The design of a playground toy

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This project report has on June 11th been submitted by Lorena Brown González and Rodrigo Palacios Certucha to the University of Skövde as a part in obtaining credits on basic level G2E within Product Design Engineering. We hereby confirm that for all the material included in this report which is not our own, we have reported a source and that we have not – for obtaining credits – included any material that we have earlier obtained credits within in our academic studies.

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Abstract

The report describes the design of a safe (within EU regulations), ergonomic, attractive, sustainable, versatile and interactive playground toy for children from ages 7 to 11. The product aims to help children develop in different aspects: physical, emotional, social and mental, in a sustainable environment. This was developed from the identification and exploration of the factors that influence the design of playground toys.

The design process was divided in the following main stages: an initial research of information, the interpretation of this data, the development of a concept, a test stage and the results. During the research, teachers and parents were interviewed and children were observed. Relevant information was also gathered. For the development, a set of creative techniques were applied and finally tested. Modifications based on the test were made to reach an accurate design.

The work done was successful to the extent established initially; although, it can be subject to improvement. The main limit was that no tests were performed on a physical prototype, therefore, there is information not yet gathered and tests that would prove if some of the assumptions were true or false.
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Appendix A
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1 Introduction

For a long time, play was considered wasteful and meaningless, it was not until the 1900’s that philosophers, psychologists and paediatricians began understanding the dimensions of play. This activity helps children develop in a cognitive way; children learn through playing. Manipulative skill, communicative skills, imagination, creativity, discovery and reasoning are some examples of areas that develop through play. Playing also enhances cooperation with others (Bruya, 1988. pp. 10-11).

Children's behaviour regarding play are influenced by the physical arrangement of a playground, the physical competence of each kid and the peer relationships between them (Barbour, 1999. p. 78).

The playgrounds that attract more attention from children are those in which they can perform a great variety of activities. Children do not consider 'fun' playscapes that do not offer a variety of activities (Jansson, 2008. p. 94). For children a playground is described by the activities they can perform not by the space in which it exists.

The mission of this project is to design a toy for children from ages 7 to 11 to develop in different aspects: physical, emotional, social and mental, in a sustainable environment. The involved parties in this project consist of the children in the target group as main users, parents and teachers as the secondary users, the experts sought for different technical aspects, the supervisors at the University of Skövde for the academic work, the industrial supervisors (Dreem Arkitekter), and the fellow product design engineering students.

1.1 Dreem Arkitekter

Dreem Arkitekter is an architectural firm that works to bring society a conscious and committed architecture. The architectural office is working to create a sustainable society both from an environmental and social perspective. An important part of Dreem's practice is to work closely with clients, who are based on responsiveness and flexibility.

The degree project that would be carried out in collaboration with Dreem is designing a toy for playgrounds that could be implemented in the firm's future architectural projects.

1.2 Purpose and objectives

In the first interview with Dreem, two different projects were proposed; the first proposal was the creation of signature furniture pieces for an architectonic project the firm is currently working on and the other proposal was the development of a playground toy. The selected project was the second one: creating and designing a safe (within EU regulations), ergonomic, attractive, sustainable, versatile (adaptable to different locations and climate conditions) and interactive playground toy for children. The selection of this project was based on the fact that the solutions are not limited and creativity plays an important role.

The academic purpose of this work is to identify and explore the factors that influence the design of playground toys. It is certain that aspects, such as children ergonomics, influence the results when designing for children. Based on this, the intention is to understand the other possible aspects that will guide the design process and how involved in the work these areas can be.

This degree project aims to design objects that can be used by children of different ages, taking into consideration their heights and the variations of the size of their body
parts. This project also aims to be inclusive, thus children with different capacities can play and enjoy the playground. Sustainability is a key aspect for this project too.

Considering the time available for the development of the project, the scheme is to develop one playground item; this toy will go through the conceptual stage, the prototyping and testing stage. Some other concepts will be sketched as part of the process; although these concepts will not reach a developing, nor testing phase. The result of the degree project is to deliver a conceptual design for a playground toy with the analysis and reflections of all the process.

1.3 Delimitations

Some limitations should be considered from the beginning. Regulations will restrict design ideas because safety is the first priority regarding playgrounds. Another considerable limitation is that there will be no budget for this project, not for the acquisition of the materials required to build the prototypes. The scale on which the prototypes will be built could also reduce the possibility of performing physical tests.

For the reasons mentioned previously, the prototypes will be developed as CAD models, drawings, sketches and scaled models. The CAD models will be tested ergonomically with the use of the digital human modelling software Jack 9.0, along with partial tests regarding the materials and visual aspects of the designed items.

1.4 Strategies and methodologies

This section is a deeper description of how the project will be managed in terms of methodology. The design process which was considered as the best way to fulfil the objective, is a User Centred Design process. The general notion of how the process works is different for each project. In the design timeline it may not be easy to distinguish the approach to the main user directly. High impact strategies like surveys or user tests with a complete pre-production prototype are desired and essential for the proper conclusion of the project, however, the project will not reach the last existing goal due to the limitations in time and resources.

User centred design (UCD) is an iterative design process in which designers focus on the users and their needs in each phase of the design process. UCD calls for involving users throughout the design process via a variety of research and design techniques so as to create highly usable and accessible products for them (APS, I. D. F. 2019).

To understand how the project is planned, along with the company, the whole project was divided in a similar way as the Double Diamond process (Design Council U.K., 2015), but extended and modified according to project outlines and the established milestones. Figure 1 shows graphically the intention of how the project was divided.
The division contemplates four stages that follow a divergence-convergence pattern. The company and the designers agree to reach milestones which will be reported at the end of each stage, ensuring controlled feedback throughout the project, by both the company and the university supervisors.

The first stage consists of a divergent search of information and research on the subject. It can be said that in general this stage does not have an actual end because learning about possible improvement or acquiring expertise on the subject does not stop if the contact with valuable information keeps on going. During this stage sketching will also begin, in order to consider as many creative solutions as possible. In this stage, the strategies present are mainly relevant for user studies, it is necessary to interact with the user in different manners to extract information. Shadowing and passive observation (Interaction Design Foundation, 2019) are valid options in this context since children do not express as adults. Since interviewing children may not be the best option to understand the way they perceive playgrounds (Esomar, 2009), this stage will include interviews of parents and teachers. The objective is to obtain external validation for the requirements of the playground toys. For a proper and context related product development, environmental validation will also come from different playground site visits. Investigation about ergonomics, safety, accessibility and materials will also be included during this part of the process.

The income of data will be analysed and translated into solutions. With this the second stage begins; this consists of a convergent period where the main task is to find a common ground for the design requirement. This is the elaboration of the list of requirements and the possible creative solutions. The list of requirements is a logic step after gathering information about playgrounds and after reading several theoretical sources related to the subject.

A complicated part of the project is the creative stage. Even through the use of two techniques, the Lotus Blossom technique (Michalko, 2016) for brainstorming and Brainwriting (Rohrbach, 1969) the creative leap may not show concrete results. To control and tackle the problem in time, the concepts generated should be submitted to an early evaluation, where the three most feasible concepts will be obtained. This point is a milestone for the project because here the presented concepts will be approved as good options to continue developing or rejected.

After the concept selection the third stage begins, a divergent stage that will consist of generating a wide proposal of materials, shapes, compositions, tests and the ergonomic evaluations that would be pertinent. The testing part is considered divergent because it is an increased information flow.
The beginning of the fourth stage, a convergence, is where the analysis of the results is discussed. The idea is to narrow down the information to concrete observations regarding the state of the product. This is a milestone that must be reported in order to perform adequate modifications and remove assumptions from the design. As an academic process, this is the point to present the results.

2 Background

2.1 Playgrounds and health

In 2010 the countries that are part of the World Health Organization in Europe, these include Sweden, made a commitment to provide by 2020 all children access to healthy and safe green spaces to play and do physical activities. The UN has also a sustainable development goal that states children, women, old people and people with disabilities should be provided with universal access to safe, inclusive and accessible public spaces (WHO Regional Office for Europe, 2017).

Urban green spaces such as parks and playgrounds are necessary for the development of healthy, sustainable and liveable cities. These interventions can bring positive healthy, social and environmental outcomes for all the population.

By the end of last year (2018), Sweden’s total population was 10 230 185, this means it increased by 109 943 persons compared to 2017 (Statistics Sweden, 2019). Around 20% of the inhabitants are children under 18. In ten years (2028), the total population is expected to reach 11 million. According to the population projection of Statistics Sweden, the number of children and young people under 18 will be 231 000 greater (Statistics Sweden, 2018).

Regarding these facts, it can be presumed that the density of most Swedish cities will grow in proportion to their population and thus more green urban areas will be required. Playgrounds constitute a part of the green spaces; the general purpose of playgrounds is to enhance the development of children (WHO Regional Office for Europe, 2017).

2.2 Children and their development

There are different aspects to consider in the wide area of children’s psychological and physical development. The psychology generally accepts Jean Piaget’s theory regarding the cognitive evolution of children. Piaget’s theory is rooted on the fact that children’s capacity to think is constantly under qualitative and quantitative change. According to Piaget’s studies the division of children’s cognitive development consists in four stages, that may occur in different age groups: sensorimotor (0-2 years) preoperational (2-7 years) concrete (7-11 years) and formal, 12 years and older (Piaget, 1936).

On the other hand, physical development obeys to different rules. It is partially identified as an age dependant variable and partially an activity dependant variable. A way to illustrate this is to observe the case of some athletes, that begin working and shaping their body to perform better in the activity, however, they will still have the same average height and proportions according to their age group.

2.2.1 Psychological development

During the sensorimotor stage, children depend in their inherited reflexes to survive and their brains are very busy absorbing unknown amounts of information. This first dependent need of basic reflexes may evolve with time, and become more complex within the first three or four weeks of growth.
This stage is then also characterized by the difficulty for children to create groups and classify their attributes. It is logic because their vocabulary is frequently insufficient for the number of surrounding concepts in their environment: how to ask a child which colour is red if no one has ever taught him that? “the child at this stage frequently cannot form a systematic ordering of any number of objects although he is sometimes able to order a few of them.” (Ginsburg and Oppe, 1987, p. 157).

At the preoperational stage, the children are able to identify and classify groups of things under a more complex scenario. The child thinks according to spatial and simple relations that generate a confusion with the position and the number of elements. They are unable to visualize the real and concrete relation between one object and the other or generate a different plan to sort the difference. The children may be able to group concepts and understand an abstract thing such as a number, but will not be able to understand the mechanic behind the subtraction and addition of a number to another.

The concrete stage is an important period for social development because children begin to think of other subjects as individuals with personal thoughts, that is to say, they develop empathy and the capacity to sustain more complex relationships, specifically with other children and their own parents. This is a process of observation and experience. Children (while looking at other children) try to behave according to logical thinking, focussing on the aspects that can be generalized due to their generally inductive reasoning. Their reasoning jumps from “my dog has fur” to “all dogs have fur”. During the state of play, this translates to their need to see how other children play to engage on the activity themselves and modify their own schemas.

Also, the concrete stage of development is where children identify attributes by comparing objects. This capacity is linked to the preoperational stage of development, when children associate the conservation of an object’s identity despite the difference in appearance i.e. grouping concepts. This way of processing information is related to physical development in playgrounds as the concepts of intension and extension are present at this age group.

The intention of an apple refers to the available schemes of red, round, or sweet. Extension refers to the members of the class, its field of application, or the objects to which these schemes apply (Ginsburg and Oppe, 1987, p. 302).

The concrete stage appears as critical in terms of adulthood behavioural results, because the children are learning multiple skills, without a proper sense of right and wrong, with an obvious demonstration of the unawareness of the social regulation mechanisms. The concrete stage is likely to be considered a tabula rasa (Merriam Webster, 2019) for the insertion of good practices that lead to a more fluid development of the formal concrete operational stage.

During the concrete operational stage (stage 4), the reasoning level turns into a more cumbersome process to study. It has now too many variables to be explained, but the one closer to the context of this thesis would be the importance of preparatory work, because children in this stage have some unbalanced cognitive abilities which may cause the undesirable effect of misconception or not understanding at all. The preparatory work is commonly shaped or presented as a concrete activity “Similarly, in mathematics, while preoperational children cannot fully understand equivalence, they can profit from considerable experience in the counting of concrete objects.” (Ginsburg and Oppe, 1987, p. 328). The stage to generate a more accurate learning of preparatory works then, would be the concrete stage.
2.2.2 Physical Development

For most designers, the main focus when designing playgrounds lays in the physical characteristics of children development because there is a direct need to provide the proper sizing of objects for children. It must be clear that there is no such thing as a children physical activity list compared to children age because the variable is depending on individual development, however, there is a difference between toddlers, a young child who is learning to walk (Cambridge Dictionary, 2019) and already walking children around 5 years old. The different capacities and how they are presented are important to know for the generation of a comprehensive routine of play. Here is where the connection between physical and psychological development is happening for the first time, to clarify, this does not describe how it happens in the children, it describes how it happens in a conceptual level.

Physical development can be studied from two perspectives: one qualitative and one quantitative. The qualitative way, would show each activity, the effect, the technique and all the concepts surrounding the exercise. For a quantitative approach, the results of any study would be presented as values and tables, graphics or formulas that would be valid for a certain population. The second type is valid for ergonomic playground toys in a physical level and that is why it matters in form of anthropometric studies.

Another reason for understanding the physical development is that children need to start playing with other children (Parten, 1932). It is also important to mention, that during this period of development, children may suffer peer rejection due to their physical differences (Green, 2015).

2.3 Risk and safety

The regulations indicate many rules that must be followed to guarantee a lawful environment for children playgrounds, however, accidents happen. It is almost impossible to predict, prevent or eliminate all the risks. Most of the regulations aim to diminish the risk as much as possible without neglecting the function and usability of the playgrounds. With a UCD perspective, the problem is to align what the children want and need with the design, to guarantee high usability and accessibility. Therefore, safety needs to be managed on behalf of the children. To manage the risk, the proposed technique is to apply a risk-benefit assessment form created by the National Children’s Bureau of the UK:

The Risk-Benefit Assessment Form is an easy-to-use tool to support play providers to balance the benefits of an activity with any inherent risk, taking into account the risks while recognising the benefits to children and young people of challenging play experiences (Ball et al., 2012).

This form is relevant because it helps to assess the playgrounds within an EU standard. Moreover, the form contains comprehensible aspects that must be achieved during the design of the toy if possible; otherwise it may be rejected during service.

After the assessment, there are other evaluations required to approach a long-term safety, these are the ergonomics tests and considerations. The value of designing ergonomic toys for children is too high to be ignored. Without going too deep into the subject it can be said that some adulthood medical conditions are tightly evolving from mistakes on early development stages (Pechtel and Pizzagalli, 2011). Examples of these conditions can be early life stress (ELS) or the carpal tunnel syndrome caused by pressure on a nerve (median nerve) in the wrist.

After the conceptualization, there are ergonomics evaluations that can be relevant to study: the reach height to avoid shoulder injury, the hand grasp to avoid carpal tunnel
syndrome or damage to finger joints and accidents, the neck natural extension, to avoid neck stress, lower back to diminish the lower back effort etc.

These are tasks that are more related to the risk, usability and access of the toys. On an effort to be more concrete about these considerations, the information will be more likely to appear as a fact in the design than as a verbal argument, however the safety regulations will be considered explicitly on the requirement list.

2.4 Ergonomics

As a definition, it is possible to identify ergonomics as “an applied science concerned with designing and arranging things people use so that the people and things interact most efficiently and safely” (Merriam Webster, 2019). The impact of understanding this science is largely discussed by researchers that consider the application of ergonomics in different areas as positive. Many papers consider the economic value of this science for large industrial management as basic; however, the literature review gave that it was difficult to find diverse research on children ergonomics because the study of ergonomics is mainly focused on adults.

2.4.1 Anthropometry of children

Anthropometry is “the study of human body measurements especially on a comparative basis” (Merriam Webster, 2019). Through the research of many different academic articles, it is possible to deduce that some anthropometric variations exist because of the difference in age, sex, ethnicity and geographical location as a natural fact. Anthropometry is part of physical ergonomics (Gupta, 2014). It can be used to relate children’s height and weight with the aspects mentioned previously.

The interest for designing a playground toy is focused on how children, during the concrete stage of development, choose to play on specific types of toys because they relate the objects to a game. It is important to consider their heights and some body dimensions, for example, their arm reach, their hand reach, their grasp, etc. As well as the strength children from ages 7 to 11 can exert. Children between this range of age vary greatly anthropometrically, a single ‘standard’ product may not fit all of the population found in this range. Adjustments and modifications are suggested by the study of children bodies and variations.

2.4.2 Physical ergonomics

Humans are different from each other by nature and they change through all of their lives; people differ in age, size and strength just to mention a few characteristics. It is also important to take into consideration that the body parts of the different people vary, not all body parts’ dimensions are similar. Studying human physical behaviour, development, needs, preferences and ergonomics help a design accommodate these variations in dimensions and physical limitations. According to Kroemer (2005, p.58) there are five approaches for the obtention of safety through ergonomics:

1. Achieve fit, proper sizes of objects
2. Ensure reach, every human can access and use devices properly
3. Provide safe clearance, objects do not obstruct or harm the users
4. Avoid entrapment, no body part should get trapped
5. Provide exclusion, barriers that separate dangerous spaces and objects from all the users

Regarding playgrounds, the way toys fit the users is highly related to safety. The most common accident in playgrounds is falling from the equipment, where these accidents
may even result in severe injuries and in some cases even death. Children fall from
the toys mainly because of the following reasons: they misjudge the distance to the
next support to put their hands or foot; children cannot grip the objects correctly; the
equipment is slippery; the children cannot reach the distances because these are too
big for them; and the hand supports are not of the correct sizes (Roderick, 2004. pp.
249-250).

It is essential to consider how far children of different ages can reach, the maximum
diameter they can grasp and other anthropometric data to ensure safety, but also to
ensure that an object can be used simply by children. It also has to be taken into
consideration that children change very fast, their bodies grow significantly through
the years of childhood.

2.4.3 Cognitive ergonomics

The definition of cognitive ergonomics accepted by the International Ergonomics
Association “is concerned with mental processes such as perception, memory,
reasoning, and motor response, as they affect interactions amongst humans and other
elements of a system” (I.E.A., 2019).

One of the purposes of the design of a playground toy is to fit the user
ergonomically, both physically and cognitively to ensure that the playground is
adequate for the capacity of children; this is particularly valuable when focusing on a
group of children.

In the last decade, important conclusions have been drawn about taking care of the
physical and mental state of people. Economic and positive changes have been
demonstrated by those companies that embrace the ergonomic perspective (Dul and
Neumann, 2006). For most cases, it has been an effort focused on physical
ergonomics in the frame of production lines and workers to reduce the physical injury
rate during company’s operations. Physical damage is easier to detect than
psychological damage, therefore it is logic to find more attended cases of physical
damage, elevating the sum invested on such type of injury rather than investing on
psychological damage prevention or care. However, there is also a chance to reduce
negative psychological effects through the understanding of cognitive ergonomics
(Belkic and Savic, 2008).

An argument, supported by research published by Pechtel and Pizzagalli (2011),
for why cognitive ergonomics focused on children may have a larger impact on
reducing negative psychological effects, is due to the fact that it is easier to avoid
stress during adulthood if there is no “early life stress”, commonly referred in
psychopharmacology as ELS.

An example of the costs that may be avoided by implementing cognitive
ergonomics in design solutions is framed in the following text:

In April, the World Health Organization released a ground-breaking study that
established a definitive link between mental health and economic productivity. The
findings were both depressing and hopeful. On the downside, depression and anxiety
disorders cost the world nearly U.S. $1 trillion annually. On the upside, every dollar
invested in treating those disorders leads to a return of $4 in terms of the ability to work
and thus contribute to the economy (Nobel, 2016).

For this reason, expanding the study of cognitive ergonomics on children and their
development is important. To ensure that children and the adults these children will
become in the future, are healthier both mentally and psychologically.
2.4.4 Accessibility

Accessibility is the consideration of people with disabilities through the design of products, devices, services and environments. It is directly connected to inclusive design which is often regarded as the design of products that can be used by people with different abilities, even if they do not have a disability. This design approach considers that differences in people's abilities are ordinary (Story et al., 1998).

As mentioned in the previous chapters, children develop through play. Children work on their social, intellectual, emotional and physical skills when they play. Children with impairments need to develop these skills in the same way as all children. In Sweden the National Action Plan on Handicap Politics (Regeringens Proposition, 1999/2000: 79) stated that the whole country had to be accessible to all people by the year 2010 (Sveriges Riksdag, 2000). In Sweden there has also been a law that since 1987 (Plan- och bygglagen) states that all public areas can be used for people with disabilities (Ministry of Health, 1987).

A study performed by Maria Prellwitz and Lisa Skår were they interview 20 children between the ages of 7 and 12 to understand how children with different abilities use playgrounds concluded that:

The results from the present study indicate that playgrounds are important environments for all children, regardless of their abilities, but they are not accessible and usable for all. The results also indicate that playgrounds do not fully support play activities for children with disabilities. This, in turn, might affect their opportunities to play and interact with their peers (Prellwitz and Skår, 2007. p. 153).

2.5 Sustainability

Nowadays, the value and weight of sustainable development is common knowledge. However, there are thousands of angles to cover that may affect how a product has a sustainable approach. In the beginning of the project, achieving sustainability was stated as a goal.

2.5.1 Materials

The first approach that could be achieved was by pre-thinking the strategy on how to use materials that are commonly found in playgrounds, based on their characteristics and the possible use of similar or better materials for any design to result from this work. Also, there are some aspects of sustainability that can be managed better through the project if there is a nonlinear strategy, which would be part of a circular economy as the C.E.C. suggests (Circular Economy Club, 2019).

The materials that are usually considered have as main characteristic to be durable, resistant and have lasting lives, this is because the lifespan of an object must usually be economic to be a one-time investment. This is part of considering the complete life cycle of the materials, including the phase after it is used for the last time.

Plastics are commonly seen on playgrounds due to their special and very wide variety of characteristics. An example of this could be the use of acrylic to colorize light and for its resistance to outdoor conditions, some acrylics can be used more than one time before being considered trash. The main structures of the different games are usually built in steel or aluminium because these can endure for longer periods. Another material that can be used for structuring the games may be wood for a more sustainable approach than steel. Reinforced concrete is suggested in general for the foundation of all of the toys due to the capacity of to absorb forces. In general, the process of making concrete may not be sustainable, but it can be reused as gravel for construction (Rodriguez, 2019).
There are of course some concepts such as recycling, reusing and reducing that apply to the objects that are created within a certain scale. Reusing is to change how an object is used. This is something to consider all along through design of playground items. Objects may not be as updated or appealing for future generations or the object was finally not performing as expected and must be replaced. A common example of materials that are reused to extend the service of the material are textiles, by substitution of the old object, placing it in a system with a lower service demand. Materials that are natural candidates for reuse, usually are products of a fine process and cannot be recycled easily, like used clothes, due to the supply complications that lead to a hard to earn profit from them with a recycling process.

For the most known of the concepts: recycling, it is expected that plastics, stones and metals among other expensive materials like gold, that represent a profit in ways that generate a strong competition between recycling and construction industries all over the world.

Circular sustainability or some now call it circular economy, an emerging popular concept defined as follows: a circular economy is an alternative to a traditional linear economy (make, use, dispose) in which we keep resources in use for as long as possible, extract the maximum value from them whilst in use, then recover and regenerate products and materials at the end of each service life (Circular Economy Club, 2019). The process is currently undergoing several changes, as technology advances, global warming follows, forcing the advanced countries to cope with emerging demands of sustainable products.

3 Pre-studies: context research

3.1 User studies

Children learn to talk at early ages and this makes it easy to assume that their way of thinking is the same as what they express, just as adults do. Listening to the thoughts children communicate is not always the best way to understand them; observing their actions and how they perform them yields a more realistic view of children’s thoughts and feelings (Cohen and Stern, 1983. pp. 4-5).

Natural observation was the selected method for a first approach to the understanding of how children play in public spaces, especially playgrounds; mainly because children are unpredictable and creative and may use objects in different ways as the original intended use. Recording and photographing the children was not approved by most parents and teachers, as a substitute, annotations and small sketches were made on site, registering activities and the toys most used by the children.

Four on-site observations were made around Skövde and one in Gothenburg. The observations in Skövde were made in the following public spaces: two were on the same public park near Slingvägen, another on the playground of the Montessorihuset Skövde and one on the playground of Trädgårdsstadens Skola. In Gothenburg the observation was conducted on Plikta Park. The average time of the observations was 30 minutes, influenced mainly because of the weather and the amount of time children stayed on the play areas. Around 40 children were observed, these children correspond to an age group between 2 and 9 years old.

The children observed in Gothenburg preferred the slides, seesaws, balancing games, climbing frames and walls. Their counterparts in Skövde used swings, seesaws and slides. The most common activities for all cases were running, jumping, stepping, climbing, balancing and crawling. The information gathered during these visits yielded important facts about the users and the way they play in this area.
After the observations and in order to gather different insights and perspectives regarding playscape uses, an online survey focused on receiving the attention of parents was distributed and also a printed questionnaire was handed to teachers at Montessorihuset. In total 28 responses were received, 18 answers of the parents' survey and 10 filled in teachers’ questionnaires.

The answers of the parents show that 4 (22.2%) of them have only 1 child. This leads to the following assumption, it is believed that most parents (77.8%) do not play with their children because they have to take care of more than 1 children, this can be seen in figure 2. This is directly related to the results of the question: what activities do you perform when you take your children to the playground? (figure 3). The most common answer was ‘look after my children’. These results also suggest that parents should always be able to see their children while they play.

![Number of kids each parent has](image1)

**Figure 2. Graphs for the answers ‘number of children each parent has’**

![Parents' activities when going to the playground](image2)

**Figure 3. ‘parents’ activities when going to the playground’**

Regarding the age of the children, the most popular answer was ages between 3 to 11 years old. This is the reason why assumptions pointed that the target group should be established in a range between 3 and 11, however, this age group was too wide and it was narrowed down to children going through the concrete stage of development (7 to 11 years old) that also coincided with the result of the survey shown in figure 4.
The information concerning the number of times the participants of the online survey visit playground areas were surprisingly lower than expected. A possible cause for this is that these answers correspond to the number of times they visit these areas during the winter because the survey was released on this period. The most registered answer mentioned that playscapes were visited once per week. When using the playgrounds, a grand majority of children have had accidents while playing (figure 5); the most common accident is falling, resulting in severe accidents 50% of the times (figure 6).
The results of the teachers’ questionnaires show that the average age of the children of 10 different classrooms is 8 years old; the youngest children enrolled in the school are 4 years old and the oldest children are 12 years old. In their playground the following equipment can be found: 6 swings (3 big and 3 small), 2 slides, 2 climbing frames (one for young children and another for the older), 2 sandboxes and 3 playhouses this is shown in figure 7.

Regarding safety and the occurrence of accidents 8 teachers (80%) reported that they have observed accidents happening and only 2 teachers (20%) mentioned not having observed any type of accidents. The types of accidents mentioned include falls, small injuries, a child being knocked by an object and cuts. The most common accident being falls resulting in severe injuries 10% of times this data is shown in figure 8.
3.1.1 User groups

The primary target group for the project, as mentioned previously, was established as children from 7 to 11 years old, including children with disabilities. The children in this age group correspond to the concrete age of development. The secondary target group is formed by children of other ages because there is no age limit for the use of the toy. This group is also formed by parents and family members that take children to the play areas and lastly teachers.

3.1.2 Personas

After the recollection of data, six personas or fictitious identities were established, to show different possible users of the playscape items and their relation to these areas. Personas are used to understand users’ needs and behaviours (Dam, 2019). Two of these are children, i.e. the primary users. The other two are secondary users such as a family member and a child of a different age group. More personas were defined, but the four shown next, helped understand the users better (figures 9 to 12). The other two personas include a nanny and a grandmother; however, these personas were not used because in the on-site observations the most common secondary users were parents. In addition, the description of two possible scenarios were included, one describing a school situation and a second one set in a residential common area. The complete scenarios can be found in appendix A.
**Figure 9. Persona 1.**

Name: Jacques Svenson  
Age: 5  
Nationality: Swedish  
Location: Gothenburg, Sweden  
Occupation: preschooler  

**“I like making noise”**

**Personality**  
Introvert  
Creative  
Patient  
Extrovert  
Uncreative  
Impatient  

**Bio**  
Jacques has two brothers, he and his family live in Gothenburg. His mother is from a little village in France. He is a bit shy and it is hard for him to make new friends. Jacques likes drawing, listening to music and playing the drums. When he grows up he would like to be a detective.

**Figure 10. Persona 2.**

Name: Lily Thorne  
Age: 8  
Nationality: Swedish, British  
Location: Gothenburg, Sweden  
Occupation: student  

**“I hang out with my friends at the closest playground”**

**Personality**  
Introvert  
Active  
Playful  
Extrovert  
Unactive  
Serious  

**Bio**  
Lily was born in Gothenburg. Her parents are from London. She has three Pomeranians, which she likes to dress up. She loves wearing costumes, specially princess dresses. Her favorite ice cream flavor is strawberry. She would like to be a veterinarian when she grows up. Lily has many friends and they meet almost every afternoon in the playground.
In order to gather even more information about playground objects and their characteristics, several field visits, other than the observations mentioned previously, to different playground areas in Skövde were realized. There following aspects are the ones that drove more interest:

1. The activities that children perform in these games.
2. The materials the toys are built with.
3. The colours and textures of the different elements.
5. Other characteristics of Swedish playgrounds.
The most common activities in the equipment of the different playscapes include: balancing on ropes or different surfaces which helps children develop motor skills; swinging in various types of swings (round swings, hammocks, wheels and chairs); climbing and hanging on frames, walls and monkey bars, these activities provide challenges; passing through openings of varying sizes also challenges children. One of the observed objects included sound to communicate with other children or users. Several of the activities are often combined into a same toy. Some of these examples are shown in figure 13.

The materials on the playground games were mainly steel tubes, wood usually with an anti-slippery layer, but also natural wood, plastic slides, plastic pieces to create nets for swings and steel slides (figure 14). The companies that produced the observed toys were mainly HAGS (2019), Kompan (2019) and Huck (2019).

For the colours three main pallets were observed, warm, cold and grey tones. In the cold pallet the most used colours were blues, green and purple. Regarding the warm collection the colours were red, yellow and brown tones. The grey spectrum went from black to brighter greys, including cold greys and warm greys. This can be observed in figure 15.

Safety is an important matter when it comes to the construction of playscape toys. All of the objects covered screw and nuts when these protrude more than 8 mm. The ropes were secured so that the ropes cannot un-tie (figure 16).
There are also some important characteristics of most Swedish playgrounds. They are mostly open spaces with open structures. In terms of equipment, they have at least 3 different types of games; benches and picnic tables for parents are also included. Preschoolers’ swings are different than those for bigger children and the objects for the different ages are usually separated in different areas.

### 3.3 Design Principles

Design principles are guidelines designers use through their designs, it can be understood as wishes that are wanted for an idea or project. Sometimes these principles may not be fulfilled or fully considered, but that does not compromise the process. This is the main difference with the requirements which are the concepts that must be fulfilled in order for a product to exists.

The design of playground toys should be versatile to catch the attention of children of different ages. Versatility should also be regarded as the different ways the children can play and use the objects in a playground, especially since there are many different manners of playing. The games should also allow the children to use their imagination and encourage free play.

The adaptation to different needs of children with varying abilities should also be considered to avoid excluding groups of children with disabilities. The inclusion of children with disabilities should not only lay on the object itself, but also engage children into peer playing even if they are different.

The playground should also facilitate the social interaction, not only between children of the same age, but also with adults and children of other ages. The toy takes into consideration a target group; however, the usability of the games must not be limited to just that population.

In order to attract children and their parents or the adults responsible of taking children to playscapes, these areas must be visually appealing. The equipment should attract and excite children. For this same reason the toys included in a playground should be easy to understand. Their use should be intuitive without limiting children’s imagination (Refshaugea et al., 2012).

The intention of the design is to morph the “language” of actual playground designed objects to have an identity easy to grasp by children and adults. This means the core of the concept must follow a set of observed characteristics from relevant playgrounds that were observed during the field.

Proportion in design properly applied obeys to real natural facts and physical forces. Then, proportion may provide a very good initial clue for modularity in production.

Simple forms in the design of playground toys lead to play elements with an open function, this means the user can perform several activities with the toy (Refshaugea et al., 2012).

In terms of scale, the dimensions of the objects and the separation between them corresponds to the anthropometric data of children in the target age group selected,
considering the variation and diversity of their body sizes. The intention of considering children with impairments in the design is also present.

4 Requirements

As a conclusion for the theoretical chapter and the studies, it is necessary to translate as much knowledge obtained from the research and synthesise these data to provide a quick source for the design work. The typical technique for this is to elaborate the list of requirements. The demands and requests showed on the list represent the most important aspects to take into consideration based on the analysis of the information obtained.

The list of requirements (Table 1) is divided in seven main topics in which the elements are classified. The topics are functionality, target group, usability, ergonomics, sustainability, safety and appearance. In the first column the elements are listed and in the following columns it is indicated if they correspond to demands or wishes. Some concepts have values for both columns that correspond to minimum values and ideal values. Then the table has a ‘units’ column that indicates how the values are measured. The last column is for the references where the requirement was found or can be based on.

The requirements in the list will be used to guide the design through the aspects demanded by the project. This list will be consulted throughout the design process and the development of the concept.

<table>
<thead>
<tr>
<th>REQUIREMENTS</th>
<th>Demands</th>
<th>Wishes</th>
<th>Units</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>FUNCTION</td>
<td>includes physical challenges</td>
<td>Yes</td>
<td>yes / no</td>
<td>Bruya, 1988.</td>
</tr>
<tr>
<td>complex and stimulating</td>
<td>Yes</td>
<td>yes / no</td>
<td>Bruya, 1988.</td>
<td></td>
</tr>
<tr>
<td>USER GROUPS</td>
<td>Primary users age groups:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7-11</td>
<td>Yes</td>
<td></td>
<td>years</td>
<td></td>
</tr>
<tr>
<td>Secondary users:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>children of different ages</td>
<td>Yes</td>
<td></td>
<td>age</td>
<td></td>
</tr>
<tr>
<td>Parents</td>
<td>Yes</td>
<td></td>
<td>yes / no</td>
<td></td>
</tr>
<tr>
<td>Teachers as responsible for the safety of children.</td>
<td>Yes</td>
<td></td>
<td>yes / no</td>
<td></td>
</tr>
<tr>
<td>USAGE</td>
<td>inspection</td>
<td>once every three months</td>
<td>monthly</td>
<td>time</td>
</tr>
<tr>
<td>risk assessment and maintenance</td>
<td>Yes</td>
<td></td>
<td>as frequent as possible</td>
<td>time</td>
</tr>
<tr>
<td>ERGONOMIC</td>
<td>adaptable to different populations.</td>
<td></td>
<td>cm</td>
<td></td>
</tr>
<tr>
<td>adjustable features regarding the size and position of the toys for different age groups</td>
<td></td>
<td></td>
<td>age</td>
<td></td>
</tr>
<tr>
<td>The minimum required inside grip diameter for 7-year-olds (also works for older children)</td>
<td>2.76 cm</td>
<td>3.17 cm</td>
<td>cm</td>
<td>Roderick, 2004.</td>
</tr>
<tr>
<td>reach (shoulder to fingertip) for 7-year-olds (also works for older children)</td>
<td>43.69 cm</td>
<td>cm</td>
<td>Roderick, 2004.</td>
<td></td>
</tr>
<tr>
<td>graspering reach for 7-year-olds (also works for older children)</td>
<td>31.50 cm</td>
<td>cm</td>
<td>Roderick, 2004.</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>step height (max) of 7-year-olds (also works for older children)</td>
<td>32.00 cm</td>
<td>cm</td>
<td>Roderick, 2004.</td>
<td></td>
</tr>
<tr>
<td>accessible to all children</td>
<td>yes</td>
<td>yes / no</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**SUSTAINABILITY**

<table>
<thead>
<tr>
<th>Sustainable approach</th>
<th>yes</th>
<th>N/A</th>
<th>European Commission, 2016.</th>
</tr>
</thead>
<tbody>
<tr>
<td>non-toxic materials</td>
<td>&gt;5</td>
<td>0</td>
<td>TU (unit to measure toxicity levels)</td>
</tr>
<tr>
<td>For bearings and joints</td>
<td>Metal must be stainless steel or with similar properties.</td>
<td>it should be properly oiled to reduce noise</td>
<td>N/A</td>
</tr>
<tr>
<td>To build a structure or a toy</td>
<td>must be structural, properly calculated, and treated with wax for a regular UV exposure</td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>To build the toys</td>
<td>Strong plastics or similar. must have a structural grade, properly calculated and coated against regular UV exposure</td>
<td>N/A</td>
<td>Curbell Plastics, 2016.</td>
</tr>
<tr>
<td>For the foundation</td>
<td>must be structural grade, properly calculated and polished.</td>
<td>N/A</td>
<td></td>
</tr>
</tbody>
</table>

**SAFETY / SECURITY**

**Regulations**

<p>| openings where fingers can get stuck | should not be between 8 and 25 | mm | Säkerhetsregler för lekplatsutrustning (provided by Dreem) |
| openings sizes | 90&lt; opening &lt; 230 | mm | Säkerhetsregler för lekplatsutrustning (provided by Dreem) |
| places where the head can get caught | should not be between 45 and 90 | mm | Säkerhetsregler för lekplatsutrustning (provided by Dreem) |
| places where hair or clothing get stuck | must not have rotating parts | | Säkerhetsregler för lekplatsutrustning (provided by Dreem) |
| fall protection and handrails | height from 60 to 85 | cm | Säkerhetsregler för lekplatsutrustning (provided by Dreem) |
| corners, edges and protruding parts | protruding part is at most 25 | mm | Säkerhetsregler för lekplatsutrustning (provided by Dreem) |
| drop height from less than 60 cm | do not need a fall base | yes / no | Säkerhetsregler för lekplatsutrustning (provided by Dreem) |
| drop height from more than 60 cm | need a fall base | yes / no | Säkerhetsregler för lekplatsutrustning (provided by Dreem) |
| maximum critical drop height | 300 | cm | Säkerhetsregler för lekplatsutrustning (provided by Dreem) |
| drop height from 0.6 m to 1.5 m | safety surface is at least 1.5 m from the nearest part playground equipment | m | Säkerhetsregler för lekplatsutrustning (provided by Dreem) |
| drop height above 1.5 m | the safety surface should be calculated with: $y = 1.5x - 0.75$ | m | Säkerhetsregler för lekplatsutrustning (provided by Dreem) |
| at the maximum drop height 3 m | the fall space is at least 2.5 m | m | Säkerhetsregler för lekplatsutrustning (provided by Dreem) |</p>
<table>
<thead>
<tr>
<th>Surfaces</th>
<th>Condition</th>
<th>Units</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>topsoil and packed-earth surfaces</td>
<td>may be used if the fall height is less than 1 m</td>
<td>m</td>
<td>Bachvarov et al, 2008.</td>
</tr>
<tr>
<td>loose-fill surface materials</td>
<td>300 mm depth to the height of 2 m</td>
<td>mm</td>
<td>Bachvarov et al, 2008.</td>
</tr>
<tr>
<td>loose-fill surface materials</td>
<td>400 mm depth to the height of 3 m spaced at least 3 m apart</td>
<td>mm</td>
<td>Bachvarov et al, 2008.</td>
</tr>
<tr>
<td>play structures more than 60cm</td>
<td>added textures must be rainproof</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>must be rainproof and fabricated with a sustainable goal</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**APPEARANCE**

<table>
<thead>
<tr>
<th>Variation in play equipment</th>
<th>6</th>
<th>10</th>
<th>n° of activities</th>
<th>Adults’ motivation for bringing their children to park playgrounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>For structural elements exposed</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>metal</td>
<td>must remain shiny and if used in a dynamic bearing (such as joints in swings or similar) the thickness must exaggerate to evoke the sensation of safety.</td>
<td>yes/no</td>
<td></td>
<td></td>
</tr>
<tr>
<td>wood</td>
<td>must have bright tones and have no corners or fillets with angles higher than 30°.</td>
<td>yes/no</td>
<td></td>
<td></td>
</tr>
<tr>
<td>strong plastics</td>
<td>must preserve their original colour through exposure to sun, water and wind.</td>
<td>yes/no</td>
<td></td>
<td></td>
</tr>
<tr>
<td>concrete and other ceramics</td>
<td>must not show cracks and have no corners or fillets with angles higher than 30°.</td>
<td>yes/no</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5 Idea generation

This chapter contains the information relevant to the most creative phase of the project. For the development of concepts during this stage creativity played an important role. To aid the idea generation methods such as Sketching, 6-3-5 Brainwriting and the Lotus Blossom Technique were chosen because of the great amount of results the methods yield in shorter periods of time (Design Council, 2019).

5.1 Sketches

The creative process was not limited to a specific period of time, it initiated with the project. Sketches and drawings were developed from the beginning without limiting the ideas. Most of the sketches were wild or did not consider the elements of the requirement list, especially the ideas developed before the creation of the requirements. Figure 17 shows a compilation of the first sketches.
Sketching is a design tool that designers use as a fast way to express and communicate ideas with others, but also to understand their own thoughts and the reasoning behind them:

This is particularly evident in the designer's use of models and 'codes' that rely so heavily on graphic images – i.e. drawings, diagrams and sketches that are aids to internal thinking as well as aids to communicating ideas and instructions to others (Cross, 2006).

For this reason, more objective methods (Brainwriting and Lotus Blossom Technique) were carried out, although not all of the first ideas were discarded completely. Some of the thoughts or parts of the ideas evolved or were taken into consideration in the next idea generation processes.

5.2 6-3-5 Brainwriting

Brainwriting, a method published by Rohrbach in 1969, it is a brainstorming technique aimed to be performed by groups of people. The purpose of this method is to help innovation processes by stimulating creativity. The technique consists of 6 working participants required to write down 3 ideas within 5 minutes, this is also the origin of the method’s name. The procedure requires participants to swap their papers with the collection of ideas, passing them onto the next person to their right. After 6 rounds, a total of 108 ideas are generated in 30 minutes.

This method was one of the first approaches in the idea generation stage; although, the process was only carried out by two persons. More people could have been included to practice the method correctly. A few ideas were generated in 30 minutes. However, the ideas generated were also very abstract and wild. These were the reasons why another method for idea generation was required.

5.3 Lotus Blossom Technique

The Lotus Blossom Technique (Michalko, 2016) is basically a matrix to limit the idea generation through brainstorming. It was taken from the IDEO Method Cards to
accelerate the selection of the idea generation technique. The method consists on placing the main ideas on the centre of each 3x3 matrix and brainstorm around them.

Humans are composed of physical and psychological aspects, in the end, this is also reflected on activities that are stimulating. Likewise, the method was performed twice to cover gross motor skills (figure 18) developing activities and the synaptic stimulating activities or more understandable as emotional activities (figure 19) that children perform when they play. The activities were based on the selection previously done, taking into consideration the research of children development and the study of existing playgrounds. The results of this method were more concrete and thus easier to develop into a possible concept in the given time for the project.

<table>
<thead>
<tr>
<th></th>
<th>blocks</th>
<th>different shapes</th>
<th>snow obstacles</th>
<th>plants in a garden</th>
<th>plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>arrange</td>
<td>straws</td>
<td>pathfinding</td>
<td></td>
<td>sandbox building</td>
<td>building</td>
</tr>
<tr>
<td>brands of things</td>
<td>numbers</td>
<td></td>
<td></td>
<td>lego</td>
<td>pillow fort</td>
</tr>
<tr>
<td></td>
<td>submarine</td>
<td></td>
<td></td>
<td>puff bags</td>
<td>bells</td>
</tr>
<tr>
<td>forest</td>
<td>exploring</td>
<td>“secret” spaces</td>
<td>“secret” spaces</td>
<td>light music textures</td>
<td>light senses play</td>
</tr>
<tr>
<td>new activities</td>
<td>aircraft</td>
<td>spaceship</td>
<td>blocks</td>
<td>balance tubes</td>
<td>sudoku tic tac toe</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>balls</td>
<td>tubes</td>
<td>puzzle</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 18. Lotus Blossom technique for emotional activities.
5.4 Preliminary concepts

After following the different idea generation methods around 30 concepts were obtained, in total there were around 50 ideas to work as a starting point. That amount of ideas was too broad to work with so the most interesting and realistic concepts were selected, resulting in seven concepts described below and also shown in figure 20.

**Light toy or colour toy:** the idea for this toy came from looking at a picture of a round glass table. The glass was stained in different colours and the light that pass through created coloured shapes on the floor. A similar idea could be used to create some sort of magnifying glasses that children could move or adjust to play with the light and colours that came through.

**Climbing slide:** physical challenges during childhood can be achieved in many ways, but the most attractive way of development for children is the state of play. The idea is to make the experience of reaching the slide, also a fun and challenging activity.

**Sandbox:** the main goal of this concept is to overcome the lack of inclusive items for playgrounds. The basic idea then is to elevate the sandbox to an average height for children in wheelchairs.

**Swing:** the surveys’ results showed that swings are one of the favourite playground objects, which is why it is included in the proposals. The twist here is that it can be used by more than one kid at a time and that it can also be used by the parents.
characteristics led to think of a hammock because it can be flexible enough to adapt to different body sizes.

**Balance and sound game**: this idea came from thinking first of a toy that could make noises so that children could use different senses when playing. At first it was thought as some surface that would generate sound when a kid stepped on it. Then, the way seesaws and balancing toys work was analysed. Seesaws are part of most playgrounds because they help children develop motor capacities. The concept was a combination of these ideas and also a reinterpretation of a game called ‘the floor is lava’.

**Shapes**: since children learn from playing, a game focused on cognitive and creative abilities would attract children to play in different ways. It was also considered that not all children want to run, climb or do other physical activities because they prefer different activities. The idea of this toy is that children can ‘draw’ of create different patterns moving different shapes held on a board.

**Needles**: this is a toy that could be enjoyed as different or not challenging. It is also part of understanding how children relate to toys or identify different playgrounds, for example ‘the whale playground in Gothenburg’ means something in the mind of many children and adults, this idea is derived from creating something known in a relatable way.

![Figure 20. The preliminary concepts as a collection.](image)

Seven concepts were still a broad number of ideas to develop, especially with the given time. It was also established in the specification of the project that one concept will be developed. This meant that the concept had to be selected.

### 6 Idea evaluation

The complication of evaluating a new idea is that usually there is not a clear point of comparison. The opposite circumstance is when there is an incremental development that allows improvement and comparison. In this case, there was a double evaluation (Pugh’s matrix and Weighting table) that considered the different perspectives deemed relevant for the selection. For the time given for the development of the project there has been only one idea evaluation.
6.1 Concept selection

All of the methods carried out for the selection of one concept were made and then the results were presented to the company. The results would help Dreem to select the concept based on objective facts. The idea evaluation process consisted of using Pugh’s Matrix and Concept Weighting. Pugh’s matrix table compares the ideas with already existing playground products (Pugh, 1990). The evaluation considers if the generated concepts are better or worse in the different demands or wishes than the existing commercial toys observed in the visits to playgrounds. The Concept Weighting method evaluates the concepts making a comparison only between the different concepts, for this method the commercial toys are not included (Ullman, 2017).

6.1.1 Pugh’s matrix

For the Pugh’s matrix (table 2), the baseline which are commercial items found in the observed playgrounds, was graded from 1 to 5 depending on how this product is related to the requests and demands written on the List of requirements. Then in order to compare the seven preliminary ideas with the baseline, a + was given when it performed better, 0 when it is considered to be the same as the baseline and a - when the idea did not improve or could be regarded as worse than the existing concept.

The results are the total number of “+”, the number of “0” and the “-” signs for each concept. Then these numbers were added to obtain a grade. As it can be seen in table 2, the three highlighted rectangles are the ideas with higher scores; the swing, the slide and the balance game could move on to the next phase according to this evaluation.

<table>
<thead>
<tr>
<th>Table 2. Idea selection: Pugh’s Matrix.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Criteria</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>FUNCTION</td>
</tr>
<tr>
<td>easy to get to</td>
</tr>
<tr>
<td>includes physical challenges</td>
</tr>
<tr>
<td>complex and stimulating</td>
</tr>
<tr>
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#### Weighting concept selection

6.1.2 Weighting concept selection

The Concept Weighting (table 3) system is a similar evaluation method, except that it does not compare the concepts to a baseline. It consists of giving the elements in the list a ‘weight’ according to their importance. To start, each line of the lists is compared to all of the other lines. When making the comparison the element of the list that is more important is given a number 1. The weight is not a rank from the most important element to the least important.

Next, the ideas are evaluated according to how well or not do they cover the wishes and demands using a scale from 0 to 3, where 3 is the highest score. The grade also corresponds to how good or bad they fulfil the requirements. Then the grade of the concepts is multiplied by the weight of the list elements and the results of this
multiplication are then added for each idea in order to obtain their total score. In the table it can be observed that the best concepts in this evaluation are the swing, the slide and the balance game.

Table 3. Idea selection: Weighting concepts table.

<table>
<thead>
<tr>
<th>Weighting concepts table</th>
<th>0= not fulfilling / N/A</th>
<th>1=BASIC</th>
<th>2=OK</th>
<th>3=GOOD</th>
</tr>
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<tbody>
<tr>
<td>Criteria</td>
<td>weight</td>
<td>C1 colour toy</td>
<td>C2 swing</td>
<td>C3 sandbox</td>
</tr>
<tr>
<td>FUNCTION</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>includes physical challenges</td>
<td></td>
<td>26</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>complex and stimulating</td>
<td></td>
<td>13</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>complex coordination capabilities: agility, motor learning</td>
<td></td>
<td>5</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>special coordination capabilities: Orientation, Balance, Rhythm, Anticipation, Differentiation, Coordination</td>
<td></td>
<td>18</td>
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</tr>
<tr>
<td>TARGET GROUP/MARKET</td>
<td></td>
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</tr>
<tr>
<td>Primary users age group:</td>
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</tr>
<tr>
<td>7-11</td>
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</tr>
<tr>
<td>Secondary users:</td>
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</tr>
<tr>
<td>children of other ages</td>
<td></td>
<td>7</td>
<td>1</td>
<td>2</td>
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<tr>
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<td></td>
<td></td>
</tr>
<tr>
<td>adaptable to different populations</td>
<td></td>
<td>8</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>adjustable features for users within different age groups</td>
<td></td>
<td>35</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>The minimum required grip diameter for 7-year-olds (also works for older children)</td>
<td></td>
<td>31</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>proper reach (shoulder to fingertip) for 7-year-olds (also works for older children)</td>
<td></td>
<td>32</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>proper grasping reach for 7-year-olds (also works for older children)</td>
<td></td>
<td>26</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>proper knee height of 7-year-olds (also works for older children)</td>
<td></td>
<td>23</td>
<td>0</td>
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</tr>
<tr>
<td>proper step height (max) of 7-year-olds (also works for older children)</td>
<td></td>
<td>28</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>accessible for children with impairments</td>
<td></td>
<td>32</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>SAFETY / SECURITY</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regulations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>openings where fingers can get stuck</td>
<td></td>
<td>37</td>
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<td>2</td>
</tr>
<tr>
<td>proper opening sizes</td>
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</table>
### Places where the head can get caught

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### Places where hair or clothing get stuck

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### Fall protection and handrails

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### Protected corners, edges and protruding parts

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### Drop height from less than 60 cm

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### Drop height from 0.6 m to 1.5 m

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<tbody>
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### Drop height above 1.5 m

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<td>0</td>
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</table>

### At the maximum drop height 3 m

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### Safety areas

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### Have textures to avoid slippery surfaces

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### Avoid closed spaces

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</table>

### Appearance

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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Innovation compared to current playground furniture</td>
<td>33</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
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<td>33</td>
<td>33</td>
<td>66</td>
<td>99</td>
<td>33</td>
<td>33</td>
</tr>
<tr>
<td>Glossy textures, Natural materials, Bright colours in general.</td>
<td>15</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2</td>
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<td>30</td>
<td>15</td>
<td>30</td>
<td>45</td>
<td>45</td>
<td>30</td>
</tr>
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</table>

### Baxter’s function analysis

Baxter’s function analysis was used for a better understanding of the concepts. The application of this analysis at this point of the process is due to the fact that there were no concepts to understand before this. Also, now that there are many concepts to understand, the problem is that there has not been a formal selection from the company, forcing the analysis on all concepts to present them more clearly. It was very important to have an idea about the functions developed on each concept to be able to figure out how complex or not a design might be. The function trees that described more precisely the ideas could also be taken into consideration when selecting the concept.

For validation of the function tree, the idea is to question “how” the functions are achieved while breaking down the main activity into sub concepts. The second part of the validation is to question “why” the function must be achieved while looking up on the functional tree. “The product function analysis is a method for systematically checking the functions of a product as perceived by the user.” (Baxter, 1995, p. 236).

A general observation of the diagrams, is that functions of playground toys are more complex when clustering different features and activities. These diagrams yield also information for areas like manufacturing and overall management of the product. The collection of function trees for the seven different concepts can be found on Appendix B.

### Concept selection with Dreem

The input provided by the company enriched the process of idea selection. This part of the process was a milestone where the supervisors at Dreem selected a concept
for development based on the tables and analysis done. They also considered appearance and the possibility to design the landscape with the toys. The light toy was selected as their favourite (figure 21).

![Figure 21. The concept the company selected.]

Their reasons to select the light toy were inclined to the composition of space and the conceptual exploration rather than looking for an economic benefit. That is why including them in this part of the process enhances the approach to the concepts they prefer without setting a specific shape or so.

7 Concept development

The original idea of the light toy involved sense-play for the sight with colours, patterns and shadows. In the process of improving the concept, it became interesting to involve the hearing sense and the sense of touch. Smell and taste could compromise some safety issues this is why these senses were not considered.

This developed into designing a main arch as frame where different elements of the toy are placed. The elements are meant to produce sound and project light when moved. The objects in the toy are different, in order to catch the attention of children. Also, the variety of activities improves the duration of the fun, since children can get bored easily and their attention span is short. Children require more activities. The toy is composed of four main elements: a spherical rattle, a set of drums, a kaleidoscope and a circular labyrinth. Figure 22 shows the light toy, in this sketch there is not a set of drums because at first it was thought as a different musical instrument created with pipes. Drums were selected after thinking about safety, because children could get their fingers stuck in the pipes.
The main components of the toy are the arch which is the structure. The foundation that holds the light toy in place. The elements (the rattle, the kaleidoscope, the drums and the labyrinth) are placed with ropes that can allow the toys to rotate. The ropes have also a mechanism which adjusts the height of the element.

7.1 Mechanism

The main parts of the mechanism for the toy are swivels and winches that maintain the objects in place, but also allow them to rotate or be moved as required. The safety swivel is this type of mechanism, that allows a free rotation of the objects, it can be more or less fast for rotations depending on the pressure applied upon the elements attached. These pieces would be out reach for the users in order to avoid any kind of injuries. The general force these may sustain are 25 kN, although it depends on the type of swivel. For the design a swivel with this capacity is recommended (figure 23). Also, to avoid any object to get entrapped in the swivel, it is placed inside a close cylinder.

As mentioned in the previous chapter, the elements of the toy can be adjusted. This would require a rope coiled around a manual drum winch, that according to client requirements could be on the floor or embedded on the arc. The winch shown in figure 24, the standard Sportsman Hand winch-W1000 (Sportman Series, 2019), for example, can support up to 453.59 kg. This mechanism would only be handled by the producer or the responsible of the installation this way it can be ensured that none of the users could have an accident with the mechanism.
7.1.1 Storyboard

Figure 25 shows a storyboard of how the objects can be used. It shows how they rotate or move. First the user shown rotates the kaleidoscope, then he plays with the rattle, shaking it. Next, we can see the user interacting with the labyrinth, there are different ways to move it. Lastly, the child uses his hand to play with the drums.

Figure 25. Storyboard showing the mechanism function.
7.1.2 Development of user experience

Through the design process and the concept development, including its iteration phase, the pursued aesthetics also evolved. The visual appearance for attracting children and parents is still a primary characteristic in terms of aesthetic; although, the concept's visual appealing is not the only reason for the users to be attracted by the product. Initially the toy only allowed playing with light, patterns and visual effects, after this iteration stage, the toy is meant for invoking sensorial play, using also the hearing and the sense of touch (Schifferstein and Hekkert, 2008).

Another characteristic that was considered originally was how intuitive the object was, it should not require instructions to be used. This task to make the object intuitive should also consider that the elements of the game can be used in different ways, without limiting children’s imagination when they play. The language of the object must follow certain characteristics from other playgrounds or things that are meant to attract children.

Figure 26 shows a Mood board created to express some of the effects desired, the colour palette proposed as well as the materiality of some elements that conform the toy.

Figure 26. Mood board.

7.1.3 Light and materials

The materials that will be proposed for the product play an important role, especially because through them the sense play will be invoked. A research for materials that could let light through, that colorized the light or could create interesting effects was then carried out. The research of these materials was done using the Material Conne-Xion database (Sandow, 2019). There is more information of each material available on their system, on the next table (5) only the main characteristics are shown. The materials presented are mainly some examples of materials that could be used in the future to create light and different patterns in the different elements of the toy.
<table>
<thead>
<tr>
<th>Name and manufacturer</th>
<th>Description</th>
<th>Physical characteristics</th>
<th>Picture</th>
</tr>
</thead>
</table>
| Plexiglas® Rnew®      | A bio-based high-performance family of thermoplastic resins. | Stiffness: Semi-Rigid  
Structure: Closed  
Surface/Texture: Matte  
Transparency: Translucent, Transparent  
Surface Hardness: Semi-Hard | ![Plexiglas® Rnew®](image1.png) |
| CURBELL PLASTICS®, TUFFAK® | Polycarbonate sheet 0.449 cm. X 190 cm. X 317.5 cm.  
$380.34 US dll x sheet | Stiffness: Rigid  
Structure: Closed  
Surface/Texture: clear  
Transparency: Translucent, Transparent  
Surface Hard  
Thermoformable  
U.V. Ray resistant | ![CURBELL PLASTICS®, TUFFAK®](image2.png) |
| Luminique Primex Plastics Corp. - Pace Facility | A range of polystyrene sheet and roll goods that exhibit an ‘edge-glow.’ | Stiffness: Stiff  
Structure: Closed  
Surface/Texture: N/A  
Transparency: Opaque, Translucent, Transparent  
Surface Hardness: Hard | ![Luminique](image3.png) |
| Streams of Light Holografik™ Luxe Films | A clear overlaminate film featuring a holographic effect that creates a stream of light that bends with movement. This material consists of graphic elements that highlight and draw attention to the visual display of light. | Stiffness: Flexible  
Structure: Closed  
Surface/Texture: Glossy, Texture  
Transparency: Opaque, Translucent, Transparent  
Surface Hardness: Semi-Hard | ![Streams of Light Holografik™ Luxe Films](image4.png) |
| Sonata Rainbow CASE PAPER | Flexible packaging film that combines a layer of iridescent film on paper. This material exhibits a highly reflective iridescent effect, which varies the colour depending on the viewing angle. | Stiffness: Semi-Rigid, Flexible  
Structure: Closed  
Surface/Texture: Glossy  
Transparency: Opaque  
Surface Hardness: Semi-Hard | ![Sonata Rainbow CASE PAPER](image5.png) |
Two-sided iridescent sheet composed of three laminated layers of film; 100% thermoplastic polyurethane (TPU), 3M Radiant Film, and Cube Light Reflective thermoplastic polyurethane (TPU). The textile is translucent but also has the ability to act as a reflective medium for colour depending on the type and angle of the light source.

Stiffness: Flexible
Structure: Closed
Surface/Texture: Glossy, Texture
Transparency: Opaque, Translucent
Surface Hardness: Semi-Hard

7.1.4 Life cycle assessment

For the design, the suggested materials are mainly plastics. To apply the concept of reusability, it is also possible to modify the original function to use as urban spaces lighting. To apply the concept of recycling, the plastics, mainly the body of the toys, would be sold to a recycling plant. In Sweden, Avfall Sverige is an important organism that works along municipalities and other companies to manage waste (Avfall Sverige, 2018).

To reuse the concrete foundation there can be pre embedded pitch diameter holes with a nut for new things to be installed, for example, street signs and new toys. Another alternative for the concrete is to re-use it as landfill or to correct river oxbows. In case of metal parts, the nearest foundry would be a good option to sell the outdated or damaged parts. Wooden or biodegradable cardboard is likely to be delivered to a recycling plant. To dispose of other parts, like light bulbs or similar, the producer company must provide specific instructions. This whole work would be including the toy as part of a circular economy.

7.1.5 Alpha prototyping

This chapter contains a first detailed visual of the toy, on this model the tests can be performed. It is already meant to fit ergonomic measurements; however, testing must reveal if there are mistakes or if modifications needed to be made. Figure 27 shows an example of the lightning created by the kaleidoscope.
### 7.1.6 Design principles application

Once the concept was more defined an evaluation to check if the design principles originally thought were being applied on the design. The results on the following table are the principles that are considered in the design and on the design process so far.

Since this work will not reach the next phases of a product development process, the evaluation of this principles can only be evaluated as far as the undergoing phase concludes. The results from this type of evaluation in a complete process usually come with external validation.

<table>
<thead>
<tr>
<th>Design principle</th>
<th>Was it achieved?</th>
<th>Why?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Versatility</td>
<td>x</td>
<td>The toy can be used in different ways. Children can play differently, even adults could also use the toy.</td>
</tr>
<tr>
<td>Accessible for children with different abilities</td>
<td>x</td>
<td>The elements in the game allow children with impairments to play because it is not only focused on the motor skills.</td>
</tr>
<tr>
<td>Facilitate social interaction</td>
<td>x</td>
<td>This needs to be tested in a full-scale prototype with children.</td>
</tr>
<tr>
<td>Sustainable</td>
<td>x</td>
<td>The life cycle of the toy does not conclude when it stops working as such, it can be reused or even recycled afterwards.</td>
</tr>
<tr>
<td>Visually appealing</td>
<td>x</td>
<td>The colour palette proposed is adequate to children and the effects of light and sound that will be produced by the toy attract children. Several interviews revealed this both for adults and children. (discussed in chapter 7)</td>
</tr>
<tr>
<td>Intuitive</td>
<td>x</td>
<td>The elements of the toy are easy to understand as well as easy to use. (discussed in chapter 7)</td>
</tr>
<tr>
<td>Invoke sense play</td>
<td>x</td>
<td>The main focus of the game is to produce colour and patterns with the light to appeal to the sense of sight, as well as noise and music to appeal to the sense of hearing. The use of the toy demands to use the sense of touch. During the sunny days, the need for electric light is not really necessary and they may perform just with sunlight.</td>
</tr>
</tbody>
</table>

### 7.1.7 Safety regulations application

Table 7 shows the Risk-Benefit Assessment form (RBA) to assess playgrounds according to the National Children’s Bureau of the UK (Ball et al., 2012). It may be used by anyone related to the design and utilization of playgrounds, but the output of the use is heavily depending on the observations of each individual. This table was used to evaluate the light toy in terms of safety.

The characteristics on the first column of table 7 are a set of ideas that are product of discussing the different points of view that are suggested by the RBA form. There are two different ways to define the observations from a design perspective: through the analysis of the list of requirements and by making assumptions based on the design of the light toy.
Table 7. RBA-FORM applied from a design perspective.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Observations filled in by Rodrigo Palacios and Lorena Brown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefits</td>
<td>Provides fun and attractive activities.</td>
</tr>
<tr>
<td></td>
<td>Enhances the chance to visit a playground for children because it is also attractive for parents.</td>
</tr>
<tr>
<td></td>
<td>The toy is adjustable to different heights, allowing it to be used by different populations.</td>
</tr>
<tr>
<td></td>
<td>It provides a sense of safety because of the general installation of urban lights.</td>
</tr>
<tr>
<td></td>
<td>It provides a different opportunity to develop cognitive abilities.</td>
</tr>
<tr>
<td></td>
<td>It is accessible for almost everyone.</td>
</tr>
<tr>
<td></td>
<td>The object can be used by different age groups.</td>
</tr>
<tr>
<td></td>
<td>It promotes peer to peer play.</td>
</tr>
<tr>
<td></td>
<td>The object may be adapted to many contexts and environments.</td>
</tr>
<tr>
<td></td>
<td>An opportunity to draw children's attention away from screens by providing similar stimulus: light, movement, and basic (fun) cognitive challenge.</td>
</tr>
<tr>
<td>Risks</td>
<td>Equipment failure</td>
</tr>
<tr>
<td></td>
<td>Rotation mechanism breaks due to wear</td>
</tr>
<tr>
<td></td>
<td>Tensile elements with elastic properties get loose due to exceeding forces applied on the fittings</td>
</tr>
<tr>
<td></td>
<td>The arc may fall if the foundation is not properly attached to the ground (ground conditions may vary from locations and would require special attention on zones with earthquake risks).</td>
</tr>
<tr>
<td></td>
<td>Vandalism in general can affect the toy’s functionality but it is not likely due to the fact that lighting provided by the toy itself is meant to keep crime away.</td>
</tr>
<tr>
<td>Local factors</td>
<td>There is room for improvement on the playground items</td>
</tr>
<tr>
<td></td>
<td>There is need of new ways of playing</td>
</tr>
<tr>
<td></td>
<td>Urban lights and landscape are tightly related to the Use of space, the municipality in Skövde for example, shows that immigrant people want more places to spend time with their families during the afternoon, which is not possible with current light conditions.</td>
</tr>
<tr>
<td>Compare design</td>
<td>The toys included are existing in one or other way as typical objects with another scale, with low risk or not known for being mildly dangerous. For example, the kaleidoscope has never killed anyone.</td>
</tr>
<tr>
<td>Decision</td>
<td>The toy has an acceptable level of risk as long as the supervision/maintenance is regular.</td>
</tr>
<tr>
<td>Actions taken</td>
<td>(This only applies for sites) the flooring of the toy is properly modified to the location.</td>
</tr>
<tr>
<td>Follow up</td>
<td>This document is a Design Stage risk-benefit assessment. It is possible that further issues come to light through the implementation of this feature and adjustments may be required. In addition, it is recommended that a post-installation risk-benefit assessment is undertaken by the client.</td>
</tr>
</tbody>
</table>

### 7.2 Dimensioning

#### 7.2.1 Ergonomic measurements

In this section, the information presented is mainly anthropometric data and the correlations of this data that were used to create a manikin family in the digital human modelling tool Siemens Jack 9.0 (Siemens, 2018). The database used for obtaining this information was DINBelg 2005 from Belgium (Motmans, 2005). The reason why this database was used was because it has the most complete data about children. Another reason was because a Swedish database with the same amount of information was not found.

The first step was to create manikins that would be studied in the tests, since the target group established was children from 7 to 11, the manikins represent children were between this age range. The anthropometric data of male and female children of ages 7, 9 and 11 were considered enough to represent this population. In total 12 manikins were created: 4 seven-year-old children, 2 males and 2 females (5th and 95th percentiles), 4 nine-year-old children, 2 males and 2 females (5th and 95th percentiles), and 4 eleven-year-old children, 2 males and 2 females (5th and 95th percentiles). The selection of these percentile values is recommended because according to Erik Brolin these percentiles are enough to represent a wide range of the population (Brolin, 2012. p. 33). The design of the toy is looking for a minimum to maximum approach so there is no reason to include the 50 percentiles.
In the following data tables (table 8 and 9) the measures used for the definition of the manikins are present. The measurements selected are the stature, the distance from the buttock to the knee and the distance from the buttock to the shoulder while sitting. These measurements are highly correlated between each other because when the manikins were being created in Jack, only the stature was taken into consideration, letting the software fill in the rest of the measurements according to its parameters. Some of the manikins created seemed very strange in their proportions. This was the reason why other measurements were considered for the definition of the manikins (buttock-knee length and buttock-shoulder length). The high correlations allowed to control the size of some body parts of the manikins and with this they were not strange. The children represented with the manikins are within the target population.

Table 8. Data of males.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Age</th>
<th>Percentile</th>
<th>Stature (mm)</th>
<th>Shoulder height (sitting) (mm)</th>
<th>Buttock-knee length (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>7</td>
<td>95</td>
<td>1152</td>
<td>364</td>
<td>361</td>
</tr>
<tr>
<td>M</td>
<td>9</td>
<td>95</td>
<td>1259</td>
<td>404</td>
<td>407</td>
</tr>
<tr>
<td>M</td>
<td>11</td>
<td>95</td>
<td>1354</td>
<td>437</td>
<td>445</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Average</td>
<td>1348.67</td>
<td>444.33</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Median</td>
<td>1339</td>
<td>442.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SD</td>
<td>141.43</td>
<td>57.31</td>
</tr>
</tbody>
</table>

Table 9. Data females.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Age</th>
<th>Percentile</th>
<th>Stature (mm)</th>
<th>Shoulder height (sitting) (mm)</th>
<th>Buttock-knee length (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>7</td>
<td>95</td>
<td>1143</td>
<td>360</td>
<td>365</td>
</tr>
<tr>
<td>F</td>
<td>9</td>
<td>95</td>
<td>1246</td>
<td>394</td>
<td>406</td>
</tr>
<tr>
<td>F</td>
<td>11</td>
<td>95</td>
<td>1353</td>
<td>432</td>
<td>446</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Average</td>
<td>1346.00</td>
<td>436.67</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Median</td>
<td>1335</td>
<td>434</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SD</td>
<td>151.19</td>
<td>57.86</td>
</tr>
</tbody>
</table>

The postures selected for the evaluation were thought to be the most common postures the children would adopt while playing with the different elements of the toy. The results of the tests are show mainly if the toys are designed correctly for the children that will use them. The following images (28) show the anthropometric measurements commonly relevant for playground toy’s design. These images were obtained from the Belgian database (Motmans, 2005). The highlighted images are the measurements used for the creation of the manikins.
Figure 28. Anthropometric measures relevant for the design of the toy. The highlighted images are the measurements used for the creation of the manikins.

The following figure (29) shows the 12 manikins that will be used to perform tests in Jack. These are the manikins that were created with the anthropometric data shown in the previous tables (8 and 9), they correspond to children from ages 7, 9 and 11.

Figure 29. Test subjects with critical anthropometric measurements.
8 Tests

There are many ways and reasons for testing objects. In the current scope, it was important to observe how some desired characteristics of the object are performing. There could be many tests, but in the timeline for this project, the best option was to perform virtual tests.

8.1 Virtual tests

Virtual tests are a way to tackle the time limitation and the budget limitation to test some of the characteristics of the toy. Also, it is simple to run and adjust the test to the variables considered every time there is an iteration in the design. For example, a change in the focus population or the age group would be very hard or expensive to test in a real-life scenario.

8.1.1 Ergonomic evaluation in Jack 9.0

The ergonomic tests were carried out in the software Jack 9.0. This program is created by Siemens to test if certain labour conditions and working postures are the correct ones or if they could harm the workers in an assembly line; for this project, it is meant to demonstrate how a posture is not suitable by altering the interpretation of the results yielded by the program. The normal interpretation is that there is or not a risk in the posture. Since the program considers biomechanical calculations on a specific environment, it may not be relevant to assess the risk. However, for the particular case of this toy it will provide a guide on how to act or to adjust the height or position of the toys based on the results of the test.

The CAD model of the Light Toy was imported into this software. The tests were the results of placing the manikins in the positions the children will be most likely adopting to play (figure 30), this way we can see if the dimensions of the object correspond to the dimensions of the children’s anthropometric data and if they could get harmed or injured because the playing posture is not correct. The level of conformity can also be evaluated.

The evaluation that was applied to the 12 different manikins placed in the 8 postures was RULA (Rapid Upper Limb Assessment) (McAtamney and Corlett, 1993). The RULA analysis is used to assess the level of risk a person is exposed to in an industrial environment due to the working positions. Even if children in a playground are not in the same environment as workers, this evaluation was selected because the postures the children are being placed on can be evaluated and identified as comfortable or adequate. The test did not evaluate the risks of injuries because the analysis considers factors that do not apply for children playing.
Figure 31. Playing postures for ergonomic tests.

Figure 31, shows errors or odd parts of the manikins that are not likely to happen in a real scenario because children are not constrained to that posture that would be uncomfortable. Image “A” contains a red square that depicts a possible position of the left wrist, but not likely at all. It can also be seen that there is a red line that shows an odd inclination of the head, since it is not bending the upper back to observe the toy.
Also, figure 31 shows that in frame D the distance between the lowest point on the drums and the floor is 30 cm which is wrong because no wheelchair could be properly accommodate a person near the toy.

On the frame E (figure 32), the objective of remarking the different position of legs is to show that there are some postures of the upper body that are closely related to the way the feet are positioned. This would be one of the details that may affect how comfortable the toy is depending on the posture the kid may adopt.

An observation about the table 10 is that the first variable considered was the total number of tests, which was 96. The postures are the second variable considered in the ergonomic evaluation. Table 10 shows the results of the RULA applied to the 12 manikins.
After observing the groups, the most vulnerable one would be formed by girls aged 9 in all the postures, attending the sizing needs of the most vulnerable group will yield the best results for a proper sizing of the toy. Another method would be to run all the simulations over and over until having the proper postures and finally a more analytic way would be to know the precise factor that affects each critical subject within different postures, ensuring a proper use of the adjustable feature. The way it was performed in order to obtain validation was to combine the first and third type of analysis to get an accurate but less time-consuming result.

8.2 Children interviews

To obtain a feedback from children, a simple interview was elaborated. During the interview the children were shown pictures of the virtual models, a physical model and an animation of the toy. The interview consisted of 4 questions:

1. What do you think?
2. Would you play with this toy?
3. Which is your favourite object?
4. Do you understand the toy?

It is a point of view that must be understood as the frame of a perception, not the whole result of an experience. These were the results:

The average age out of the 33 interviewed subjects was 9 years old. The majority would use the toy, partially. Most of their answers were only focused on one of the objects. It can be understood that the design fails to generate many attractive activities for the focus group; however, it succeeded in attracting 88% of the children to at least one game in the toy.

The question that sought to discern the popularity of the games showed a preference for the drums above the other toys by 6%, but the other games were almost even in terms of popularity. This may be due to the fact that the children are more
familiar with drums or they prefer the design. Since the difference yielded is not too important, no actions were taken from this feedback.

As a side answer, some of the children thought the toys looked like candy. This suggests there may be room for a test that checks the level of attraction originated on a biological level, such as what would happen if the playground has food related information, for example: A climbing wall with the shape of a strawberry, a sandbox with chewing gum appearance.

On the aspect of intuition, the question was if they understood how to play, without instructions: 85% of the children would have a clear idea of how to play and the rest would need an example first. Out of the 85%, 40% had minor doubts about the toy but nothing that could not be solved by an interaction with the toy. The conclusion is that children think of this toy as simple, therefore, intuitive.

8.3 Test results interpretation

This chapter contains a deeper analysis of the results obtained after the RULA. Most of the values were considered as yellow (odd posture or wrong position of the toy) and it was important to understand why were the tests giving such results. Table 11 took into consideration the yielded values for males and females of age 9 which were the most critical results.

The analysis consisted in observing the values the RULA gave to the different body parts and giving them an importance grade based on how much would this body parts (column 2 of table 11) will be or not subject of injury or to be an uncomfortable position.

Table 11. RULA Result analysis.

<table>
<thead>
<tr>
<th>Importance</th>
<th>RESULT BREAKDOWN</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGE GROUP: 9 YEARS OLD PERCENTILE 5 (F and H in the figure 29)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>MEDIUM</td>
<td>UPPER ARM</td>
</tr>
<tr>
<td>HIGH</td>
<td>LOWER ARM</td>
</tr>
<tr>
<td>NONE</td>
<td>WRIST</td>
</tr>
<tr>
<td>LOW</td>
<td>WRIST TWIST</td>
</tr>
<tr>
<td>TOTAL</td>
<td>3</td>
</tr>
<tr>
<td>MEDIUM</td>
<td>NECK</td>
</tr>
<tr>
<td>LOW</td>
<td>TRUNK</td>
</tr>
<tr>
<td>TOTAL</td>
<td>2</td>
</tr>
<tr>
<td>First value</td>
<td>H - F5</td>
</tr>
</tbody>
</table>

POSTURES

The results underlined with red show a tendency in the wrist to be misplaced, this is likely to add fake risk to the evaluation in a considerable way.

The results coloured light red are the ones that add medium risk values to the results, then those must be interpreted.

The values underlined with blue indicate a change in the height of the toy must be done to accommodate the population.

In the case of postures two and four, the toys are the pushing balls and the kaleidoscope in the same order. This means the explanation for the results is that the toy in that particular setting is not for children with 9 years old, reinforcing the need for toys in different positions, i.e. two options of height on the same type of toy to achieve safety. This is already provided given the fact that the postures underlined in green are the same but for lower or higher objects, tested with the same subject, representing a lower, null or acceptable level of risk.
This is however, a case study to determine the how to place the toys in the arc according to a specific population. There is no need for further testing or evaluation since the risks could be easily avoided by the adjustable feature of the toy.

8.3.1 List of requirement comparison

The objective of comparing the initial requirements with the design achieved for the light toy, was to evaluate if every aspect was accomplished or if there should be modifications in order to fulfil the requirements. On table 12, there are some of the aspects that can be evaluated so far; however, some requirements must be evaluated in the future stages of the process that were not developed during this project.

<table>
<thead>
<tr>
<th>REQUIREMENTS</th>
<th>Accomplished</th>
<th>Missing</th>
<th>comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>FUNCTION</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>includes physical challenges</td>
<td>x</td>
<td></td>
<td>could include more physical challenges</td>
</tr>
<tr>
<td>complex and stimulating</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>USER GROUPS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary users age groups:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7-11</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secondary users:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>children of different ages</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parents</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Teachers</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>USAGE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inspection</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>risk assessment and maintenance</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ERGONOMIC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>adaptable to different ethnic groups</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>adjustable features for different age groups</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>inside grip diameter for 7-year-olds</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>reach (shoulder to fingertip) for 7-year-olds</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>grasping reach for 7-year-olds</td>
<td>x</td>
<td></td>
<td>However, no features for the blind or visually impaired were designed.</td>
</tr>
<tr>
<td>accessible to all children</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SUSTAINABILITY / MATERIALS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sustainable approach</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>non-toxic materials</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metal</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wood</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>strong plastics</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>concrete and other ceramics</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SAFETY / SECURITY</td>
<td></td>
<td></td>
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corners, edges and protruding parts  |  x  
drop height from less than 60 cm  |  x  
reduce injuries  |  x  
All contact areas must have extruded textures to avoid slippery surfaces  |  X  

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| variation in play equipment  |  x  
| For structural elements exposed |
| Metal  |  Not exposed  
| Wood  |  x  
| strong plastics  |  x  
| concrete and other ceramics  |  Not exposed  

8.3.2 Improvements and modifications

After observing the tests, the height of the drums was incorrect on two aspects: it was not allowing children in wheelchairs to use toy, since there was no leg room for the chair to get close. There was also a height related odd posture that had to be corrected by placing the toy higher.

The height change was from a separation of 35 cm from the ground to a 60 cm distance. That height is common for almost all children and smaller wheelchairs comfort access.

A second issue was the design of the foundation, it was not properly managing the accidental forces that could be easily applied on the arc. The improvement was to extrude the foundation in the opposite direction of the possible accidental forces, removing the risk of tumbling.

9 Results

This chapter contains the drawings, models and renders that represent in different mediums the solution of the light toy. This collection of images is intended to explain in a more graphical way, how the light toy is in detail: the elements of the toy, the different environments and how the user could interact with the product. Moreover, these images could help to understand the materials and how will the toy be built.

9.1 Sketches and drawings

The following drawings (figures 33, 34 and 35) show the intention, critical problems solved and material proposals. The final concept has 4 main toys shown in figure 33.

The 'Rattle' is a plastic ball filled with smaller bouncing balls. These make sound when the big ball is shaken, but they are also shinny or colorful to reflect and refract...
light. As the small balls bounce inside the translucent container, they illuminate and create different effects with the light.

Drums are instruments that involve the sense of touch and the sense of hearing, most of the times also accompanied by the sense of sight, although this sense is not necessary to play with this toy. The drums are presented in different sizes in order to produce different sounds. These are placed on rigid plate made of wood or plastic.

Kaleidoscopes have always attracted children because of the way they display light and how the patterns showed change every time the toy is turned. These kaleidoscopes will also contain artificial light, this way they can work at any time and even if the day is not sunny. The inclusion of artificial light will also help illuminate the playscape in general.

The labyrinth makes the children engage in a fun activity where they develop their cognitive skills, for example the problem-solving skill. The tiny balls they have to move across the labyrinth also produce sound when bouncing through the walls. The balls are of different colors and reflect the light as the toy is moved.

These elements of the toy are the first proposals meant to be included in the design; however, more may be designed to expand the options available.

Figure 33 shows the main features and characteristics of the toy, as well as the different elements that conform the toy (the drums, the rattle, the kaleidoscope and the labyrinth). Then the following figures (34 and 35) are the technical drawing for the details of the toy and its foundation. These drawings show the proposed materials and the measurements.
Figure 33. Characteristics of the toy.

**LIGHT TOY**

**RATTLE**
The ‘Rattle’ is a plastic ball filled with smaller bouncing balls. These make sound when the big ball is shaken, but they are also shiny or colorful to reflect and refract light. As the small balls bounce inside the translucent container, they illuminate and create different effects with the light.

**DRUMS**
This element of the toy is composed of a rigid surface that could be plywood or even plastic, where several drums of different sizes are placed. Drums are instruments that involve the sense of touch and the sense of hearing; most of the times also accompanied by the sense of sight, although this sense is not necessary to play with this toy.

**KALEIDOSCOPE**
Kaleidoscopes have always attracted children because of the way they display light and how the patterns change every time the toy is turned. These kaleidoscopes will also contain artificial light, this way they can work at anytime and even if the day is not sunny. The inclusion of artificial light will also help illuminate the playscape in general.

**LABYRINTH**
The labyrinth makes the kids engage in a fun activity where they develop their cognitive skills, for example the problem solving skill. The toy balls they have to move across the labyrinth also produce sound when bouncing through the walls. The balls are of different colors and reflect the light as the toy is moved.

**SCALE**

**PROPORTION**

**ADJUSTABILITY**

**CUSTOMIZATION**
This is a schematic drawing of a proposal for the steel placement in the foundation beams. It is surfaced with 1” of concrete to protect the steel from humidity, an additive during the concrete mix may add protection to the general service integrity of the foundation. Steel corrugated bar separation, steel quality, steel bar diameters and packaging must be determined with the plastic-elastic limit methods.
9.2 Models

In this chapter there are some pictures of a physical model (figure 36) that were used to understand how the objects hang. Virtual renders are also included, these are meant to depict the toy as a complete solution (figure 37 and 38). Some details of the elements of the toy are shown in figure 39. The chapter ends with a collection of views (figures 40, 41 and 42) of possible environments in which the toy can be placed.

9.2.1 Physical model

The clay model was used for the children’s feedback interviews to help explain the toy and how it works.
9.2.2 Virtual model: The Light Toy

Figure 36. Physical model of the Light Toy.

Figure 37. Virtual model of the Light Toy.
Figure 38. Front view of the virtual model of the Light Toy.
These are the close ups of the toys: drums (top left), kaleidoscope (top right), labyrinth (bottom left) and the rattle (bottom right).

Figure 39. Elements of the Light Toy.
These are environments and scenarios that describe playscapes.

Figure 40. Children playing with the 'Light Toy' during winter time.

Figure 41. The 'Light Toy' shown in a public area in Gothenburg.
10 Discussion

Designing for children can be a complex task. Keeping the balance between safety and fun, without losing a creative solution was the biggest challenge. For the project, the limitations became also a source of opportunity: not understanding children turned into a research of their context, growth and understanding. Even when it would have been better to reach a final product and improved results with a full-scale prototype test, the result was knowledge.

It would have been interesting to develop a full-scale prototype or even parts of the toy. The kaleidoscope for example, could have been built and tested individually. The results from those partial tests could reveal if the objects would work as expected or if they would need any type of modifications.

Regarding the ergonomic tests, the evaluation done in Jack 9.0 yielded relevant information about the possibility of children being injured when playing. The results showed if there were chances of risk, although this should be further analysed with the proper methods. It is also important to mention that since one of the main features of the toy is that it is adjustable, risk can always be avoided by changing the placement of the games.

This project considered design principles which may be misunderstood as requirements. We consider them different because design principles are abstract ideas that are wanted for the design, but may not be taken into consideration or fulfilled which is where they differ from requirements, aspects that must be fulfilled for the correct completion of the product.

Through the process, the constant reflection of the technical and theoretical aspects also added value to the work. Sometimes, complicated discussions became cornerstones for positive changes in the design, so listening to each other's arguments enriched the process itself. The industrial supervisors, the academic supervisors and the design team will always have a small difference of opinion on which is the best path to follow, but the goal is always the same: design.

10.1 Limitations in the results

The main limit for the thesis is that no tests were performed on a physical prototype, therefore, there is a lot of information not yet gathered and tests that would prove if some of the assumptions were true or false. A secondary limitation on the design of
the toy is the time to gather enough information to produce it. This information includes the evaluation of the most logic and accurate manufacture procedures and costs.

### 10.2 Fulfilment of the objectives and purpose

The company provided freedom in the selection of the project and demanded to select between designing an object that could be used in many projects and an emblematic piece for one project. The design team selected to develop a conceptual design for a playground toy that could be used in many projects along with secondary goals the design finally met: to be inclusive, sustainable, ergonomic and stimulating. There were other aspects that were more basic requirements for the design of playground toys: safety, fun, adaptability to different locations and people.

The comparison with the list of requirements offered a brief on these aspects. To explain how some attributes of the toy are fun or attractive, the study of product experience was essential and done, although it is something that this work failed to demonstrate with raw data; fairly, some of the children interviews demonstrated children found at least one game in the toy attractive. At a first glance this shows that the toy is appropriate and interesting for children which was the most important result since it is real feedback from possible users.

The overall process cannot be considered a complete user centred design, since the project had little contact with the user in the general, at least less than expected. That was not part of the general original plan, at first it was thought to include children in the idea generation stage. Although, the user can still be involved if the project continues the process.

The resulting toy design has features such as adaptability, modularity and customization which leave room for the design of more toy and objects that can be used in the same structure. This makes the concept open to modifications and changes depending on what children require and want to play with. This means that the toy may exist in different configurations and thus be used by children of different scenarios and even in different cities and countries.

The process and the focus angle were difficult to control, it became wide even with the double diamond method. In the end, it had to be narrowed down to something realistic and concrete. The structure and division of the project’s phases was adequate, it helped the process to be carried on time. To summarize, the work done is successful to the extent established initially; although, it can be subject to improvement.

### 10.2.1 Recommendations for future development

Personally, we wanted to develop the project deeper, but part of the work has not been performed because of the time limitation. It would have been a better approach to design the toy in modules for a quick packing, transportation and building. These types of solution must reach all the design, including the foundation. This way the value added to the toy is higher and becomes much more competitive. Also, there are a lot of unknown effects of the toy on different scenarios, it would be recommended to have a lot of tests before production. The following stage, would be to set production automation goals.

Another fact is that before building a full-scale prototype, it would be better to have the opinion of a set of experts in the field: playground supervisors, designers with experience and production engineers that will lead to improve the solutions.
10.3 Improvements for the design process

The first and most important stakeholders in this work, are the children. They are users that have an important perspective about toys and playgrounds, these users were not involved properly. The children could have been part of the idea generation and concept selection. Also, there should be more information gathered from the group of children involved; they should be known subjects and remain the same subjects through the whole process. This would ensure continuous feedback throughout the whole process.

Considering the span of time assigned to the project, it would be better to eliminate certain parts of the process that turned out to be a time consuming and not relevant for the final concept development. An example of these were the scenario scripts, personas and Baxter’s function analysis for the concepts that were not selected. The scenarios and personas are techniques that help understand the target user, but for this project these didn’t worked as planned.

The number of personas created, especially the secondary users, do not represent the diversity of these users. In general, the personas could have been more complete with the identification of goals and frustrations or other personality traits. The reason why the personas were not developed completely as the method suggests is that more information about the users was understood with the field studies and the initial surveys.

Another improvement regarding the function analysis would be to use this method earlier in the design process because understanding deeper the concepts would really aid the idea evaluation. The function analysis trees did not help the selection of a concept as it was expected. In the end only the function analysis of the selected concept was taken into consideration in the development of the project.

An important improvement that can be done in upcoming projects is to make very clear the definition of the project and its scope. This was done in the beginning, but resulted to broad and open that when the process was being carried out it was difficult to control how deep a subject must be studied.
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Appendix A

School:
The bell rings and it is now time for the children to go out and play. The recess duration is 45 minutes. The teacher tells the children to put on their jackets, form a line and head outside. As soon as they cross the door, the children start running towards the playground as they scream happily. The teachers yell to one of them to be careful, she then sits on one of the benches close to the playing area.

Some girls go to the swings, they don’t like playing with the boys. ‘Today we will be pirates’ yells a little boy. ‘Can I be the bad one?’ asks another. They go to a tree to grab some sticks that they will use as magic swords. They pretend that the slide is the plank through which pirates make their enemies walk into the ocean.

There is another group playing hide and seek; a girl with round glasses counts to a 100. Two boys argue because they are hiding in the same spot. The teacher asks if they could both stay in the same place; they decide to listen to her and stop arguing. Another girl runs into a tiny plastic house, she thinks she can’t be found there.

Some of the older boys organize themselves into two teams; they want to play football. Another teacher, the 4th grade teacher, is convinced to be the referee. As the match starts, a teacher yells: ‘you get down here; you’re going to hurt yourself’. One of the children playing as a pirate climbed to the top of the playground structure. The teacher grabs the child by the wrist and tells him he should not do that.

The bell rings, the recess is over. All of the teachers ask the children to gather around and go to their classrooms.

Residential leisure space:
‘Ding’ the elevator announced it had arrived to the ground floor. Three girls walked out of it; the older sister grabbed the hands of the two younger. She knew that if they stayed together their parents would let them go out by themselves more often. The walked outside the building and turned left, at the corner was the common area with the playground. The eldest sister asked the other two girls’ which game did they want to go to. They told her they wanted to use the slides.

The girls arrived to the games; other children were there playing already. The girls climbed the ladder of one of the slides. On top was an older boy, around 13, he was sitting in the slide but he would not go down. One of the sisters asked the boy if they could use the slide. ‘Wait for your turn’ replied the boy. The sisters waited for some minutes, but the boy was not moving. The youngest girl got tired of waiting so she walked next to the boy and pushed him. The boy rolled down the slide and hit his arm when he fell to the ground. He started screaming, the girls didn’t know what to do; they climbed down to check the boy.

A woman ran to get to where they were, she asked what happened and then called an ambulance because she did not want to move the boy to avoid more injuries. The woman then called the boy’s parents and the sisters’ too. The biggest girl then realized they would never go to the playground by themselves anymore.
Appendix B

Figure 1. Function analysis for the concept 'Balance game'.

Figure 2. Function analysis for the concept 'Colour toy'.

Figure 3. Function analysis for the concept 'Climbing slide'.
Figure 4. Function analysis for the concept 'Swing':

MOH

SWING

REST

provide a safe comfortable surface

lie down

APPLY FORCE

sit

add pendulum joint

provide ergonomic height

provide frame

provide supporting seat

provide chain

provide a mesh flexible surface

Figure 5. Function analysis for the concept 'Sandbox':

MOH

SANDPLAY

add sand to the container

provide container

provide sand

adjust accessible features and set a proper volume

include ramp for toddlers

adjust depth to children wheelchair height
Figure 6. Function analysis for the concept ‘Push needle’:

- **PUSH NEEDLE**
  - make a gesture/hand position/
  - assemble
  - provide needles
  - provide frame and foundation
  - provide thick perforated surface
  - include an easy to reach surface through anthropometric diversity analysis
  - enable safe playing for diverse age groups and capabilities
  - adjust needle framing to be easy to push
  - provide safe (dense) distance between needles to avoid injury

Figure 7. Function analysis for the concept ‘Moving shapes’:

- **MOVE SHAPES**
  - Grasp figure easy
  - apply force
  - assemble
  - design an ergonomic border and surface for the shape
  - provide shape
  - provide shell
  - provide mechanism to hold shapes