teacher

All children have special needs in some way, this should be seen as something natural, according to the teachers. The child should be encouraged by the adults to find their keys for a good study environment. The aim should be to remove obstacles in the environment. The adjustments made in the classroom need to result in an improvement for one or more children. if not, the change should not be done. Most children can easily adjust to new circumstances, if they did not find a place or seating, they continued searching. They did not always use furniture as intended and were not bound to specified features in the same way as adults.

Figure 5.14. Children does not always use the furniture as intended.

DESIGN RECOMMENDATIONS:

U18: The study solution should enable the child to screen off the surrounding environment, for example by reduce stimulus, such as noise, visual elements and distracting objects, like smartphones or toys.

U19: The design must allow different usages and settings without risk of harming the child.

5.3 Psychological considerations

The psychological considerations treat age-differences, aspects concerning attention and, emotional aspects of current and potential study solutions for children.

5.3.1 Age-differences

The needs were described as differing by age, but the children's rooms needed the same kind of furniture; a bed, a work station, storage and space for friends, according to the parents. Their style, interests and preferences changed by the years, the younger children preferred more colorful interior and the teenagers more neutral colors like black and white. The solution needs to enable re-furnishing and these changes in lifestyle and preference to attract both children and their parents. In the families with the youngest children, age 6 and 7, the parents were responsible for deciding and purchasing the furniture. As the children get older, they were more involved in the decision making. Both parents and children in different ages though it was important that the furniture's match each other in shape and tonality. When purchasing new study furniture's factors such as style, flexibility and whether it fits the room were often superior to ergonomic factors. The furniture's should be comfortable, but both children and parents found it hard describing which ergonomic features they requested. Another struggle for the parents was to visualize what needs their children might have when they get older, since it depends on what interests they develop. They were all unanimous that the need of an ergonomic study solution increases by age, since the child spend more time doing homework the older they get.

Figure 5.20 The younger children often used the kitchen table for studying.

Figure 5.21 The teenager's study place goes in black and white.

The older children did spend more time in their own room and were able to sit longer time spans and should, therefore, be able to do so without distraction. The younger children were moving around more, more often sitting on the floor and had a bigger need of adults present. They also needed to take breaks more often. One of the

Montessori teachers believed that it is a preconception that the older children do not want to be sitting on the floor while working, they were just not getting the option.

Height adjustable working tables, boxes, and trays can make an environment usable for different ages. Furthermore, the tools need to be dimensioned for children, smaller and more lightweight, so it is easy to use even for the youngest children, according to teachers, parents and the children themselves.

Making the right choices was described as difficult for children, even for the older ones, but with age the awareness of how their enviroment should be increased. The teachers allowed the students to make their own choices to a higher extent when they had shown that they were able to make the right decisions. Letting the children get involved in taking care of their study material and laptops did make them more engaged and responsible.

> *"I don't think it has to do with age (how children want their study environment), it depends on the proficiency and learning objectives, rather than the adolescent's physical wishes"*
>
> Teacher

DESIGN RECOMMENDATIONS:

U20: The study solution should be attractive to both parents and children of different ages.

U21: The older children spend more time doing homework, that requires more ergonomic solutions which support postural changes and breaks for movements.

U22: The solution should be flexible and able to customize, which allow the solution to grow with the child.

U23: A solution with the child in charge makes them more engaged and responsible.

5.3.2 Improve and maintain attention

Most of the children preferred a calm and quiet environment without too much hustle and bustle, but still with the opportunity to move around. Some children needed an adult by their side in the beginning or sometimes throughout the lesson to accomplish their tasks. Others needed a clearly defined task to accomplish. At one of the visited schools each lesson started with a defined activity followed by the main task of the lesson and a summarizing activity in the end. All was written down on the whiteboard as a frame of the lesson. Images and symbols were another tool to clarify the task, especially to improve the younger children's understanding and learning. Some children needed to be sitting all by themselves, others had a high need of moving

around. To have something to touch or squeeze could increase concentration for children that easily get restless.

> *"It often seems like a student doesn't work, but in fact they are. They may ponder, observe other students and how they are solving different problems or in other way processing their thoughts"*
>
> *Teacher*

The sound level was considered one of the prior factors to enable attention. Damages caused by noise is hard to recognize, both for children and adults, according to one teacher. Furthermore, noise can be both distracting and tiring. Healthy children are able to sort out some of the noise, but children with neuropsychiatric disorders or mental disorder are more sensitive and can't restrict their impressions at the same level, according to another teacher. Headphones or earmuffs were two tools used to isolate sound and noise. It gave a signal to the people around that the child did not want to be disturbed. Some students used music to filtrate the surrounding environment. Many of the older children tended to sit in their own room, if they had one, to reduce disturbing noise. The furniture can contribute to the level of noise in a room, both positively and negatively. Protective pads on the tables and chairs can reduce scraping noise, and hollow furniture can induce a clattering environment. These factors should be considered when designing furniture for studying, according to the teachers.

Other things that could be distracting in the surrounding environment were activities outside or in another room, toys, magazines or smartphones. Some children could not be sitting by a window since they got distracted by the activity outside. Drawers, papers and other objects in the room could also distract, as well as smartphones and parents working in the kitchen.

By creating a solution were the children want to leave their mobile phone, some distraction could be reduced. One teacher mentioned a charging hub where all students leave their phones during the teaching session as a good example where the students get something positive out of a desired behavior. The teachers mentioned that using the child's own driving forces and interest, by letting them choose their own projects for example, increases their motivation, attention and focus.

DESIGN RECOMMENDATIONS:

U24: Reduce the number of impressions, sound and noise, lights among other things to reduce distractions and enable focus and attention.

U25: Tools to clarify the task with a defined start, middle and end of the task can help the child achieve their goals.

U26: The solution should use the child's own driving forces in order to create a desirable behavior as the greatest extent possible.

5.3.3 Emotional aspects

In the survey, third-grade and ninth-grade children were asked which emotions they wanted to feel while studying. Both the older and the younger students wanted to feel focused, alert and calm, the third-grade students also answered happy, smart and fast and the ninth-grade students answered interested and creative. Both the environment and other factors can create different emotions for the child.

Different parts of the school can create different emotions. The hallway was one example described by one of the teachers. The room is crowded, and jackets are often found by the floor. The children wanted their space to be the same as they left it. Colors can affect the children's emotions as well, at the Montessori school color spots in the painting room has been left to increase a feeling of creativity and freedom.

According to a teacher, too much and garish color do not foster play. It works only in a short time period and only as a small part. The current trend with more nature-based colors is better adjusted to the children's need. It helps children focus and triggers their fantasy and creativity, according to the teacher. The teachers also mentioned that children with ADHD or within the autism spectrum generally are more sensitive of colors, tastes, and impressions.

> *"Under-stimulated children are not the problem today, it's the opposite. Most children are over-stimulated and need help to relax. More natural colors, not so bright, can be one tool for that."*
>
> *Teacher*

DESIGN RECOMMENDATIONS:

U27: The solution should be associated with positive emotions, such as focus, energy and peace.

U28: Nature-based colors helps children focus and trigger their creativity.

6. DESIGN GUIDELINES

The guidelines are categorized under four headlines; strive for a healthy workplace, growing with the child, a solution with the child in charge, and facilitate everyday life. Each category presents conclusions drawn from the recommendations identified in the theory chapter (T1-T20) and the user-study chapter (U1-U28), The design recommendations included in the guidelines are presented at the end of each section. A complete list of all design recommendations in numerical order is attached in Appendix 11 and the list of recommendations connected to each design guideline is presented in Appendix 12.

6.1 Facilitate everyday life

Small space living and siblings sharing rooms may lead to an increased need for children's own place. A quiet and cozy place is as a factor of great importance for children's learning. A solution that enables the child to disconnect from the surrounding could improve their attention and quality of the studying. Small space living may also result in need of a more flexible solution. The families living in apartments wished for a solution that could fit into a small room but still offer enough space for the child to spread out their work and invite a parent or a friend to join. A solution that could be pulled out or elongated when needed could solve that need without making the room seem cramped.

The solution must be compatible with a variety of tasks. Children's homework include both reading, writing, calculating and repeated vocable practicing both on paper and with a laptop and the study solution may not only be a place for studying. The desk is also being used as a place for play and relaxation: building Lego, craft, and paint, reading or playing on devices such as Nintendo or a computer. The activities may change as the child gets older, but storage, charging possibilities and a hidden place for cables are desirable features consistent over time. For most homework, a desktop size of 800x600 seems to be enough, but other tasks may require a larger workspace.

The solution should be compatible with digital devices, such as laptops and smartphones, with hidden yet easy to access solutions for cables and charging. Proper storage, preferable with drawers and adjustable sections for their equipment, are essential for a complete study solution. Necessary equipment should be reachable for the child and encourage order and simplify cleaning. Dimmable lighting is another request by both children, parents, and teachers, to adapt the light to different moods, or create a certain atmosphere in the room. The lighting system could with advantage be compatible with IKEA's smart lighting system, which offers different colors, temperatures, and brightness.

Facilitate everyday life is connected to:

6.2 Strive for a healthy workplace

The design should be associated with positive emotions, such as focus, energy, and peace to encourage the child's development and study environment. This can be achieved by working with color, shape and form, texture and heft. Nature-based colors may improve focus and trigger creativity, while symmetric and soft shape and haptic feedback can exaggerate the attractiveness of the product.

The design of the study solution should be coherent in cognitive- and operational efficiency as well as in safety aspects. This can be obtained by using well-known elements and multimodal information, such as haptic, visual and auditory. Each feature of the solution must outweigh the potential risk of the child playing or misusing it.

Create a flexible solution that enables different body positions such as standing, sitting and lying as well as different angles of the desktop. Change of posture and position is the main priority when designing ergonomic furniture for studying. However, static positions nevertheless require a design that ensures good posture and comfort and gives the right support to the user to a greater degree than a solution where posture frequently changes. After puberty postural support, especially for the lumbar curve, becomes even more important. Also younger children should be encouraged to develop positive postural habits. Support for the lumbar spine combined with a neutral sitting posture, is therefore essential when sitting for longer timespans.

Furthermore, unnatural postures often occur in order to see clearly, and the user is not aware of a fatiguing posture until they feel stiff or sore. The solution should accordingly encourage changes in position and posture, consider visual demands by helping a proper visual setting on the desk and to offer appropriate lighting. The lighting should be dimmable, with an illuminance of at least 500 lux but preferable 1000 lux when reading or doing precision work. The direction of the light should be adjustable to avoid glare.

Reading or writing on a computer or paper requires different positions of the workspace. A slanted work surface can help a comfortable posture while reading but

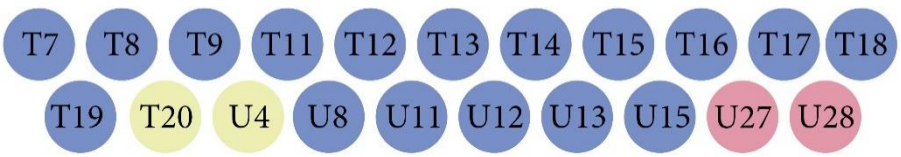
would not improve posture while writing. An adjustable desktop that can be sloped in different angles is therefore recommended.

Tasks should be able to do with the body in a neutral position and storage and equipment often needed should be placed in the neutral zone of reach. To decrease the risk of fatigue and create an inclusive solution the design should accommodate alternative methods for applying forces and making adjustments.

The measurements of the desk and chair must match each other, and the users, this should be securely set if the proposed equations and anthropometric recommendations are used. Use the popliteal height as the prescription measurement and start with the seat height when deciding sizes for desk and chairs. Gender differences become more significant after puberty, with the need for a greater range of sizes, even for younger children no one-size-fits-all solution exists, since their growing spurts differ in time. The exact number of sizes needs further analysis. Be aware that anthropometric data usually do not include children with impairments; other sources may be necessary if the aim is an inclusive design. The universal design principles is a useful tool to enable a solution for the many people.

New solutions should be tested and evaluated before implementation to ensure that the design improves comfort and posture for the intended user.

Strive for a healthy workplace is connected to:



6.3 Growing with the child

A study solution that grows with the child does not only need to fit the child according to sizes; it also needs to be attractive through all different stages of the child's life. Both parents and children want their workplace to be easy to clean and keep organized. All families mentioned a damaged surface, with glue, color, and scratches as a problem for a long-lasting desk. The solution must therefore be durable, easy to clean and keep in shape, with high quality in material and construction to remain its attractiveness and inducement of positive emotions throughout the products life. The taste and preferred style of the furniture vary from individuals and changes as well when aging. A cozy and comfortable, padded, chair is however a desirable solution for a majority of the children. The shifting, and different preferences, could be met by a solution with possibilities to customize and easily change expression which may also strengthen the emotional bond to the furniture over the years.

The solution must consider and accommodate each developmental stage of the intended user. This means that the design must be intuitive even for a child in the pre-operational stage yet encourage the inner scientist of the child in the formal operational stage. The youngest children’s thoughts are irreversible, they are not capable of repeating a task backwards, which means that adjustments needs to be clear in each direction. They are also characterized by symbolic thinking and an exuberant fantasy which could be used to trigger curiosity and learning. The oldest children, on the other hand, are able to try hypothesis and abstract thoughts. A solution that helps organize different perspectives and thoughts could support the older children’s learning.

In the same manner the equilibrium between challenge and competence in the ZPD model should be promoted in order to empower the child’s development. This means that the adjustment should be intuitive and simple enough for the youngest children, but still facilitate options that are appealing for the oldest children as well. A flexible solution that can adapt to new behaviors and needs encourage and trigger learning.

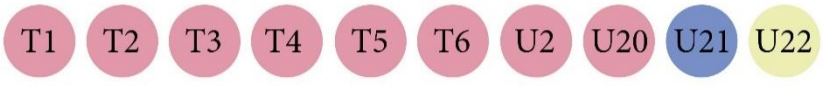
The executive functions describe key elements essential for the understanding of children's learning processes; the solution should aim for enhancing the executive abilities, such as cognitive flexibility, goal setting, information processing, and

attentional control. Easy adjustments with limited cognitive load required, tools to clarify the task with a defined start, middle and end, and the possibility to screen off parts of the surrounding environment are examples of such enhancements.

The youngest children may need a solution that helps keeping information, organizing and executing tasks with more than one step and exploring safely without an adult present. 6-year-olds could benefit of a solution that allows mistakes and where corrections easily can be made. The child is progressively by age able to maintain their attention for more extended periods, with an extended working memory and attention span, and are spending more, and longer, time doing homework. A more sedentary behavior causes higher ergonomic demands on the solution and natural breaks for movement is of importance.

Children's learning and development are enhanced by interaction with adults or friends. The solution should encourage this kind of interactions. A parent or friend should thus be able to sit by the child to promote learning, this is particularly important for the younger children.

Growing with the child is connected to:



6.4 The child in charge

The children should not only be in the center of the product development, they should also be an active part throughout each step of the development process. Their thoughts, needs, and experience should be met with humble respect and the strive for ethical symmetry. A solution with the child in charge reinforces the feeling of the solution as their own makes them more engaged and responsible. A solution that allows the child to contribute to the design and expression, not only consume, can give the child a place to express and develop a stronger sense of self and an emotional bond to the product.

The solution should encourage children's independence and learning by simple instructions for adjustments and easy access to their equipment and study material. Strengthen the design with haptic and visual elements. Symbols, colors, and textures can improve user experience and transfer information for different users. Make sure the adjustments are easily made, if the intention is that all the children should do them by themselves, and give feedback to the user when each setting is done.

However, children may not use the furniture as thought; let this be an opportunity for a variety of usage and positions. Children in certain ages are risk takers, and an important part of development is to explore the environment by balance and test limitations. The solution should endorse this and use the child’s driving forces to create a desirable behavior to the greatest extent possible. The full understanding of cause and effect is not developed until the twenties, and the design must protect the child from injuries, encourage healthily, and desired behavior and inhibit an acceptance for mistakes. Consequences of bad posture are hard for both adults and children to recognize, the solution must, therefore, protect the child from positions that are directly harmful.

Motoric distraction element, such as balance pallets or squeezers, could benefit focus for some children. Others prefer a static furniture, without any distracting objects. Reduce obstacles in the environment and create dedicated spots for vital equipment, such as smartphones, laptops, chargers, pencils, eraser, and paper. Drawers are one example where distracting objects can be stowed. The more obstacles that can be

removed the merrier. Most adjustments are helpful for the majority of children but could be crucial for children with certain difficulties.

By allowing different usages and settings, each child could find an environment that suits their need, screened off or open, dynamic or static, high or low. A majority of the children prefer a quiet study environment to keep focus. Reducing the number of impressions, such as sound, colors, noise, lights among other things could help many children keep focus. A solution that enables the child to screen off the surrounding environment, for example by reducing noise, visual elements and distracting objects, like smartphones or toys, could accordingly support their learning.

The child in charge is connected to:

7. CONCEPT DEVELOPMENT

This chapter describes the development of the final concept, from idea generation through concept elimination and refining into a final concept. By the end of the chapter, the main results from the concept evaluation are presented. The final concept represents a first iteration of how the design guidelines can be visualized.

7.1 Created ideas

The ideas considered different body positions when studying, from lying on a madras or floor to standing or sitting in a roof-hanging chair. Flexible solutions that could be changed to enable a variety of positions was investigated and different features to reduce stimuli and increase focus was also explored, among other things. Some of the mood boards and sketches, showed in Figure 7.1-7.6 and Appendix 9, made by the third-grade students were used as inspiration for the idea generation. Figure 7.7 shows some of the sketches made during the idea generation session.

Figure 7.1-7.6 A selection of the mood boards and sketches of a study solution made by third-grade students

7.2 Concept elimination

Some combined ideas with the desk integrated to the chair were investigated; however, the body position and the workspace were two major limitations for these ideas. Instead, three chair solutions and three desk solutions were chosen and evaluated by a modified Pugh matrix, presented in Table 7.1 and 7.2. The criteria were derived from the guidelines by selecting the aspects that could be evaluated at an early stage of the development. Each criterion was defined as mandatory or desirable, depending on its importance. Each concept is briefly described below, followed by the Pugh-matrix and its results.

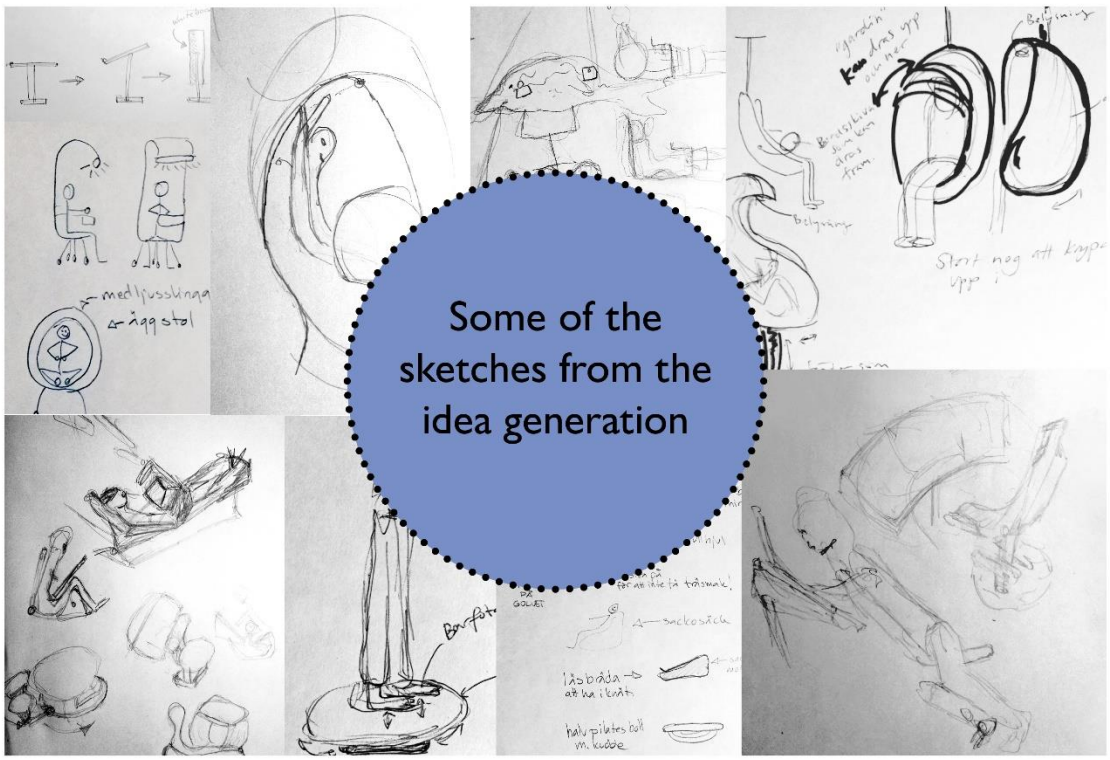


Figure 7.7 A selection of the generated ideas.

The Dynamic Pallet, Figure 7.8, were executed with dynamic movements in all directions, a soft padded seat that could be adjusted from seating- to standing height.

The Daydreamer Chair, Figure 7.9, had a wide seat, which enables the user to cuddle up and sit, as well as a more traditional seating position. *The daydreamer* was height adjustable to fit both the smallest and the biggest children. The vision screen was applied to give a feeling of coziness and reduce stimulus from the surrounding environment.

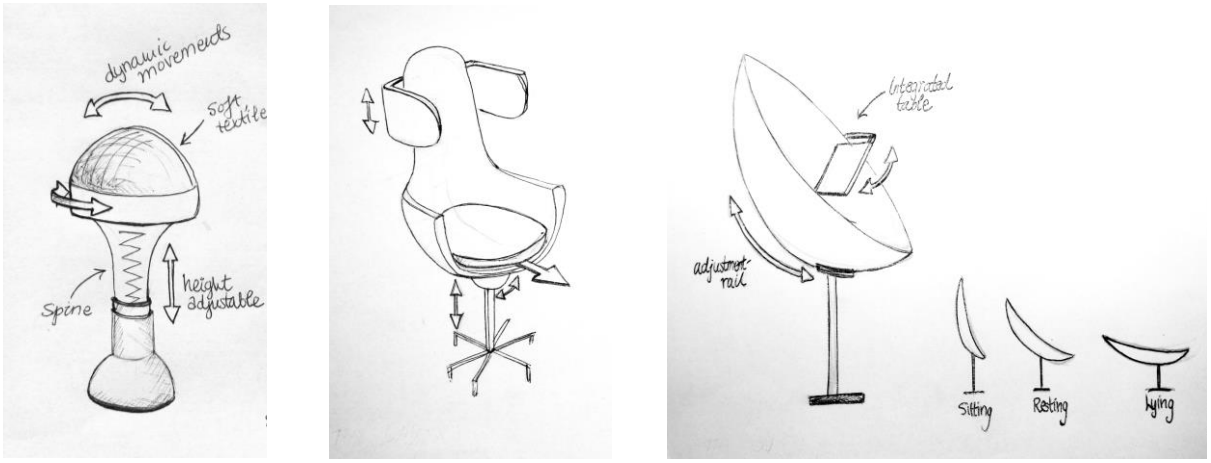


Figure 7.8-7.10 The three chair-solutions; The Dynamic Pallet, The Daydreamer Chair and The Moon

In Figure 7.10 is *The Moon* showed. The chair had a shape of a moon, inspired by one of the child's sketches (see Figure 7.4). The shell could be adjusted in different positions, from seated to entirely lying. To enable writing was a small, flexible tabletop added, that could be turned inwards, into the shell.

Table 7.1 Pugh matrix for concept elimination of chair solution

Chair solutions

CRITERIAS [Mandatory or Desirable]		The dynamic pallet	The daydreamer	The moon
Allow different body positions				
Standing	D	Yes	No	No
Sitting on chair	D	Yes	Yes	Yes
Lying	D	No	No	Yes
Lumbar and spine support	M	No	Yes	Yes
Adjustable in sizes	M	Yes	Yes	No
Reduce stimulus				
Vision	D	No	Yes	Yes
Sound	D	No	Yes	Yes
Motoric distraction	D	Yes	Yes	Yes
Easy to clean	D	No	No	No
Soft and comfortable	D	No	Yes	Yes
Compatible with a desk	M	Yes	Yes	Not fully
Can be used without desk	D	No	Yes	Yes
Suitable for small spaces	D	Yes	Yes	No
Past all mandatory criteria		No	**Yes**	No

The Tilt Desk, shown in Figure 7.11, had both a static and a tiltable part of the desktop to allow different work positions. Drawers were placed to the right, underneath the worktop. The height could be adjusted by an electric control in front of the desktop.

The Tinyscreen, Figure 7.12, was a small and movable desk with castors and tiltable worktop. A screen was placed on the sides and front of the desk, to reduce impressions from the surrounding.

The Blackboard, Figure 7.13, had a writable surface which could be tilted in upright to a flat position. The height could be adjusted from almost floor level up to a standing position to enable a variety of work positions.

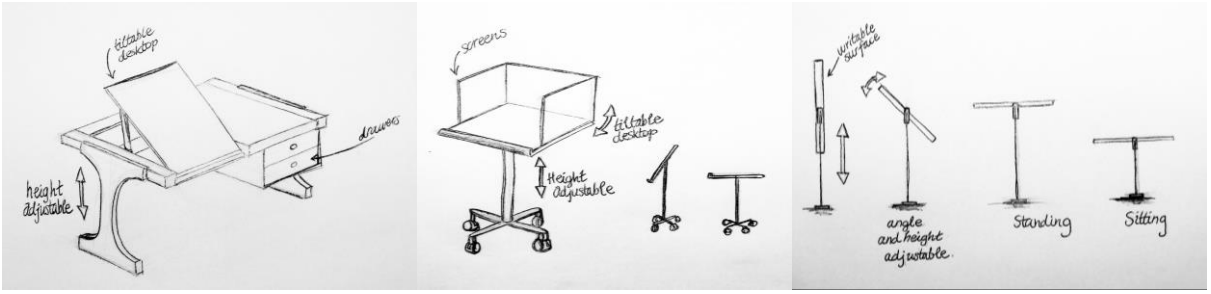


Figure 7.11-7.13 The three desk-solutions: The Tilt, The Tinyscreen and The Blackboard

Table 7.2 Pugh matrix for concept elimination of desk solution

		Desk solutions		
CRITERIAS		The Tilt	The Tinyscreen	The Blackboard
Allow different body positions				
Standing	M	Yes	Yes	Yes
Sitting on chair	M	Yes	Yes	Yes
Sitting on floor	D	No	No	Yes
Lying	D	No	No	Yes
Tiltable desktop	D	Yes	Yes	Yes
Adjustable in size (height)	M	Yes	Yes	Yes
Enough workspace (>600x600)	M	Yes	No	Yes
Reduce stimulus				
Vision	D	No	Yes	No
Sound	D	No	Yes	No
Motoric distraction	D	No	No	No
Easy to clean	D	No	Yes	No
Offer storage	D	Yes	No	No
Include solution for cables	D	Yes	No	No
Suitable for small spaces	D	No	Yes	Yes
Past all mandatory criteria		**Yes**	No	**Yes**
Number of YES		7	-	8
Number of No		7	-	6

Of the three chair concepts, one, *The Daydreamer*, passed all the mandatory criteria. This solution was therefore chosen for further development. Two of the desk solutions past the mandatory criterion, *The Blackboard*, and *The Tilt*, with almost the same number of desirable criteria each (8 and 7 met). The idea with eight criterions met, *The Blackboard* was more flexible, both in size and usage with a wide variety of settings for the desktop, the solution was therefore estimated to reflect the guidelines the best.

7.3 Final concept

The concept consisted of a desk and office-chair that can be used together but also separate. The concept should be seen as one, out of many, examples of how the guidelines can be transformed into a solution. The primary objective of the generated concept was to develop a solution that encourages different body positions (U4, U8, U12) and enhance a comfortable and correct posture (T7, T12, U13, U15), for all children within the age-range (T8, T16, T17, T19, U21, U22). The exact measurements and technical specifications are not set. However, approximate measurements were investigated to get a hint of proportions and the size of the furniture, which are presented in section 7.3.1 followed by a presentation of the desk and chair. The design recommendations that have been applied onto the concept are continuously presented in the text.

7.3.1 Approximated measurements for the study solution

The DINED anthropometric database was used (2018) to obtain the approximate anthropometric measurements and sizes. The applied method was derived from design recommendation T16, search for highest and lowest value in each population, and T19, use the popliteal height as prescription measurement. The percentiles were

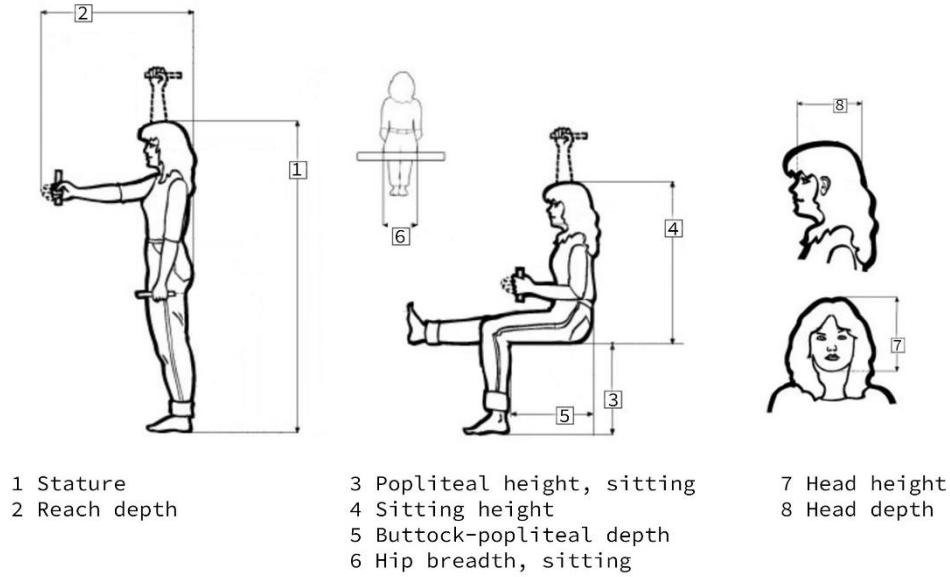


Figure 7.14 The used measurement from the Dined (2018) database

strictly set since the database did not included the extent of data that would be preferred according to T16. No account was taken regarding extreme-values for safety reasons (T17) and the project did not considered children with impairments (T18). The conclusions from this process are shown in table 7.3 and the body dimensioned considered are presented in Figure 7.14.

Table 7.3 - Approximate measurements of the desk and chair

Desk

Furniture measurement	Body dimension	Equation	Lowest value [mm]	Highest value [mm]	Approximate measurement on furniture
Desk height	1. Stature	No equation available	947	1932	1900 mm
Only the highest value was of interest since the desktop can be adjusted almost on floor-level. No available data for eye-height when standing, therefore, stature is used as a proximate measure. The maximum height of the desk is set to 1932 mm when positioned in about 15 degrees angle. The legs could be lower, about 1600 mm, since the fixating point is in the middle of the worktop.					
Desktop depth	2. Reach depth	No equation available	529	1372	650 mm
If the depth value is too high, the child would not be able to make adjustments on position and height for the desk by themselves (U5, U19, U23). This criterion needs to be weighted against the need of enough working space (U9).					
Desktop length	Not relevant	Not relevant	600	1200	820 mm
There should be enough space for a child to spread out their work and have a parent or friend on their side (U1, T6, U2). 600 mm is usually considered enough space for a person sitting by a table. The length of the desk impinges the total weight and complicates the adjustment of the desk.					

Chair

Furniture measurement	Body dimension	Equation	Lowest value [mm]	Highest value [mm]	Approximate measurement on furniture
Seat height	3. Popliteal height sitting	(PH+SC) cos30° (PH+SC) cos5°	231	523	Between 200 to 525 mm.
The seat height can be adjusted in every height between the maximum and minimum level. SC, shoe correction, is set to zero.					
Backrest height	4. Sitting height		532	929	929 mm
Only the highest value are of interest. The vision screen can be adjusted in height to fit the smaller children.					
Seat depth	5. Buttock-popliteal depth	0.8 BPL 0.95 BPL	240	578	Between 190 to 550 mm
To enable a correct sitting position for all users are the padded seating adjustable from 190 to 550 mm seat depth.					
Seat width	6. Hip breath sitting	Equations only applicable when armrest are used for support while sitting by a desk.	155	400	600

				The seat width should be enough to allow the user to creep up, into the chair, while reading or doing tasks where no desk is needed. The armrests are used as support and stabilization of spine and arms while sitting nestled. When sitting by the desk, the desktop constitutes the function of armrests, thus allow a wider seat width (Castellucci et al., 2015).
Vision screen height	7. Head height	155	247	200 mm at its widest point.
				The height should give a feeling of cosines and embrace without feeling clumsy or cutting off too much of the surrounding (U18, U24).
Vision screen length	8. Head depth	158	212	350 mm
				The vision screen needs to be long enough to screen off most of the side view, but jet short enough to enable the user to see sideward when bending forward a bit.

7.3.2 The desk

The desk has a quite simple shape with a desktop attached to two legs on each side via two support rails. The legs are designed with vertical tracks that enable adjustments in height and slope of the desktop (T12, U4, U8). The desktop can be set almost to floor level, up to a horizontal height of about 1600 mm from the floor, this enable both lying, sitting on floor, sitting on different chairs and standing position while working. The desktop can also be adjusted in three different angles; about 15° below horizontal level, about 45° and almost vertical with an approximate 80° slope. A writable and magnetic, blackboard surface is added to the front of the desktop. This can be used for making to-do-lists, practicing vocables or making notes or drawings to facilitate the homework. The desktop was chosen to make a design that involves the user and makes them feel in control of the expression and evolvement (U23) of the furniture and hence constitutes a furniture that grow with them (U22). The writable desktop also enables the child to write down instructions, checklists or other supportive information that improve learning and helps clarify the task (U25).

Figure 7.15 Sketch of the desk

To ease the usage for children with visual limitations, and clarify the edge of the desktop, it is framed with a light wood material, such as ash or birch. One example on how multimodal information are applied in the concept (T15).

When positioned in the 80° slope, the desktop can be used as a blackboard or presentation board, this enables problem solving together and presentations for parents or friends since the surface is visual from a wider field, one way to visualize design recommendation T6, encouraging interactions with others. All heights and slopes enable a variety of tasks as stated in design recommendation U1 with a neutral body position (T9). The upright position of the desktop does also make the desk more flexible in small spaces since the desk does not take up as much floorspace as when in the horizontal stage (U10). The edge on the bottom of the desk has a rounded, bulged edge to reduce the risk of things falling in the upright position. A small selection of equipment can also be placed by the edge, easily accessible (T10). Paper can be attached to the desktop by a magnet, to keep the right position.

Figure 7.16 Sketch showing angles and heights of the desktop

To stabilize the construction the legs are made of a black matte coated steel with a wide base. The material characteristics of steel also make the construction durable, as stated as an important aspect in design recommendation U7, especially the tracks are exposed for impulse forces while making adjustments in angle and height. The color pallet of the desk is matte and discrete to fit in different homes without distracting the child from the task (U28).

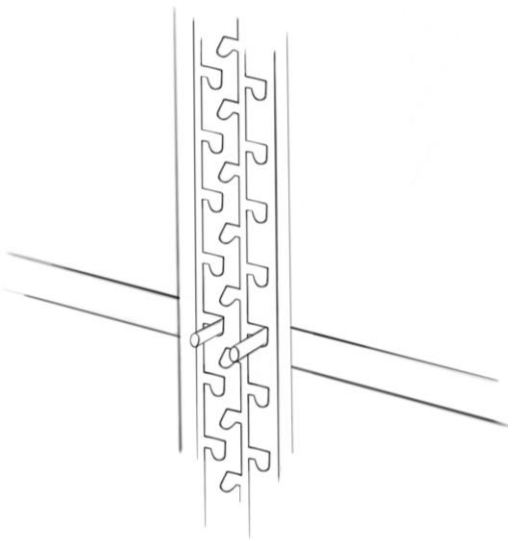


Figure 7.17 Sketch of the adjustments rails

7.3.3 The chair

The base of the chair is similar to a traditional office chair but with a wider seat that allow the user to crawl up, into the chair, while reading or doing tasks where no desk is needed. The bottom of the seat is padded and adjustable in depth to allow correct thigh support for all users. A spine-pad, with a soft convex shape, is adjustable by the high backrest for spinal support of the lumbar curve (T7). Both the spine pad and the seat are padded with cold-foam, a resilient polyurethane foam, for ventilation and some shaping after the body. Design recommendation U13 and U15 consider the

comfort of the chair, as a soft and cozy place, with high backrest and different paddings. U27 and T1 consider the inducement of positive emotions when seeing and using the study solution. The shape and function of the chair were created to envision these design recommendations by using a soft shape of the sitting shell, smooth edges, padded seat and a backrest and vision screen that surround the user. The wide seat could also enable different sitting positions, as stated in design recommendation U12.

A vision screen is applied at the end of the backrest, which also can be adjusted in height, in order to screen off some of the surrounding environment and distracting stimulus and enhance the embosomed feeling (U18, U24). The vision screen can also be used as support for the head and neck while the child is cuddled up in the chair. When the child wants to be able to look aside, for example when parents are helping or working with friends, the vision screen can be taken off (T6, U2). The armrests are used as support and stabilization of spine and arms while sitting nestled. When sitting by the desk, the desktop constitutes the function of armrests, thus allow a wider seat width.

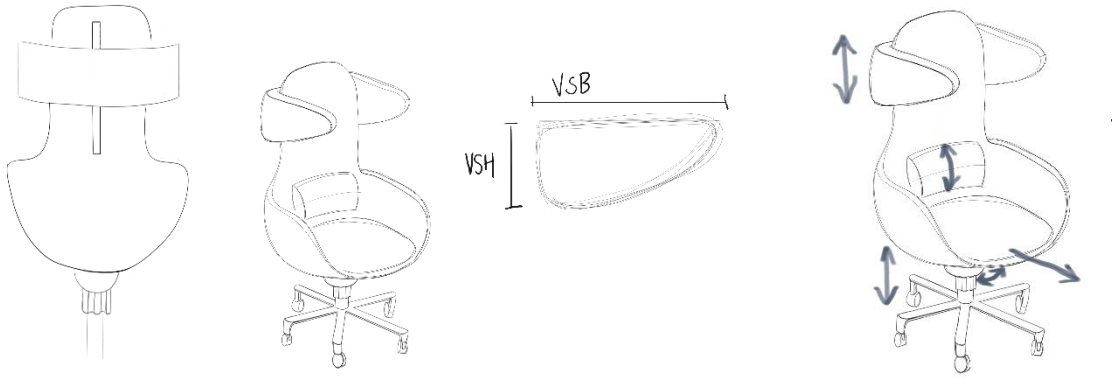


Figure 7.18 Sketches of the chair-solution, vision screen and the adjustments that can be done

The height of the chair can be changed by a lever mechanism underneath the seat shell, that are pulled up, like a traditional office chair. The seat height should be set so that the child can get fully support for their feet from the floor. A built-in spring creates small motions in each direction of the seat shell as a motoric distraction feature (U14). The resistance is set by a rotatable element in the bottom center of the seat shell, to adapt to different weights and preferences, fixated in a static position when fully applied. The user can choose whether they want casters, with a pressure-sensitive brake mechanism, or not on the chair. Without casters the chair is more stable and static as well as easier to get up and down on. The chair equipped with casters enable more flexible movements and increases the reach distances. The brake mechanism keeps the chair fixated while seated and releases when sitting in the chair (U11).

The seat shell is made of wood plastic composite, a mixture of 30 % wood and at least 55 % recycled plastic, the same material as is used for the dining chair Odger (IKEA, 2018b). A durable solution (U7, T1) that can grow with the child (U20) was considered important. The composite is speckled and smooth, with rounded edges and lines, which makes it easy to clean and persevered to scratches and long-term use. The vision screen, seat and spine pad are all covered in a removable rough fabric that can be taken off and machine washed.

7.4 Evaluation of concept

A first user evaluation was made to try some features of the concept. The evaluation included aspects from the executed interview with an educator specialized in children with special needs as well as user-studies with three children within the age-range. The educator specialized in children with special needs was evaluating the concepts by sketches and information given about the features while the evaluation with the children included two parts of evaluation with lo-fi prototypes, one visualizing the size of the desktop, and its approximate weight and one cardboard model of the vision screens followed by questions related to sketches of the concept. The adjustments and intuitiveness of the design could not fully be evaluated at this early stage, whiteout full-scale models and the right control devices. An evaluation was also made regarding which design recommendations the concept fulfilled or not, this is further discussed in section 8.2 and summarized in Appendix 15.

7.4.1 User evaluation with lo-fi prototypes

Soft and cozy, creative, calm and fun was expressions and emotions the children associated with the chair, which was in line with design recommendation U15, U27 and T1. The wide seat of the chair was perceived as inviting by both the children and the teacher. The teacher could see some children, who needs to distance from the surrounding environment, cuddle up, into the chair and make it their own space (U23). The vision screens on the chair was considered a good solution for reducing stimulus and improve concentration (U18, U24), although the option to remove them was essential to enable a parent or friend to sit on the side and help (U2, T6). One of the children did not like the vision screens at all, the other two thought they would enjoy and use them. One child enjoyed the vision screen since it also could be used while taking a break, resting against the vision screen.

Figure 7.19 The desktop size represented by a piece of plywood with a child trying to grip it.

The teacher suggested that the castors should be offered as add on to ease sitting down and standing up for children with motor impairments. Both the children and the

teacher advocated that the dynamic movements (U14) should have a switch off function to enable a static mode, the teacher could see some of the children benefit from such feature but none of the children preferred it compared to a static chair.

Figure 7.20 A prototype of the vision screen made of cardboard.

The desk gave an impression of being hard and dark, with interested and happy as associated emotions. The children considered the size of the desktop enough for doing homework (U9), but some preferred a larger space to enable more creative work (U1). None of the children had a problem to grip the desktop on each side and move it up- and downwards, the weight (2.8 kg) was also acceptable. Whether this is applicable even for the youngest children in the target group is not ensured and needs further evaluation. The children could see themselves doing a variety of tasks while using the desk (U1), such as having presentations for parents, painting and doing their homework by the desk.

The concept was considered inspiring and encouraging for different posture and body positions (T7, U4, U8, U12) by the flexibility in settings and height adjustments and both the children and the teacher could see potential in the concept (U20).

7.5 Sustainability aspects of the concept

A concept that extends the products life and enable usage during the shaping and defining years in the child's life was considered important since the main green-gas emissions of IKEA depend on the extraction of raw material and the product life of customers' homes (IKEA, 2018a) The changing needs and preferences during childhood require a flexible and durable solution that can grow with the child, and adapt to new behaviors and needs.

Figure 7.21 shows the Eco-design Strategy Wheel with eight categories related to the life-cycle of a product. The considerations that have been made related to these categories are presented and discussed below. A few aspects, such as production and distribution of the product are not addressed in this project.

Design for innovation involves among other things, building a flexibility for technological change, integration of multiple functions into one product and share among multiple users.

By not integrating any electrical features into the furniture, such as charger devices or lights, greater flexibility for technological change has been achieved. The desktop is big enough for computers and tablets, and the requirements of space are likely decreasing rather than increasing because more homework is done on laptops or other devices now than before. Both the chair and the desk enable multifunctional usage, the chair working as both an armchair and an office chair and the desk as a blackboard, easel and a traditional desk. The wide age range and easy size adjustments on the furniture enable siblings to share workplace if wanted, which is both space-, economic and resource efficient.

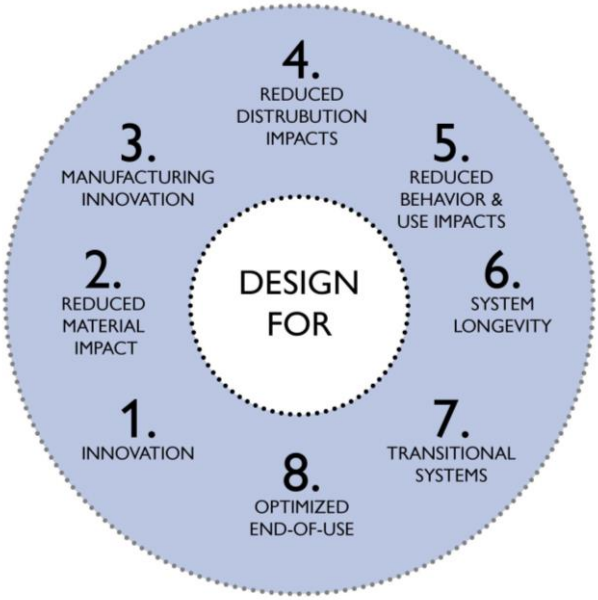


Figure 7.21 The EcoDesign Strategy Wheel that was used as a tool for generating a sustianable concept (Based on White, Pierre & Belletire, 2013)

The material suggestions are based on comfort, resource and durability demands. As much recycled and renewable materials as possible should be used, and as few different materials as possible to facilitate the assembly- and disassembly process. The project did not address production and distribution of the product. Both energy and material consumption are low during use since the adjustments are made by human power, and notes can be taken directly on the worktop if wanted, the solution does not consume any new energy during usage. To meet stage six, system longevity, the aim has been to create a timeless solution, with a matte and natural color palette and simple, clean shape for both the chair and the desk. One big concern was the durability of the desktop, by allowing and encouraging the user to write on the surface are marks no longer a problem. Another aim was to create an emotional bond between the user and the solution, which increases the products life (Chapman, 2010). By making a solution where the child is in charge, by being able to adjust and create the study environment required by themselves, is probably a stronger bond to the solution created. Any specified solutions for an upgrade of the product has not been made, but one feature could be changeable seat pads with different hardness and structure to further customization. When the product no longer can be reused each component should be recyclable or reused to greatest extent, and the disassembly should be easy to do.

8. DISCUSSION

The project aimed to investigate the ergonomic and emotional aspects of children's development and user needs for the development of study solutions for children at home. The project resulted in design guidelines and a conceptual solution reflecting these guidelines. In the following sections the fulfillment of this project is discussed, firstly by discussing the guidelines and their strengths and weaknesses followed by a discussion about the generated concept. Chapter eight finishes with a discussion about the methods and processes used in this project.

8.1 Discussion regarding the formulated guidelines

The project had a holistic approach exploring the physical, psychological and emotional aspects of children's learning and study place at home, which could be seen as both the strength and weakness of the project. By only constituting physical aspects, a significant part of children's needs when studying at home would be missed out. On the other hand, the extent of the project made it difficult to reach a theoretical saturation in each area.

The physical aspects consider children's physical development, biomechanics and reach zones, visual- and lighting demands on a workstation, the use of anthropometric measurement, equations for defining the size of a chair and desk and a theoretical description about trends in seating. The physical aspects are generally more clearly defined than the emotional and psychological aspects since more research is applied and translated into recommendations within this field. The anthropometric methodology and the equations for defining the sizes could be considered theoretically saturated since no extensive data was found during the literature search. However, the equations for dimensioning desk and chairs for children are based on school environments and school furniture. Similarities in tasks and biomechanical aspects resulted in the assessment that the results could be generalized and used in the context of a home as well. It should however be mentioned that, though, studying at home allows a freer manner that should be encouraged and may affect the design, for example by making a more flexible solution that could be adjusted into a larger variety of body positions without disrupting others.

Another distinction between the equations in a school- and home context is the height of the backrest. Castellucci et al. (2015) and Yanto et al. (2017) suggest a backrest right below the subscapular or in the limit of the subscapular line while Pheasant (2003) states that the backrest could be higher, supporting the neck. Chairs in school are usually equipped with lower backrests, as Castellucci et al. and Yanto et al. recommend, while traditional office chairs for adults often are equipped with high backrest supporting the neck. A high backrest supporting the neck gives extra support but may also limit the movement of arm and shoulders. However, spinal support seems to be the most crucial factor for posture, which is included in both cases, the exact height is secondary.

Another difference that could be seen was the benefits of dynamic chairs. Studies (Gregory, Dunk & Callaghan, 2006; O'Sullivan, O'Keeffe, O'Sullivan & Dankaerts, 2013) showed in some cases a minor increase of muscle activation and reduction of pelvic tilt. Le and Marras (2016), on the other hand, found dynamic seating to involve less muscle activation than regular chairs and concluded the phenomenon dynamic seating as not beneficial enough to override the reported increase of discomfort and safety risks associated with sitting on an unstable surface. The selling points used for dynamic sitting solutions in the benchmark could, therefore, be questioned.

Nevertheless, both teachers and children witness of increased focus while using balance pallets. From an ergonomic perspective, dynamic sitting solutions can be challenged, but there may be other beneficial aspects of children's learning that with limited duration and frequency may override these factors.

Furthermore, some limitations could be seen in available research on children. Parts of the results in the theory chapter, such as the biomechanics, lighting and visual recommendations, refer to adults with the assumption that it applies to children. Therefore, the recommendations should benefit from further investigations with the perspective of children to assure their generalizability.

The result is not generalizable as a result of the characteristics of a qualitative study that has been applied in the user study. The project has however reached some level of data saturation from the home visits with few new topics and aspects highlighted in the last interviews. Commonly aspects mentioned in all visits was the need for storage, a desktop that is big enough to fit the child's equipment and functional solutions for cables, lights, and devices. The families did not seem to reflect specifically about the ergonomic aspects of the furniture children used when studying. The families current solutions were often chosen because of practical reasons (the pallet could be stored under the desktop, the chairs were originally used as dining chairs) or comfort and style (a specific color, comfortable to sit in). When asked about what ergonomic aspects they would consider when buying new furniture most answers included already well-known technical specifications such as height adjustable desktop and chair, a well-dimensioned chair with backrest. Luchs, Scott-Swan, and Griffin (2016) highlight this risk of bias towards minor modifications to existing products during the discovery mode. More informative answers were gathered when questions were asked about their current solution, where the children could reflect and reason deeper about their thoughts. The children could also show specific features or aspects in a more freely manner than would have been possible if the interview did not take place at their homes. Another way to get new, not as 'biased', answers was by repeating what the participants said and ask almost the same question again which often resulted in a more extensive answer (e.g. the wish for a desktop-solution that could both be used lying on the floor, sitting and standing or a desktop with several layers that could be pulled off to make the surface new again). Other user needs had to be translated from the families, or teachers, description into relevant user insights (the creation of a solution that feels like mine, the need of a flexible solution that could be customized to remain attractive, aging with grace, etc.).

The families were all unanimous in the shifting needs by age but how these shifting needs could be manifested in the future could not be clearly defined. The questions were, therefore, more oriented on how the children's needs had changed from the past. Even this could be hard for some families since some of the participating children were 6 years old and did not have any homework jet.

Regardless of all the limitations mentioned above, four guidelines describing crucial aspects when developing furniture for children could be formulated. The guidelines are in several ways connected to existing principles and guidelines, both considering children's rights, usability, and universal design principles. Even though some of the recommendations need further exploration to be more clearly defined and thereby easier applicable, the guidelines could be considered building the first step to a useful framework for the development of study solutions for children. The aim of the study could, therefore, be considered achieved.

8.2 Considerations regarding the concept

The aim was to create a concept that reflects and visualizes the formulated guidelines. When evaluating which and how many of the design recommendations that the concept fulfilled 46 % was considered achieved at this stage, 29 % accomplished to some degree, 7 % needed further evaluation before their fulfillment could be assessed and 17 % of the design recommendations were not considered fulfilled. In Appendix 15 the full evaluation is presented and down below the results of this evaluation further discussed.

The aspects that were not fulfilled by the concept concerned storage (U6), lighting (U16, T13, T14), alternative ways to apply forces (T11) and, the consideration and use of extreme values (T17) and extended data for children with impairments (T18). Storage was a common requirement from the families. The final concept does not include any solution for storage or lighting, both two essential elements for a complete workstation for the child. Integrating storage into the desk would limit the flexibility and design by reducing the potential body positions and angles of the worktop. Some smaller storage could be added, for example by offering containers that can be attached to the racks on the legs, or in the upper side of the desktop or a side pocket for the chair. A movable drawer unit, big enough to fit papers and books, could as well be included in the concept to meet this user needs. The lighting was intentionally not covered as a boundary of the project.

How well the adjustments controls and settings on the concept match each user in the target group (U5, T2, T3, T5) was not possible to evaluate at this early stage. The children in the user evaluation were familiar with the adjustments of height on the chair, but one child highlighted difficulties to make these adjustments when you are light-weighted, an aspect that needs to be considered and evaluated before implementation. The children could easily move the panel (representing the desktop) up- and down during the test. However, the user evaluation involved children in the middle of the target group and the youngest children (5-year-old) may find it hard to make these adjustments. The concept needs further testing and evaluation by children of different ages and with different capabilities to ensure that the changes are easy to make without any risks of injury or high physical effort. Design recommendation U11

states “The features of the desk needs to outweigh the risks of the children playing or misuse them”. The rails in its current form could potentially constitute a risk for pinching, which may be a safety risk during usage that needs to be further evaluated before U11 can be considered fulfilled. There is a delicate balance between the encouragement for the child to use the furniture themselves, try them out, stretch limits and still not get hurt and whether the current concept, especially the desk, stands on the right side of these line needs further testing before it can be stated. It is particularly complex since there are significant differences between the youngest children and the oldest, not only are there bodies different the older have also major cognitive advantages that make their ability to understand several-step instructions, keep information and understand cause and effect more refined. Design recommendation T2, T3, and T5 consider these changes and encourages the developer to examine and use these differences to attract all children in the age range, which can be made in a variety of ways. *The Blackboard* desktop which could be adjusted both in height and slope was one way to create a flexible solution that could attract and enhance learning for both the youngest and the oldest children. However, further evaluation is needed to find out whether these features were achieving these design recommendations or not.

Another user-need that not was fully met by this concept was a solution for cables and devices. Since the desk is flexible, and its purpose is to be able to put the desktop in an upright position while it is not used, a permanent solution for the cables would probably obstruct this flexibility. A possible solution for those who are going to use the desk as more static furniture would be to add two, or more, holes at the back of the desktop and a cable management net underneath the desktop, where charger cables can be drawn through and placed. For the same reason the adjustments were done manually, not electrically, since the desk should be usable both in the middle of the room as well as stationary by a wall without the need of socket. The mobility of the desk would be improved by adding casters, but it may impact the stability and increase the risk of tipping, which was assessed to overrule the mobility factor. These two factors may be an obstacle for children with strength impairments or the youngest children in the age range.

One struggle was to decide whether the chair should be equipped with a dynamic element or not. As mentioned above, did not the studies from the theory chapter show any advantages of that kind of features, rather the opposite, often because of the lack of backrest on dynamic chairs. However, many of the children from the school visits preferred the balance stools over traditional chairs, and the teachers described positive changes in focus for many children when using the balance stools. Other children did not at all like that kind of feature. The user evaluation showed that the dynamic movement feature was considered less crucial for the design compared to the other elements. The technology in Swoppster, see Benchmark analysis in Chapter 3, was interesting, especially the option to adjust the resistance in the movements depending on the child’s weight and preferences. A significant difference between the

developed chair and Swoppster is the big seat shell and backrest that adds mass, as well as the wide age range for this project. There may be limitations in the technology used for Swoppster to achieve the same, or broader, spectrum of resistance that is required to meet the differentiated user needs. Adding extra features of the chair also impact the functionality and complexity of the product, at the end affecting the price.

The concept does not only reflect the guidelines, though it also stretches the view of how a study solution for children could look like. The chair can be used as a cozy place for reading as well as a more traditional office chair, and the desk can be used lying on the floor, sitting, or standing. The flexibility within the concept triggers the creativity and enables the child to use the furniture in a way that they prefer and that enhance their learning (U21), which also increases the chance that the child creates an emotional bond to the product (T1), take good care of it and associates it with positive emotions (U20).

8.3 Discussion about method and process

The project started with a benchmark analysis to understand the current market. The PNI-analysis gives the initial thoughts of a concept, but it is not validated through research or other theoretical ground than the executor's own knowledge (Österlin, 2010). This may result in incorrect implications that, in the worst case, can affect the outcome of the project. The extension of the literature study has probably depreciated the majority of these false assumptions, for example by involving research about dynamic- and kneeling chairs. The benchmark analysis has primarily been used as inspiration and as a tool to understand the current market without consciously influence the guidelines.

As mentioned in section 8.1, because of the broad scope, neither a systematic review of ergonomic guidelines nor a theoretical saturation of data could be achieved. The project should rather be seen as an introduction to the ergonomic considerations that need to be made when developing study solutions for children than a complete guide. Some areas need further evaluation and research before they can be fully implemented, such as how furniture can induce positive emotions at a child or how the furniture encourage children's development in each stage of their life without excluding others. The project may have benefited from a more defined scope, and the limitations mentioned above may have been reduced. However, this would have resulted in guidelines and a solution only considering a minor part of the areas involved in children's learning.

Part of the data collection was made parallel to the user-study which enabled new directions even later in the research. On the other hand, the user study could not add and deepen the knowledge on areas where the research was inadequate since these lacks were not known. This iterative approach where data collection and data

synthesis are done collaterally is however advocated by the design thinking methodology (Luchs, Scott-Swan & Griffin, 2016).

The user-studies have been executed in schools and homes in the Gothenburg region. Home visits have been made at families with children of different ages and genders. Nonetheless the result can not reflect all children in the defined target group, that would require a larger sample and a more qualitative, measurable and systematic, selection and execution of the project. These aspects need to be considered when the results are interpreted and applied.

The participating teachers, parents, and children have all contributed to different perspectives. One of the priorities has been to include the children, into the process, and explore their thoughts about their study environments and needs when doing homework. Children have contributed both in the user-study phase (also defined as discover mode), the idea generation and in the early evaluation of the concept. This is both in line with the D4CR principles (Designing for Children's Rights Association, 2018) as well as a reflection of an UCD-approach (ISO 9241-210, 2018a).

Both parents and the children may need more time than a one-hour interview or workshop in order to reflect on the issues addressed in this project, especially if they have not discussed them earlier. The chance to create a more ethical symmetry (Johnsson and Karlsson, 2013) may also be improved if the user insights were gathered from more than one meeting. Solutions for the school environment may not be applicable in the home context, and the teacher's perspective is highly influenced by their experiences in the classroom. On the other hand, some valuable insights may have been missed if teachers were not included in the project. During the interviews, it was clear that the teachers have reflected on how the environment should be arranged to encourage learning. The teachers shared their experiences of improvements (e.g., different options in sitting solutions, the opportunity to screen off the surrounding environment, structure the lecture) and failures (targeted adjustments for individuals, distracting elements in the environment, etc.) that could be used in the project.

Some consensus could be seen, particularly in the interviews with the families (the need for a big workspace, storage, a place as the child's own, etc.). The teachers, on the other hand, represented different pedagogical orientations which made some of their thoughts and approaches different (i.e., their view on how the children should be seated, how lecture was held, and how learning could be encouraged). A common input, the pedagogical orientations aside, was their view on how adjustments for children with different needs should be executed (inclusive and if possible available for all children) and their thoughts about stimulus and the benefits of reducing them (such as noise, movements, phones, etc.). The use of different pedagogical orientations broadened the view on learning and added perspectives but made the

data saturation more difficult. Additional school visits would be necessary to achieve that.

The workshop gave some information about how the children wanted their study environment to be and their preferred expression and style of study furniture, especially the questionnaire were considered informative. The more creative part with sketches and mood boards, on the other hand, were hard to interpret and analyze afterwards, without the children present. The possibility to ask questions and understand their thoughts during the workshop was limited since they needed support and directions all along. The difficulties could be overruled by being two or more instructors, having a smaller group or create time afterward for interviews.

To enable different perspectives and the benefits of sharing ideas the idea generation session was made with other participants. The idea generation and concept development would, however, benefit from further iterations. The ideas and the final concept chosen could have been different if the idea generation phase was executed in additional steps and may have fulfilled a more considerable extent of design recommendations. The final concept presented in this project is the first stage of visualizing the created design guidelines. However, the concept needs further development to assure the fulfillment of some of the guidelines that could not be evaluated at such an early stage. Nonethelss a majority of the defined design recommendations was met, and the concept has therefore fulfilled its purpose.

9. CONCLUSIONS

In this chapter are the main conclusions drawn from this project presented, its applications and areas for further research.

9.1 Conclusions

The purpose of the current project was to formulate guidelines for study solutions for the home environment with the target group defined as children between 5 and 14 years of age. Furthermore, the aim was to create one concept solution reflecting these guidelines. The project resulted in four design guidelines that constitute recommendations based on the literature and user-study. The guidelines followed by their connection to conventional design principles that have been used in this project are summarized in Table 9.1.

Table 9.1

DESIGN GUIDELINES			
Facilitate everyday life	Strive for a healthy workplace	Growing with the child	The child in charge
Flexible in size with an adequate desktop-size (about 600x800mm) Support a variety of tasks Proper storage for paper, books, pens and other equipment Make the equipment reachable and easy to access Durable material, especially the desktop is subjected for a lot of wear Compatible with digital devices and hidden cable-solution Compatible with smart-lighting	Associated with positive emotions Coherent in usability Safety in handling and use Offer and encourage flexible body positions by for example flexible height and angle of desktop Postural support, especially spinal support is of importance Matching sizes of desk- and chair and right anthropometric measurement used with sizes for all ages Proper lighting Testing before implementing	Empower the child's development at each stage. Make the child feel competent and challenged to encourage development and support executive functions Be and remain attractive throughout the child's development. Make the solution able to customize Support interaction with adults and friends	Make the child an active part of the development and use of the solution by familiar and simple instructions Enhance the feeling of the solution as "my own place" The usage may not be as intended, make it safe Support learning by reducing distracting stimulus and impressions Customize features to match individuals. Such as motoric distraction, different padding, colors, usage. Help the child get started and organize their work
DESIGNING FOR CHILDREN' RIGHTS: D4CR-principles			

Space for play and chill	Safe and proactive	Everyone can use Explore and support growth Active and play with others	Influence matter Communication I can relate to Include me
Not covering	Do not misuse data, Understand and recognize commercial activities		
UNIVERSAL DESIGN PRINCIPLES AND ITS GOALS			
Size and space for approach and use	Simple and intuitive Tolerance for error Low physical effort Body fit Comfort Wellness	Equitable use Flexibility Accommodate a wide range of body sizes and abilities Personalization	Perceptible information Awareness Understanding
Not covering	Social integration, Cultural appropriacies		
USABILITY			
Appropriate transfer of technology	Consistency Compatibility Error prevention and recovery Explicitness Feedback	Consideration of user-resources	User-control Visual clarify Prioritization of functionality and information

How are these guidelines meant to be used? The scope of this project was limited in terms of the width of the research question and its differences in the level of abstraction. The physical ergonomic requirements of a workplace seem to be further and more broadly explored than the emotional and psychological aspects. This means that the physical aspects express itself more clearly and often easier to measure and therefore less abstract than some of the emotional and psychological aspects of ergonomics. Less clearly defined design implications have been found for the

emotional and psychological aspects of this project. Therefore, the application of these recommendations is a field for further research.

Notwithstanding these limitations, some conclusions regarding the guideline's usefulness can be stated. The majority of the guidelines can be used as a tool during the creation mode, referring to the Design-thinking model (Luchs, Scott-Swan & Griffin, 2016), such as recommendations considering physical aspects (e.g., proper lighting, flexible body positions, storage, sizes). Other recommendations should be considered during the creation mode, but also be used as aspects to investigate during the evaluation mode, such as the child's impression and emotions related to the solution, usability- and safety aspects and the solutions impact on children's learning in each stage of their development. Lastly, some of the guidelines require further iterations in the identifying phase, to achieve a theoretical saturation and be more clearly defined.

Children's study environment is of great importance for their learning and development, which can be supported and empowered by ergonomic furniture that fits their needs. This project has highlighted some of the physical, psychological and emotional aspects that need to be considered when developing study solutions for children between 5-14 years of age. Nonetheless further research and investigation within this area is needed.

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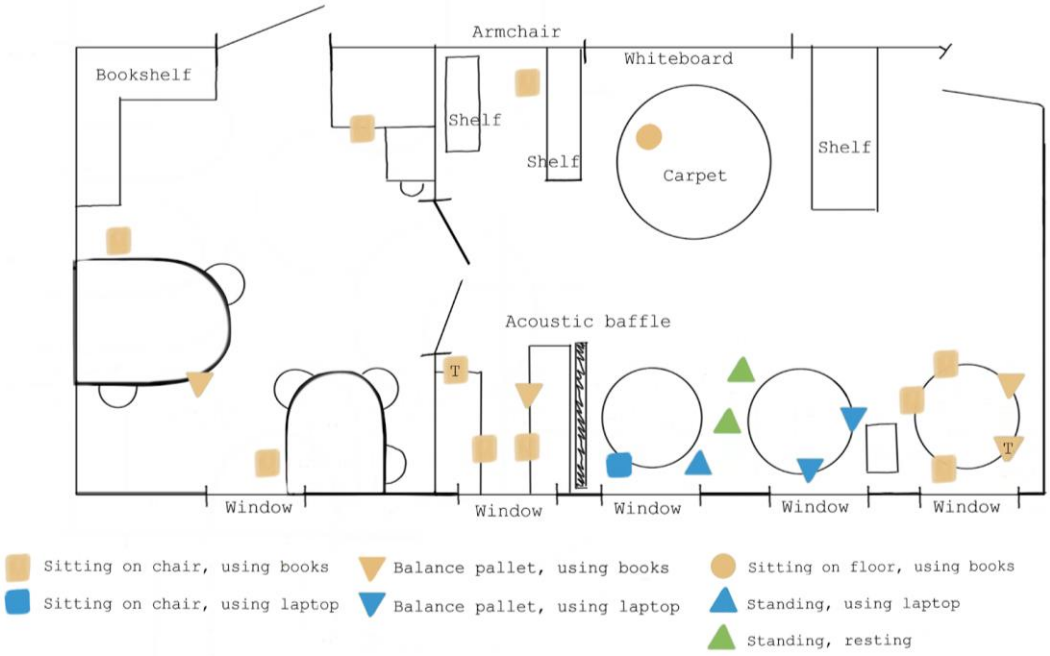
Appendix 1 - Observation Guide and Summary School Visit 1.1

OBSERVATIONSGUDIE SKOLBESÖK
Ta med: måttband

Skola	Skolbesök 1, klass 1		
Årskurs	3-5		
Tidpunkt för observation	8.57-10.07		
Varaktighet	ca 1h		
Miljön i allmänhet	Anteckningar		
Hur är miljön utformad?	Ta bild på bänkar, stolar, hela miljön, om det finns en särskilt studieplats		
Hur är miljön utformad? (skissa)	Hur är bänkar/bord placerade? Lägg till anteckning som beskriver vad de gör på respektive station		
Stol	Ja	Nej	Hur?
Är stolen anpassningsbar?		X	2 typer av stolar, 1 balanspall
Klarar barnet att göra detta själv?	-	-	Kan enkelt flytta stolar/pallar själva men ej justerbar i övrigt
Storlek på stol Ange även mått i mm	Ja	Nej	Observation av 10 barn i rummet. Ange antal som uppfyller uppsatt kriterium och ej.
Sitshöjd Kan barnet stödja fötterna i marken/mot fotstöd?	4 3	 2	Pall Stol
Totalhöjd När nackstödet till nedre delen av skulderbladen eller högre?	3		Endast aktuellt för stol, gränsfall för många
Sitsbredd Ryms hela barnets rumpa och lår på stolssitsen?	4 3		Stol Pall
Sitsdjup Kan barnet sitta med fötterna i marken och nå ryggstödet utan att sitsen trycker i knävecket?	2	2	
Bänk/Bord	Ja	Nej	Hur?
Är bänken/bordet anpassningsbart?		X	Kan välja att sitta vid olika stationer med olika höjder på borden
Hög- och sänkbart		X	
Vinkel på arbetsyta		X	
Klarar barnet att göra detta själv?	-	-	-
Storlek på bänk/bord Ange även mått i [mm]	Ja	Nej	Observation av 10 barn i rummet. Ange antal som uppfyller uppsatt kriterium och ej.
Arbetsyta Får alla barnens arbetsinstrument plats?			Ja, alla kunde välja plats så deras material får plats. Många valde att sitta på mattan/golvet vid arbete med stort material

Höjd Möjliggör höjden att barnet kan vila underarmar på bordet samt hålla korrekt position på ryggen?	-	-	
	Mått i [mm]		
Längd	-		
Djup	-		
Har bänken/bordet ytterligare funktioner? (ex. Krok, förvaring, stöd, eluttag)	Ja	Nej	Vad finns?
		X	
Färgsättning	Färg		Vart finns färgerna?
Vilken är den dominerande färgen i rummet?	Vit		Väggar, ljusa golv
Vilka andra färger finns?	Ljust trä, blå		Hurtsama för respektive elev är blå, tråtfärgade hyllor, idmaterialen bidrar med färg, övrigt neutralt
Belysning	Ja	Nej	Beskrivning
Arbetsbelysning		X	
Är arbetsbelysningen riktbar?		X	
Är arbetsbelysningens styrka reglerbar? Hur?		X	
"huvudbelysning"	X		Mycket belysning i taket
Ytterligare belysning	X		Ljuslyktor, tänder vid ex. lunch
Ljudnivå Finns ljudreducerande element på följande ställen:			
stol		X	
bänk/bord		X	
Väggar/tak		X	
Övriga studieplatser	Ja	Nej	Hur är de utformade? (bild, besvara frågor ovan på separat blad)
Finns övriga studieplatser i klassrummet?	X		Hela klassrummet är uppbyggt med olika stationer och lösningar för att möta olika behov. Fotäljer, bord med stolar/pallar. Matta att sitta på osv.
Generella reflektioner	Anteckningar		
Övrigt	Några av de elever som sitter på mattan föredrar detta för att de enkelt kan växla position och "sträcka" när de sitter på stol upplever de det mer statiskt. Sitter oftast på golv när de jobbar med papper och böcker. När de jobbar med dator sitter de vid databord eller vid bord och stol. Två elever har hörselskåpor på sig under arbetet under tiden jag är där, för att skärma av ljud Två elever sitter i ett hörn med uppsikt över hela rummet. Gillar att sitta lite trångt, det är "tomt" och "mörkt" "mysigt som en katt att sitta trångt". Har datapport för att få upp datorn från golvet (får ej ha den direkt mot golvet pga. ventilation (datorn blir för varm). Databordet är lite väl litet, de rymmer inga böcker utan endast datorn.		

Appendix 2 - Observation Guide and Summary School Visit 1.2

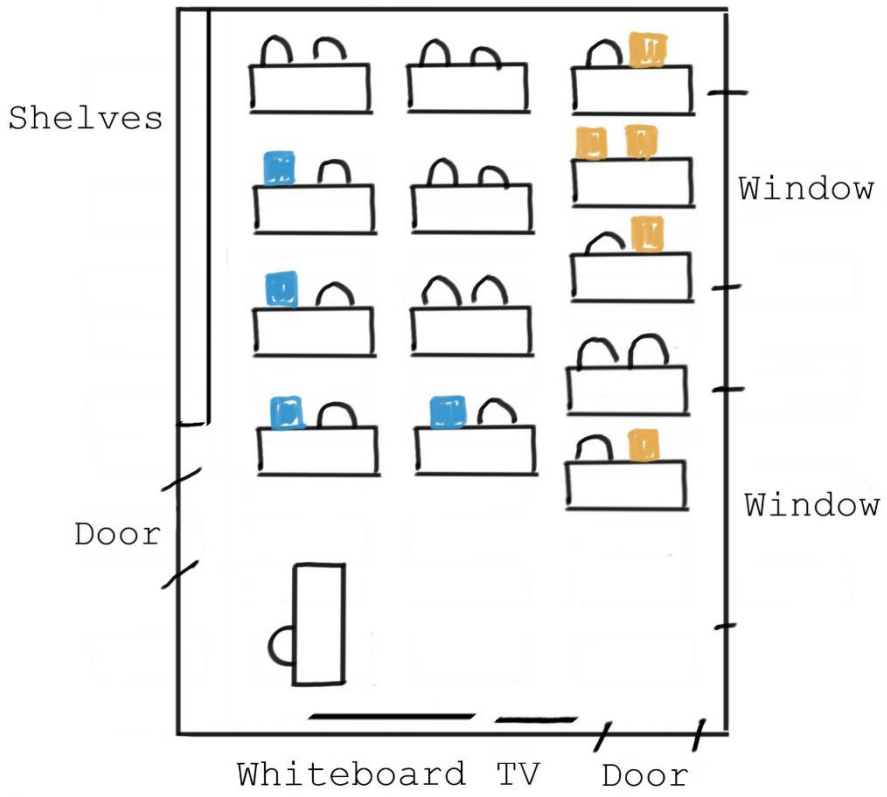


Ta med: måttband

Skola	Skolbesök 1, klass 2		
Årskurs	3-5		
Tidpunkt för observation	10.17-10.30		
Varaktighet	ca 15 min		
Miljön i allmänhet	Anteckningar		
Hur är miljön utformad?	Ta bild på bänkar, stolar, hela miljön, om det finns en särskilt studieplats		
Hur är miljön utformad? (skissa)	Hur är bänkar/bord placerade? Lägg till anteckning som beskriver vad de gör på respektive station		
Stol	Ja	Nej	Hur?
Är stolen anpassningsbar?		X	Samma typ av möbler som i första klassrummet
Klarar barnet att göra detta själv?	-	-	Kan enkelt flytta stolar/pallar själva men ej justerbar i övrigt
Storlek på stol Ange även mått i mm	Ja	Nej	Observation av 10 barn i rummet. Ange antal som uppfyller uppsatt kriterium och ej.
Sitthöjd Kan barnet sitta med fötterna i markeringen?			
Tolvhöjd När mellanlåret till nedre delen av studieriksten eller högre?			
Sitsbredd Fyrna hela barnets rumpa och lår på sittbredden?			
Sitsdjup Kan barnet sitta med fötterna i markeringen och nå ryggstödet utan att sitsen trycker i knävecken?			
Bänk/Bord	Ja	Nej	Hur?
Är bänken/bordet anpassningsbart?		X	Kan välja att sitta vid olika stationer med olika höjder på borden
Höjd och sänkbart		X	
Vinkel på arbetsyta		X	
Klarar barnet att göra detta själv?	-	-	-
Storlek på bänk/bord Ange även mått i [mm]	Ja	Nej	Observation av 10 barn i rummet. Ange antal som uppfyller uppsatt kriterium och ej.
Arbetsyta Får alla barnens arbetsinstrument plats?			Ja, alla kunde välja plats så deras material får plats. Många valde att sitta på mattan/golvet vid arbete med stort material

Höjd Möjliggör höjden att barnet kan vila underarmar på bordet samt hålla korrekt position på ryggen?	-	-	
	Mått i [mm]		
Längd	-		
Djup	-		
Har bänken/bordet ytterligare funktioner? (ex. krok, förvaring, stöd, eluttag)	Ja	Nej	Vad finns?
		X	
Färgsättning	Färg		Vart finns färgerna? På samma sätt som i klassrum 1
Vilken är den dominerande färgen i rummet?	Vit		Väggar, ljusa golv
Vilka andra färger finns?	Ljust trä, blå		Hurtsama för respektive elev är blå, träfärgade hyllor, lärmaterialen bidrar med färg, övrigt neutralt
Belysning	Ja	Nej	Beskrivning
Arbetsbelysning		X	
Är arbetsbelysningen riktbar?		X	
Är arbetsbelysningarna styrka reglerbar? Hur?		X	
"huvudbelysning"	X		Mycket belysning i taket
Ytterligare belysning	X		Ljuslyktor, tänder vid ex. lunch
Ljudnivå Finns ljudreducerande element på följande ställen:			
stol		X	
bänk/bord		X	
Väggar/tak		X	
Övriga studieplatser	Ja	Nej	Hur är de utformade? (bild, besvara frågor ovan på separat blad)
Finns övriga studieplatser i klassrummet?	X		Hela klassrummet är uppbyggt med olika stationer och lösningar för att möta olika behov. Fotöljer, bord med stolar/pallar. Matta att sitta på osv.
Generella reflektioner	Anteckningar		
Övrigt	Även i detta klassrum finns ett inre något mindre rum där vissa elever kan dra sig undan. En elev väljer att sitta där för att enklare kunna koncentrera sig. Det är betydligt lugnare där inne jämfört med i det stora klassrummet		

Appendix 3 - Observation Guide and Summary School Visit 2



OBSERVATIONSGUDIE SKOLBESÖK
Ta med: måttband

Skola	Skolbesök 2		
Årskurs	7 + 9		
Tidpunkt för observation	8.20-9.20		
Varaktighet	1 h		
Miljön i allmänhet	Anteckningar		
Hur är miljön utformad?	Ta bild på bänkar, stolar, hela miljön, om det finns en särskilt studieplats		
Hur är miljön utformad? (skissa)	Hur är bänkar/bord placerade? Lägg till anteckning som beskriver vad de gör på respektive station		
Stol	Ja	Nej	Hur?
Är stolen anpassningsbar?	X		
Klarar barnet att göra detta själv?	X		
Storlek på stol Ange även mått i mm	Ja	Nej	Observation av 10 barn i rummet. Ange antal som uppfyller uppsatt kriterium och ej. Endast 6 stycken satt hela lektionen.
Sitthöjd Kan barnet sticka fötterna i marken/mot golvet?	6		Mot golv samt mot fotstöd
Totalhöjd När ryggstödet till nedre delen av skulderbladen eller högre?	5	1	För långt ned
Sitsbredd Rymma hela barnets rumpa och lår på sittbenen?	6		
Sitsdjup Kan barnet sitta med fötterna i marken och nå ryggstödet utan att sitsen trycker i knävecket?	3		Vissa elever satt ej som "avsett" på stolen vilket gjorde att detta inte inte kunde avgöras
Bänk/Bord	Ja	Nej	Hur?
Är bänken/bordet anpassningsbart?		X	
Hög- och sänkbart		X	
Vinkel på arbetsyta		X	
Klarar barnet att göra detta själv?	-	-	-
Storlek på bänk/bord Ange även mått i [mm]	Ja	Nej	Observation av 10 barn i rummet. Ange antal som uppfyller uppsatt kriterium och ej.
Arbetsyta För alla barnens arbetsinstrument plats?	6		Flera satt vid ett bord avsett för två personer

Höjd Möjliggör höjden att barnet kan vila underarmar på bordet samt hålla korrekt position på ryggen?	-	-	
	Mått i [mm]		
Längd	-		
Djup	-		
Har bänken/bordet ytterligare funktioner? (ex. Krok, förvaring, stöd, eluttag)	Ja	Nej	Vad finns?
		X	
Färgsättning	Färg		Vart finns färgerna?
Vilken är den dominerande färgen i rummet?	Vit		Väggar
Vilka andra färger finns?	Ljust trä		Bänkar, hyllor
Belysning	Ja	Nej	Beskrivning
Arbetsbelysning		X	
Är arbetsbelysningen riktbar?	-	-	
Är arbetsbelysningens styrka reglerbar? Hur?	-	-	
"huvudbelysning"	X		
Ytterligare belysning		X	Punktbelysning vid tavlan
Ljudnivå Finns ljudreducerande element på följande ställen:			
Mot		X	
Bänk/bord		X	
Väggerfekt	X		Väggplattor i tak som dämpar ljud
Övriga studieplatser	Ja	Nej	Hur är de utformade? (bild, besvara frågor ovan på separat blad)
Finns övriga studieplatser i klassrummet?		X	
Generella reflektioner	Anteckningar		
Övrigt	Många elever vill sitta och stödja mot två stolar, sitter rätt nedhasade.		

Appendix 4 - Questionnaire workshop

1. Jag vill helst göra mina läxor (ringa in den bild som stämmer bäst)

1. Liggandes på mage *2. Liggandes på rygg* *3. Sittandes på golvet* *4. Sittandes på stol eller annat* *5. Stående*

2. När jag gör mina läxor hemma vill jag känna mig (Ringa in den eller de känslor du vill ha)

Intresserad	Arg	Glad	Motvillig	Förvånad	Harmonisk
Skamsen	Snabb	Stressad	Skyldig	Ledsen	Accepterande
Inspirerad	Lugn	Fokuserad	Fundersam	Oinspirerad	Långsam
Snabbtänkt	Smart	Rolig	Pigg	Trygg	Kreativ

Om du inte hittar den känsla du vill känna kan du skriva den känslan här istället

_____

3. När jag gör mina läxor vill jag vara... (Ringa in 1 alternativ)

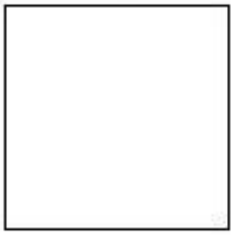
Själv Med en kompis Med en förälder Med ett syskon

Eller med någon annan, vem i så fall? _____

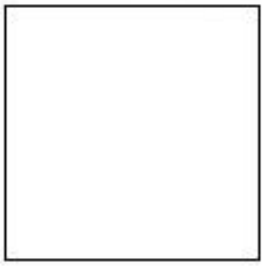
4. Såhär vill jag att det ska vara där jag gör mitt skolarbete (ringa in de ord som stämmer in på hur du vill ha det)

Mörkt	Varmt	Tyst	Mjukt	Mysigt	Ordning
Ljust	Kallt	Livat	Hårt	Omysigt	Stökigt

5. Möbeln skulle ha denna färg



6. Möbeln skulle vara tillverkad i detta material



Appendix 5 - Summary answers questionnaire

ÅK 3		totalt 20 svar			
Kroppsposition					
Liggandes på mage	Liggandes på rygg	Sittandes på golvet	**Sittandes på stol eller annat**	Stående	
9	0	2	**10**	0	
Känslor					
Intresserad	Arg	**Glad**	Motvillig	Förvånad	Harmonisk
6	1	**11**	4	5	6
Skamsen	**Snabb**	Stressad	Skyldig	Ledsen	Accepterande
1	**12**	3	2	1	3
Inspirerad	**Lugn**	**Fokuserad**	Fundersam	Oinspirerad	Långsam
3	**10**	**12**	3	4	5
Snabbtänkt	**Smart**	Rolig	Pigg	Trygg	Kreativ
7	**12**	4	9	6	6
Frisvar:					
Tråkig	Rastlös				
1	1				
Hur					
Själv	Med en kompis	Med en förälder	Med ett syskon	Farmor	Husdjur
5	**7**	8	3	1	1
Rummet					
Mörkt	Varmt	**Tyst**	**Mjukt**	**Mysigt**	Ordning
3	9	**13**	**11**	**14**	8
Ljust	Kallt	Livat	Hårt	Omysigt	Stökigt
10	4	2	2	1	4
Färg					
Guld	Blå	Grön	Lila	Limegrön	Brun
2	5	4	4	1	3
Orange	Vit	Svart	Rosa		
1	2	1	4		
Material					
Gummi	Vaxduk	Stål	Rotting	**Marmor**	**Trä**
4	1	2	1	**7**	**5**
Skumgummi	**Tunn textil**	**Glas**	Hårdplast	Betong	
6	**4**	**4**	1	1	

ÅK9		totalt 5 svar			
Kroppsposition					
Liggandes på mage	Liggandes på rygg	Sittandes på golvet	**Sittandes på stol eller annat**	Stående	
0	0	0	**5**	0	
Känslor					
Intresserad	Arg	Glad	Motvillig	Förvånad	Harmonisk
4	0	2	0	0	2
Skamsen	Snabb	Stressad	Skyldig	Ledsen	Accepterande
0	0	0	0	0	0
Inspirerad	**Lugn**	**Fokuserad**	Fundersam	Oinspirerad	Långsam
2	**3**	**3**	0	0	0
Snabbtänkt	Smart	Rolig	Pigg	Trygg	**Kreativ**
2	1	0	2	0	**3**
Frisvar: Motiverad					
Tråkig	Rastlös				

Hur					
Själv	Med en kompis	Med en förälder	Med ett syskon	Farmor	Husdjur
5	0	0	0	0	0
Rummet					
Mörkt	**Varmt**	**Tyst**	Mjukt	**Mysigt**	**Ordning**
0	**4**	**3**	0	**3**	**4**
Ljust	Kallt	Livat	Hårt	Omysigt	Stökigt
3	0	0	0	0	0

ÅK3+9					
Kroppsposition					
Liggandes på mage	Liggandes på rygg	Sittandes på golvet	**Sittandes på stol eller annat**	Stående	
9	0	2	**10**	0	
Känslor					
Intresserad	Arg	**Glad**	Motvillig	Förvånad	Harmonisk
10	1	**13**	4	5	8
Skamsen	**Snabb**	Stressad	Skyldig	Ledsen	Accepterande
1	**12**	3	2	1	3
Inspirerad	**Lugn**	**Fokuserad**	Fundersam	Oinspirerad	Långsam
5	**13**	**15**	3	4	5
Snabbtänkt	**Smart**	Rolig	Pigg	Trygg	Kreativ
9	**13**	4	11	6	9
Frisvar:					
Tråkig	Rastlös				
1	1				
Hur					
Själv	Med en kompis	Med en förälder	Med ett syskon	Farmor	Husdjur
10	**7**	8	3	1	1
Rummet					
Mörkt	Varmt	**Tyst**	**Mjukt**	**Mysigt**	Ordning
3	13	**16**	**11**	**17**	12
Ljust	Kallt	Livat	Hårt	Omysigt	Stökigt
13	4	2	2	1	4
16	17	18	13	18	16

Appendix 6 - Interview guide school visit

Förklara bakgrunden och upplägget.
Fråga om det är okej att spela in intervjun. Intervjun kommer transkriberas.

1. Bakgrund

1. Vad heter du?
2. Vilken yrkesroll har du?
3. Hur länge har du arbetat inom skolan?
4. Vilka åldrar har du arbetat med?
5. Vilken ålder arbetar du med i dagsläget?

2. Miljön i stort

1. Vad tycker du om utformningen av ditt/era klassrum?
2. Hur utformas klassrummen och övriga utrymmen hos er?
3. Vem sköter inköpen till skolan?
4. Har ni någon särskild kravspecifikation ni utgår ifrån vid inköp av studiemöbler?
5. Hur väl är möblerna anpassade efter barnen?
6. Kan du nämna några goda och dåliga exempel på detta?
7. Hur bör miljön utformas sett till belysning?
8. Hur bör miljön utformat sett till ljud?
9. Hur bör miljön utformas sett till färg?
10. Hur tänker du kring placering av barnen?
11. Kan du se kopplingar mellan barns emotioner och miljön?

3. Läxor och skolarbete

1. Hur mycket används digitala hjälpmedel i undervisningen?
2. Vilken typ av hjälpmedel?
3. På vilket sätt påverkar detta utformningen av klassrummet och möblerna?

4. Skillnader utifrån ålder och behov

1. Vilka utmaningar finns för att barnen ska behålla fokus under genomgångar?
2. Vilka utmaningar finns för att barnen ska behålla fokus under eget arbete?
3. Har elever i olika årskurser olika krav på sin studiemiljö? På vilket sätt?
4. Vilka skulle du säga är de största skillnaderna på studiemiljön här på SU-enheten kontra andra skolor?

5. Avslut

1. Vilken typ av arbete får barnen med sig hem/ska göras utanför schemalagd skoltid?
2. Vilka aspekter måste man ta hänsyn till för att barnen ska kunna utföra dessa uppgifter hemma?

Appendix 7 - Poster for recruitment of families

HEJ!

SÖKES: En familj med ett eller flera barn mellan 5-14 år, som vill visa och berätta mer om sina studieplatser hemma.

FINNES: Designingenjörsstudent som vill utveckla studiemöbler utifrån barnens önskemål och tankar.

I höst skriver jag, Ann Forsman Sjöberg, mitt kandidatarbete i Design- och Produktutveckling på Chalmers Tekniska Högskola tillsammans med Barnens IKEA. Målet med projektet är, att med forskning och barnens egna tankar, skapa riktlinjer för IKEAs fortsatta utveckling av deras studiemöbelsortiment. Riktlinjerna kommer behandla ergonomiska aspekter, såväl emotionella, fysiska som psykiska. Som en viktig grund vill vi involvera de potentiella användarna – barnen och deras föräldrar.

HUR? Jag kommer hem till er en tid och datum vi bestämt tillsammans. Under max en timme får ni visa era studieplatser hemma och jag får chansen att ställa fördjupande frågor. Ni kommer att ha möjlighet att få dela med er av era tankar kring hur en bra studieplats är utformad och jag får en förståelse över era behov och önskemål när det kommer till studieplatser. Ert/era barn får gärna vara med och visa och berätta.

NÄR? Någon dag/kväll under vecka 41-43 dvs. (8-26/10).

VEM ÄR JAG? En 27-årig Chalmerist som tar mina sista steg mot examen. Tidigare har jag bland annat jobbat med inflytande och demokratifrågor på såväl mellan- hög och gymnasieskolor i Umeå Kommun, med titeln ungdomsombud. Där har jag bland annat anordnat många workshops, speeddates med politiker & unga och stöttat elevråd och föreningar. Jag brinner för användarcentrerad design som är utformad i linje med IKEA:s vision om produkter för de många människorna och hoppas att ni vill vara med och förverkliga denna vision i detta projekt.

INTRESSERAD ELLER FRÅGOR?
Mejla mig på **sjann@student.chalmers.se**

Vi hörs! **/Ann**

Appendix 8 - Observation- and interview guide for home visits

Bakgrund					
Plats		Datum		Tid	
Hur många är ni i familjen?		Hur många barn?		Ålder på barnen	
Hur bor ni	Villa	Radhus	Bostadsrätt	Hyresrätt	Annat
Antal kvm		Har barnen eget rum	Ja	Delar med syskon	Nej
I vilket rum sitter barnen när de gör sitt skolarbete?	Kök	Vardagsrum	Eget rum	Annat rum	

När sitter ni och pluggar på vilken plats?

Hur brukar ljudnivån vara i rummet?
Hur påverkar det barnet?

Märker ni skillnad på barnets emotioner i olika rum?

På vilket sätt använder barnet dator när de studerar?
Hur mycket används datorn?
Ställer det andra krav på miljön?

Titta på de specifika **studieplatserna**: Ta överblicksbild på studieplatsen samt fota specifika lösningar som lyfts Ta bild på hur barnet sitter samt hur föräldern står/sitter när den ska hjälpa barnet.

	Plats 1:	Plats 2:

Hur tycker ni att platsen är anpassad efter era barn?
Varför väljer barnet att sitta här och göra sina läxor?
Vad är bra med denna studieplats?
Finns det något ni saknar med studieplatsen?
Under hur lång tid brukar barnet sitta och göra sitt skolarbete?
Finns det något som distraherar barnet under denna tid?
Finns det något i miljön som gör att barnet kan koncentrera sig bättre?

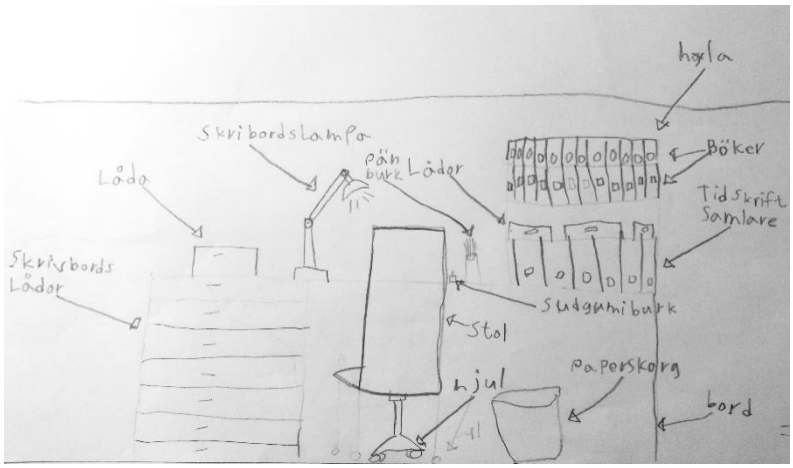
Hur är belysningen utformad?		Finns följande		Är den	
		Ja	Nej	Dimbar	Riktbar
	Allmänbelysning				
	Punktbelysning				
	Arbetsbelysning				

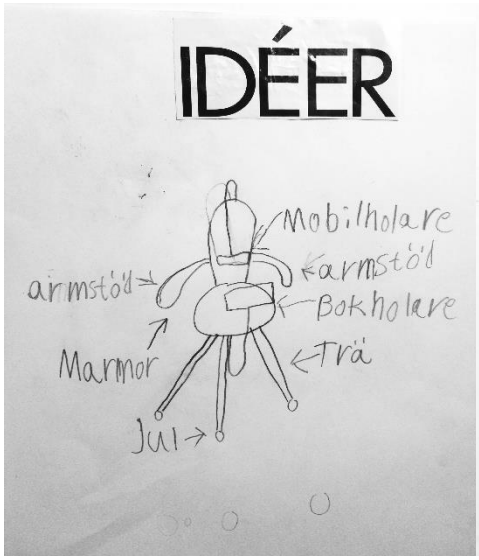
SKRIVBORD (ta bild på skrivbord om det finns något)
Har barnet/barnen eget skrivbord?
Vilka typer av aktiviteter gör barnet vid skrivbordet?
Vad är bra med skrivbordets utformning?
Finns det någonting ni saknar med detta skrivbord?

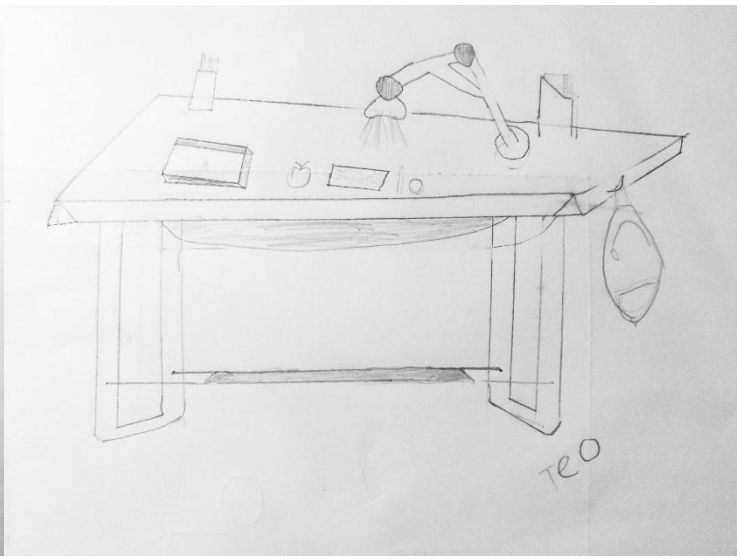
Är bänken/bordet anpassningsbart?	Ja	Nej	Hur?
Höj- och sänkbart			
Vinkel på arbetsyta			
Klarar barnet att göra detta själv?			
Brukar barnet göra dessa justeringar?			
Storlek på bänk/bord	Ja	Nej	Kommentar

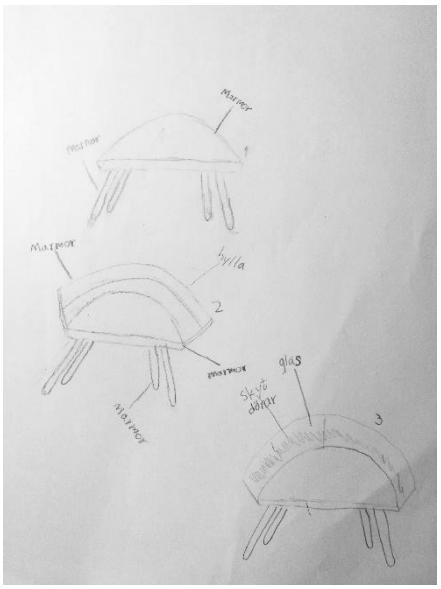
Arbetsyta Får alla barnens arbetsinstrument plats?			
Höjd Möjliggör höjden att barnet kan vila underarmar på bordet samt hålla korrekt position på ryggen?			
Mått i [mm] Längd x Djup x Höjd			
Har skrivbordet ytterligare funktioner? (ex. Krok, förvaring, stöd, eluttag)	Ja	Nej	Vad finns?
SKRIVBORDSSTOL (ta kort på skrivbordsstol/sittmöbel som används om det finns någon) Vilken stol använder barnet oftast? Finns en särskild stol till skrivbordet? Vad är bra med denna stol? Finns det något som ni saknar med denna stol?			
Är stolen anpassningsbar?	Ja	Nej	Hur? Ta gärna förklarande bild.
Höj- och sänkbar			
Justerbart ryggstöd i höjdled			
Justerbart ryggstöd framåt-bakåt			
Klarar barnet att göra detta själv? Brukar barnet justera inställningarna ibland?			
Storlek på stol	Ja	Nej	Ange även mått i mm
Sitshöjd Kan barnet stödja fötterna i marken/mot fotstöd? Totalhöjd Når nackstödet till nedre delen av skulderbladen eller högre? Sitsbredd Ryms hela barnets rumpa och lår på stolssitsen? Sitsdjup Kan barnet sitta med fötterna i marken och nå ryggstödet utan att sitsen trycker i knävecket?			
Framtida lösning Om ni skulle köpa en studiemöbel till era barn, vad är då viktigt för er? (låt de först svara på detta generella, fråga sedan specifikt) Föredrar ni något särskilt material? Föredrar ni någon särskild färg? Föredrar ni någon särskild utformning eller stil? Vilka funktioner bör studiemöbeln ha? Finns det begränsningar i vilket utrymme den får ta i rummet? (mäta om de ej nämner ett specifikt mått) Hur stor arbetsyta behöver barnet? Hur tror ni att barnets studiemiljö kommer ändras när de blir äldre? Vilka skillnader finns i barnets studiemijö kontra när det var yngre? Om ni vill hitta en studiemöbel som är ergonomiskt utformad, vad tittar ni efter?			

Appendix 9 - Children’s sketches and mood boards



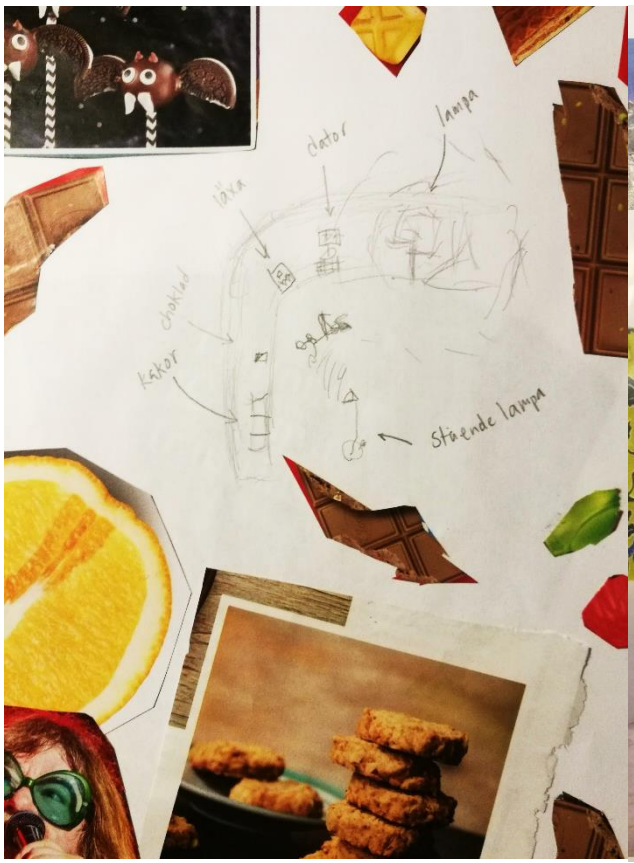




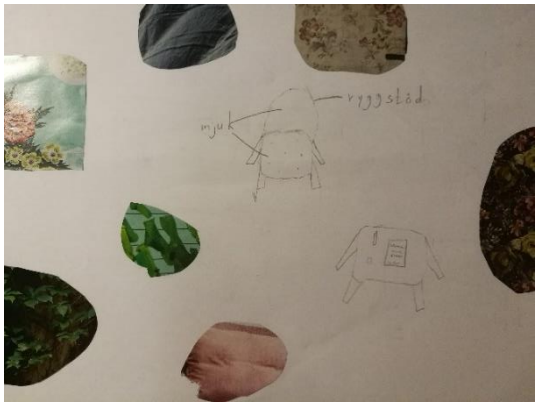


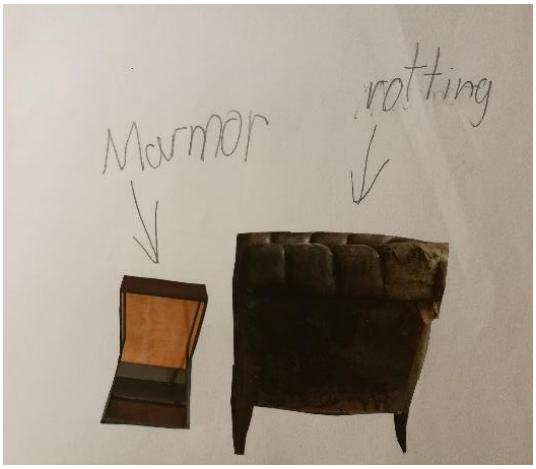

GAMMAL


Kudde för foten

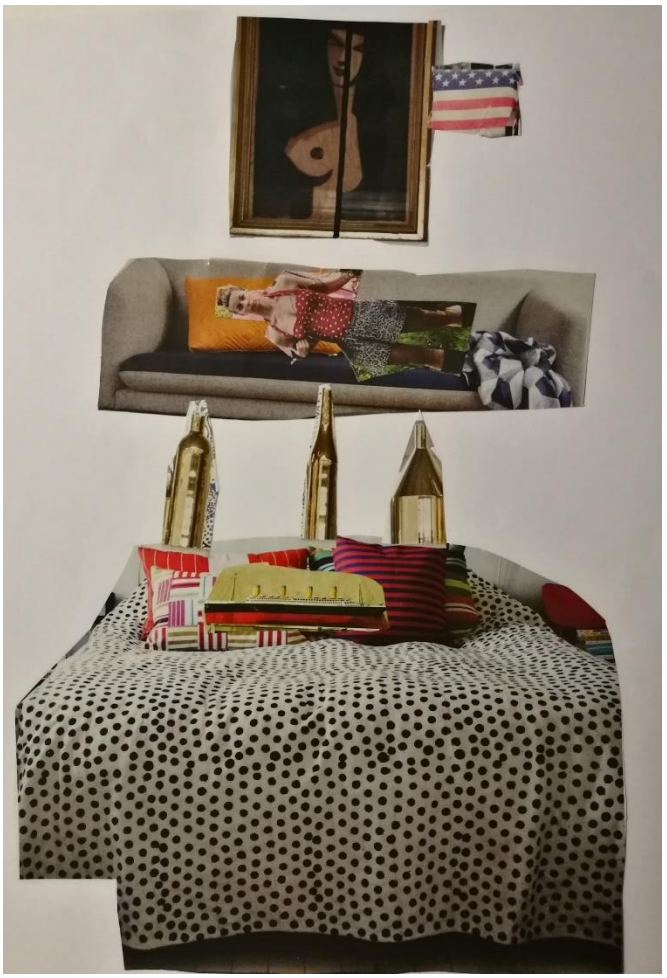

dator
lampa
bäcken
klocka
kakor
Stående lampa


NATUR
BÄST


mjuk


Marmor
rotting


Sötare citrus




LOVE
LOVELY
LINEN
FÄRGKICK


Premium
70%
COCOA SALTY LIQUORICE

Appendix 10 - Sizes and measurements from DINED

		stature	eye height standing	elbow height standning	arm lenght	reach depth	shoulder height	politeal height sitting	elbow heigt sitting
dutch 93	5 female, 0.01%	977	x	x	359	555	741	241	90
dutch 93	5 male	991	x	x	367	529	754	242	92
dutch 93	5 mix	983	x	x	361	541	748	240	89
dutch growrh	5 female, 0.01%	947	x	x	x	x	x	x	x
dutch growrh	5 male	964	x	x	x	x	x	x	x
dutch growrh	5 mix	954	x	x	x	x	x	x	x
dutch 93	6 female, 50%	1227	x	x	496	858	966	326	168
dutch 93	6 male	1225	x	x	499	848	958	329	167
dutch 93	6 mix	1226	x	x	498	853	962	328	168
dutch growrh	6 female, 50%	1187	x	x	x	x	x	x	x
dutch growrh	6 male	1201	x	x	x	x	x	x	x
dutch growrh	6 mix	1194	x	x	x	x	x	x	x
chilean	6 female, 0.01%	1174	x	x	x	x	x	231	76
chilean	6 male	1198	x	x	x	x	x	247	89
chilean	6 mix	1157	x	x	x	x	x	238	80
dutch 93	12 female, 99.9%	1804	x	x	766	1372	1477	511	283
dutch 93	12 male	1810	x	x	819	1319	1497	534	280
dutch 93	12 mix	1809	x	x	796	1348	1487	525	283
dutch growrh	12 female, 50%	1553	x	x	x	x	x	x	x
dutch growrh	12 male	1540	x	x	x	x	x	x	x
dutch growrh	12 mix	1547	x	x	x	x	x	x	x
chilean	12 female 50%	1536	x	x	x	x	x	396	215
chilean	12 male	1526	x	x	x	x	x	397	204
chilean	12 mix	1531	x	x	x	x	x	397	210
dutch growrh	14 female, 99.9%	1854	x	x	x	x	x	x	x
dutch growrh	14 male	1932	x	x	x	x	x	x	x
dutch growrh	14 mix	1900	x	x	x	x	x	x	x
chilean	14 female, 99.9%	1601	x	x	x	x	x	461	323
chilean	14 male	1676	x	x	x	x	x	496	313
chilean	14 mix	1747	x	x	x	x	x	503	338

		eye height sitting	sitting height	buttlock-polipeteal depth	buttlock-knee depth sitting	hip breadth sitting	head height
dutch 93	5 female, 0.01%	418	532	247	316	155	156
dutch 93	5 male	445	557	237	304	164	157
dutch 93	5 mix	432	538	240	310	160	155
dutch growrh	5 female, 0.01%	x	x	x	x	x	x
dutch growrh	5 male	x	x	x	x	x	x
dutch growrh	5 mix	x	x	x	x	x	x
dutch 93	6 female, 50%	550	664	342	416	233	193
dutch 93	6 male	553	664	332	407	228	199
dutch 93	6 mix	552	664	337	412	231	196
dutch growrh	6 female, 50%	x	x	x	x	x	x
dutch growrh	6 male	x	x	x	x	x	x
dutch growrh	6 mix	x	x	x	x	x	x
chilean	6 female, 0.01%	422	x	265	323	x	x
chilean	6 male	446	x	258	324	x	x
chilean	6 mix	435	x	262	324	x	x
dutch 93	12 female, 99.9%	814	929	533	654	400	243
dutch 93	12 male	808	914	537	651	357	247
dutch 93	12 mix	811	922	535	653	385	247
dutch growrh	12 female, 50%	x	x	x	x	x	x
dutch growrh	12 male	x	x	x	x	x	x
dutch growrh	12 mix	x	x	x	x	x	x
chilean	12 female 50%	686	x	449	540	x	x
chilean	12 male	668	x	438	529	x	x
chilean	12 mix	677	x	444	535	x	x
dutch growrh	14 female, 99.9%	x	x	x	x	x	x
dutch growrh	14 male	x	x	x	x	x	x
dutch growrh	14 mix	x	x	x	x	x	x
chilean	14 female, 99.9%	819	x	549	642	x	x
chilean	14 male	880	x	562	672	x	x
chilean	14 mix	880	x	578	683	x	x

		hip breadth sitting	head height	head depth	grip cirumference	breadth over the	hip circumferenc	Head depth			
dutch 93	5 female, 0.01%	155	156	160	55	208	x	160	Data 5-15 år	Lowest value[mm]	Highest value [mm]
dutch 93	5 male	164	157	159	56	221	x	159		1042	1874
dutch 93	5 mix	160	155	158	56	215	x	158	1. Stature	Dutch growth, female 5 years	Dutch growth, male 15 years
dutch growrh	5 female, 0.01%	x	x	x	x	x	x	x		268	490
dutch growrh	5 male	x	x	x	x	x	x	x	2. Popliteal height s	Chile 2012, female, 6 years	Dutch 1993, male 12 years
dutch growrh	5 mix	x	x	x	x	x	x	x		126	283
dutch 93	6 female, 50%	233	193	184	87	292	x	184	3. Elbow height sittir	Chile 2012, female, 6 years	Chile 2012, male 15 years
dutch 93	6 male	228	199	185	86	298	x	185		478	827
dutch 93	6 mix	231	196	185	87	295	x	185	4.Eye height sitting	Dutch 1993, female 5 years	Chile 2012, male 15 years
dutch growrh	6 female, 50%	x	x	x	x	x	x	x		268	519
dutch growrh	6 male	x	x	x	x	x	x	x	5. Buttlock-popliteal	Dutch 1993, female 5 years	Chile 2012, male 15 years
dutch growrh	6 mix	x	x	x	x	x	x	x		350	632
chilean	6 female, 0.01%	x	x	x	x	198	x	x	6. Buttlock-knee dept	Dutch 1993, male 5 years	Chile 2012, male 15 years
chilean	6 male	x	x	x	x	222	x	x		251	499
chilean	6 mix	x	x	x	x	209	x	x	7. Breadth over the e	Dutch 1993, female 5 years	Chile 2012, female 15 years
dutch 93	12 female, 99.9%	400	243	212	152	450	x	212			
dutch 93	12 male	357	247	212	142	458	x	212			
dutch 93	12 mix	385	247	212	147	454	x	212			
dutch growrh	12 female, 50%	x	x	x	x	x	x	x			
dutch growrh	12 male	x	x	x	x	x	x	x			
dutch growrh	12 mix	x	x	x	x	x	x	x			
chilean	12 female 50%	x	x	x	x	413	x	x			
chilean	12 male	x	x	x	x	401	x	x			
chilean	12 mix	x	x	x	x	407	x	x			
dutch growrh	14 female, 99.9%	x	x	x	x	x	x				
dutch growrh	14 male	x	x	x	x	x	x				
dutch growrh	14 mix	x	x	x	x	x	x				
chilean	14 female, 99.9%	x	x	x	x	561	x				
chilean	14 male	x	x	x	x	589	x				
chilean	14 mix	x	x	x	x	607	x				

Appendix 11 - Structure for interview with the special need educator

Steg 1: Förklara bakgrund samt vad som kommer ske idag. Be om godkännande att spela in intervjun.

Steg 2: Finns det saker i den fysiska miljön som kan anpassas för barn med
- Svårigheter att koncentrera sig?
- Svårigheter att sitta still?
- Läs- och skrivsvårigheter?
- Svårigheter att tolka och förstå uppgifter?

Steg 3: Stolen Titta på koncept för stolen. Förklara funktioner och bakgrund.
Vad är dina spontana tankar om konceptet?
SWOT
Vilka styrkor ser du med stolen?
Vilka svagheter finns med konceptet?
Vilka möjligheter finns för detta koncept?
Vilka hot finns för detta koncept?

Steg 4: Bordet Titta på konceptet för bordet. Förklara funktioner och bakgrund.
Vad är dina spontana tankar om konceptet?
SWOT
Vilka styrkor ser du med bordet?
Vilka svagheter finns med konceptet?
Vilka möjligheter finns för detta koncept?
Vilka hot finns för detta koncept?

Steg 5: Förfina koncept med hjälp av universell-design principerna
DESIGNPRINCIP 1: LIKVÄRDIG ANVÄNDNING
En utformning som är attraktiv för alla användare, som erbjuder samma funktioner utan att utestänga någon grupp. Där integritet, säkerhet och trygghet erbjuds likvärdigt.
➢ Finns det någon grupp som är direkt exkluderad av utformningen?
➢ Finns det något som kan göra stolen mer tillgänglig för en större grupp användare?

DESIGNPRINCIP 2: FLEXIBILITET VID ANVÄNDNING
En utformning som möjliggör individuell anpassning genom att tillåta olika användningssätt oavsett om användaren är t.ex. höger- eller vänsterhänt, samt oberoende av användarens precision och takt.
➢ Vilka olika situationer ser du att stolen skulle kunna användas?
➢ Finns det studiesituationer där stolen inte är lämplig?
➢ Saknas någon funktion i konceptet?

DESIGNPRINCIP 3: ENKEL OCH INTUITIV ANVÄNDNING
Utformningen är enkel att förstå oavsett erfarenhet, kunskap, språkfärdigheter eller koncentrationsnivå hos användaren. Utformningen bör reducera antalet komplexa element, vara konsekvent, tillåta olika läs- och skrivfärdigheter. Funktioner bör rangordnas utifrån hur viktiga de anses vara och ge återkoppling till användaren under och efter användning.
➢ Finns det funktioner som kan tas bort för att skapa en enklare lösning?

DESIGNPRINCIP 4: TYDLIG INFORMATION
Utformningen kommunicerar nödvändig information oavsett användarens sensoriska förmågor och omgivande förhållanden. Informationen tydliggörs på flera sätt, med bilder och symboler, verbalt och taktilt med hög läsbarhet. Utformningen är också kompatibel med olika tekniska lösningar för att möta användare med exempelvis sensoriska begränsningar.
➢ Är inställningarna lätta att förstå?
➢ Om inte, hur kan de förtydligas?

DESIGNPRINCIP 5: TOLERANS VID FELHANDLINGAR

Utformningen minimerar felhandlingar och följderna av eventuella misstag kan repareras. Detta uppnås genom att utforma en produkt som minimerar felhandlingar och mildrar konsekvenserna genom exempelvis skyddskåpor eller varningar vid felhandlingar. Omedvetna handlingar där uppmärksamhet krävs försvåras.

➢ Finns det något i utformningen som kan utgöra risk för användaren att skada sig?

➢ Finns det situationer där användaren kan hantera produkten fel som leder till att produkten skadas?

DESIGNPRINCIP 6: LÅG FYSISK ANSTRÄNING

Utformningen kan användas effektivt och bekvämt med liten risk för utmattning. Detta uppnås genom att användaren kan bibehålla en neutral kroppsposition, att rimlig ansträngning krävs för att utföra uppgifter, repetitiva uppgifter undviks och statisk eller långvarig fysisk ansträngning minimeras.

➢ Främjar utformningen en komfortabel och god kroppshållning?

➢ Finns det delar i utformningen som kan förstärkas för att skapa en lösning som uppmuntrar till varierande kroppspositioner?

DESIGNPRINCIP 7: STORLEK OCH UTRYMME ANPASSAT FÖR ÄNDAMÅLET

Utformningen medger lämpliga utrymmen och storlekar för att möjliggöra framkomlighet, nåbarhet, hantering och användning oavsett användarens kroppsstorlek, hållning eller mobilitet. Detta uppnås genom tydlig överblick och nåbarhet till viktiga element för användaren, oavsett dess position. Utformningen möjliggör varierande grepp utifrån olika handstorlekar och funktioner samt tillräckligt utrymme för hjälpmedel eller personliga assistenter.

➢ Är bordsskivans storlek tillräcklig? Stor nog för att rymma saker men tillräckligt liten för att enkelt kunna styras undan samt reglera positioner på

Appendix 12 - Interview guide user-evaluation

Steg 1: Förklara bakgrund, vad som kommer hända, frivilligt deltagande.
Steg 2: Testa hantering av arbetsytans storlek
Barnet ombeds att greppa arbetsytan och röra den upp- och ned i luften.

- Hur kändes det att greppa ytan?
- Var det svårt att nå vardera sida om arbetsytan?
- Hur kändes det att röra ytan upp och ned?
- Hur upplevde du tyngden på skivan?

Steg 3: Test av storlek på arbetsytan vid läxläsning
Skivan läggs ovanpå matbordet och barnet ombeds ta fram skolarbetsmaterial så som det ser ut då de har läxor.

- Vad tycker du om arbetsytans storlek?
- Är ytan tillräckligt stor för att rymma alla saker du behöver när du gör läxan?

Steg 4: Testa utföra en uppgift med ”skygglappar/stimuliavskärmare” monterat på stolen.
Skygglappar i papp monteras i rätt höjd på stolen och barnet ombeds lösa en uppgift med dessa på.

- Hur tyckte du att det var att lösa uppgiften med skygglapparna/stimuliavskärmarna på stolen?
- Vad tycker du om storleken på skygglapparna/stimuliavskärmarna?

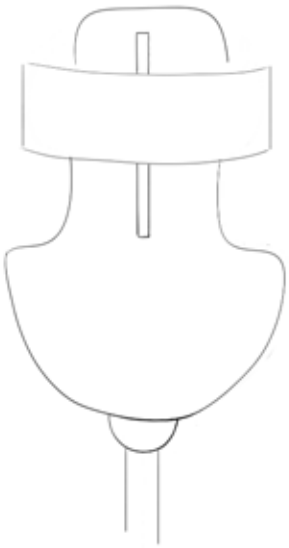
Uppgiften de får svara på är en ”mini-enkät” som knyter samman med frågor ställda till en åk 3 klass.
Steg 5: Presentera stolen med skisser samt beskrivning av de olika funktionerna.

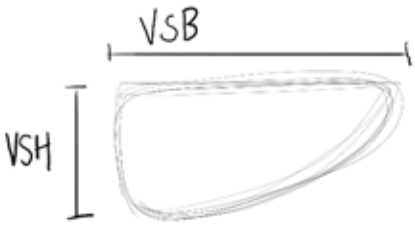
- Vad tycker du om stolen?
- Vad gillar du?
- Vad ogillar du?
- Är det någon funktion du saknar?
- Är det någon funktion du tycker känns onödig?
- Tycker du att det är enkelt att förstå hur olika inställningar görs?
- Om du gick i en affär och skulle köpa en skrivbordsstol, skulle du välja någon annan stol eller denna? Varför?

Steg 6: Presentera skrivbordet med skisser samt beskrivning av de olika funktionerna.

- Vad tycker du om skrivbordet
- Vad gillar du?
- Vad ogillar du?
- Är det någon funktion du saknar?
- Är det någon funktion du tycker känns onödig?
- Tycker du att det är enkelt att förstå hur olika inställningar görs?
- Om du gick i en affär och skulle köpa ett skrivbord, skulle du välja något annat skrivbord eller detta? Varför?

Enkät för användartest barn





1. Vilka känslor får du när du tittar på skisserna av stolen? (ringa in)

Intresserad Arg Glad Motvillig Förvånad
Harmonisk

Skamsen Snabb Stressad Skyldig Ledsen
Accepterande

Inspirerad Lugn Fokuserad Fundersam Oinspirerad
Långsam

Snabbtänkt Smart Rolig Pigg Trygg
Kreativ

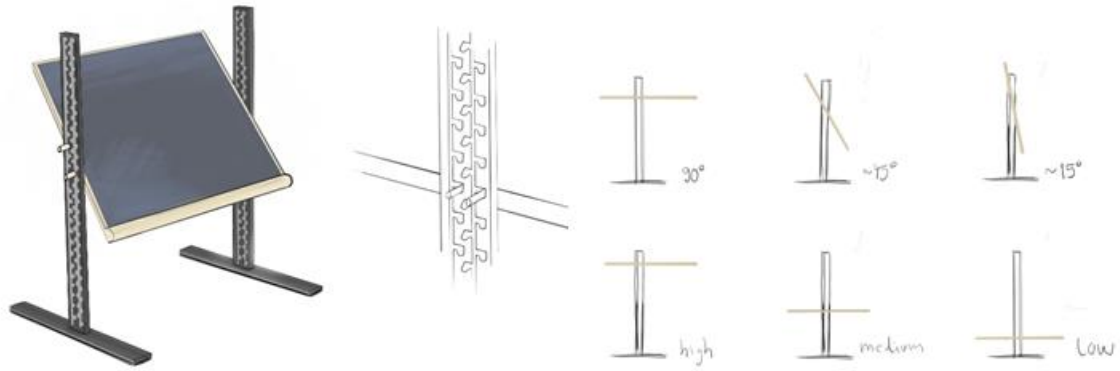
Om du inte hittar den känsla du får när du ser på stolen kan du skriva den här under istället

2. Vilket av alternativen tycker du stämmer bäst in på stolen?

Mörk Varm Tyst Mjuk Mysig
Ordning

Ljus Kall Livat Hård Omysig
Stökig

SKRIVBORD



1. Vilka känslor får du när du tittar på skisser av skrivbordet? (ringa in)

Intresserad Arg Glad Motvillig Förvånad
Harmonisk

Skamsen Snabb Stressad Skyldig Ledsen
Accepterande

Inspirerad Lugn Fokuserad Fundersam Oinspirerad
Långsam

Snabbtänkt Smart Rolig Pigg Trygg
Kreativ

Om du inte hittar den känsla du får när du ser på skrivbordet kan du skriva den här under istället

2. Vilket av alternativen tycker du stämmer bäst in på skrivbordet?

Mörk Varm Tyst Mjuk Mysig
Ordning

Ljus Kall Livat Hård Omysig
Stökig

Appendix 13 - Design recommendations listed in numerical order

Design recommendations from the theory chapter

T1: The solution should aim for inducing positive emotions, both intuitive and throughout the products life. Consider shape, physical feel and texture as well as function to induce an emotional durable design.
T2: The solution must consider and accommodate each developmental stage of the intended user, which means that the design must be intuitive even for a child in the pre-operational stage yet encourage the inner scientist of the child even in the formal operational stage
T3: The feeling and level of challenge and competence are linked together and enhanced by interactions and assistance from adults and friends. The solution should empower learning by challenge the child and yet make them feel competent.
T4: Language is an important tool for learning and contextualizing. The solution should accommodate the use and development of language during learning.
T5: The solution must consider the developmental level of the child's executive functions and should strive for enhancing that development.
T6: Cognitive development generally and executive functions specifically develop in synergy with others, parents and peers. The solution should, therefore, encourage these interactions.
T7: The design should enable positive postural habits as a foundation for the future and promote a healthy physical development of the child. This is particularly important for the spine, including the lumbar curve and neck.
T8: Gender differences become more significant after puberty, resulting in the need of a greater range of sizes to match everyone within the age range.
T9: A majority of the tasks, especially frequent and repetitive, should be able to do with the body in a neutral position.
T10: Storage and equipment often needed should be placed accessible, and preferable in the neutral zone of reach.
T11: The design should accommodate alternative methods for applying forces to enable a wider range of users and an inclusive design.
T12: To reduce the risk of harmful postures, the design should consider visual demands by encouraging a proper visual setting on the desk (place visual field between 0-30° below the horizontal line), including viewing distance (minimum 500 mm) and a 20° slope on the desk.
T13: The solution should offer proper lighting, dimmable, with an illuminance of at least 500 lux but preferable 1000 lux when reading or doing precision work.
T14: The direction of the light should be adjustable to avoid glare.
T15: Use multimodal information, haptic, visual and auditory, in order to create an inclusive and intuitive solution.
T16: Assure that the right anthropometric measurements are being used. Search for the highest and lowest value in each population, both for boys and girls.
T17: Use extreme-values when necessary, for example when there is a risk of injury.
T18: Be aware that anthropometric data usually do not include children with impairments. Use other sources when needed.
T19: The measurements of the desk and chair must match each other, and the users. This should be securely set if the proposed equations and anthropometric recommendations are used. Use the popliteal height as the prescription measurement and start with the seat height when deciding sizes for desk and chairs.
T20: New solutions should be tested and evaluated scientifically before implementation to secure that the solution meets the desired ergonomic requirements.

Design recommendations from the User-insights-chapter

U1: The solution must be compatible with a variety of tasks. Children's homework includes both reading, writing, calculating and repeated vocable practicing both on paper and with a laptop.
U2: A parent or friend should be able to sit by the child to encourage and help learning, this is particular important for the younger children.
U3: The solution should be compatible with digital devices, such as laptops and smartphones, with hidden yet easy to access solutions for cables and charging.
U4: The solution should be flexible with a variety of settings and positions.
U5: The solution should encourage children's independence and learning by simple instructions for adjustments and easy access to their equipment and study-material.

U6: The solution should offer proper storage, preferable with drawers and adjustable sections for their equipment, reachable for the child.
U7: The solution must be durable, easy to clean and keep in shape, with high quality in material and construction.
U8: The desk should allow a variety of positions, both in height and angle of the desktop.
U9: For most homework a desktop size of 800x600 seems to be enough, but other tasks require a bigger workspace.
U10: The solution must be flexible and fit in small spaces.
U11: The features of the desk need to outweigh the risks of the children playing or misuse them.
U12: The solution should encourage changes in position and posture.
U13: Different padding could increase the child's focus and sitting comfort. A majority of the asked children prefer a padded, soft, seat.
U14: Motoric distraction with inbuilt balance functions could benefit focus for some children, others prefer a static furniture.
U15: The chair should give support for a good sitting posture with a comfortable seating. The backrest should be smooth without bumps. A high backrest is preferred by the asked children.
U16: Dimmable lighting is requested by both children, parents and teachers, to adapt the lighting to different moods, or create a certain atmosphere in the room.
U17: The design must consider any cables, to minimize their visibility and reduce the risk of damage if the cable gets cut or worn.
U18: The study solution should enable the child to screen off the surrounding environment, for example by reduce stimulus, such as noise, visual elements and distracting objects, like smartphones or toys.
U19: The design must allow different usages and settings without risk of harming the child.
U20: The study solution should be attractive to both parents and children of different ages.
U21: The older children spend more time doing homework, that requires more ergonomic solutions which support postural changes and breaks for movements.
U22: The solution should be flexible and able to customize, which allow the solution to grow with the child.
U23: A solution with the child in charge makes them more engaged and responsible.
U24: Reduce the number of impressions, sound and noise, lights among other things to reduce distractions and enable focus and attention.
U25: Tools to clarify the task with a defined start, middle and end of the task can help the child achieve their goals.
U26: The solution should use the child's own driving forces in order to create a desirable behavior as the greatest extent possible.
U27: The solution should be associated with positive emotions, such as focus, energy and peace.
U28: Nature-based colors helps children focus and trigger their creativity.

Appendix 14 - Design recommendations listed by each design guideline

Facilitate everyday life

T10: Storage and equipment often needed should be placed accessible, and preferable in the neutral zone of reach.

U1: The solution must be compatible with a variety of tasks. Children's homework includes both reading, writing, calculating and repeated vocable practicing both on paper and with a laptop.
U3: The solution should be compatible with digital devices, such as laptops and smartphones, with hidden yet easy to access solutions for cables and charging.
U6: The solution should offer proper storage, preferable with drawers and adjustable sections for their equipment, reachable for the child.
U7: The solution must be durable, easy to clean and keep in shape, with high quality in material and construction.
U9: For most homework a desktop size of 800x600 seems to be enough, but other tasks require a bigger workspace.
U10: The solution must be flexible and fit in small spaces.
U16: Dimmable lighting is requested by both children, parents and teachers, to adapt the lighting to different moods, or create a certain atmosphere in the room.
U17: The design must consider any cables, to minimize their visibility and reduce the risk of damage if the cable gets cut or worn.

Strive for a healthy workplace

T7: The design should enable positive postural habits as a foundation for the future and promote a healthy physical development of the child. This is particularly important for the spine, including the lumbar curve and neck.
T8: Gender differences become more significant after puberty, resulting in the need of a greater range of sizes to match everyone within the age range.
T9: A majority of the tasks, especially frequent and repetitive, should be able to do with the body in a neutral position.
T11: The design should accommodate alternative methods for applying forces to enable a wider range of users and an inclusive design.
T12: To reduce the risk of harmful postures, the design should consider visual demands by encouraging a proper visual setting on the desk (place visual field between 0-30° below the horizontal line), including viewing distance (minimum 500 mm) and a 20° slope on the desk.
T13: The solution should offer proper lighting, dimmable, with an illuminance of at least 500 lux but preferable 1000 lux when reading or doing precision work.
T14: The direction of the light should be adjustable to avoid glare.
T15: Use multimodal information, haptic, visual and auditory, in order to create an inclusive and intuitive solution.
T16: Assure that the right anthropometric measurements are being used. Search for the highest and lowest value in each population, both for boys and girls.
T17: Use extreme-values when necessary, for example when there is a risk of injury.
T18: Be aware that anthropometric data usually do not include children with impairments. Use other sources when needed.
T19: The measurements of the desk and chair must match each other, and the users. This should be securely set if the proposed equations and anthropometric recommendations are used. Use the popliteal height as the prescription measurement and start with the seat height when deciding sizes for desk and chairs.
T20: New solutions should be tested and evaluated scientifically before implementation to secure that the solution meets the desired ergonomic requirements.

U4: The solution should be flexible with a variety of settings and positions.
U8: The desk should allow a variety of positions, both in height and angle of the desktop.
U11: The features of the desk need to outweigh the risks of the children playing or misuse them.
U12: The solution should encourage changes in position and posture.
U13: Different padding could increase the child's focus and sitting comfort. A majority of the asked children prefer a padded, soft, seat.
U15: The chair should give support for a good sitting posture with a comfortable seating. The backrest should be smooth without bumps. A high backrest is preferred by the asked children.

U27: The solution should be associated with positive emotions, such as focus, energy and peace.
U28: Nature-based colors helps children focus and trigger their creativity.

Growing with the child

T1: The solution should aim for inducing positive emotions, both intuitive and throughout the products life. Consider shape, physical feel and texture as well as function to induce an emotional durable design.
T2: The solution must consider and accommodate each developmental stage of the intended user, which means that the design must be intuitive even for a child in the pre-operational stage yet encourage the inner scientist of the child even in the formal operational stage
T3: The feeling and level of challenge and competence are linked together and enhanced by interactions and assistance from adults and friends. The solution should empower learning by challenge the child and yet make them feel competent.
T4: Language is an important tool for learning and contextualizing. The solution should accommodate the use and development of language during learning.
T5: The solution must consider the developmental level of the child's executive functions and should strive for enhancing that development.
T6: Cognitive development generally and executive functions specifically develop in synergy with others, parents and peers. The solution should, therefore, encourage these interactions.

U2: A parent or friend should be able to sit by the child to encourage and help learning, this is particular important for the younger children.
U20: The study solution should be attractive to both parents and children of different ages.
U21: The older children spend more time doing homework, that requires more ergonomic solutions which support postural changes and breaks for movements.
U22: The solution should be flexible and able to customize, which allow the solution to grow with the child.

The child in charge

U5: The solution should encourage children's independence and learning by simple instructions for adjustments and easy access to their equipment and study-material.
U14: Motoric distraction with inbuilt balance functions could benefit focus for some children, others prefer a static furniture.
U18: The study solution should enable the child to screen off the surrounding environment, for example by reduce stimulus, such as noise, visual elements and distracting objects, like smartphones or toys.
U19: The design must allow different usages and settings without risk of harming the child.
U23: A solution with the child in charge makes them more engaged and responsible.
U24: Reduce the number of impressions, sound and noise, lights among other things to reduce distractions and enable focus and attention.
U25: Tools to clarify the task with a defined start, middle and end of the task can help the child achieve their goals.
U26: The solution should use the child's own driving forces in order to create a desirable behavior as the greatest extent possible.

Appendix 15 - Evaluation: fulfillment of design recommendations

Facilitate everyday life	YES	Y/N	NO	Needs further testing	comments on functions that meet the design recommendation
T10: Storage and equipment often needed should be placed accessible, and preferable in the neutral zone of reach.		x		x	The edge enables a limited set of equipment to be placed upon the worktop, not sure if it is enough. The concept needs to be complemented with a drawer or another storage solution
U1: The solution must be compatible with a variety of tasks. Children's homework includes both reading, writing, calculating and repeated vocable practicing both on paper and with an laptop.	x				The desk allows different positions of the desktop to fit different types of tasks. the chair can both be used while doing work by the desk or reading
U3: The solution should be compatible with digital devices, such as laptops and smartphones, with hidden yet easy to access solutions for cables and charging.		x			This would reduce the flexibility of the desk. Holes for cables in the top of the desktop could enable more hide cables. A box or similar could be used as cable management underneath the desktop.
U6: The solution should offer proper storage, preferable with drawers and adjustable sections for their equipment's, reachable for the child.			x		the concept needs to be complemented with a drawer or another storage solution
U7: The solution must be durable, easy to clean and keep in shape, with high quality in material and construction.	x				blackboard surface, legs of steel, washable textiles and a composite with natural speckledness
U9: For most homework a desktop size of 800x600 seems to be enough, but other tasks require a bigger workspace.	x				
U10: The solution must be flexible and fit in small spaces.	x				multifunctional chair (armchair and office chair), able to tilt the desktop in an upright position
U16: Dimmable lighting is requested by both children, parents and teachers, to adapt the lighting to different moods, or create a certain atmosphere in the room.			x		the concept does not include any lighting solution
U17: The design must consider any cables, to minimize their visibility and reduce the risk of damage if the cable get cut or worn.		x			same as U3
Strive for a healthy workplace					
T7: The design should enable positive postural habits as a foundation of the future and promotion of healthy physical development of the child. This is particularly important for the spine, including the lumbar curve and neck.	x			x	different positions and settings to meet all children in the target group
T8: Gender differences become more significant after puberty, resulting in the need of a greater range of sizes.	x				
T9: Tasks should be able to do with the body in a neutral position	x			x	but needs to be tested with 1:1 scale prototypes to see how the children use the chair and desk
T11: The design should accommodate alternative methods for applying forces.			x	x	Both the desk and the chair have only one way to make the adjustments at this stage. How this could be extended or made more efficiently should be a topic for further iterations.
T12: To reduce the risk of harmful postures, the design should consider visual demands by encouraging a proper visual setting on the desk (place visual field between 0-30° below the horizontal line), including viewing distance (minimum 500 mm) and a 20° slope on the desk.	x			x	The 0-30° can be assured by making the right height adjustment for the user. The viewing distance depends on how close the chair is to the desktop but with the correct settings should even this recommendation be met.

T13: The solution should offer proper lighting, dimmable, with a illuminance of at least 500 lux but preferable 1000 lux when reading or doing precision work.			X		the concept does not involve any lighting solution
T14: The direction of the light should be adjustable to avoid glare.			X		the concept does not involve any lighting solution
T15: Use multimodal information, haptic, visual and auditory, in order to create an inclusive solution		X		X	The adjustments controls are separated by other colors (visual) and material (haptic). The desktop should give a distinct feeling when the position is set as feedback to the user.
T16: Assure that the right anthropometric measurements are being used. Search for the highest and lowest value in each population, both boys and girls.		X		X	DINED-database only offered a limited selection of data. A more extensive database must be used and prototypes in scale 1:1 be used for evaluation.
T17: Use extreme-values when necessary, for example when there is a risk of injury.			X	X	No considerations regarding injuries in this stage. The rails on the desk may need refining to assure that they are safe from pinching.
T18: Be aware that anthropometric data usually do not include children with impairments, other sources may be needed.			X	X	The width of the desk should be enough for a person sitting in a wheelchair; space may be too small for turning around so the user may need to back at first and then make a turn.
T19: The measurements of the desk and chair must match each other and the users, this should be securely set if the proposed equations and anthropometric recommendations are used. Use the popliteal height as the prescription measurement and start with the seat height when deciding sizes for desk and chairs.	X				A wide range of sizes, both on the desk and the chair should enable correct measurements for all users.
T20: New solutions should be tested and evaluated scientifically before implementation to secure that the solution meets ergonomic requirements.		X		X	A first user-evaluation was made, but it needs to be complemented with several evaluations along the way until a finished product.
U4: The solution should be flexible with a variety of settings and positions	X				
U8: The desk should allow a variety of positions, both in height and angle of the desktop.	X				
U11: The features of the desk needs to outweigh the risks of the children playing or misuse them.		X		X	The rails on the legs of the desk may need some modification to be safe.
U12: The solution should encourage changes in position and posture.	X			X	The desktop enables different positions and settings and new ways of learning. If this is appealing to children and encourage them to change position more often needs to be further evaluated.
U13: Different padding could increase the child's focus and sitting comfort. A majority of the asked children prefer a padded, soft, seat.	X			X	The chair has a padded seat, spine- and neck pillow for comfort. These elements could be customized by creating different types of padding, how they should be composed needs further evaluation.
U15: The chair should give support for a good sitting posture with a comfortable seating. The backrest should be smooth without bumps. A high backrest is preferred by the asked children.	X				
U27: The solution should be associated with positive emotions, such as focus, energy and peace.		X		X	The children in the user evaluation considered the desk to be associated with the feeling interested, fun, happy, energized, accepting, inspired, creative, thoughtful, smart and focused. The chair was associated with the feeling calm, fun, creative, focused, thoughtful, interested, surprised, inspired. The fulfillment of this design recommendation needs to be further evaluated since the answers from the children differ a lot.

U28: Nature based colors helps the child focus and trigger their creativity.	X				the desk has wood, matte black colors, and the chair could come in different matte and sober colors
Growing with the child					
T1: The solution should aim for inducing positive emotions, both intuitive and throughout the products life. Consider shape and form, physical feel and texture as well as function to induce an emotional durable design.				X	needs further evaluation
T2: The solution must consider and accommodate each developmental stage of the intended user, which means that the design must be intuitive even for a child in the pre-operational stage but yet encourage the inner scientist of the child even in the formal operational stage.		X		X	
T3: The level of challenge and competence are linked together. The solution should empower learning by challenge the child and yet make them feel competent.		X		X	
T4: Language is an important tool for learning and contextualizing. The solution should accommodate the use and development of language during learning	X			X	The vision screen reduce some of the noise which allow the user to talk out loud without disturbing the surrounding as much. The blackboard can be used to structure thoughts and train vocables etc.
T5: The solution must consider the developmental level of the child's executive functions and should strive for enhancing that development. The youngest children may need a solutions that helps keeping information, organizing and executing tasks with more than one step and exploring safely without an adult present. 6-year-olds could benefit of a solution that allows mistakes and where corrections easily can be made. The oldest children have a more extended working memory and attention span, wherein natural breaks for movement could be of importance.		X		X	Blackboard can be used to write and clarify tasks, post its or other papers can be attached, most of the a are familiar, the vision screen reduce surrounding elements etc.
T6: Cognitive development generally and executive functions specific develop in synergy with others, parents and peers. The solution should, therefore, encourage these interactions.	X			X	The flexible desktop enables different usage where friends and parents can be involved. There is space for a friend or parent even though it is quite limited.
U2: A parent or friend should be able to sit by the child to encourage and help learning, this is particular important for the younger children.	X			X	Further testing to assure the space is considered enough when sitting two.
U20: The study solution should be attractive to both parents and children of different ages.				X	The user evaluation showed a positive result but was only based on one adult and three children
U21: The older children spend more time doing homework, that requires more ergonomic solutions.	X			X	Needs to be tested on how the child is sitting and using the furniture
U22: The solution should be flexible and able to customize, which allow the solution to grow with the child.		X		X	The concept can be customized in several ways, needs to be clarified what the customer wants to be able to customize
The child in charge					
U5: The solution should encourage children's independence and learning by simple instructions for adjustments and easy access to their equipment and study material.		X		X	The children in the user-evaluation had some trouble understanding how the adjustments on the desk should be made. The adjustments controls on the chair was more familiar and therefore easy to understand. This needs further evaluation with real prototypes
U14: Motoric distraction with inbuilt balance functions could benefit focus for some children, others prefer a static furniture.		X		X	there is no consensus on whether the solution should offer motoric distraction elements or not.
U18: The study solution should enable the child to screen off the surrounding environment, for example by reduce	X			X	the vision screens are used for this purpose, but it needs further testing if they

stimulus, such as noise, visual elements and distracting objects, like smartphones or toys.					fulfill their purpose
U19: The design must allow different usages and settings without risk of harming the child.		X		X	Needs further evaluation with prototypes and correct adjustments control
U23: A solution with the child in charge makes them more engaged and responsible.		X			The youngest, and weakest, children may have trouble to make the adjustments on the desktop. The lightest kids may have difficulty adjusting the height of the chair as well.
U24: Reducing the number of impressions, sound and noise, lights among other things is important.	X			X	vision screen, noise-reducing elements with the padded chair and a solid desktop
U25: Tools to clarify the task with a defined start, middle and end of the task can help the child achieve their goals.		X		X	The writable desktop enables the user to write down instructions or supporting elements. Supportive papers can also be placed on the surface by the magnets.
U26: The solution should use the child's own driving forces in order to create a desirable behavior as the greatest extent possible.				X	The design of the concept is aiming for inducing a positive and harmonic feeling while doing homework and the place should feel like the child's own, but this needs to be further evaluated.