beatwheel

A PROGRAMMABLE MUSIC INSTRUMENT

THE PRODUCT REPORT

Eduardo F. Tapia Olmos & Jesper Ortvald Erichsen, MA4-ID2, June 2017

TITLE

Beat Wheel,
A Programable Music Intrument

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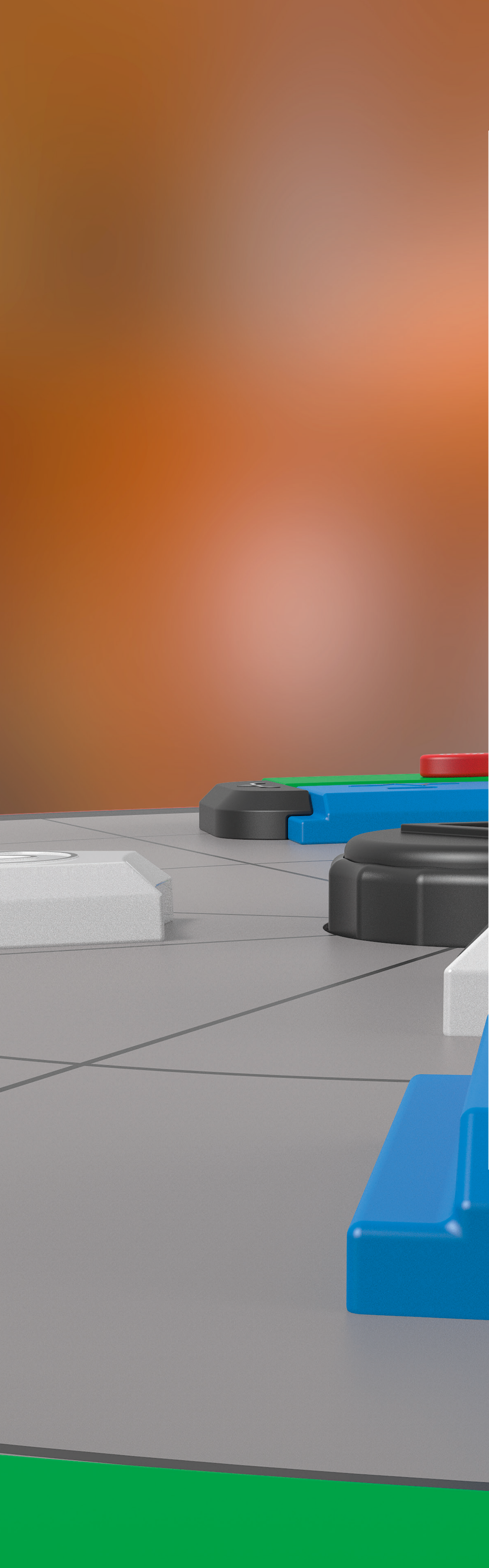


WHAT IS THE BEAT WHEEL

Beatwheel is an easy-to-use musical instrument for training computer programming competences in children between six and nine years old. Beatwheel introduces kids the basics of coding by empowering them to compose their own sounds and original music. Through its tangible interface, Beatwheel takes the code out of the computer. It offers children a physical syntax to write a computer program and orchestrate music.

Beatwheel platform reads a piece and reproduces their assigned function. Through the Beatwheel software, users can see and modify the source code assigned to each piece. Children arrange and change the pieces' position and visualize them in the screen, making it possible to drag and drop the pieces in the screen that shows where to locate them.

Beatwheel trains kids with the logic within computer programming by making it closer to them through music composition, artistic thinking and insight events.

LITTTLE COMPOSERS!

The pieces are assigned with pre-defined code arguments that stand for small looping sound tracks. Children put together the pieces to arrange a configuration in the Beatwheel and create sounding system as a whole. The beatwheel is in a constant live loop, which means that it allows to write and modify the code in-real time just like kids might perform live with a guitar.

The live code compilation functionality of the Beatwheel allows children to make constant changes in the pieces setup and thereby play it as an intrument that affords music composition, coordinate sounds and orchestrate several voices in-the-doing.

Beatwheel is a music companion for children experimenting and exploring the world through music. Kids can create a loop and use it as an advanced metronome to play along with their own performance.

LITTLE HACKERS!

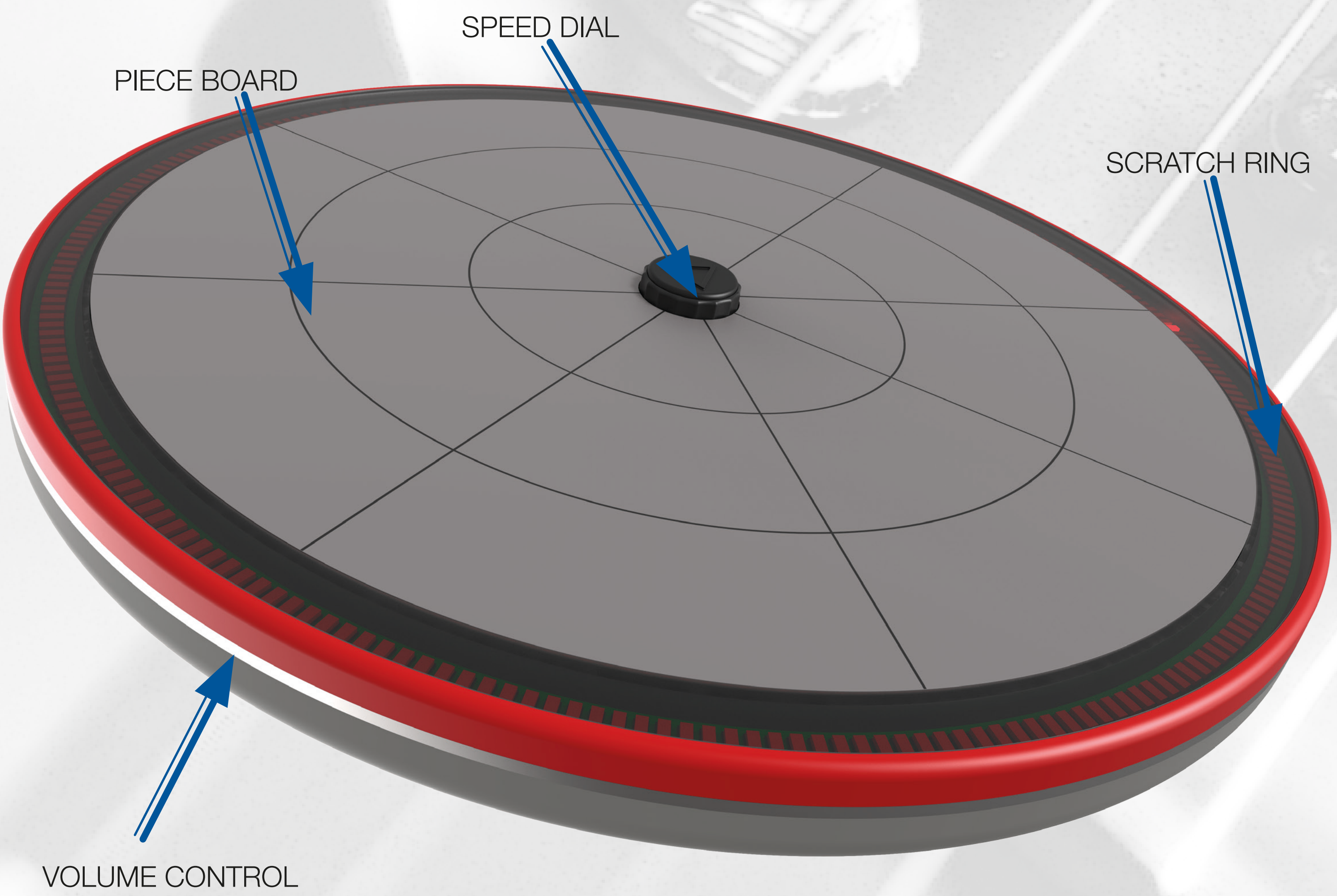
Beatwheel uses physical pieces in dialogue with a digital interface for facilitating the learnability of the syntax needed in a computer language. It opens design up to create a steping stone as a new form of entry point to the world of computer programming.

Children learn to code in three scalable layers that can be inversely transformed: 1) arranging the pieces to create harmonic musical sentences, 2) use the visual drag and drop colored blocks of each pieces' code in the screen to modify the parameters, and 3) accessing directly to the source code in the script screen to go deeper building on each piece's identity.

Having physical pieces to create sounding music in the form of easy-to-program combinations, Beatwheel uses sound to convey multiple inputs directed to sensory pathways and thus facilitate the core of computer programming languages.

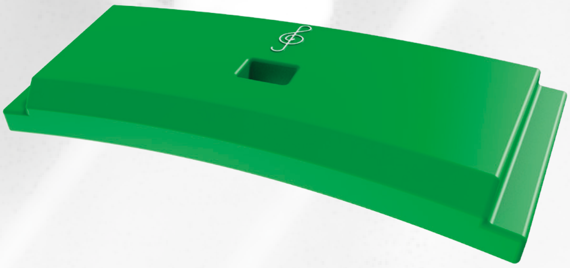
THE BEAT WHEEL PLATFORM

The platforms defines a workspace for kids to interact with the Beatwheel. It serves as visualisation area of play-time and entertainment whereas the sound creates a medium for tangible hands-on programing. Each piece fulfills a specific function for composing music. The platform reads the pieces through EMR converting the piece's type and position into code and sending it to the computer through a USB or Bluetooth connection.



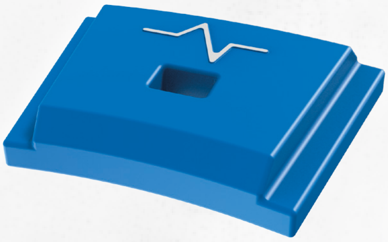
GRASPING THE SOUND

THE MELODY



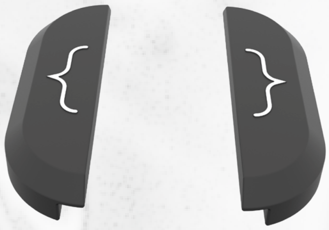
The code attached to this piece is a succession of musical tones in the form of chords and arpegios with different sequences of pitch progressing in the foreground.

THE RHYTHM



These pieces have attached a code with different sequential pattern of durations relative to a beat or pulse as the background.

THE INSTRUMENT

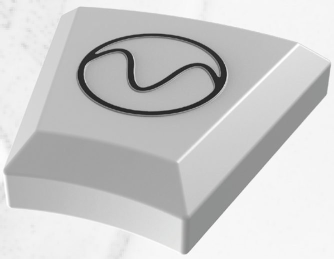


It declares a melody or rhythm with a musical instrument. It defines their duration by placing their start and end with brackets.

THE EFFECT

These pieces is inserted in a melody or rhythm and have attached a code that enhances sound processes such as echo, reverberation or distiortion.

THE AMBIENT

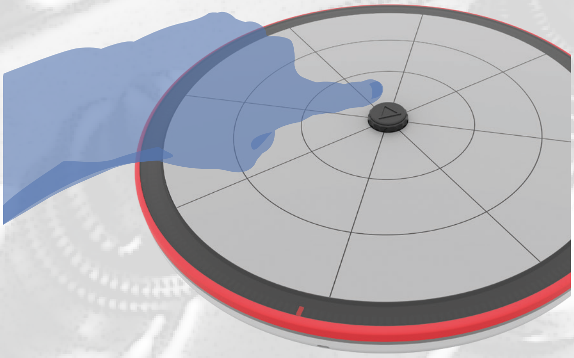


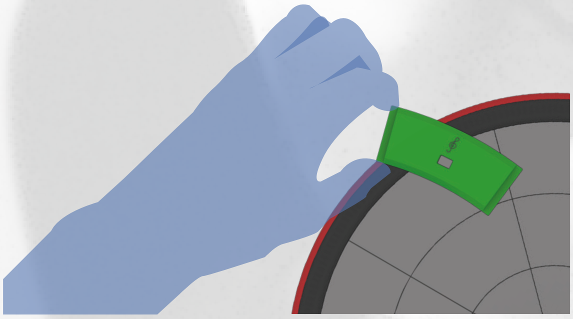
These pieces have attached a sound sample that displays environmental sounds that have a connection with the objects or actions that produce them.

THE BEATWHEEL STEP-BY-STEP

1. TURN THE VOLUME UP!

Turn on the Beatwheel by pressing the play button for five seconds and execute the autorun. The play button intitiates the live looping and lights up the scratching ring sequentially as the tempo is set.



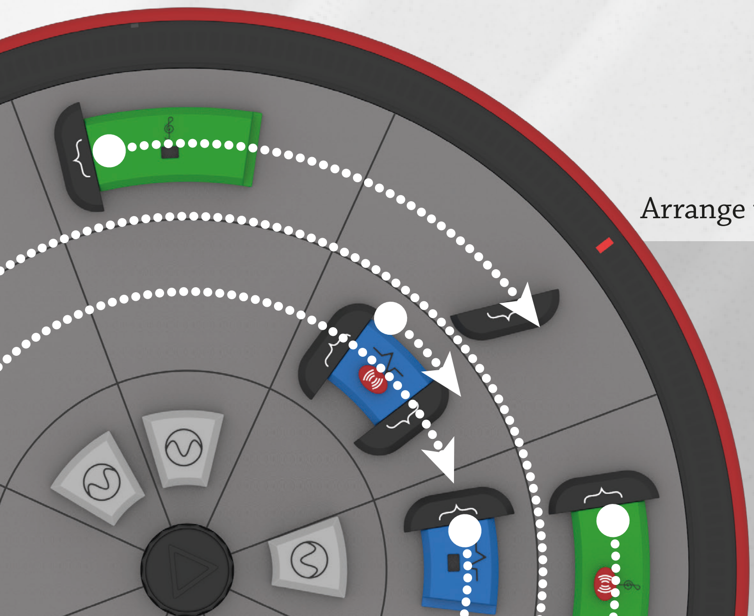


2. ORCHESTRATE AND COMPOSE

Experiment and explore with the order of the pieces in the delimited divions and hear the differences by changing duration with their position and length distance.

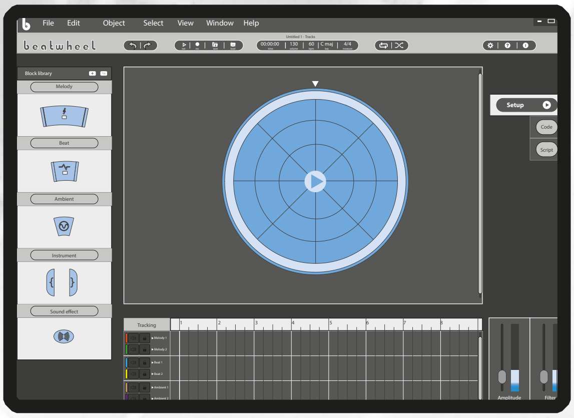
3. SCRATCH LIKE A DJ!

Move back and forth the lighted up ring to play with the tempo and changing it by speeding it up or slowing it down. Slide the hand through the volume control to regulate the overall amplitude.



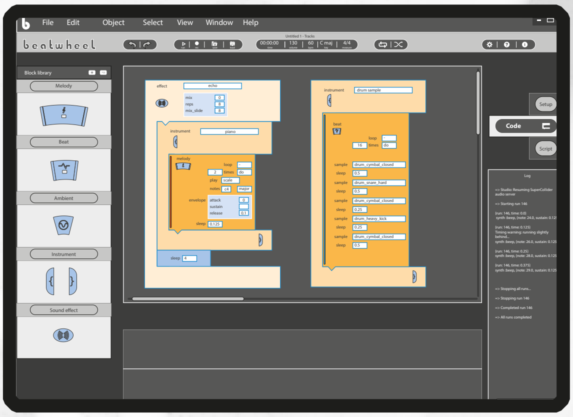
Arrange the brackets to coordinate the start and end of each sound!

THE SOFTWARE STEP-BY-STEP



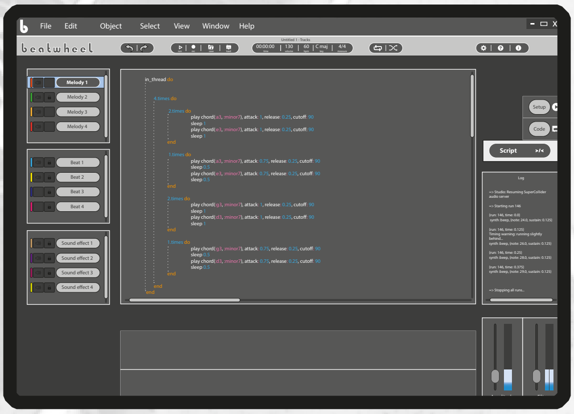
SEE YOUR SYNTAX!

Children can both arrange and change the pieces’ position and visualize them in the screen, and drag and drop the pieces in the software screen that shows them where to locate them



CODE WITH BLOCKS!

Pieces’ variables are visible with their numerical values in the code screen with colored boxes which are displayed in real-time along with the pieces placement. This facilitates the understanding of the syntax between the physical pieces and the script.



EDIT THE SCRIPT

Modifications are possible within this level to radically change the core code of each piece’s identity being used. It increases the possibilities to rise the level of sophistication in respect of sound and music.

USE SCENARIO: PLAY-TIME!

Beatwheel can be fun to explore and experiment with, specially for kids dreaming with perfoming live. The first time you use the Beatwheel, the software presents an intro tutorial that walks you trough the basics of sound computation and music composition.
Beatwheel is designed for kids to code easily their own melodies, rhythms and sound effects in the computer, for then create new musical arrangement using the platform.

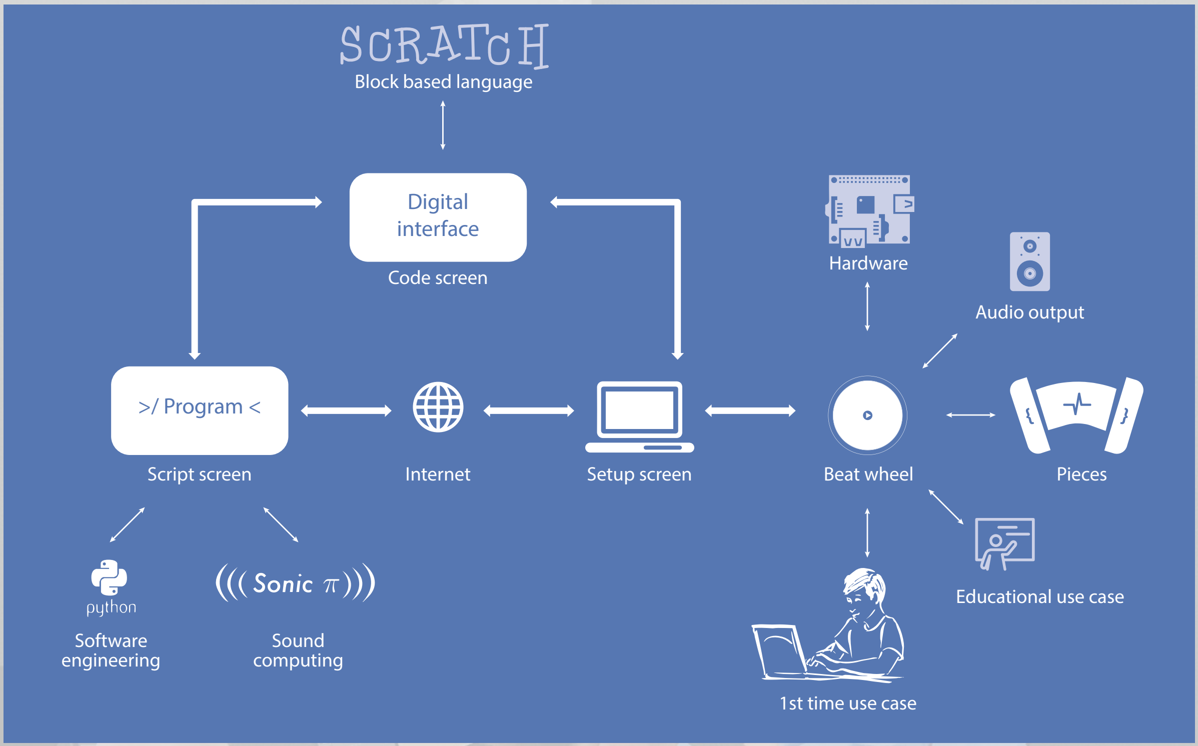
CODING AND MUSIC FOR ALL!

Beatwheel is a playful tool: a programmable music instrument which purpose is to give a competence for the future. This means that the core of the Beatwheel is that everyone that use it, will learn to write a computer program by making original music. Parents wanting to engage with their kids can use the Beatwheel as a third place to meet, therefore converging new knowledge acquisition in computation with creativity and music.

USE SCENARIO: EDUCATION TIME

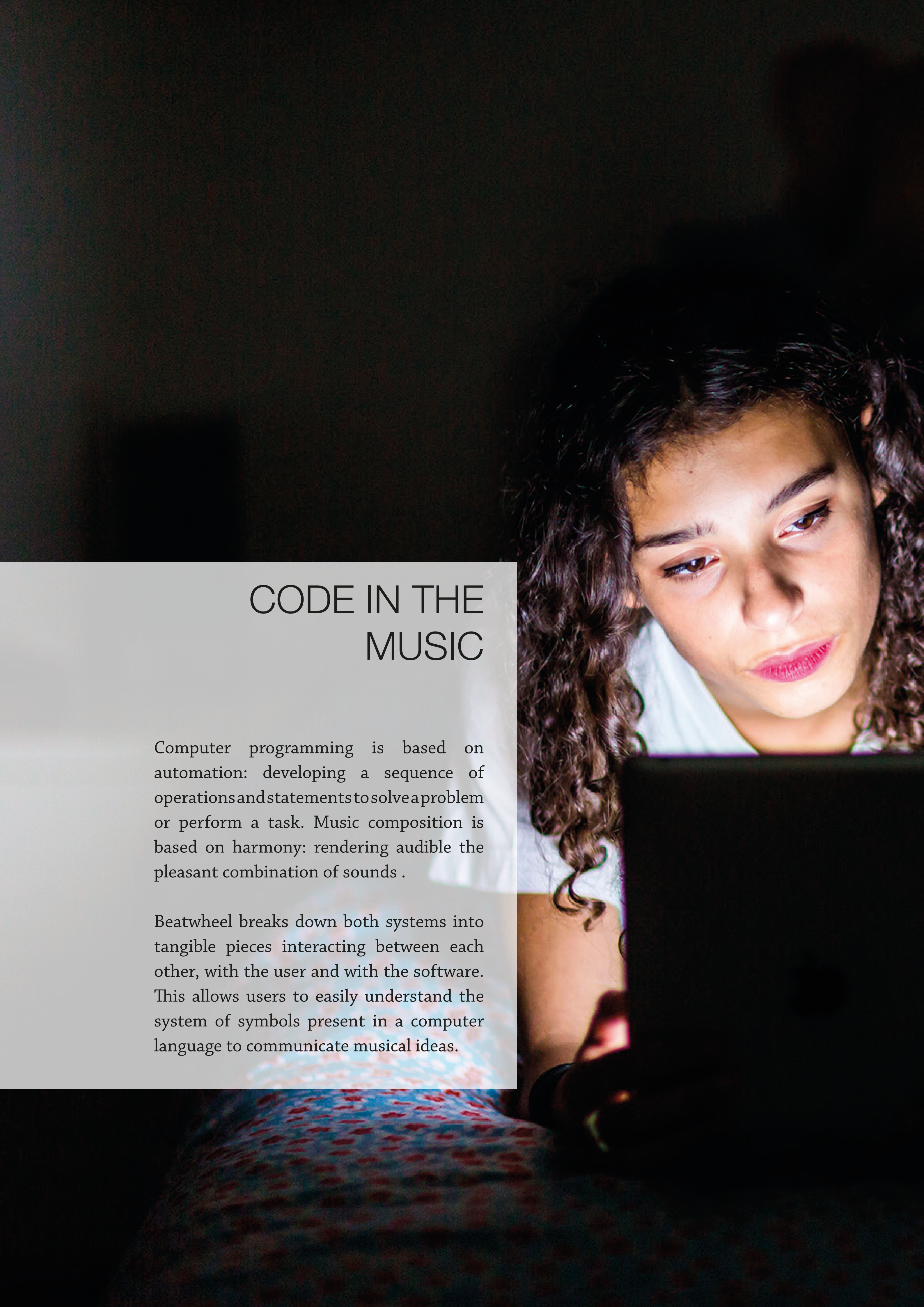
Beatwheel is designed to fit inside the classroom. Coding clubs for young children are emerging in Denmark and the world in a common effort to involve kids with the technological world.

Including scalable levels of complexity present in the product, teachers use the Beatwheel to introduce kids with the basics of computer programming and encourage them to go deeper into constructing their own source code reaching high levels of musical sophistication.



SYSTEM ARCHITECTURE

There is a front-end and a back-end interaction. The front-end displays the positioning of the pieces read by the platform and the code arguments of each piece using a block-based interface with Scratch language. The back-end develops the overall software by using the language Python 3, and it displays the lines of each piece's code written in Sonic Pi language. Beatwheel is grounded on the setup screen functionality, the physical pieces and the play-time use case.



CODE IN THE MUSIC

Computer programming is based on automation: developing a sequence of operations and statements to solve a problem or perform a task. Music composition is based on harmony: rendering audible the pleasant combination of sounds .

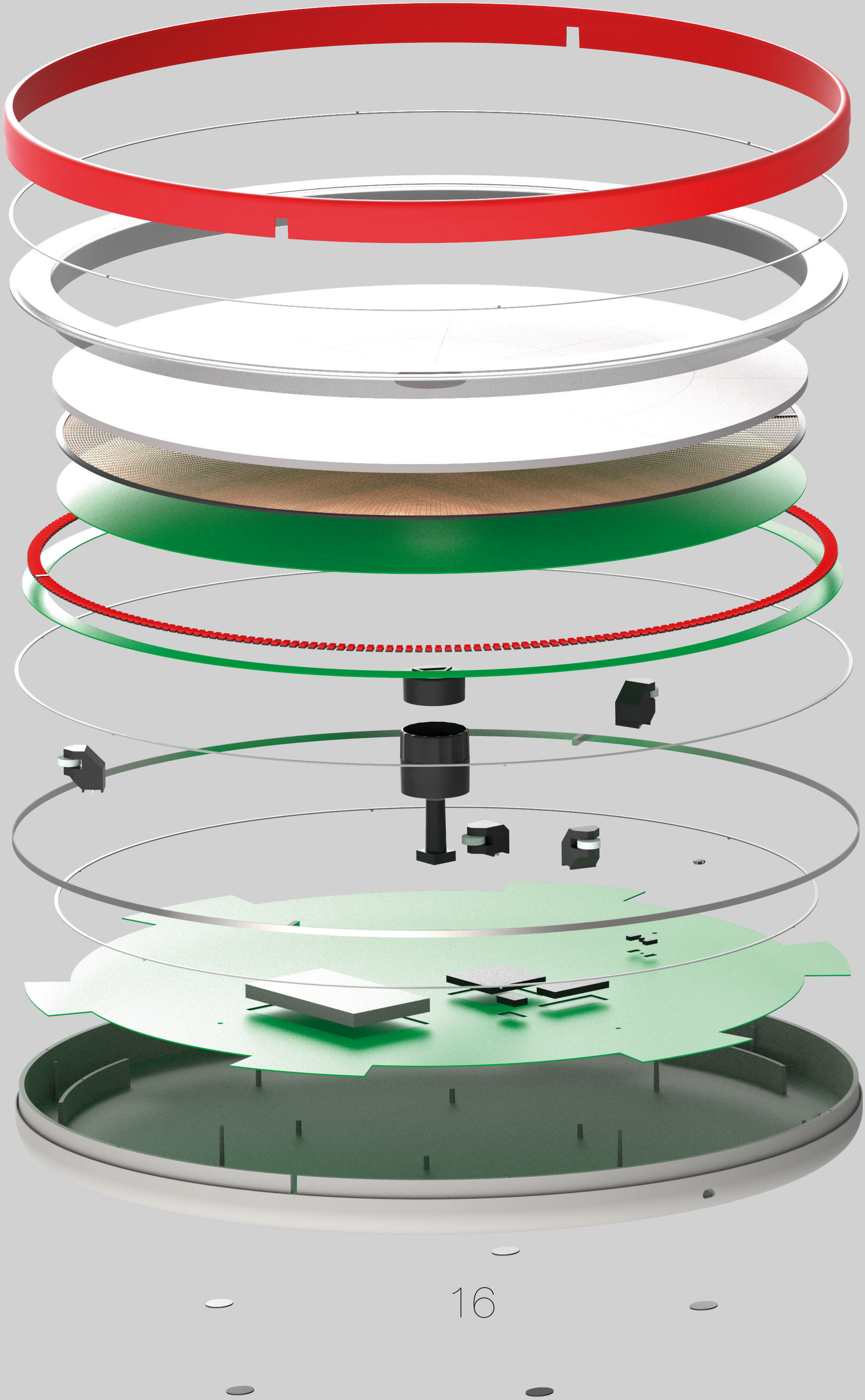
Beatwheel breaks down both systems into tangible pieces interacting between each other, with the user and with the software. This allows users to easily understand the system of symbols present in a computer language to communicate musical ideas.

beatwheel

MUSIC IN THE CODE

Beatwheel opens design up to convey the thought processes within the logic of computer programming together with computational models of music empowering kids to easily create their own musical pieces.

Beatwheel trains children to declare variables, write arguments, iterate, set conditional statements, construct data structures, algorithms, and to program multiple flows of control by training kids to set simultaneous threads of sound.



CONSTRUCTING THE BEAT WHEEL

ELECTROMAGNETIC RESONANCE DIGITIZING

Beatwheel uses the technology of EMR to calculate the positioning of each piece and giving to each type a unique identification.

RASPBERRY PI

Beatwheel uses an internal computer to do the calculations making it possible to only send the code string, and thus make the data transfer minimal and agile.

HDPE SCRATCH WHEEL

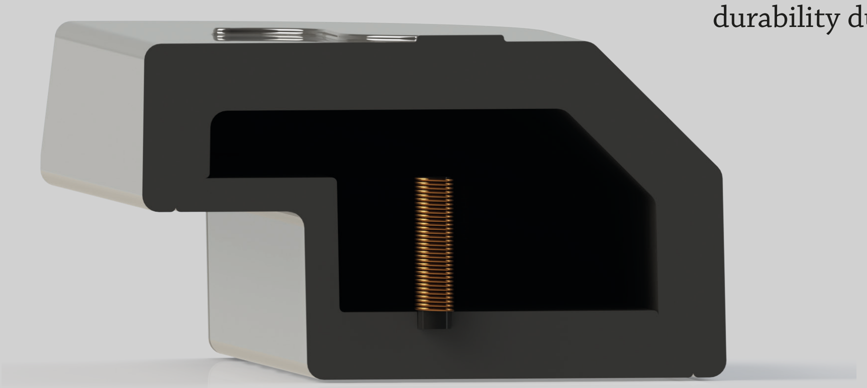
By making the outer scratch ring of a low friction material like HDPE it is possible to create a feeling of smooth change of play position

ABS CASING

With a casing made out of ABS the Beatwheel is able to withstand the stress it will take by being used by children

PP PIECE SHELLS

Making the pieces shell out of PP it is possible to create low cost pieces with a long durability during use of the Beatwheel



REMAINING IN DEVELOPMENT

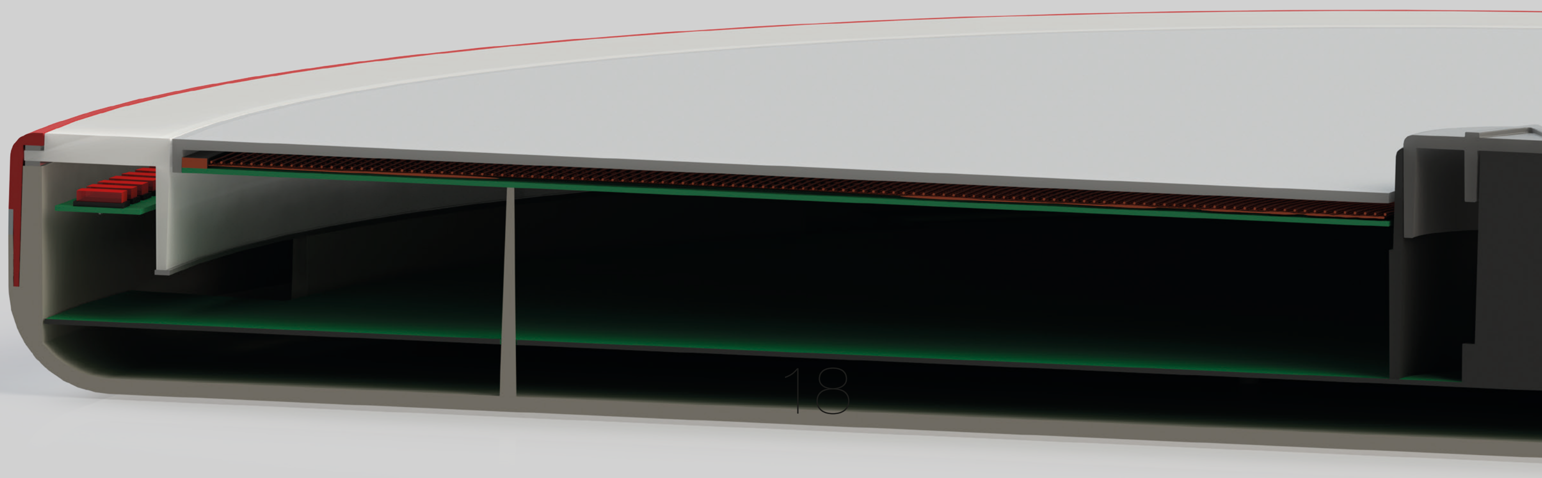
THE SOFTWARE

The Beatwheel Software needs more specification in regards of inter-connection with external servers and host service. The links between the internal buttons, special options and intro tutorial box messages of the software need to be precised. This can be done by dividing the sub-tasks on the interaction flowchart developed in the process report into smaller sub-functions with their own interaction flow modelling.
In regards of the connection of the Beatwheel with servers, it can be achieved by creating an on-line open site for optimising the changes of each piece's code source in order to provide users the opportunity to share their music, code setup and pieces arrangement. The eventual creation of a Beatwheel social site can serve for explotation of its potential .

THE HARDWARE

The standard way for a EMR system is a square but because it functions through a grid it is possible to approach the circle of our board as a rectangle. Though this approach it will make it easier to create for an electronic engineering body with expertise on hardware. At the same time, the EMR system is normally set up as one input which means that it will also require extra programming time to make possible the digitizing and let the platform know when the pieces are to work as one in the ways they interact .

PRICE FOR THIS DEVELOPMENT: 675000 DDK



PRODUCTION COST

For the production price of the Beatwheel the main cost parts comes in the EMR digitizer and the production of the plastic components for both the platform and the pieces. Meaning that the more Beatwheels are ordered the increased contribution margins gets as seen on the selling unit chart. This should be possible with an expansion of the private market share to other countries than Denmark and if is sold to a greater age span than 6 to 9 year olds children.

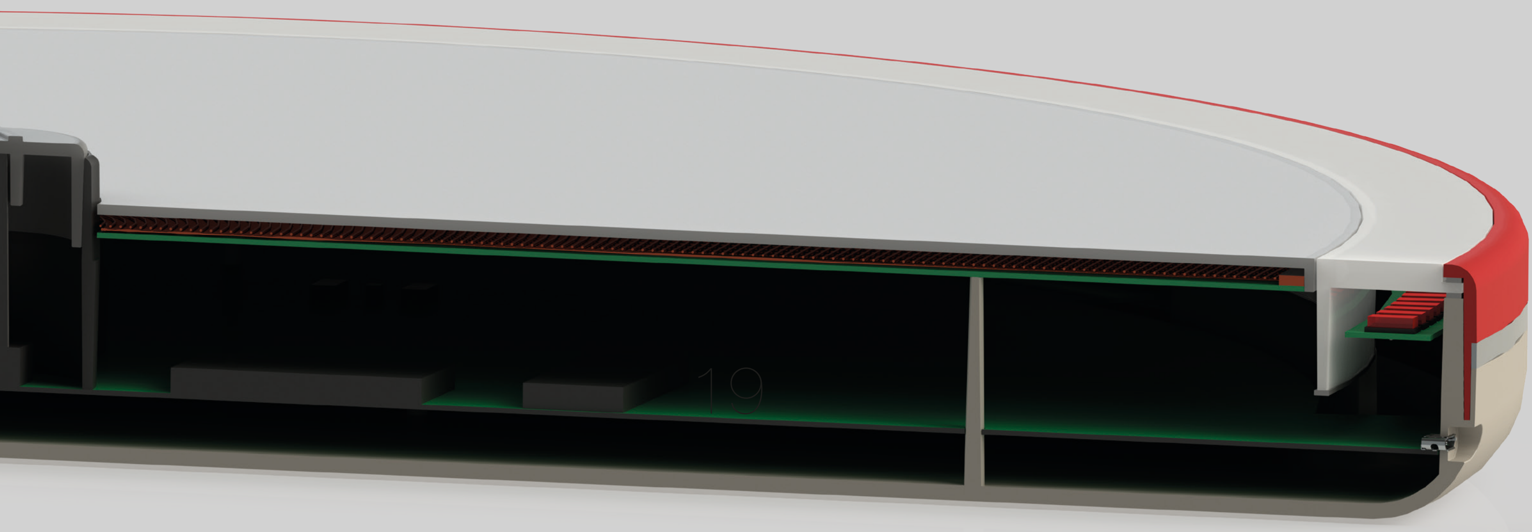
When wanting to buy a Beatwheel there are two main possibilities, either with a platform or not. If a platform is bought the software is included, but the pieces are needed to make everything work. In the other hand if pieces are bought, then an activation code for downloading the piece's source code to the software is included and it will be the way to expand the possibilities of the actions possible with the Beatwheel. The pieces will be sold mainly as sets of a music style thereby creating the possibility of selling themed sets and creating additional sales.

WHEN SELLING 29.900 UNITS OF THE BEAT WHEEL OVER 4 YEARS

Units ordered at a time	15.000	50.000
Production price in DKK	659	593
Sales price in DKK	844	844
Contribution margin	22%	30%

RETAIL PRICE & SOLD SOLUTIONS

Platform & 6 of each piece	DKK 1.899
Platform	DKK 999
6 of each piece	DKK 900
6 of one type piece	DKK 180



REACHING THE MARKET

Parents and schools are demanding for products that give children play experiences that ensure new skills acquisition, particularly in science and technology.

The current market is lacking from integrated offerings that provide learning with an easy-to-read computer code as tools that allow kids to relate with their peers and that creativity through problem solving, artistic thinking and insight events.

Beatwheel targets these needs through live looping, tangible interfaces and easy-to-do music. It affords to compose and modify sounds and code in-real time where children arrange phrases in computer language through physical pieces to musically comunicate their ideas with the Beatwheel.

THE STRATEGY

Beatwheel is delivered by Beatwheel Corporation to the world through co-activating and inter-connecting chain operations in two external layers and one middle layer: manufacturing, buyers and partnerships respectively.

The manufacturing layer serves the production of the units, their assembly and their shipping. The middle layer of partnerships consists on retailers, public governments and sponsors, and is the one mediating in between Beatwheel Corporation and the layer of buyers (parents, schools, coding camps).

To purchase the Beatwheel, the corporation offers agreements with schools consisting on complete implementation of science and technology educational programs, while coding clubs agreements consists on providing specialized software on music computing. Agreements with sponsors are focused to negotiate the market share.

VALUE GAIN

END-USERS

Beatwheel will make children get fun by learning-while-doing due to its live looping performance. It will make sure they acquire a new skill in sound and music computing.

PARENTS

Beatwheel is an easy-to-program musical companion therefore it provides parents with a new platform to engage with their kids with more autonomy and freedom.

SCHOOL PRINCIPALS

Schools pursuing the renewal of their educational programs with computer programming, will find a solution in Beatwheel with its tangible syntax.

CODE TEACHERS

Beatwheel provides teachers an easy communication of the complexity behind coding due to the immediate feedback between physical and digital changes.

TECHNOLOGY SPONSORS

Beatwheel gives stakeholders a new and fresh perspective to explode the market of computer programming with music.

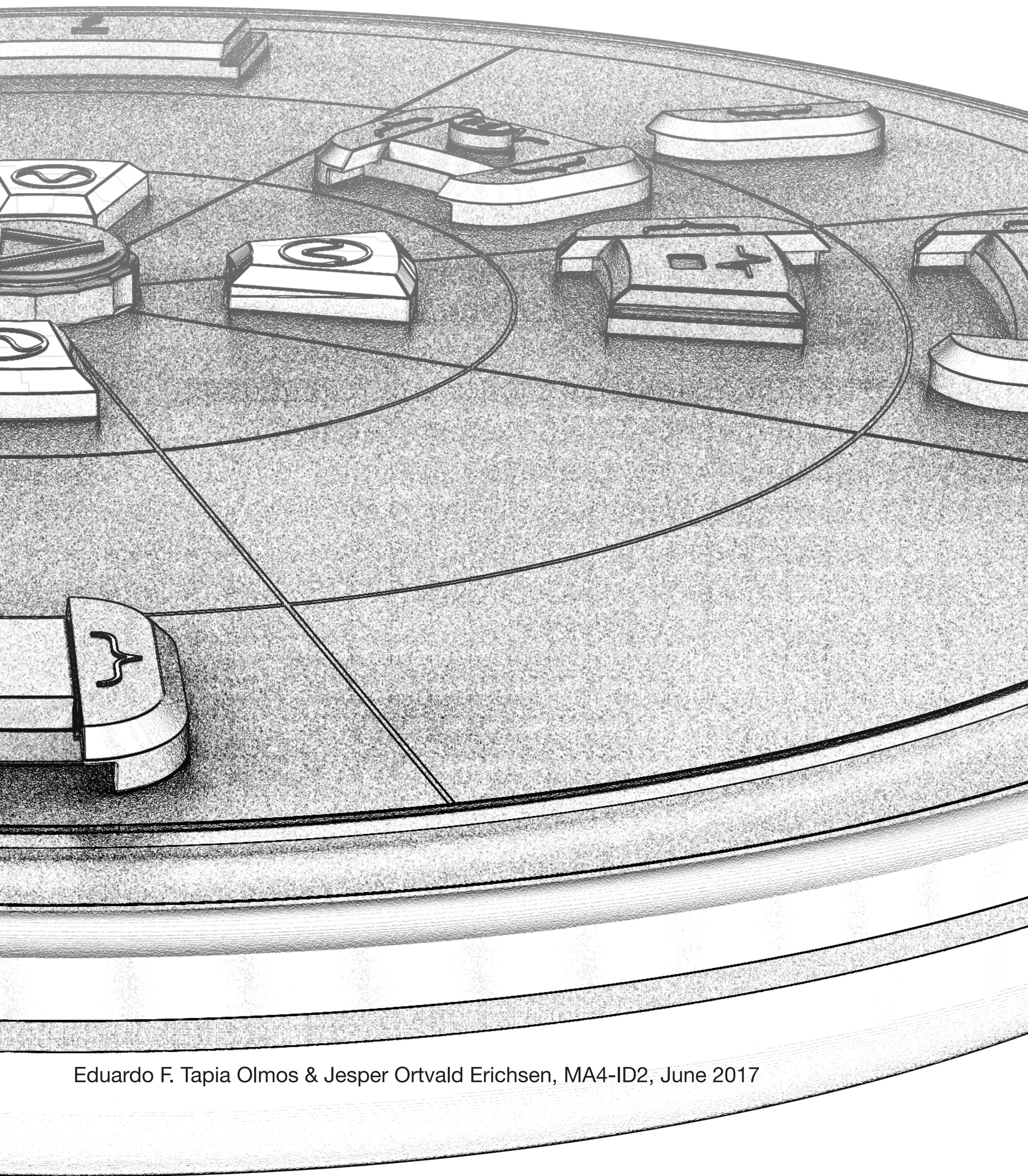
SUMMARY

The beat wheel potential lies in the aspect of combining programming with music. This creates a potential for the Beatwheel since no other programming tool is approaching the code teaching with music. Having competing solutions approaching the code teaching through movement and robotics, the Beat Wheel can stand out as different because of its approach of using music to make the code come to life in the hands of the user. Secondly it creates a potential as it is both an instrument and a code learning tool. This means that the Beatwheel will be able to reach a greater market potential over time than its competition as it can be sold to both musicians and programmers.

beatwheel

A PROGRAMMABLE MUSIC INSTRUMENT

THE PROCESS REPORT



Eduardo F. Tapia Olmos & Jesper Ortvald Erichsen, MA4-ID2, June 2017

TITLE

Beatwheel, a programmable music instrument

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ABSTRACT

At the present, two emergent global trends in the toy industry are taking place: 1) breaking gender stereotypes between boys and girls in toys and play, and 2) training basic competences of computation in young children by teaching them to code in a specific programming language. Teaching computer programming as educational programs has the objective to empower children's community with technology daring as competences for the future, having the problem of communicating kids with the mental processes for writing code and develop a computer program. Gender stereotypes in toys, shape in a biased manner cognitive, emotional and social abilities of kids, therefore augmenting the breach of social inequality through generating gendered professional competences and stereotyped career patterns needing innovative solutions that respond to this problem.

Beatwheel is the solution that opens design up to introduce and convey the basics of coding through empowering kids to compose their own sounds and music through a tangible interface and a user-friendly software design.Beatwheel is an easy-to-program musical instrument that conjures playful experiences and learning environments.

Beatwheel is a rechargeable device that takes the code out of the computer. It contains the syntax on physical pieces assigned with a code argument standing for a specific musical function that users arrange to write a program and create music. The software allows kids to visualize and access the source code of each piece and modify parameters through a colored block-based coding language. Beatwheel amplifies learning accesses for all kids with no gender distinction making coding and fresh music available for everybody while offering special agreements for schools and coding camps.

SPECIAL THANKS TO

Volunteers at Coding Pirates, Aalborg.
Joachim Hejslet, music producer.
Mads Nielsen, software engineer.

READING GUIDE

Methods and analyses were performed by the project group based on research insights, scientific articles, web sites, academic knowledge and design experience. The document is divided in five main chapters. The first chapter corresponds to Phase 0 where the initial stage of the project is focused to identify market gaps and opportunities in the toy market and industry. The second chapter corresponds to the Framing phase where the problem and solution space are defined together with a characterization of the creation of customer's values per market segment. The third chapter corresponds to the Product Development phase where the concept direction was decided and carried out. The fourth chapter corresponds to the Detailing phase where the solution was refined in respect of technical and commercial aspects. The fifth chapter corresponds to the Onward stage where conclusions, reflections and further work are elaborated. The document shows relational tables, maps, diagrams and photographies. Each map and diagram are colored accordingly to each chapter. The process report has bibliographic references indicated with squared brackets, references to worksheets indicated with squared brackets: [WS_XX]. At the end of the report a section of appendix is included that contains a list with illustrations, worksheets and bibliography.

INTRODUCTION

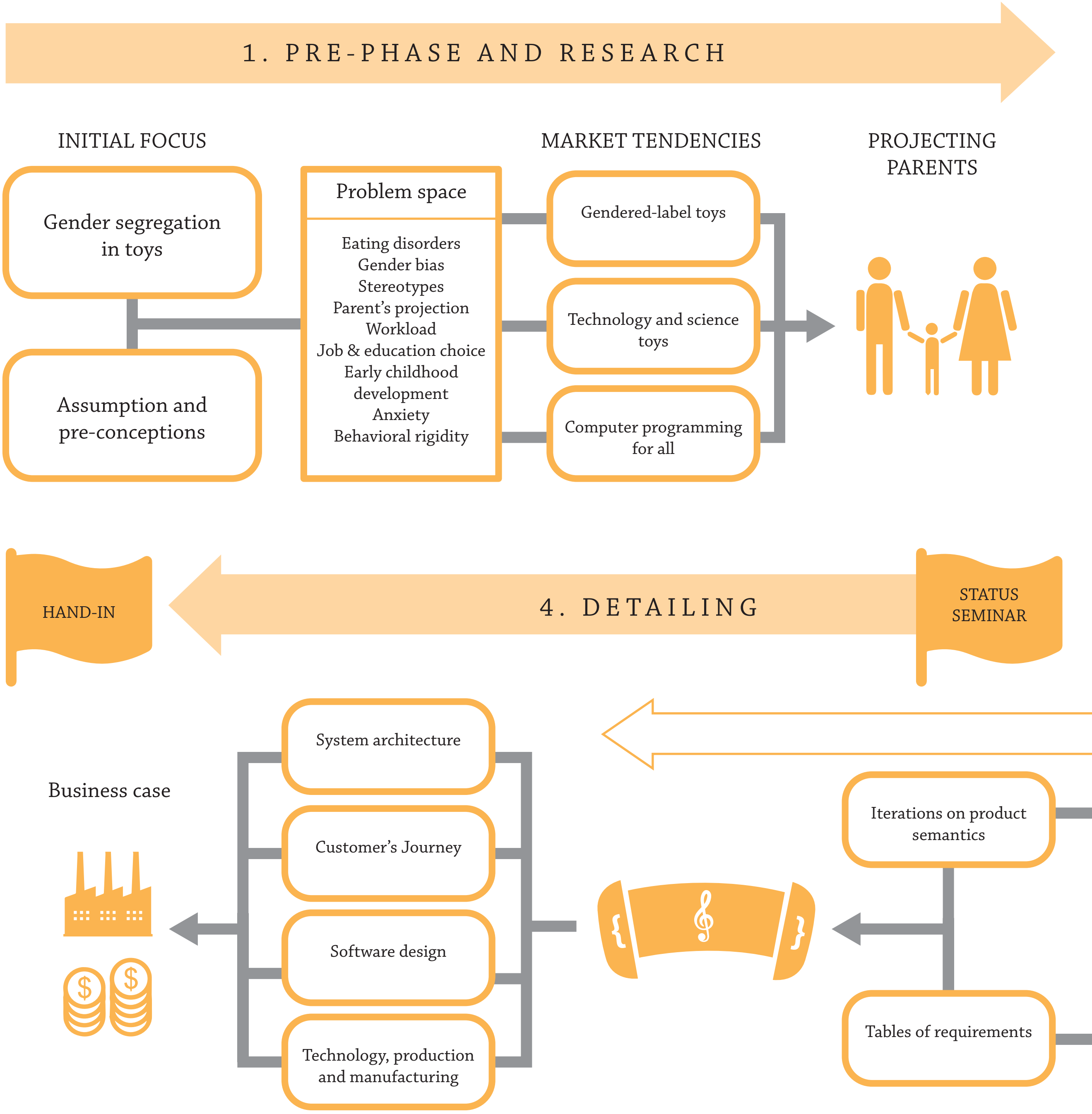
The following document presents the design process corresponding to the Master thesis of Group 2 at the fourth semester of the Master's programme of Industrial Design, Aalborg University. The project's mains theme is 'Tangible interfaces on music and sound computation' presenting the design of Beatwheel, a programmable music instrument for training computer programming competences in children between six and nine years old. The aim of the project is to bring families and children the future of the digital world, the language of the machines and inter-connectivity with a playful and humanitarian-oriented solution with creativity at its core.
This document contains the whole series of actions, steps and decisions that were taken in order to identify a problem, to leverage useful data for idea generation of the solution, and to integrate a design product system involving system, software and hardware design.
In the other hand, the product report exposes the Beatwheel with its use features, construction technicalities and financial aspects.

TABLE OF CONTENTS

PROCESS TRACKING

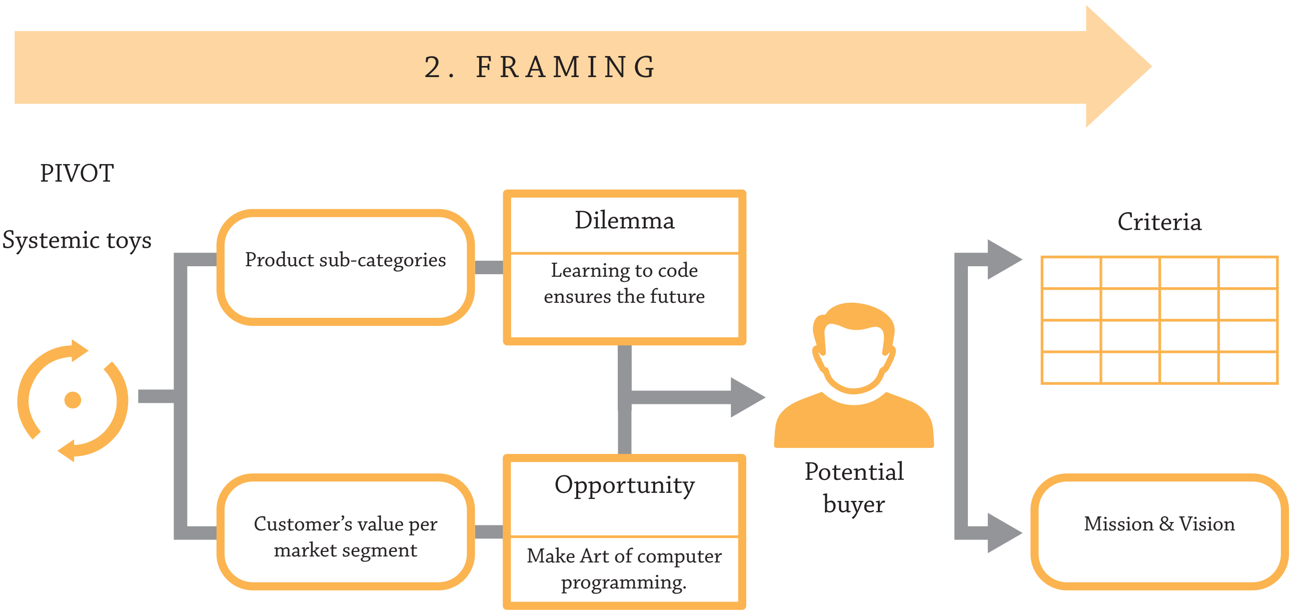
PROJECT MANAGEMENT

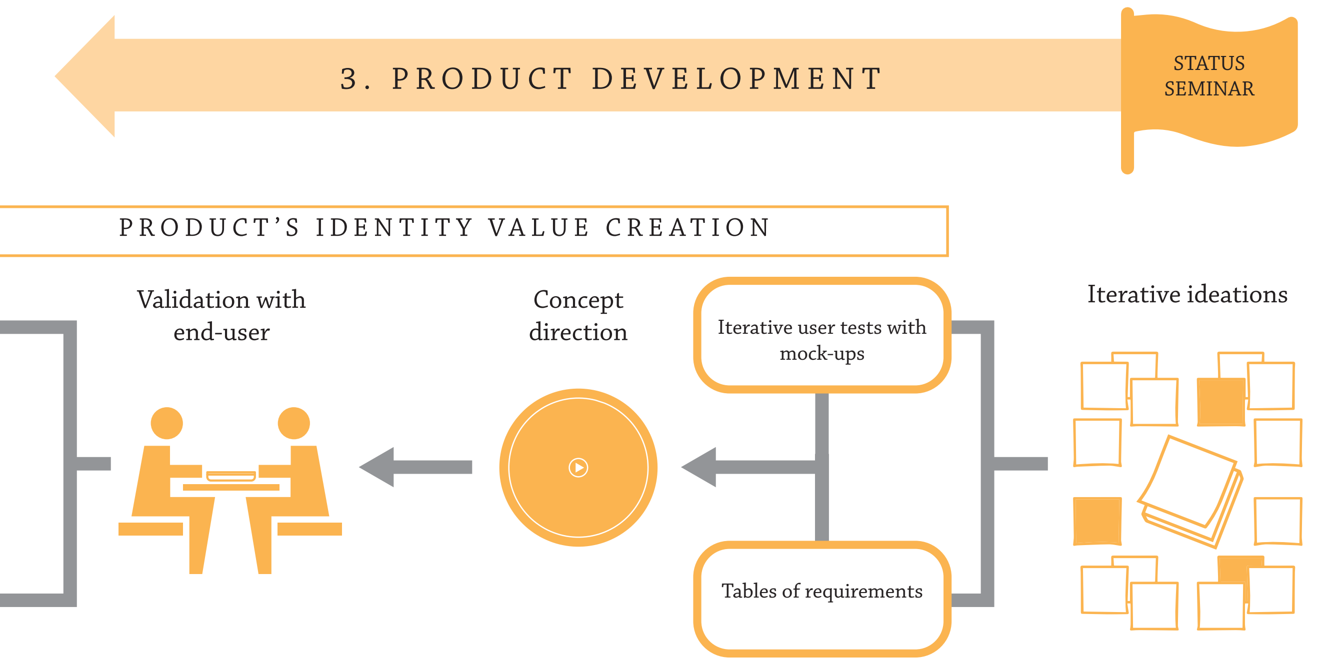
The team adopted an approach based on setting up goals through milestones specifying the necessary content they should fulfill. Gathering and collecting inputs through rapid and agile sample probing was emphasized for accomplishing them. The strategy and method consisted on mantaining close contact with key



Ill. 1: Process Tracking Map

informants that were interviewed accompanied by models and proposals for solutions. Design tasks were divided accordingly to the core competences of each member while new idea generation stages were approached in togetherness to prioritize and manage time.



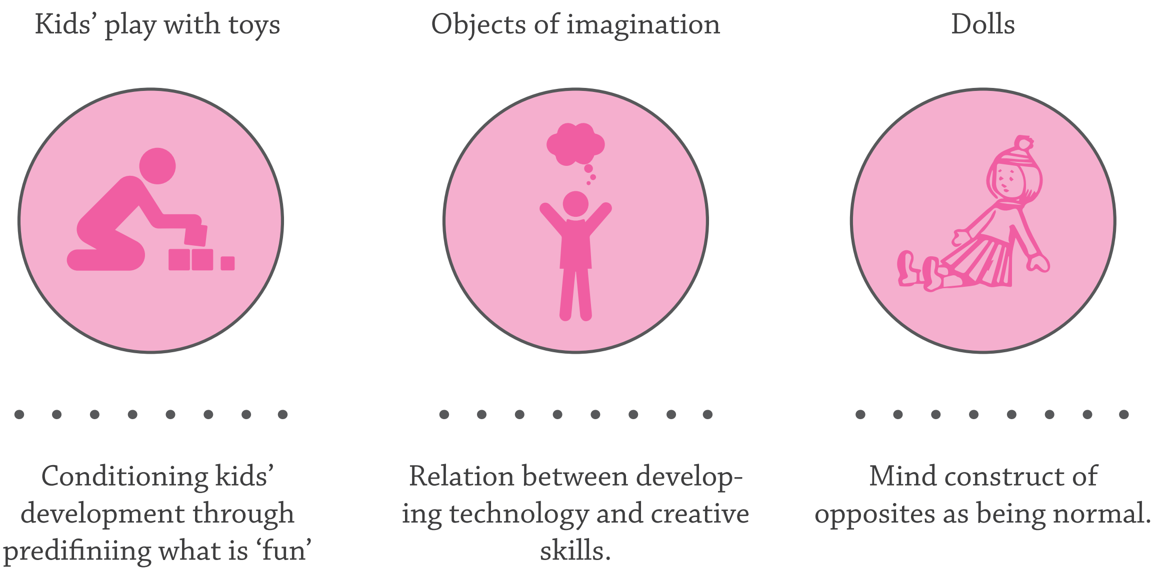


Ill. 2: Phase 0

PHASE 0

The following chapter describes the process that led to formulating the problem space and leveraged the data for defining the target group.
This phase had the objective to identify a business and technology gap in the toy market through researching and defining the state-of-art of toy tendencies for envisioning a solution space.

INITIAL FOCUS



Ill. 3: 'Assumption on gender segregation in toys'.

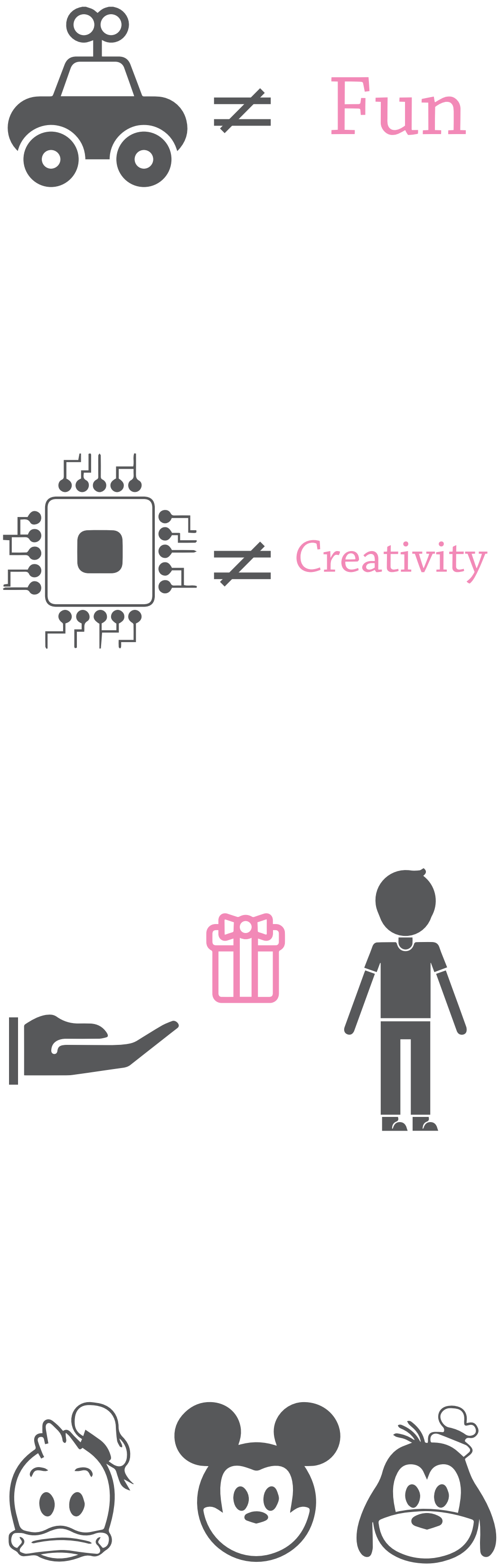
The project group began by making assumptions on the topic of gender segregated toys where each group member made an individual brain map. 'Illustration 3' shows each of the central ideas. This activity was made in order to generate search areas and rule out biased asssumptions [WS_001].

On the first cluster of assumptions, corresponding to 'Kids' play with toys' showed that a) different types of toys offer children predefined play scenarios that may limit creativity (e.g. videogames); b) creativity in toys only leads to physical creation mostly focused on construction; and c) there is a social and a cultural dimension, presenting key actors with different interests and activities with different objectives.

On the second cluster of assumption, corresponding to 'objects of imagination' showed that a) there are a kind of 'Zero-First Order Technology' [Von Foerster, 2003] products referring to activities which maintain a low or non-existent level of technology and products and devices with high level of technology; b) social actors identified as 'givers' [WS_003] of the toys, reflect themselves by giving children toys, or in more abstract words: objects of imagination; c) 'healthy' overall climate toys seek to offer and establish through 'developing' symbolic, physical and social plains.

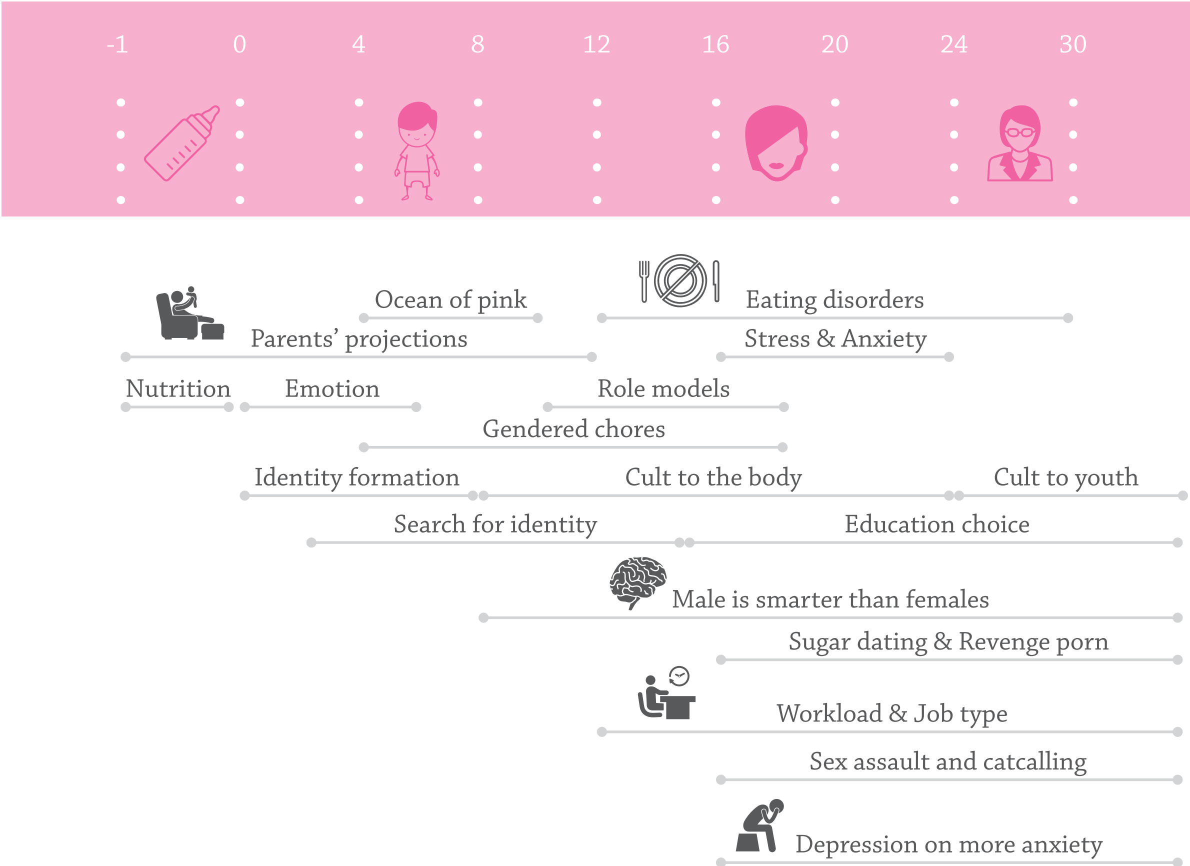
In the third cluster of ideas corresponding to 'dolls', showed that a) dolls are framed already as something for 'opposite of something' as being only for girls; b) it limits imagination; c) are a predefined social construct since they keep reproducing traditional models and rules, they are framed under 'imitation' thinking (e.g

imitate what parents do), and dolls seem to develop physical aspects only (e.g need to be thin/fit/muscular to be pretty).
From this it was concluded that toys do not necessary have to be fun. And the way that toys arrive to children's domain is key to find specific social agents or 'social warriors'. A high amount of technology does not necessarily mean 'dive into your imagination' creativity and/or fun.
The projec group believe that toys are framed in a way that they should develop something in kids to become another something. That is a main conditioning. Also, toys related with a specific 'known' universe (e.g the theme of the toy: a movie, fairy tale, tv show) or a meta-universe may hinder creativity.Creativity does not necessarily mean fun and educational. The search areas that wered derived from this stage then were: a) what is fun, b) how is the technology - creativity relation, c) why do people offer by giving toys, and d) which are the features of meta-universes.



Ill. 4: 'Conclusions on gendered toys'.

PROBLEM SPACE



Ill. 5: 'Problem mapping'

After having clarified each member's assumptions on gendered toys, the project group proceeded to evaluate socio-technological problems in regards of gendered toys and its projection over a time-line of a user from -1 (intrauterine) to 30 years old and beyond. The problems identified were included using the brain storming method, and were evaluated if they constituted a root cause, a symptom or an understanding to gender through a discussion among the members of the project group [WS_008].

Among the most relevant problems revolving around gender segregation in toys for children, it was identified the role of parents' projections of children from -1 to 12 years old [Eccles, 1999]. This points out to the notion that parents seek to project themselves through their kids with preconceived ideas of how to raise their children in regards of values. In the second place, eating disorders were of a relevant, but not explicit, relation with the action of gender stereotypes in toys. There was identified an increase in the number of adolescents and adults between 12 and 30 years old with stress, anxiety and eating disorders related with body image, mental health, phobias, and behavioral rigidity that were treated through specialized therapy. Thirdly, toys that are targeted to be specifically for boys emphasized play within the topics of science and spatial skills, therefore shaping core competences in these areas [Weisgram et al. 2014] and therefore contributing to the stereotype that males are more intelligent than females between the ages of 8-30 . Lastly, the choice of work type and its intrinsic workload were considered a factor that triggered stress between the ages of 12 years old and up [Jacobsen et al. 2015].

The conclusion is that the role of stimulation during the early childhood in the hands of parents was identified to be crucial for the future development of children. Toys were regarded to be an object that shapes the development of children at a social, cognitive and emotional level [LEGO, 2016]. Approaching gender stereotypes in toys was found to be relevant societal issue for the project since kids' core competencies may be affected by gendered features of toys [Weisgram et al. 2014].

Ill. 6: 'Parents in earlychildhood'

MARKET TENDENCIES

	Based on age with any price						Based on price (DKK) at 5-6				
	any	0-2	3-4	5-6	7-8	8+	0-100	100-300	300-500	500-900	+900
Duplo	2	12	5	2				1	1	4	1
Plushies	2	9	3	2	2	1	3	4		4	
Lego	3			1	3	3	2	1	3	3	
Creative	4	3	7	9	3	5	7	8	6	2	
Outdoor play toys	4		3	4	4	6		6	3	3	
Electrical	6	1	7	9	8	8		6	11	20	2
Remote control	3		2	2	2	3			4	7	1
Baby Dolls		6	4					5	2		
Franchise toys	5		10	10	8	5	16	7	11	2	
Frozen	1		4	2	2	1	3	3	2		
Pokémon	3		3	3	3		2	3			
Nerf	14		1	5	10	15	7	1	5		
Animal	2	7	2	3	2	1	2	3		11	3
Play house	1	2	1	2				1	1	1	
Music	1		3	1	1			1	2	6	
Costumes			2	1		1		1	1		
Board games	2		1	2	2	3		1	1		1
Cars	3	2	4	2	2	3	1	1	8	10	1
Training toy		6									

Ill. 7: 'Market tendencies table'

For mapping out the trend concerning available toys for children, the gift finder online tool was used, and then a table was created [WS_02]. This tool is available in both BR and Toys R Us websites to get a visual representation of the trend, to look at difference age groups and price levels in the 5 to 6 years old.

Toys indentified with the gift finder were put into a table shown in 'Illustration 7'. The amount of each toy clasified were based on age with any price, and price for children between 5 and 6 years old.

For indentifying toys available for children, the different ages were grouped each two years starting from 0 and up to 8 years old.

The results from the gift finder show that in the years from 0 to 6 is mostly filled with imitation toys, either in the form of like what mom and dad uses and toy versions of music instruments. But also with plushies, many varieties of creation toys like play-doh, pearls, and colouring equipment. The third type that is seen mostly in this age group are toys with the look of some animal. It is also in this age group that costumes are found.

In contrast the years 5 and up are mostly dominated with equipment for play, like nerf guns, children scooters, and remote controlled cars. Also, there are pre-packaged make-it-your-way set, like race tracks and LEGO. There are also products that are non-age specified in the form of board games and disco lamps.

Common in all but the group of 0-2 year olds are franchise products mostly from TV-shows and movies. However, there were found products where the brand is known for something else like LEGO making costumes of their product lines.

This analysis was useful to create a clear image of the age group for different types of product. Also, there were common grounds

MARKET TENDENCIES

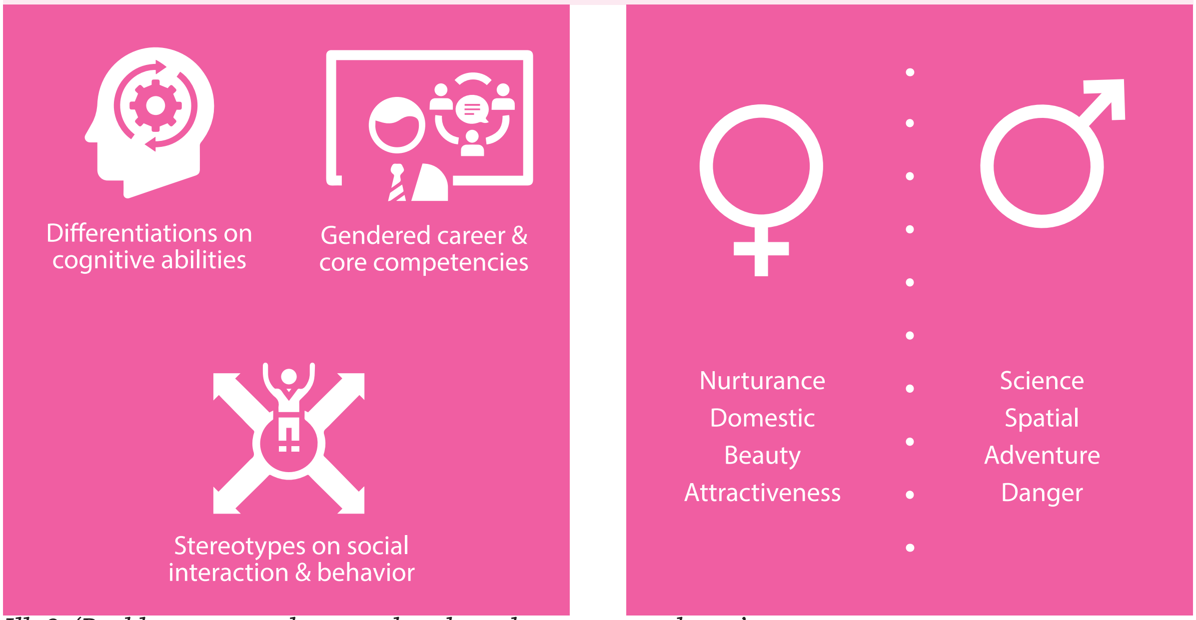
Ill. 8: 'Toys in the market'

of the different types of products among different age groups that helped to give a grasp on the landscape of the different toys. However using a limited view in the form of having only the results from the companies' algorithms which only give a small snap-shot of the reality.

As a conclusion from visits to toy stores, desktop research, and an interview with a sales officer, toys segregate their features according to gender not only in their physical and functional properties but also in the play experience. This was found to be relevant for the project as a possible direction that could correlate out assumptions on the problem space.

The project group decided to perform bibliographic consults that may confirm and validate the conclusions derived from the project group's observations in regards of gender-typed toys and their availability in the market.

INITIAL DIRECTION



Ill. 9: 'Problems on gender-typed and gender-segregated toys'

Having framed the problem space with an expression in the market, the project group performed a literature desktop research on gender segregation [Blackburn et al. 2008], and evidence from Denmark on children and gender inequality [Jacobsen et al. 2015]. These articles were useful to get an overview of the state-of-the-art in regards of gender segregation from a sociological perspective.

The main measurement of gender inequality as an effect of gender segregation is wage rate differences of women in respect of men. From this review it was concluded that gender inequality is a shared societal problem across countries, where many of them are taking inclusive actions to generate more equality of opportunities in the labor market. In Denmark, women receive a hit in their careers, workload and possibilities for promotion after the first child's birth.

In the other hand, a literature review was made in regards of gender-typed toy play [Green et al. 2004], parental gendered attitude [Dawson et al. 2016] gender cognition in transgender children [Olson et al. 2015] and gender labels and gender-typed toys [Weisgram et al. 2014].

From this review, the project group decided to set as an initial direction the role of gender-typed play in toys for children. Toys that are heavily gendered in their physical attributes shapes differentiations of cognitive abilities and difficulting cognitive flexibility. Gender-typed play provides explicit and implicit gender labels to social agents in the children's circle therefore shaping career interests and competencies. Also gender-segregated toy play shapes differentiated gender development and therefore stereotypical responses during social interaction and behavioral tendencies. Due to this variables in the problem space, the project group decided to further elaborate upon the differences of gender-typed play in the design of systemic toys for children between 6-7 years old.

INITIAL PROBLEM

Toys in the mass market mirror and consolidate societal values and gender inequality, to which children are exposed from a young age thus affecting play as a fundamental and vital activity in humans [Woodhead, 2005]. The project seeks to promote a healthy development of 'self' in children in their identity-forming years through toy play experiences. There is an opportunity for creating alternatives toys coupling with new trends and emerging values.

TARGET MARKET

For narrowing down a target market from the societal issue behind gender-typed toys and gendered stereotypes the toy industry was analyzed. For this purpose, the analysis included the most recent products competing in the market, the best sold products in toys fairs, and products that were directly facing the societal issue of gender stereotypes in play. The analysis revised the eastern and western market, in small, medium and large companies, from kick-starter startup teams to long established firms [WS_006]. Three main categories in the trends were identified:

a) STEM education toys, developing skills of science, technology, engineering and math. Consisting mainly in programmable robots, DIY equipment and teaching of basics of coding skills to boys and girls.

b) Storytelling toys developing a different narrative with the play experience. Consisting mainly in theatrical wearables, role model toys and themed toys.

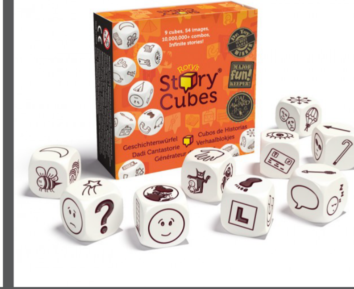
c) Stress relief toys, developing plaftforms for relaxation consisting on toys focused on developing empathy, interactive pets and fidgets.

From this analysis it was concluded that gender inequality in toys was approached as a marketing and sales strategy by companies which products have been stigmatized to be oriented as being only for boys or for girls by establishing a cross-gendered barrier. Furthermore, there were identified other trends that approach the issue to gender inequality beyond the physical properties of products making no gender distinction in their formulation and the play experience they entail.

The analysis of trends in the target market was used as a reference for the project group to locate its position concerning gender inequality and its feasibility. Also it allowed a visual representation of the categories identified. However it was identified that other countertrends such as the choice of some parents to use products with a low amount of technology and almost non-existent was still prefered.

The project group decided to study the social actors involved in the categories identified that may be owning the problem.

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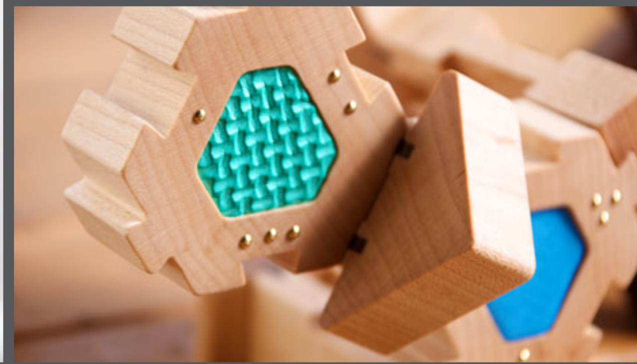
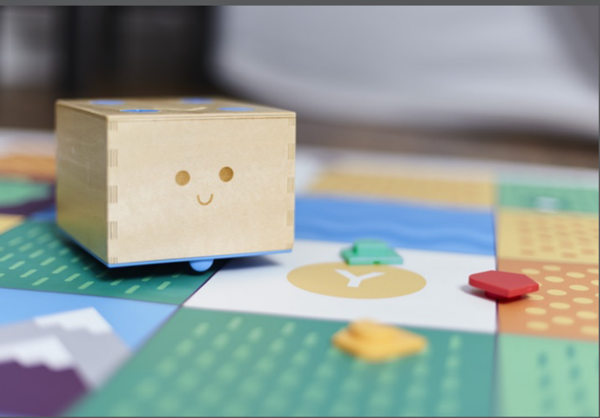
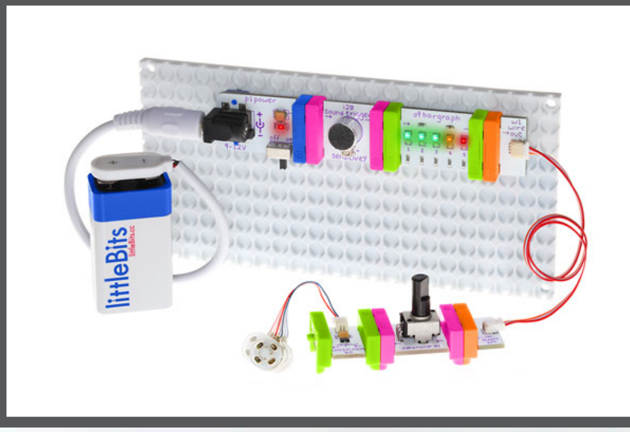




littleBits



KANO
KANO

Atlas Beetle

CONCLUSION

It was observed that a major trend approaching gender stereotypes was developed by initiatives inspiring girls to engage into science and technology through computer programming [WS_005]. It was decided to specify sub-groups in the target group and sub-categories among the toys tendencies that may be somehow developing this initiative with design.

Ill. 10: 'Girls who code'

TARGET GROUP

PROJECTING PARENTS

As a result from surveys, interviews with lead-users [WS_007], and previous analysis in regards of the problem space, market tendencies and initial direction, the project group decided to further work with parents that project themselves through their children as a contrast to those who just give children what they want. Projecting parents have predefined how the children are to be raised. They try to give toys that fit with the idea of 'what is good for the child' and encourage skills of creation with toys that can tell any story. These parents often try to go against dominant societal norms but they want to give things that are liked by creating equality between children.

Ill. 11: 'Projecting parents'

Ill. 12: Framing

FRAMING

The following chapter describes the process from which the group framed the project by delving into the customer's value per market segment and defining the project's mission and vision.
This phase had the objective to integrate search areas through scoping the internal and external environment of the project for allowing novel idea generation into the solution space.

PRODUCT CATEGORIES

Toys were divided into sub-categories in systemic toys together with their sucess and technical criteria. For approaching this analysis, the tendencies in the toy market and industry were grouped according to their commonalities in regards of their physical properties and functional aspects, for then being divided among eight classifications. The technical criteria were defined according to the requirements for the product performance, their parts and components specifications [WS_009]. The success criteria were defined as the principle for the toy to fulfil its play experience. The sub-categories defined were:

a) Plastic construction blocks: focused on modular pieces with an interlocking system.

b) Themed collectable sets: lines of products with focus on details based on associated stories.

c) Sensory-based interaction: products focused on delivering sensory stimulation.

d) DIY equipment: products focused on crafting tools with specific functionalities.

e) Physical/Digital play: Products focused on using digital technologies to enhance the product's performance.

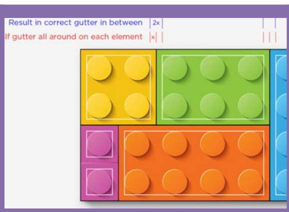
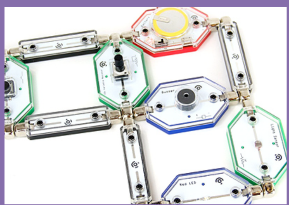
f) Magnetic pieces: products which interface is based on neodymium magnets.

g) Pedagogic entertainment: these kind of products are framed under educational programs.

h) Board games: product with a rule based system focused on dialogue interaction between players.

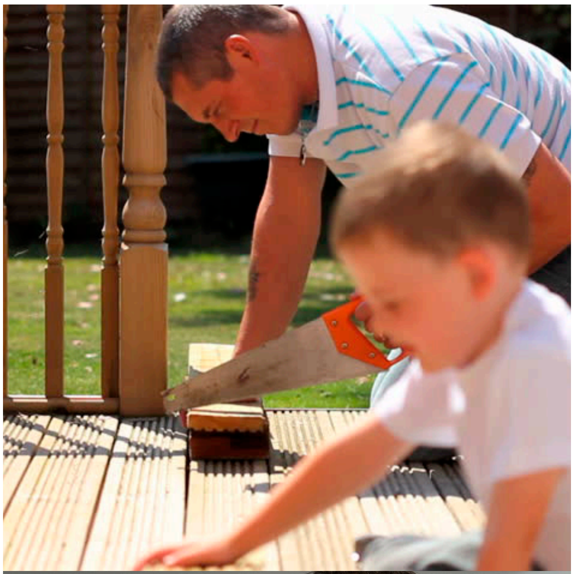
Once the sub-categories were completed with different products, the most representative were chosn and displayed in a table shown in 'Illustration 13'. This activity was useful since it allowed to visualize more specific and tangible characteristics within the categories of systemic toys. The results of this exercise were used eventually in the development of the project to find correlates between the customer's value per market segment and the initial frame.

PRODUCT CATEGORIES

Plastic construction blocks		> Interlocking system between pieces. > Easy union and separation. > Brick-based shape language. > Modules can be freely recombined. > Standardized union method for all pieces. > Support game expansion. > Success when new configurations are formed
Themed collectable sets		> Line-based production with associated story. > For children between 4-12 years old. > Scaled miniature replicas of objects. > Themed realistic details. > Support game expansion. > Success when scenarios and characters are combined.
Sensory based interaction		> Focus on tactiliy and texture diversity. > Cross-sensation inputs: smell - haptic - sound. > Group and social play. > Completion of challenges (guessing, puzzles, composing) with degrees of difficulty. > Success when communicating challenge completion.
DIY equipment		> Step-by-step assembly. > Tools with specific functionalities. > Crafting produces a mechanical and/or electronic outcome > Group and social play. > Completion of challenges (guessing, puzzles, composing) with degrees of difficulty. > Success when manipulating equipment crafted.
Physical & Digital play		> Easy to use drag and drop operations. > Easy to comprehend string construction. > Block based shape language. > Use of digital technologies to enhance product performance. > Success when integrating a string interaction based on defining a function + variable + value.
Magnetic pieces		> Use of neodymium magnets as standard union. > Modules can be freely combined. > Easy to separate and integrate. > Success when pieces form a functional configuration.
Pedagogic entertainment		> Focus on learning through tactility > Interrelated shapes and sizes. > Group play. > Block based shape language. > Form cozy-classrooms. > Educational methods-based products. > Success when achieving desired learning indicator.
Board games		> Rule based play. > Base platforms. > Small symbolic tokens. > Dialogic interaction between players. > Success of renewal when game with same rules leads to different resultant outcome.

Ill. 13: 'Sub-categories of Systemic Toys'

TARGET GROUP CATEGORIES



The target group was divided into sub-groups identifying their values together with their main interest.

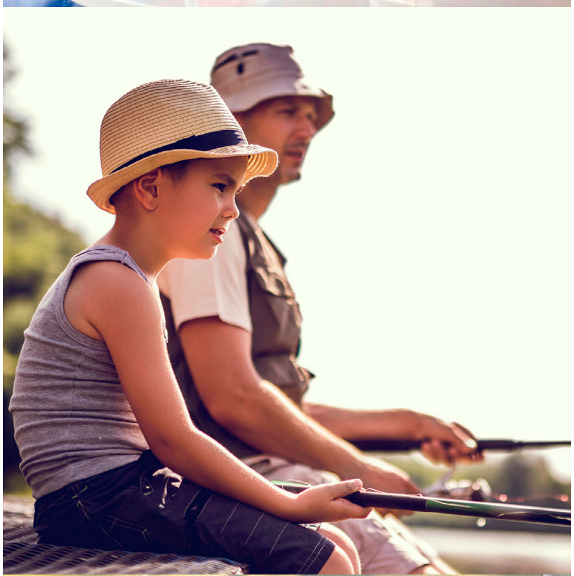
a) The DIY parent: Their core value is learning-while-doing, meaning they can always make their own project and nothing is beyond repair. They value creation as a way to make things the way you need them. Their interest consist to go to second-hand stores looking for their next project in their workshop with an ongoing small project.

b) The pragmatist/pacer parent: Their core value is to create results while planning ahead. They are the parents that look always for the best to their children being price a secondary factor, and they often are the ones saying 'I know the way forward'. They trust on what experts say is good, and they believe that perfection is achieved by trying. Their interest consist to see TED talks, and going to mindfulness seminars. They often read books on how to be a better parent.

c) The hippie parent: Their core value is sustainability and solidarity, regarding values of taking care of each other and togetherness as fundamentals. They often go against dominant social norms, and they tend to pay extra for harmless eco-friendly products. Their interest consists on being yoga instructor, to have a garden in a small homestead. They also have traveled all over east asia to find them selves.

TARGET GROUP CATEGORIES

d) The artist parent: Their core value is to create for developing imagination and the freedom to be. They regard everybody as having an artistic side. They often have high quality tools for expression and value practice as a way to perfection. Their interest consist on finding time to create new art, and they introduce their children to different art forms and encourage them to explore the world through social settings and nature.



e) The outdoor parent: Their core value is to get the fingers dirty by feeling the nature, feeling the object and being in the now. If you do not know if you can try. They learn while doing, and often think of pain as being OK. They like to pay for high quality tools. Their interest consist on talking long walks in nature, hunting or as a scoutleader. They live close to a large open field with an out-door kitchen.

Ill. 14: 'Target group categories [WS_010]'

f) The geek parent: Their core value is technology and they can go further with it. They believe everything is fixable by finding solutions online, and also that technology should be everywhere where new things should be high-end. Their interest consists on having a room full of old tech they might use later, and on playing computer games for relaxation. They have most of their social interactions online and have a gadget for everything.

PERSONA

Ill. 15: 'Joachim Hejslet'

After the project group decided to delve on the category of projecting parents as a target group, and specifying this category into six profiles by identifying the customer's values per market segment, it was observed that most of lead-users and problem owners had shared values.
The project group located an internal contact as a potential buyer to build a generalized characterization of our persona.

Name: Joachim Hejslet.
Age: 45 years old.
Occupation: Music Producer, father of four children.
Aalborg, Denmark.
He was consulted for probing the solutions in the Product Development phase during Testing 02. His insights were taken into consideration for designing the final solution.

Direction 1				
Target group category	DIY	Pragma-tist/pacer	Hippie	Artist
Sucess criteria	When kids broaden their view by learning.	Thinking two steps ahead by meeting a challenge.	Self-reflective attitude and intuitive behavior.	When skills overcome physical/digi-tal platforms
Technical requirment/ Product criteria	Focus on tactility and texture.	Dialogic interaction bt. players.	Focus on learn through tactility.	Easy-to-do string construction.
Customer's value per target group	You can always make your own.	Planning ahead.	Solidarity.	You always need to keep trying.
Product subcategory	Sensory based interaction	Board game	Pedagogic entertainment.	Physical/digital play.

Ill. 16: 'Problem-Opportunity detection'

Once the customers' values and interest were identified, together with the technical requirements and success criteria of product sub-categories, a correlation matrix was made [WS_011]. The project group proceeded to specify a direction by identifying their separated relations shown in 'Illustration 16' and by evaluating parameters such as project timeline, specific knowledge needed by group members to carry out the solution, level of significance for addressing the problems identified were considered.

The opportunities identified were a) focus on tactility and diversity of textures, offers the opportunity to create an active sensory-based interaction in toys; b) a dialogic interaction between players, offers the opportunity to provide direct feed-back and feed-forward while meeting a challenge; c) Focus on learning through tactility, offers the possibility to provide a constructive learning feedback as a way to train self-reflective attitude; and d) easy to comprehend string/brackets construction by overcoming physical/digital platforms offers the possibility to make coding and programming an artistic technique.

From this correlation matrices the project group decided to delve on the conjunction between arts and computer programming as a possible direction for the solution space worthy of investigation.

Ill. 17: 'People who-cares'

The project group proceeded to specify influencers in the areas of computer programming and the world of arts that might be concerned with introducing children to the basics of coding with an artistic turn.

In the area of computer coding, there are influencing people that are skilfull masters using the computer language. These people were considered to be inventing the language of coding for their applications on interconnectivity, artificial intelligence and machine learning. Parallel to these people, there are those who are familiar with computer programming and its language for its applications on global economics, management and project related work. These persons were considered as users of the coding language rather than inventors.

The similar behavior was observed on influencers in the world of arts. There is people inventing the artistic language from creative writing to music, and there are people using arts as a communication tool as a profession, specially for treating mental disorders.

From these influencers it was concluded that a major trend regards learning coding skills at early life as a pathway to future success where toys are an opportunity for bringing playful aspects into the hard-rational edges of computation and coding.

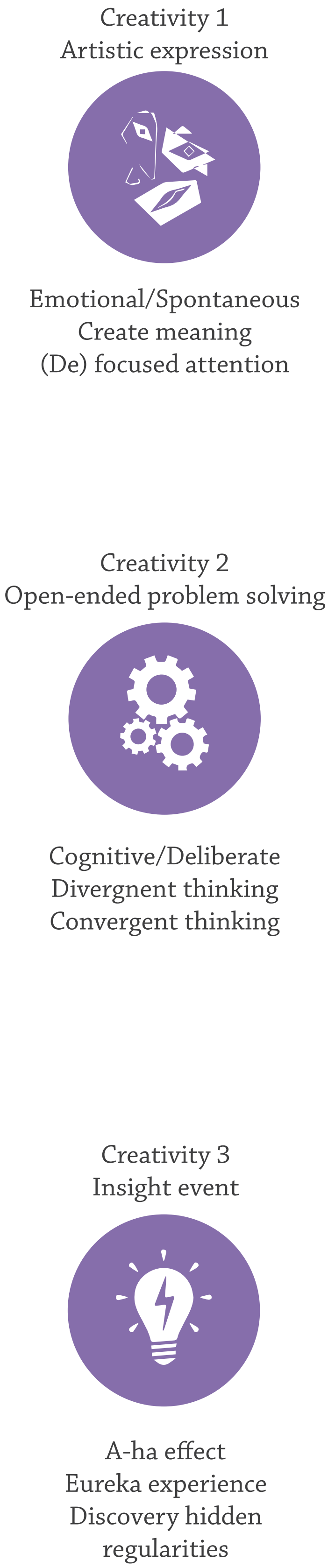
CONTEXT

What is out there						
What out-there is doing						
What out-there is not doing	Provide an easy-to-read code	Provide tools for kids to relate with peers	Means to go beyond low-level code	Provide eureka experience	Provide knowledge transfer	Training technique acquisition
What is people doing	Browsing in iPad	High-level education	Coding and tech camps	Alternatives to stereotypes	Avoid cutting-edge technology	Emotional training
What is people looking for	New skills through play	kids in computation	Lower entry bar	practice and discipline	Explore through the body	reflective attitude
Why is artistic coding an opportunity	Low entry level to go beyond advance	Make code without writing it	Make tech & computation non-geek	Easy-to-do knowledge transfer	Explore the code with the body	Train techniques for expressing emotions

Ill. 18: 'Positioning of artistic coding'

With the new direction of artistic coding framed in current trends within influencers the project group proceeded to specify its position into the market [WS_013].
For doing this, the two focal areas of artistic coding were divided to find out the activity of their respective industries in respect of the offerings they are producing and make possible the approach of the needs of projecting parents as shown in 'Illustration 18'.
From this matrix it was concluded that making computer code an artistic language is positioned as a way to bring the future of the digital world to and machine language to children and parents in a playful manner through encouraging our users to express themselves artistically.
Having defined the context of our project the group proceeded to specify the set of sucess criteria that the solution should fulfill in regards of both aspects of coding and arts.

PRODUCT CRITERIA



Ill. 19: 'Types of creativity'

For composing the set of sucess criteria that the solution should fulfill in regards of artistic coding, the project group moved to analyze the concept of creativity, since it composes a core value for users in respect of our persona, target group and target market.Three types of creativity were identified [Dietrich et al. 2004, 2010] as shown in 'Illustration 19'.

Creativity 1 corresponds to artistic expression and is characterized for involving emotional information with a spontaneous processing mode. The main mechanism of artistic expression is shifting from focus to defocused attention attributed to the right brain hemisphere. Artistic expression involves a mean of freedom where meaning is generated for example: free-jazz compositions, paintings, and art therapy.

Creativity 2 corresponds to open-ended problem solving and is characterized for involving cognitive information with a deliberate mode of processing knowledge. The main mechanisms of solving open-ended problems are shiftings between modes of divergent and convergent thinking attributed to the left brain hemisphere. Open-ended problem solving involves logic, analysis and critical thinking for example: solving an equation, executing a piece of music.

Creativity 3 corresponds to the insight event and is characterized for involving the 'a-ha' effect or eureka experience attributed to interconnections of brain's areas. Insight event involves the discovery of hidding regularities for example: figuring out a story plot, visualizing solutions.

Artist's creativity

input: a-ha moment (C3)
learning curve: cognitive/-deliberate technique (C2)
output: artistic expression (C1)

Programmer's creativity

input: problem-task (C2)
learning curve: a-ha moment (C3)
output: solution (C2)

Ill. 20: 'An artist's and a programmer's approach to creativity'

After having identified the types of creativity, the project group decided to analyze their correspondance which the individuals belonging to the art world and the coding dimension. To build the creative process carried out by an artist and a programmer it was considered the type of creativity they use as an input, the learning curve they need to do in order to achieve an output as shown in 'Illustration 17'

In the case of the artists, they use as an input the a-ha moment of creativity 3, for instance a mental image of a painting. Then they go to the learning curve of cognitive information for performing the appropriate technique for then prodocing an artistic expression as an output.

In the case of the programmers, their main inputs corresponds to a specific problem or tasks they need to solve. Then they go in the learning curve for achieving the a-ha moment of insight events and produce an appropriate and original solution.

From this analysis it was concluded that both artists and programmers present different kinds of creativity with the insight event as a common aspect. As the objective of the project is to bring both arts and coding together, then the solution pursued with the concept of artistic coding should account a creative process:

- input: emotional and spontaneous (C1)
- learning curve: a-ha moment (C3).
- output: problem solving (C2).

PRODUCT CRITERIA

Ill. 21: 'Success criteria'

Once the criteria for the value aspired with the solution was defined, the sucess and technical requirements for the working principle were formulated. For this purpose, the technical criteria evaluated when finding an opportunity were considered in contrast with the customer's value per market segment. An ideation was made using the brain storming method with sticky notes:

- Learn a skill: users should be able to acquire a new ability with the solution either art or code related.
- Think two-steps ahead: the solution should encourage planing and analytical thinking.
- Intuitive behavior: the solution should promote the capacity of reflection of the experience.
- Beyond digital play: The solution should low the entry level of computation to exceed the basics and high-complexity of coding.
-String construction: the solution should be able to take the code out of the computer by facilitating principles of computation with tangible pieces.
-Dialogic interaction: the solution should encourage a dialogue between creator and receiver.
- Tactility and texture: the solution should use diverse textures and a physical tactility to generate a tangible understanding of the principles of coding.

From this stage it was concluded that the basic criterias was set for opening a new category of toys consisting in artistic coding, bringing code into arts and arts into coding as the direction of the project solution. The project group proceeded to formulate the mission and vission of the project.

MISSION AND VISSION

VISSION

To provide our users with the freedom of expression within artistic creation and the beauty of simplicity within pcomputational programming by taking the code out of the computer and make it an artistic technique for sound and music composition.

MISSION

To bring coding and computer programming to our users through a playful product and a humanitarian-oriented solution for making them feel comfortable with the future of the digital world, empowering them as creators instead of consumers. [WS_012]

Ill. 22: 'ID Tech camp

Ill. 23: Product Development

PRODUCT DEVELOPMENT

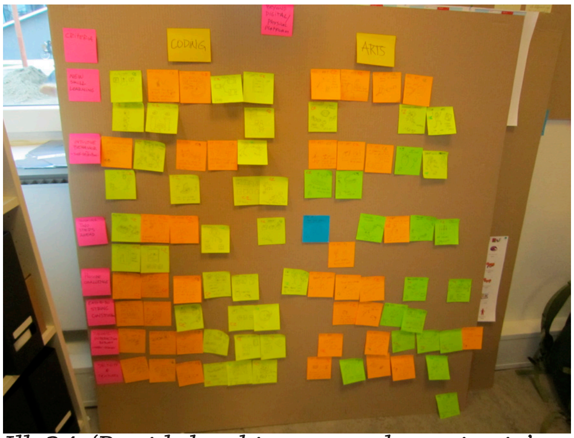
The following chapter describes the integrated design process from which the group conceptualized the solution to artistic coding through form giving, design of use dynamics and formulating the product requirements.

This phase had the objective to integrate into a design concept through shape exploration, iterative ideations and user testing for defining the project's direction.

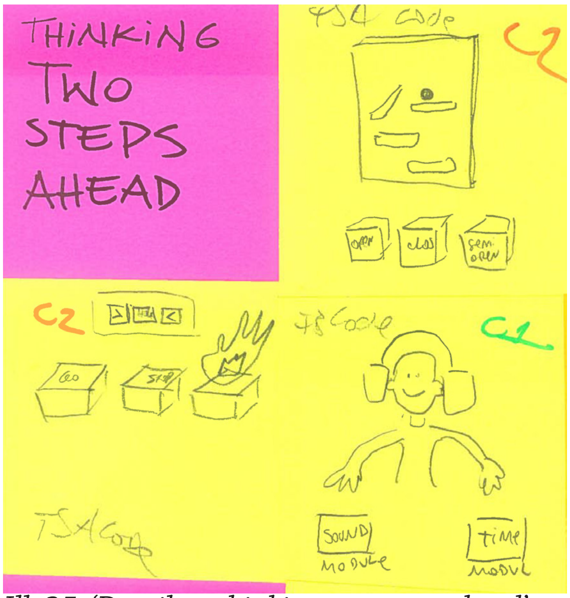
IDEATION 01

FIRST ROUND

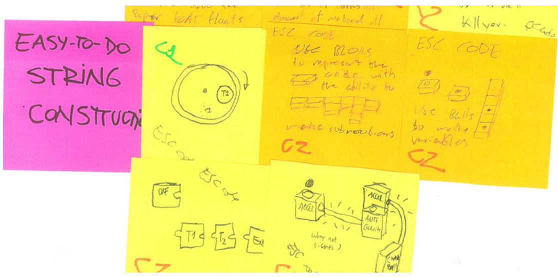
Once the mission and vission of the project was set the group proceeded to find a direction for the concept-development phase.
To avoid ideation ending up being just isolated ideas a multiple set approach was adopted. The ideation structure consisted on first, a 5-minute sketching session with both a coding and artistic solution approach with different headlines taken from the previous section 'Product Criteria'. 'Illustration 24' shows on pink post-its the headlines and the ideas divided in either creativity or coding oriented.
Each of the ideas were then categorised as being mainly creativity 1, 2, or 3 with the aim of combining them in an input, a learning curve, and an output setup where the order was either 2-3-1 or 1-2-3. Combining the sketches in this way to help remove ideas and refine them to better fit with defined criteria. 'Illustration 25-26' show in detail two headlines with their respective ideas that were sketeched. From this round, four ideas were further integrated into more finite solutions that were then evaluated based on the mission with the parameters of playfulness versus imitation, Human versus Machine oriented emotion depiction, intuition versus instruction, and Creating versus Consuming. Each of the ideas where then given a score of 1 to 5 with 5 being all the first parameter. The mean was then calculated for each with playfulness and creating being counted twice, the four best scoring were then chosen for being broken



Ill. 24: 'Rapid sketching on product criteria'



Ill. 25: 'Detail on thinking two steps ahead'



Ill. 26: 'Sketching on easy-to-do string'

down in their what, working principle and value from which a mood board for each direction was made [WS_015].

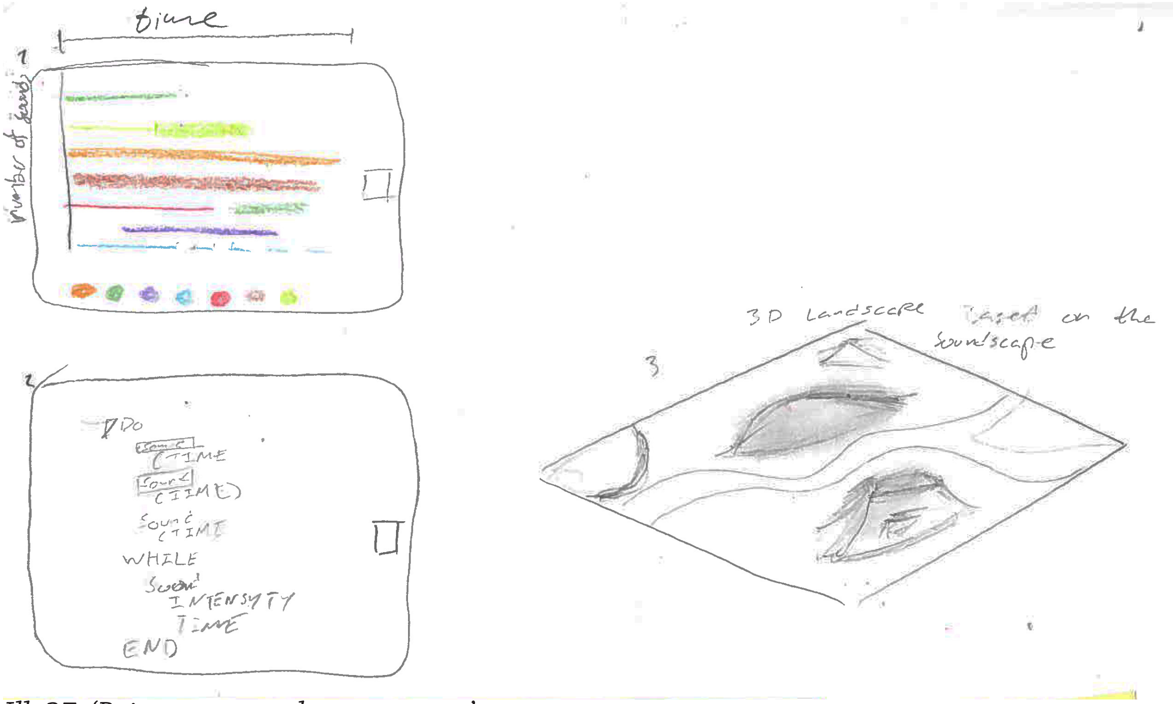
IDEATION 02

SECOND ROUND

The initial round of ideation was useful to breakdown visually the product criteria into smaller components that were integrated into four main concept directions. The objective of this second phase of ideation was to combine the initial separate visualizations together with the types of creativity as stated before in order to manage at a more tangible level the notion of artistic coding.

The names of the integrated concepts are: 1) Paint your soundscape; 2) Soundbites; 3) Program your shadow figure; and 4) Music jewels. These ideas were assigned a value to the parameters identified and were then compared in a relational matrix as shown in 'Illustration 27'.

FIRST CONCEPT DIRECTION

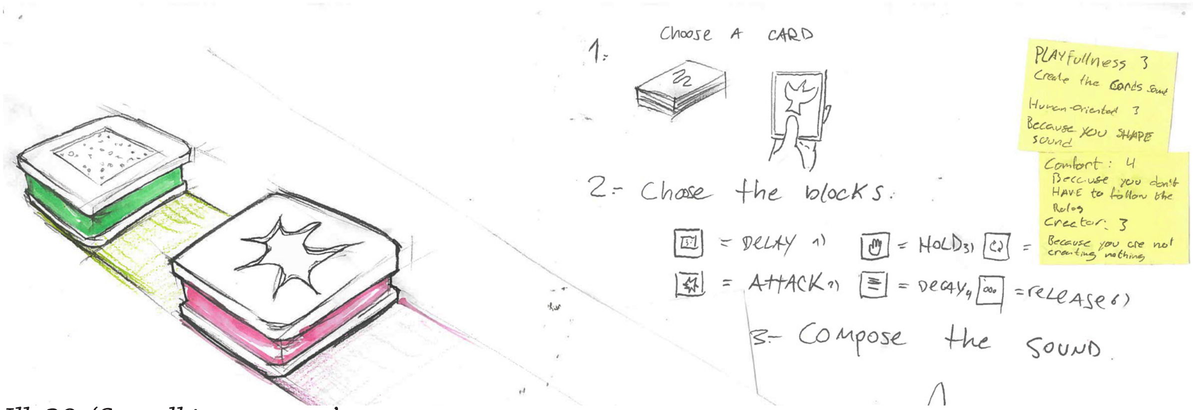


Ill. 27: 'Paint your soundscape concept'

The first concept direction was 'Paint your soundscape'. It consists on a physical three-dimensional display that uses pins to represent a landscape that changes with the sound coded in a mobile device application where users can alter the landscape and modify the sounds, or write a code and then visualize its physical translation in the landscape. The application consists on a user-friendly interface to code sounds by drawing lines, where the colour represents the type of sound, their length is the duration and thickness is the pitch.

IDEATION 02

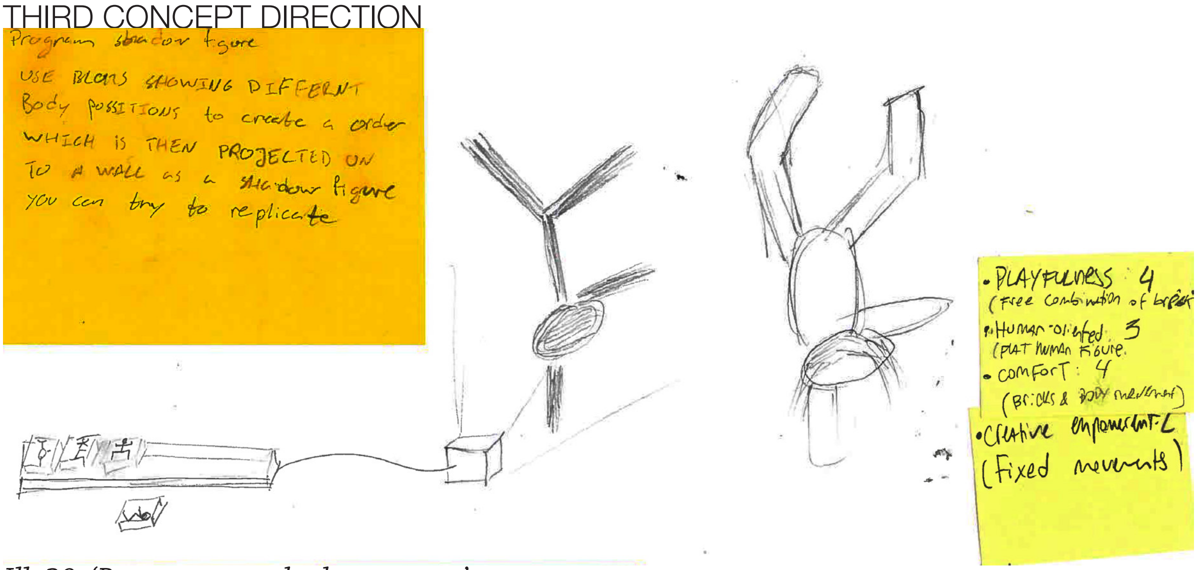
SECOND CONCEPT DIRECTION



Ill. 28: 'Soundbites concept'

The second direction consists on different modules with lights that represent a phase of the sound envelope (Attack, Sustain, Release). Sensors detect the distance between them and reproduce the sound signal. It uses cards with sound sources that a player chooses and aligns the modules to form a sound so another user guesses the sound source by looking the blocks.

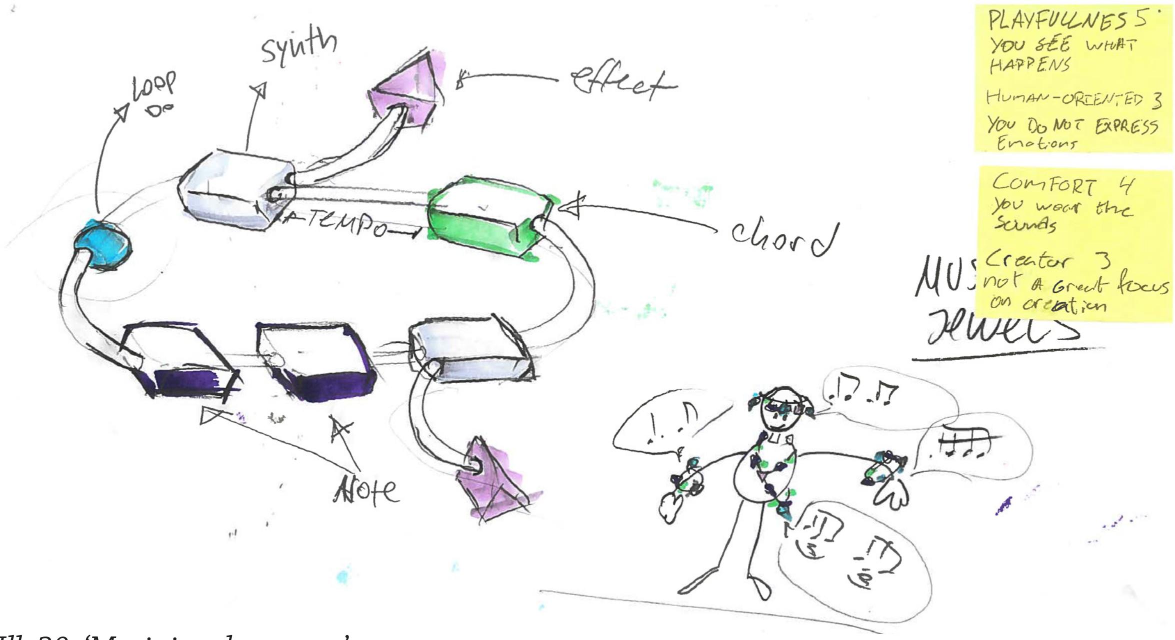
THIRD CONCEPT DIRECTION



Ill. 29: 'Program your shadow concept'

The third direction is 'Program your shadow' where the user aligns blocks in a bar-workspace. Each block stands for a body posture that users can combine for then being projected in the form of Chinese shadows. Users can replicate the postures and try to imitate them as a result from the code they wrote using the blocks.

FOURTH CONCEPT DIRECTION



Ill. 30: 'Music jewels concept'

The last direction are separated blocks that represent a sound and music function where users combine in a linear circuit for setting up parameters and use them as sounding wearables.

EVALUATION

For deciding which direction should be further developed, the project group compared them by using a relational matrix evaluating the fulfilment of the mission. From 'Illustration 31' it was observed that the first concept direction scored a higher mean value with an order of creativity types 2 (artistic expression: input) - 3 (insight: learning curve) - 1 (problem solving: output). Note that direction 4 is the lowest mean with a different creative order.

Concept name	Playfulness	Human-oriented	Comfort	Creator	Mean	Creative order
Soundscape	5	3	5	5	4.667	2-3-1
Music Jewels	5	3	4	3	3.833	2-3-1
Shadowfigure	4	3	4	2	3.167	2-3-1
Sound bites	3	3	4	3	3.167	1-3-2

Ill. 31: 'Evaluation table'

Having the integrated concept directions evaluated in respect of the mission, the project group proceeded to further specify them both: a) accordingly to the logic of abductive thinking [Dorst, 2011] in respect of what they are, how do they work and what is the value they provide to our target group, sub-groups and persona; and b) using moodboards to characterize the background scenario pursued with each solution for a specific age range.

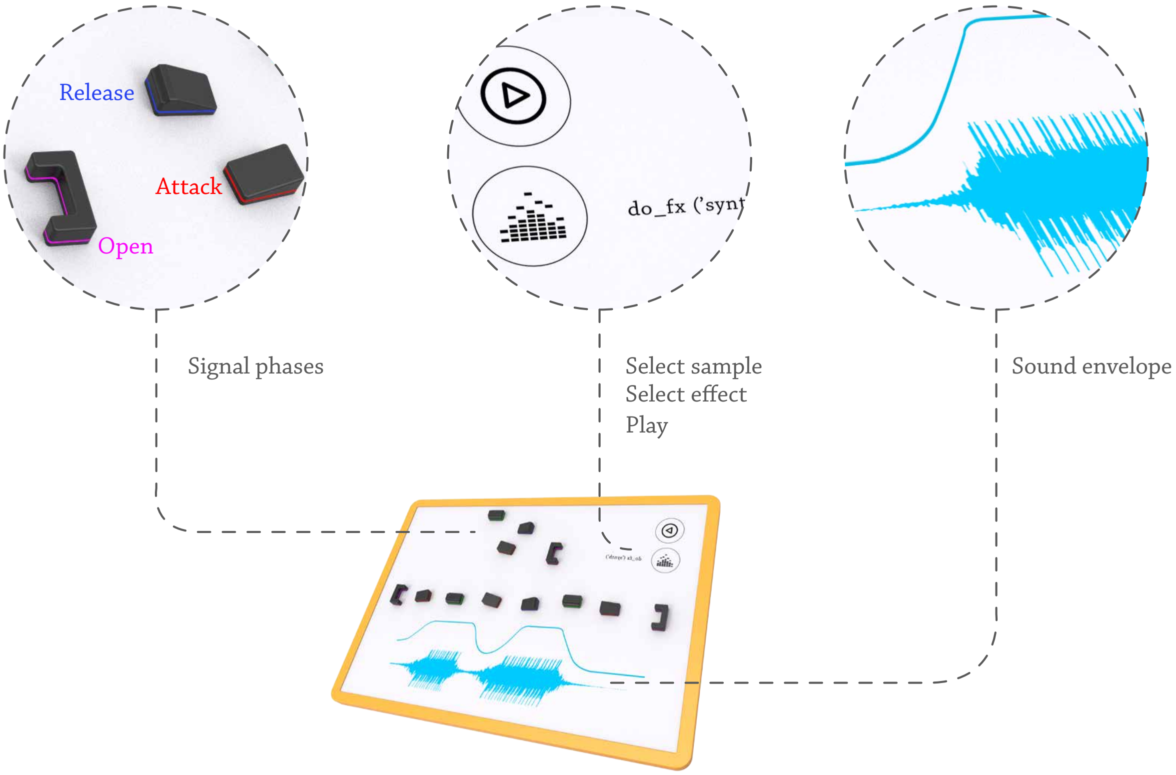
Concept name	WHAT (thing)	HOW (working principle)	VALUE (aspired)
Soundscape	Mobile app, tactile display, user-friendly code interface, sound display.	Convert lines of color into sound, convert sounds into a physical landscape.	New understanding of sound, introduction to abstract ideas, visual display of sound.
Music jewels	Wearable accesories, autonomic sound modules, sounding jewels.	Pearl based string construc-tion, circuit connection.	Wearable music, tangible interface coding, make and wear your own sound, new understanding of sound.
Shadowfigure	Work bar, light projection, block based language code.	Box string construction, chinese shadows, movement recognition.	Task breakdown, shadow mirrors users, body decoding.
Sound bites	Sound signal blocks, board game, block based sound creation.	Segmented sound signals, sound imitation, autonomic sound display.	Shape sounds, new understanding of sounds, collaborative play.

Ill. 32: 'Logic of abductive thinking'

The biggest strength of this ideation approach is the relative quick deep dive into the solution space with a simple approach to make more refined ideas and a way to end out with few distinctive directions with individual identities. However, the down sides to it lies in that it is important that all participants have a clear understanding of the meaning behind the outcome of each part. It is also important to have defined the overall themes for the basic requirements together with a clear way of proceeding when combining the initial sketches.
Using the relational table, abductive thinking and moodboards the project group decided to develop the first and fourth concept being the former the highest mean value of the mission and the latter an effort to convey a different creative order.

Ill. 33: 'Moodboard: 6-8 year old children'

SOUNDBITES



Ill. 34: 'Soundbites concept'

The project group decided to develop representative renderings and foam models of Soundbites for validating it with stakeholders. 'Illustration 34' shows the specifications of the concept depicting a touch screen where modules are placed. Users manipulate the modules and arrange them accordingly in order to create a sound envelope using the pieces as tangible interfaces that represent a phase of the sound signal. Users can combine them and obtain different sounds where brackets pieces open the signal beggining and end. The touch screen should read each of the pieces' position and use the distance between them to output the duration of the signal's phase. Also the rotation of the pieces can increase or decrease the changes of frequency pitch.

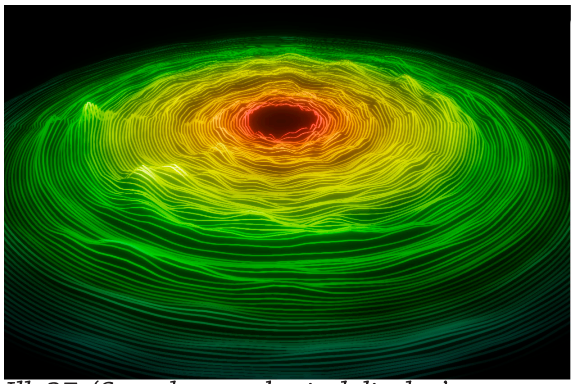
Ill. 35: 'Moodboard: Soundbite background'

CONCEPT DIRECTIONS

SOUNDSCAPE

Ill. 36: ‘Soundscape rough concept of interface’

For presenting Soundscape to our stakeholders the project group presented rough visual representations of both the digital interface and the physical display. Users use the digital interface to draw lines of sound that are read by the physical display that changes accordingly to the sound track composed by the users. The physical display consists on a round three-dimensional grid may with pins that users can manipulate to change the sounds, therefore it gives immediate feedback of how the sound coded visually looks like. The three dimensions of the grid represent in the Y-axis the time variations of the sound employed, the X-axis correspond to the frequency variations of the sound selected



Ill. 37: ‘Soundscape physical display’

where the Z-axis consists on the amplitude of each track. The grid shown in ‘Illustration 37’ changes its form in conformity with the colour lines drawn by the user in the digital interface [WS_016].

TESTING 01

VALIDATION WITH STAKEHOLDERS

Both concepts were presented to the Danish initiative Coding Pirates (Aalborg) contacted by the project group. They have presence all along Denmark and it develops IT skills, computer programming, robotics and digital technologies for young boys and girls [codingpirates.dk]. The first insight was that the two concepts presented could be used as introduction tools or to get an instant feedback on the code type that was presented. Other insights were that to use it as a coding tool it would be important to include the possibility to go both ways when creating something: children should both be able to create the sound output by either the line painting or block set up and then see the code or write the code and then see how it would look as painted line and placement of blocks. Concerning the possible depth of the solutions presented was shallow because of their simplistic input and output though they could be interesting as an add-on to existing early introduction coding programmes [WS_017].

Ill. 38: 'Coding pirates logo'

RESULTS FROM INTERVIEWS

Playful Tool	Skillful toy
• Needs to make the code explicit.	• Users should be able to extract meaning from the code.
• Switch back and forth between alternative and traditional ways of programming.	• The product should provide scalable challenges able to be solved by coding.
• Immediate feed-back: Instant visualization of the code.	• The modules of the product should represent parts of the code.
• Needs to make the code explicit: tangible and visual feedback.	• The solution should enable short-cuts for known skills.
• An add-on to existing coding language (Python 3)	• The solution should be a stand-alone product.
• For kids between 6 and 7 years old: Co-operative product.	• Radical approach of innovation.
• Incremental approach to innovation.	
CONCLUSIONS	
• It has to be part of an alternative mode of education.	• It has the most competing products on the market and industry.
• The solution should be combined with existent coding languages.	

Ill. 39: 'Initial set of requirements'

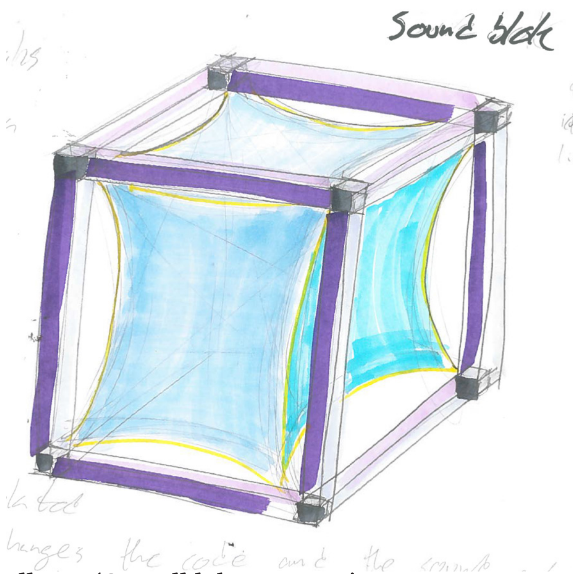
IDEATION 03

THIRD ROUND

The insights from Testing 01 consisted on the initial set of requirements. Once the directions were validated the project group decided to discard Soundscape since it did not provide a learning curve in computer programming, and it would compete on the market with entertainment toys instead of technological tools. Iterations where made to challenge Soundbites to produce linguistic variations of 'Artistic Coding' during session of 15 minutes rounds iterating on the initial requirements derived.

SOUNDBLOK

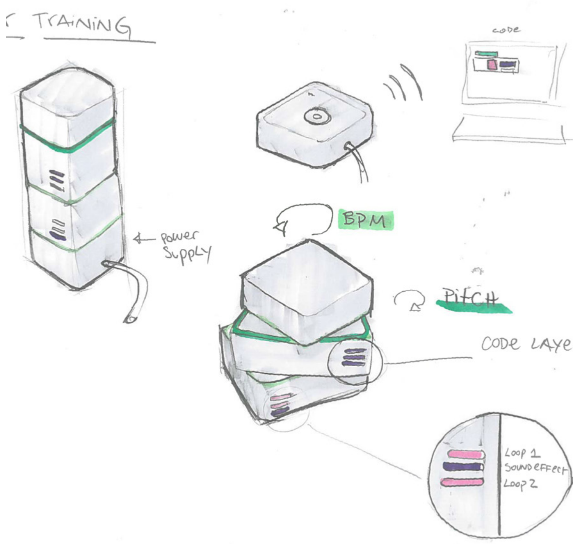
This concept is a frame with sensors that contains a base shape filled with grains/ sand that users manipulate. Users interact with the sand base where the sensing frame reads the changes made on it and translate that into a sound. Sound is displayed in code so users can visualize the changes of the sand in the form of lines of code. Sounblok is a modular product therefore can be combined with similar modules and conform a larger configuration.



Ill. 40: 'Soundblok variation'

THE TOWER TRAINING

This concept consists on four stackable units that represent an array of musical loops. The units are feeded with a power supply unit at the bottom which is sending the information to the computer via WI-FI displaying the code of the sound loops. The units can be placed and rotated in different order therefore, changing BPM, pitch or amplitude parameters and use them to create new music. Lights in each unit shows which loops are sounding and which is the time between one and the other.

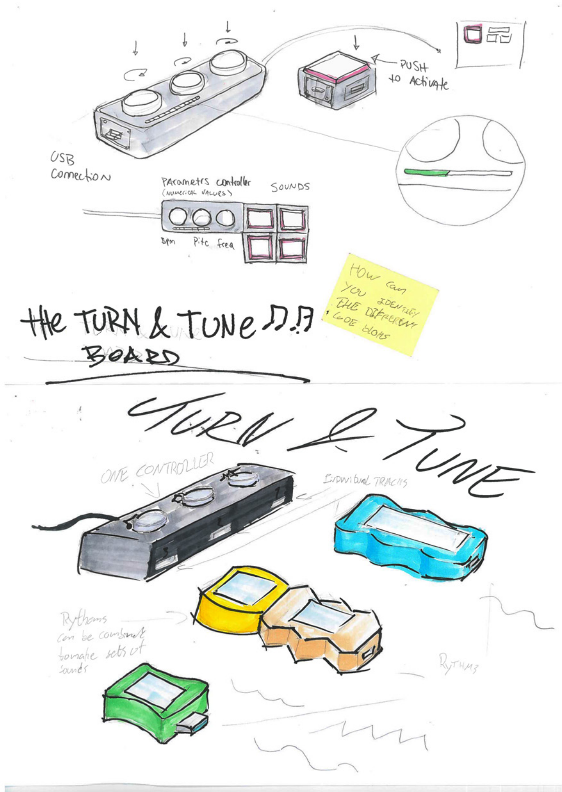


Ill. 41: 'Tower training variation'

IDEATION 03

TURN AND TUNE

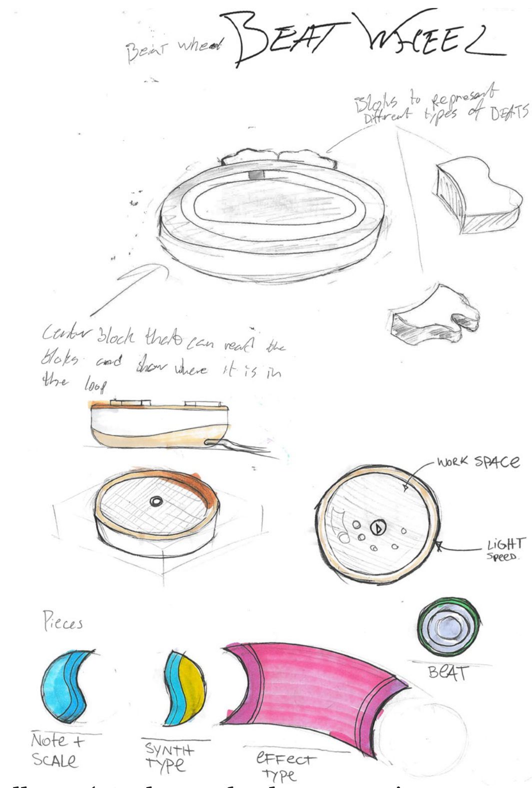
This concepts emulates a sequencer by incorporating a control board that regulates speed, pitch and amplitude of the sounds by using dials. Modular pieces having buttons can be connected and arranged through USB docks and assign a specific code to the piece that can be played with the board. The pieces have particular shapes that represent the shape of the sound envelope, a zig-zag shape represents short signals with no sustain phase while a curved represents a signal that has a prolonged attack and a prolonged decay. The board is connected to the computer for displaying the code and to provide power to the rest of the pieces.



Ill. 42: 'Turn and tune variation'

THE BEAT WHEEL

This concept is a central unit that read pieces representing coded beats and displays in the computer the order they have in an infinite loop. This variation changed its central unit to have a touch screen as a workspace that reads different pieces position, where each one represent the code for a sound effect, a synth type and note + an scale, together with a coded beat. The central unit incorporates a spinning light that symbolize the continuous compilation of the code embedded in the pieces' configuration.



Ill. 43: 'The beat wheel variation'

TESTING 02

VALIDATION WITH STAKEHOLDERS

The project group presented to two more volunteers of Coding Pirates and to Joachim Hejslet (Persona) wooden modules accompanied of sound samples to test the validity of the solutions. It was decided upon the requirements of Playful tools to develop the models since it deemed more possibilities to fulfill the project's mission in providing humanitarian-oriented solutions to building computer programming competences instead of making toys that entertain users. The phase consisted on in-depth interviews with stakeholders that were presented and pitched the solutions.

TURN AND TUNE

Ill. 44: 'Turn and tune model'

The project group decided to develop the Turn and Tune concept for being a device that offers an introduction to sound computing that can be further used to compose music. The objective of the model was to test key aspects of interaction and communication such as shape of pieces, icons assigned for regulating each sound parameter and possibilities of combinations between the pieces. Also, it was tested the potential of the solution to be part of educational sessions of coding courses and/or tech camps such as Coding Pirates. Turn and Tune consists on a control board with external modules that can be assigned with pieces of code corresponding to different sounds such as beats and melodies. The external modules can be attached to the central board and between them where the users press the buttons and rotate the dials to start playing music with the sounds they have coded.

SOUNDBITES

Ill. 45: 'Soundbites model'

The project group decided to continue developing Soundbites for being a solution proposal with a direct feedback and feedforward between physical and digital interfaces. The objective of this model was to test size differences between using an iPad as the touch screen or a bigger autonomous board as initially designed. Also the project group decided to test communication aspects in respect of the use of brackets to convey the syntaxes used on computer programming languages, together with the shape of pieces to communicate a programming function such as a melodies made by chords and arpeggios, beats made by drum samples and sound filters such as echo or reverberation.

Volunteers in Coding Pirates declared that Soundbites is a good solution since both in code and sound it provides immediate feedback which is needed by children by modifying lengths between the pieces and observing the change. However it was made clear that users would not be able to understand strings of code from Sonic Pi or Python 3 as the languages used to compose the sounds. This made clear that a step is needed that is buffering inbetween the modification of the pieces and the code script where the volunteer argued that children would understand better if the block of the physical interface are also blocks in the digital interface to convey the lines of code.

```
define :beatpiece2 do
  16.times do
    use_bpm 60
    sample :drum_cymbal_closed
    sleep 0.5
    sample :drum_snare_hard
    sleep 0.5

    sample :drum_cymbal_closed
    sleep 0.25
    sample :drum_heavy_kick
    sleep 0.25
    sample :drum_cymbal_closed
    sleep 0.5
  end

end
```

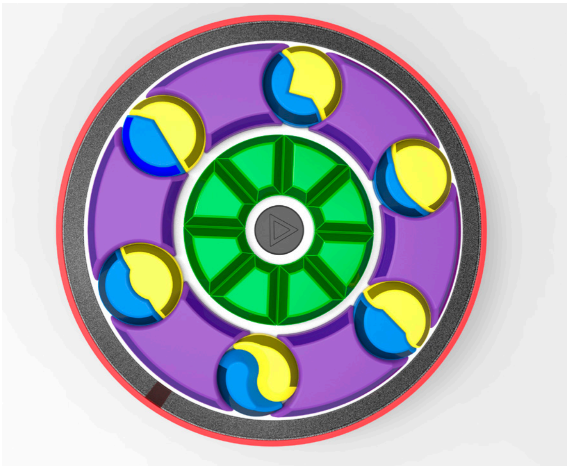
Ill. 46: 'Sample of code from a beat piece'

TESTING 02

THE BEAT WHEEL

Ill. 47: 'The beatwheel model'

The project group decided to develop The Beatwheel for being a proposal that create focus and structure in both building coding competences and composing music by arranging the pieces' configuration. The beatwheel offers the possibility to access each pieces code for refinement and tuning each sound function such as rhythm, sound effect, instrument, and melody as a way to convey educational and learning objectives. The objetive of the model was to test possible configurations with the pieces beside the one shown in 'Illustration 47'. The project Persona, Joachim Hejslet stated that the solution as a sole music station that supports multitracking should be able to take it onto the stage, and the use of colors to distinguish the pieces would be more pedagogical and intuitive to use the product in a more explorative way.



Ill. 48: 'The beatwheel configuration'

TABLE OF REQUIREMENTS

For translating the stakeholders' insights into a table of requirements with design parameters the project group decided to use the Kano Model [Malcom, 2014]. For developing a playful tool that can act as a programmable musical instrument requirements were divided between quantitative and qualitative functionalities with basics technical aspects that compose the core of the solution, performance requirements that compose the interaction and behavioural aspects and delighters that add requirements of playfulness. Furthermore, the insights showed that as well as the tangible interface, a digital platform of the software should be developed [WS_018].

QUANTITATIVE	QUALITATIVE
BASICS	
• Individual modules to control the system and working environment. • Each configuration of code should be able to be read and displayed on the computer. • Each module should stand for a 'sounding function'. • The user should be able to do his/her own music.	• Each module should represent a specific array of code, function, variable and task.
PERFORMANCE	
• 6 to 7 years old children should be able to understand each module's code. • Real-time in-action live-looping coding.	• The solution should include low-cost technology available in the market
DELIGHTERS	
• Users should be able to play along with other instruments while manipulating the solution. • The solution should be able to cast the code and music to other devices.	• The product should have special purchase agreements for coding courses.

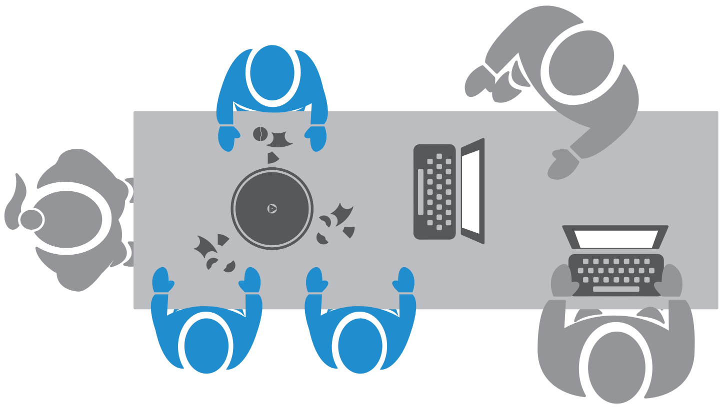
Ill. 49: 'List of requirements'

Requirements were built based on insights and previous results from iterative ideations. The project group decided to keep developing Beatwheel as final solution for being the most preferred by stakeholders, for it conveys better a tangible interface for code-alike configurations and provides a more direct playfulness through being an stand-alone product.

TESTING 03

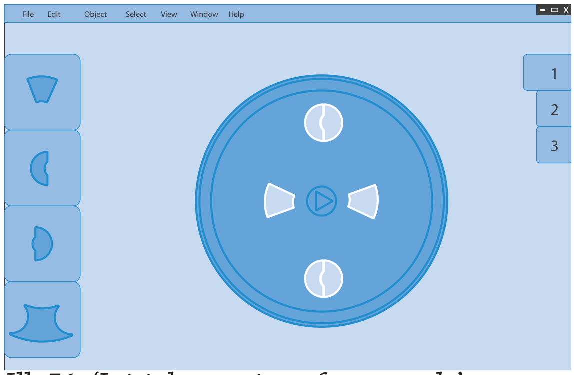
VALIDATION WITH END-USERS

Once a product direction was decided, the project group proceeded to test it with end-users corresponding to students from Coding Pirates in an age group of 10-13 years old. The setup for this test consisted on The Head of department, 3 users and the two group members.

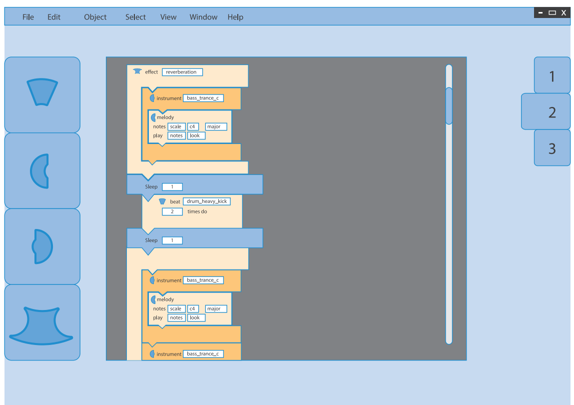


Ill. 50: 'Setup illustration of test with users'

'Illustration 46' shows the setup for the tests. One of the group's members acted as a guide that presented the product, where the second member was reproducing the sounds in the computer corresponding to the configurations made by the children. Wooden models were presented to children accompanied by a computer showing the initial interface for the software design together with a second computer acting as audio output for the sounds programmed. The end-users where asked questions to know their preferences in respect of the solution where the Coding Pirates representative interpreted the usefulness of their answers. Children declared that having tangible code pieces, and a block based interface makes the understanding of computer language easier, where composing music made it fun to try.



Ill. 51: 'Initial setup interface sample'



Ill. 52: 'Initial code interface sample'

PRODUCT REQUIREMENTS

RESULTS FROM VALIDATION

For refining the solution into technical details and business aspects, previous requisites were divided into requirements for creativity (music composition possibilities), for learning (build programming competences), and for easy-of-use (intuitive comprehension of the product) that could serve for further comparison and evaluation of the solution.

CREATIVITY	LEARNING
• The solution should have the ability to change pitch, amplitude and beats per minute (BPM). • The product should presents means to produce melodic sounds by presenting possibilities of combinations. • The solution should be able to be used as part of a performance. • Making sounds using instrument samples, musical tones, sound effects, beats and rhythms. • Anything the users do should create a sound. • Users should be able to change tempo (BPM) by spinning the speed definer.	• The solution should have both physical and graphical representations of the code. • Each piece should be differentiated by colours and icons. • Users should be able to modify the software and change the pieces' features. • Users should be able to modify each piece and change the software.
EASY OF USE	
• The soultion should be a 'plug-and-play' product. • The product should have a continuous code compillation. • Users should be able to control each sound aspect at once using the object. • Users should be able to select each piece using the software. • The solution should be a self-containing stand-alone station.	

Ill. 53: 'Final requirements of functionality'

Despite the solution had a positive balance with end-users further specifications of the product semantics need to be developed such as: building of cognitive processes mediating between the form and shape of pieces- the understanding of block based code - and their translation into musical sounds. Also, use cases need to be developed for the scenarios of a single user playing with the Beatwheel and its use in educational scenarios. Furthermore, basic aspects of software engineering need to be developed too: user interface, user experience and interaction flow modelling.

Ill. 54: Detailing

DETAILING

The following chapter describes the process from which the project group integrated, executed and refined the concept solution by defining the product semantics (idiom), the system architecture, software design and business case.

This phase had the objective to define the aesthetics of the product's design language and base for software engineering through applying service system design tools for defining the project's business strategy and plan.

PRODUCT SEMANTICS

IDIOM INVESTIGATION

In order to design the pieces of Beatwheel three rounds of iterations were made to test the language of the product. For this purpose 9 subjects with different backgrounds (eight males and 1 female) were recruited randomly. The sessions consisted in presenting the functionalities of the Beatwheel, the initial software interface and foam models. Subjects were pitched with the project description, together with the functionalities of the modules and they were asked to compose a musical piece by using the different modules while the group member coded their configuration using the software Sonic Pi to translate them into sounds. 'Illustration 50' shows the setup with the basic form of the pieces per iteration phase and the subjects' background [WS_019-021].

PHASE	ITERATION 01	ITERATION 02	ITERATION 03
IDIOM / SUBJECT			
1	Industrial Design	Subject 1 from Iteration 01	Architecture
2	Industrial Design	Sustainable energy planning and management	Industrial Design
3	Industrial Design	Sound and Music Computing	Subject 3 from Iteration 01
4	-	Sound and Music Computing	Industrial Design

Ill. 55: 'Sample Preaparation table'

Subjects' performance were photographed and were asked to compare the different Idiom proposals. Their observations were written and then processed using a relational matrix in order to find commonalities and differences in respect of the understanding that shape communicated the relation between programming preferences and music composition

Ill. 56: 'Subject 1 - Iteration 03'

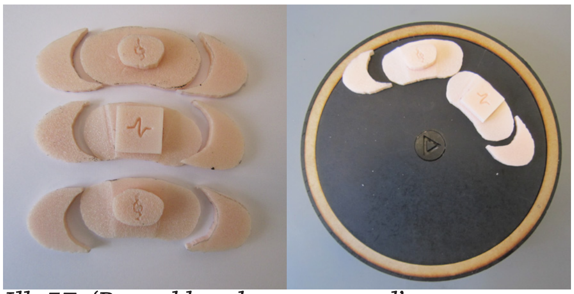
PRODUCT SEMANTICS

ITERATION 01

The first round objective was to identify the facility of the pieces' set to convey the desired information in respect of their function meaning a piece to declare a musical instrument, a piece to declare and define a melody or rhythmic beat, and a set of pieces to declare a sound effect and their duration [WS_XX].

FIRST PROPOSAL

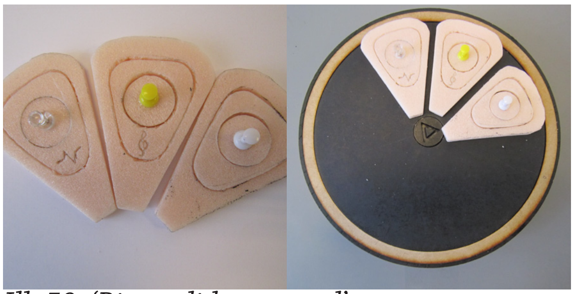
Brackets function is to declare the duration of a sound, and a sound effect. The ground piece corresponds to a musical instrument where a melody/beat piece is added. For this configuration, subjects stated that is good that three layers of sound can be manipulated, and it suggests a sequential reproduction needs to be followed to play.



Ill. 57: 'Round brackets proposal'

SECOND PROPOSAL

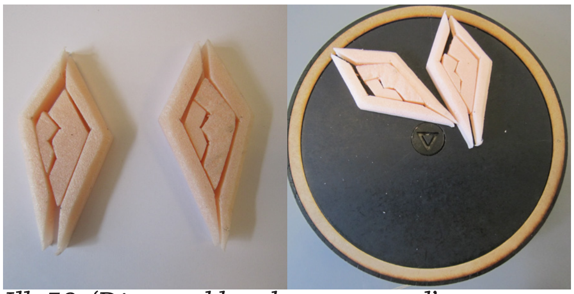
Outer piece is a musical instrument, middle piece is a melody/beat and inner piece is a sound effect. 8 sections were made. Subjects declared an in-out sequence facilitates understanding the coding language, and it mantains a hierarchy of sizes.



Ill. 59: 'Pizza-slide proposal'

THIRD PROPOSAL

The outer brackets are a sound effect, the larger half-dentate diamond is a musical instrument and the smaller half-dentate piece is a melody/beat. Subjects declare having a closure communicates better the togetherness of the pieces.



Ill. 58: 'Diamond brackets proposal'

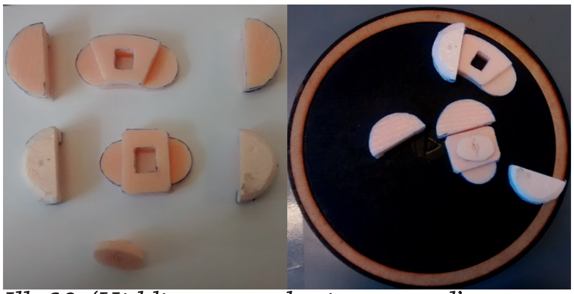
ITERATION 02

This round objective was to make evident that brackets can be moved to declare the duration of the pieces and to identify the optimal interlocking system in the hierarchy of geometries for doing a musical piece.

This round counted with one subject from the previous phase, and three non-design participants to evaluate the learning-ability of the solution.

FIRST PROPOSAL

Brackets represents a sound effect and the sound duration, ground piece is a musical instrument, and the stackable piece is a melody/beat. Subjects declared that icons are needed to distinguish the pieces and they had a good interlocking system



Ill. 60: 'Hidding parenthesis proposal'

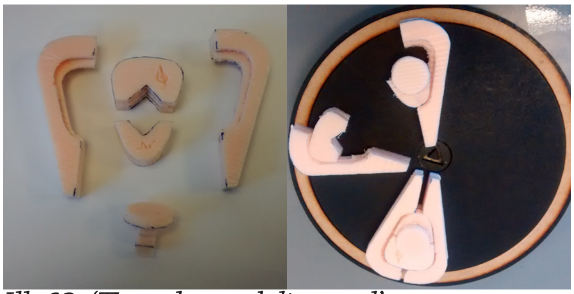
SECOND PROPOSAL

Brackets are an instrument and its duration, the ground piece is a melody/beat and the sound effect is introduced on it. Subjects declared that is good for multitracking and good the melody/beat is the core, but there was not a good interlocking system.

Ill. 61: 'Visible parenthesis proposal'

THIRD PROPOSAL

Brackets are instruments and their duration, beat and melodies are separated with icons, while the sound effect is placed on them. Subjects declared that beats and melodies should not conform a unity and that brackets were too large and limited the possibilities for multitracking.



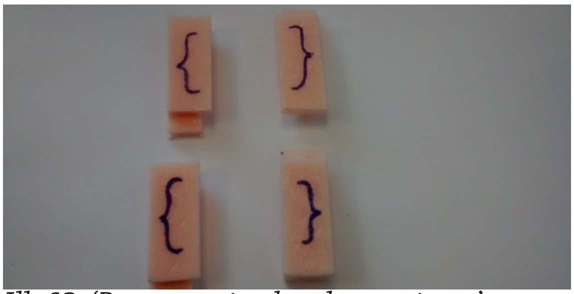
Ill. 62: 'Three-layered diamond'

ITERATION 03

Iterations showed that brackets and their function were the decisive component that defines the core of the interaction use. This round was focused to identify the optimal idiom on the brackets and included non-designers, fresh and previous design participants.

FIRST PROPOSAL

Brackets can be aligned by a male-female assembly, explicit parenthesis were drawn that are used in computer programming languages. Subjects declared that is good it has an icon you find in a computer and they are similar to the ones used on music.


Ill. 63: 'Programming brackets as icons'

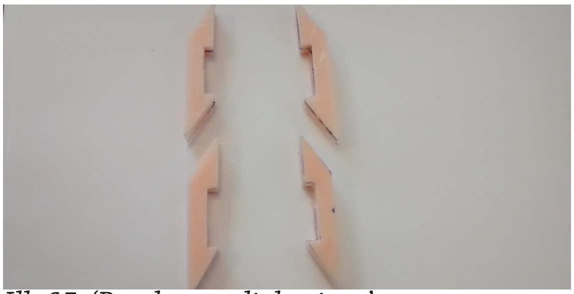
SECOND PROPOSAL

The brackets were mantained in the shape and the included a groove on the bottom to slide the rest of the pieces. Subjects declare that the shape is not enough by itself and should be larger to place a melody/beat starting at the same time.


Ill. 64: 'Brackets in shape'

THIRD PROPOSAL

Brackets were shaped to be aligned when put in the same section and to indicate the start and end of a sound. Subjects declared that they did not convey the information and they were non-coherent with the loop being played with the Beatwheel.

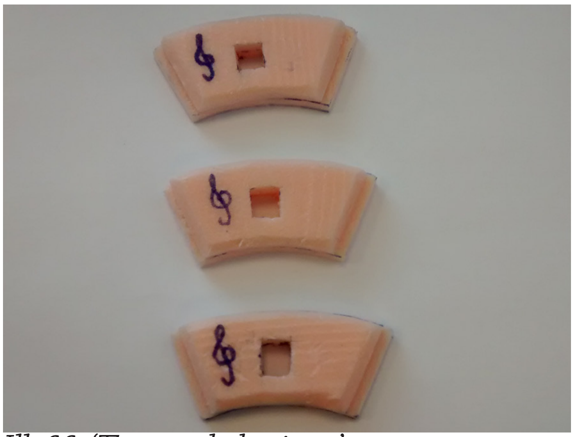

Ill. 65: 'Brackets as lightnings'

RESULTS

From Iteration 01 it was concluded that pieces should stand for at least three layers of multi-tracking and maintain a hierarchy of sizes in respect of their sound function with a common interlocking system. From Iteration 02 it was concluded that pieces should be distinguished with icons and colours having the melody and beat as core pieces, where the musical instrument is incorporated to them while the sound effect was seen to be perceived as a an external element that is added. From iteration 03 it was concluded that brackets should be subtle in shape with clear icons of the same brackets that are used on computer programming for being coherent with the project mission. The following section exposes the final shapes for each piece's identity and their function that were derived from previous iterations. Each piece is to be read by the Beatwheel and recall their respective source codes.

MELODY PIECE

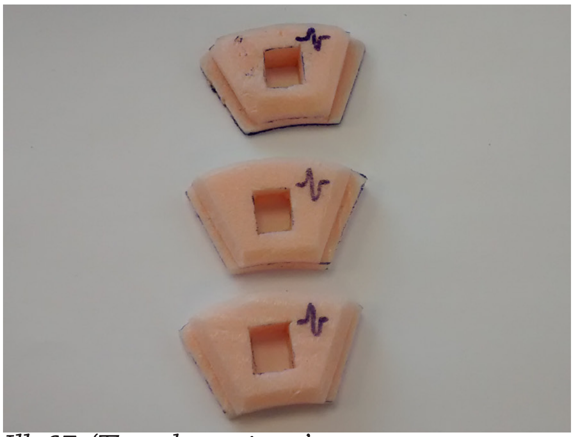
The function of the melody piece is to display an array of code that represent a succession of musical tones such as chords, scales and arpeggios with different pitch frequencies. The melody piece needs an instrument that reproduce the code on it, since otherwise it would be information attached. 'Illustration 66' depicts the pieces with a G-key symbol in the side and a squared groove for the sound effect to be added.



Ill. 66: 'Three melody pieces'

BEAT PIECE

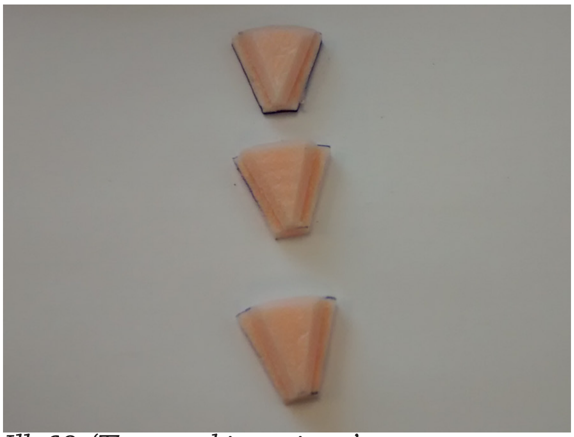
The function of the beat piece is to display lines of code that represent the basic unit of the background rhythm (pulse) with drum and/or bass samples. The beat piece needs an instrument that reproduce the code on it, as the same as the melody piece their internal lines of code can be altered by the user. 'Illustration 67' depicts the pieces with a sound wave icon in the side for being a common representation of electric pulse.



Ill. 67: 'Three beat pieces'

AMBIENT PIECE

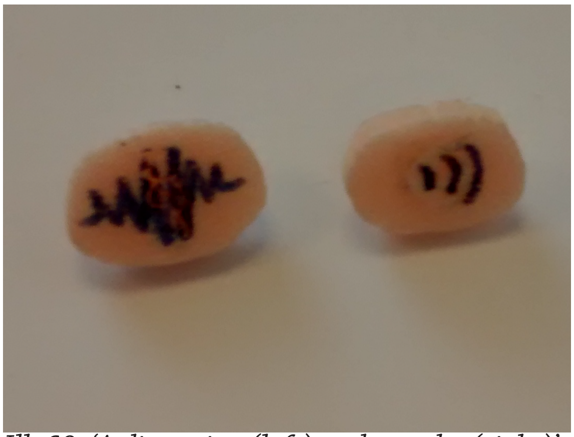
The function of the ambient piece is to display a sample of environmental sounds as atmospheric aggregates of the track composed by the user such as animals, water flowing, rain falling or wind. These pieces do not need brackets since they are in a constant loop, as well as an icon since the sound sample can be changed from the source code.



Ill. 68: 'Three ambient pieces'

SOUND EFFECT PIECE

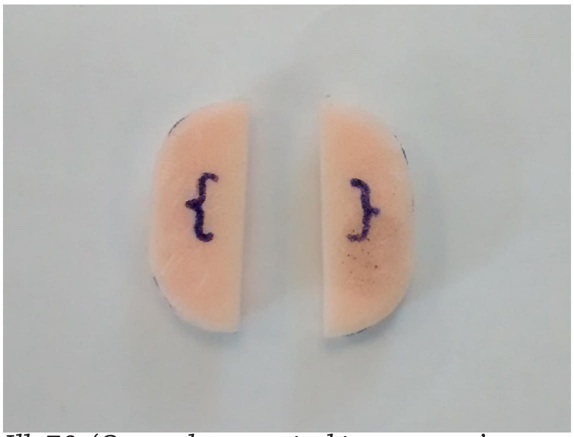
The sound effect's function is to display an array of code as an additive to the melody or beat by creating enhanced sound processes such as echoes, reverberation, distortion, low-pass or high-pass filters. These pieces are added in the squared fit on the melody and/or beat pieces. They have representative icons of the effect they cause.



Ill. 69: 'A distortion (left) and an echo (right)'

MUSICAL INSTRUMENT BRACKETS

These pieces' function is to declare the function of defining a specific musical instrument to the code on the melody/beat piece such as piano, violins, or synthesizer. The distance between them represent the length duration of the piece's sound they are attached to. They incorporate an open-closed parenthesis used on computer programming and music composition.

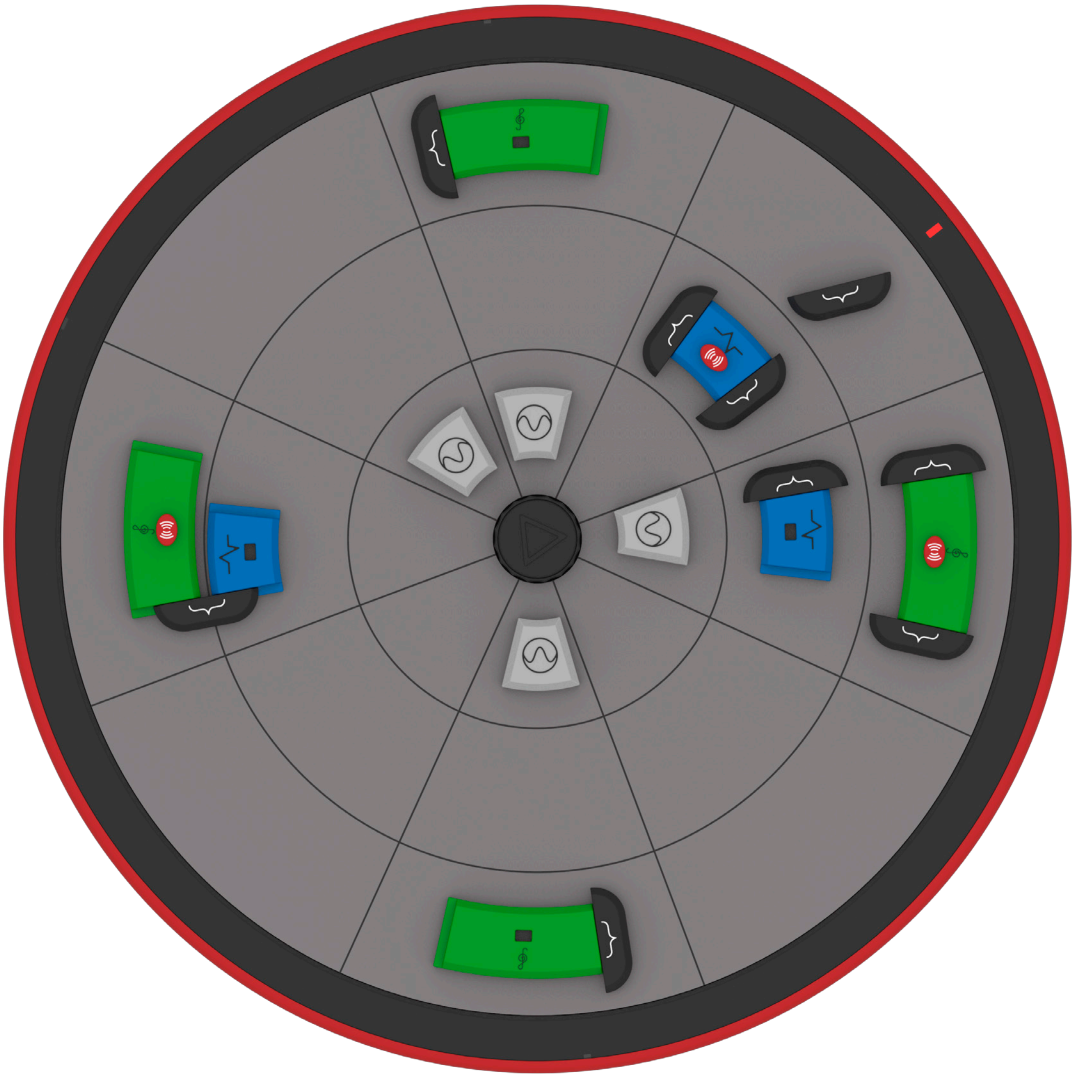


Ill. 70: 'Open-close musical instrument'

BEATWHEEL

THE CONCEPT

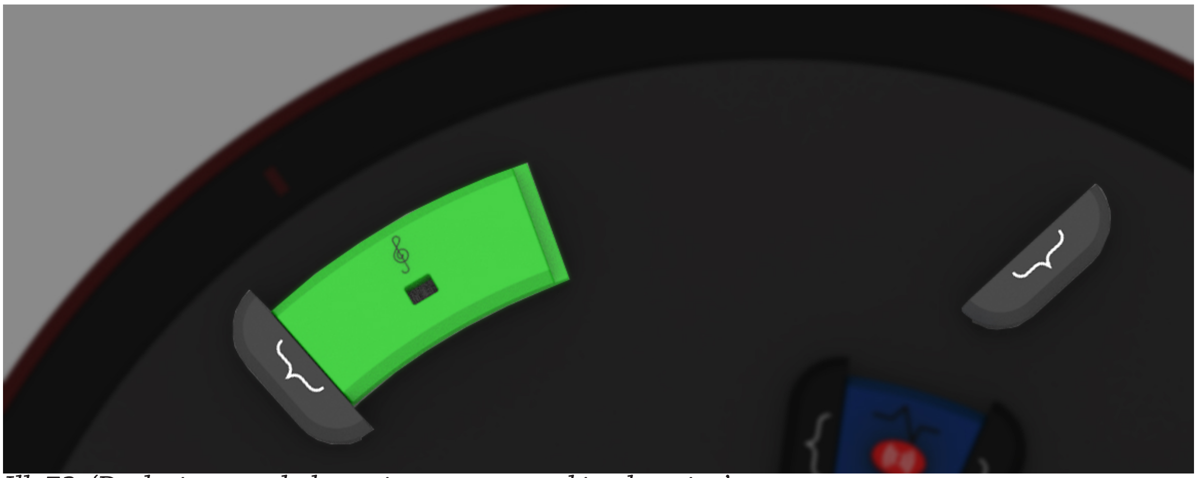
Beatwheel is a programmable musical device which through a touch screen and an internal computer recognizes each piece to recall arrays of code written in Sonic Pi language. Its tangible interface of pieces allows to configure them into melodies, beats, ambient sounds and musical instruments to which sound effects can be added. Beatwheel includes a software that users can access and change each piece's source code and modify them accordingly. A spinning light indicates the compilation of the code and the course of the loop and by manipulating each piece's distance they can perform live music. Beatwheel allows an immediate feedback of the user's performance arranging the pieces and live coding.



Ill. 71: 'Beatwheel top-view with an arrange of all the pieces'

DECLARING VARIABLES AND FUNCTIONS

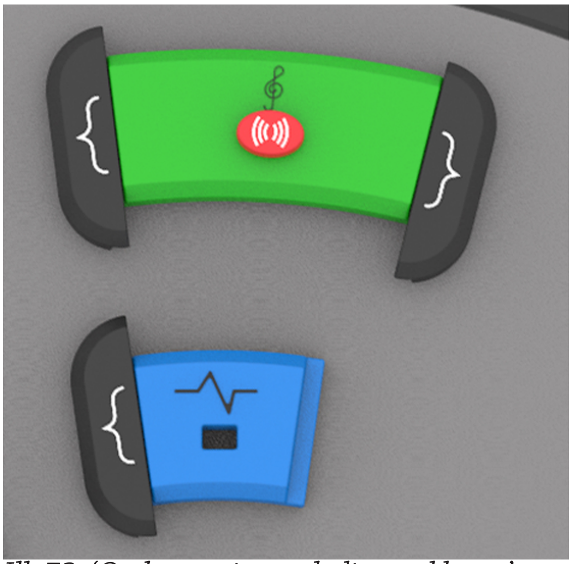
Users play the Beatwheel in two ways: with a tangible interface and with a digital interface. Each piece declares a function which is displayed in the computer and reproduced through the speakers. Users can arrange the pieces in the Beatwheel and see the code in the screen, and change the variables and function of each piece on the screen and hear the change. For declaring a function 'Illustration 72' shows a melody piece declared with a musical instrument where the space between the brackets defines the duration, when the melody will start and when will it end. Since Beatwheel is a loop with one beat per second and 8 seconds in a row, users can displace these brackets and pieces for performing live and watching in real-time their music in computer language therefore developing coding skills and competences.



Ill. 72: 'Declaring a melody, an instrument and its duration'

MULTITRACKING

Users align the instrument brackets to assign when the pieces should sound simultaneously and thus orchestrate their tracks. By arranging multiple pieces users synchronize the cues for each melody, beat or effect therefore conditional statements are made. Beatwheel fits three layers of orchestration divided in eight sections. Melodies run in the outer layer for being the foreground, the beats in the middle as background and ambient sounds in the last.



Ill. 73: 'Orchestrating melodies and beats'

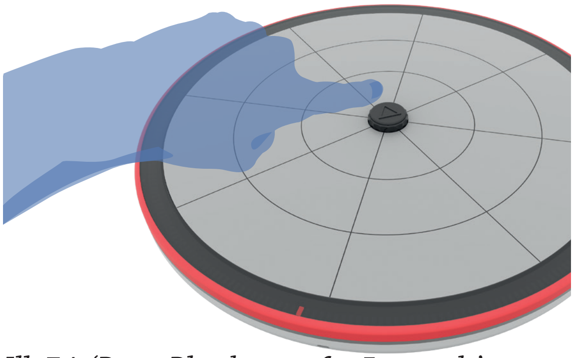
BEATWHEEL

The concept is plug and play device with a central platform which contains the internal hardware and is connected to the computer that is displaying the digital interface. The central platform includes an activation button that plays or pause the loop. By rotating, it changes the tempo indicated with 256 LED lights that light up sequentially to the compilation of the code.

Each piece has a predefined array of code with modifiable parameters. The pieces are recognized by having an internal RFID chip which is detected by the touch screen stored in the internal memory of the Raspberry Pi inside the Beatwheel. The central platform contains a lithium battery which is charged by a USB connection and powering the Beatwheel.

TURNING ON THE BEATWHEEL

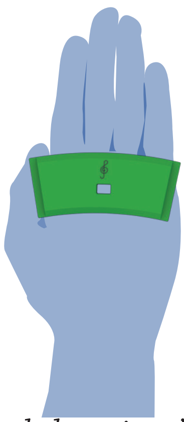
For turning on the Beatwheel users press the play button for five seconds which turns on the LED lights surrounding the platform and executes the auto-run of the Beatwheel software. By pressing the play button during a live performance, the LED light up sequentially as the tempo is set.



Ill. 74: 'Press Play button for 5 seconds'

PLACING PIECES

Once the Beatwheel has been turned on and activated in the computer, users proceed to place the pieces, press play and explore the different sound functions. For example, the code of a melody piece is pre-set to reproduce a C4 chord by choosing randomly the respective tones of the chord (i.e. C4-E4-G4) and reproducing them with sound envelope of an 0.01 attack, and a 0.25 release along six octaves from the initial C4.

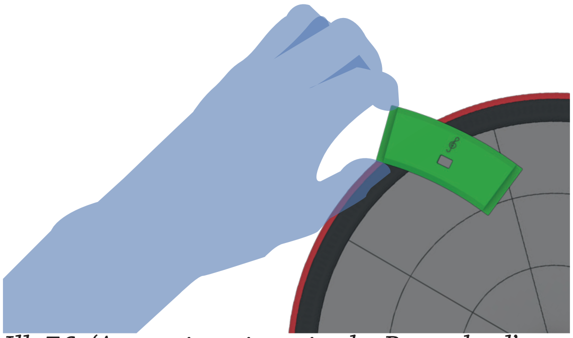


Ill. 75: 'Select and place pieces'

BEATWHEEL

ARRANGEMENT OF PIECES

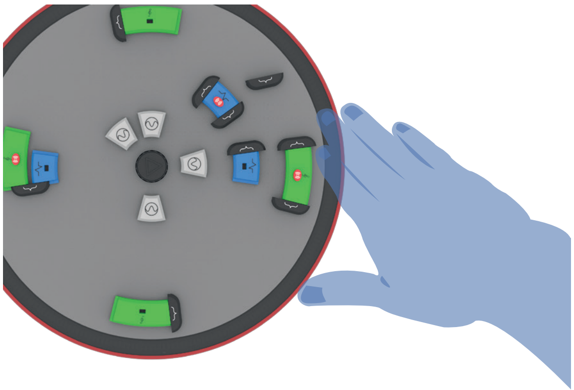
Users can begin experimenting with the order of the pieces in the marked divisions in the Beatwheel and hear the differences by changing their position and length. Previous research showed that test subjects preferred delimited sections to begin composing instead of a blank workspace.



Ill. 76: 'Arranging pieces in the Beatwheel'

SCRATCHING

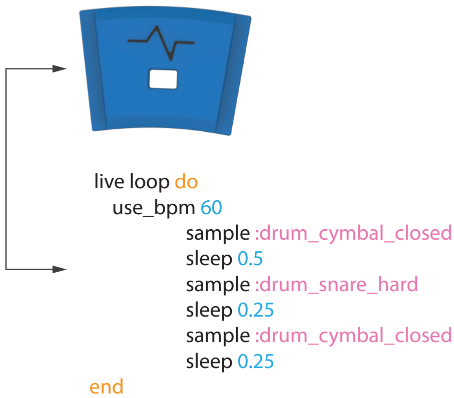
In between the touch screen and the LED lights there is an sliding ring that acts as a turntable scrubbing that users move back and forth to play with the tempo and changing the LED spin by slowing it down or speeding it up. The platform includes a metal layer with a touch sensor that users can slide and regulate the overall volume of their music.



Ill. 77: 'Moving back and forth to scratch'

PIECE IDENTITY

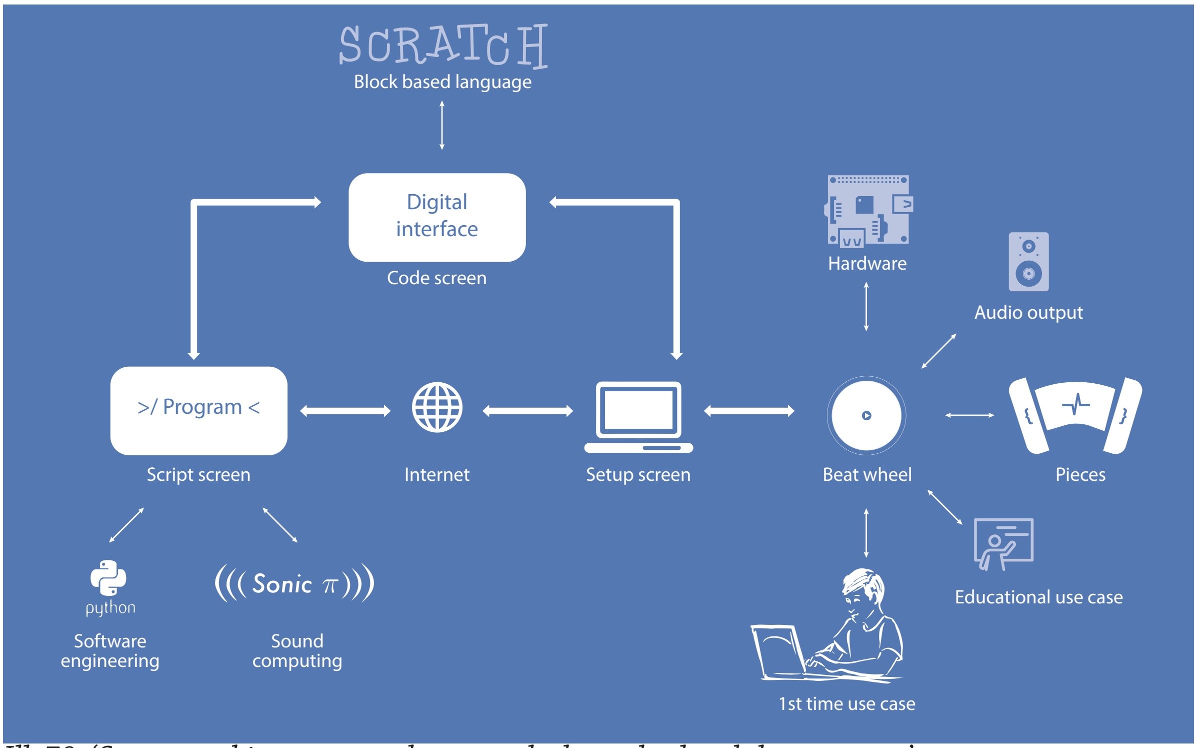
Each piece is assigned a code argument with functions and variables that are triggered once they have been placed in the platform and can be reproduced when they have been declared with a musical instrument and a duration. 'Illustration 78' shows an array of code that represents a loop at 60 bpm with three drum samples separated by sleep time. The brackets are used to start and stop the loop of each piece's code.



Ill. 78: 'A code argument assigned to a beat'

SYSTEM ARCHITECTURE

For specifying the interaction flow between the Beatwheel and the computer a system architecture was made as shown in 'Illustration 79'. The map shows which resources are to be used for displaying the code of the pieces and for programming the software as well as the components that are in communication with the Beatwheel where the project group focused on detailing the first use case, the dialogue between the pieces and the computer.



Ill. 79: 'System architecture map between the beatwheel and the computer'

Since Beatwheel provides immediate feedback to the user through sounds and through a software, the project group was assessed by a Software Engineer. The software works at two layers: a front-end digital interface and a back-end script. They have two sub-layers of core functions: the digital interface displays the positioning of the pieces on the platform over a time-line (setup screen) and displays the code arguments of each piece using a block-based language (code screen). This can be done by using the existing language: Scratch. The back-end script develops the overall software by using the language Python 3, and it displays the lines of each piece's code written in Sonic Pi language (script screen). The project group decided to define the design of the setup screen functionality for being the core aspect of communication between the physical product and the digital interface. For this purpose, two use context were identified: a first-time use for play and an educational context for training skills.

USE CONTEXT

STAND-ALONE PLAY TIME

The initial research and framing developed the project from designing skilful toys to designing a playful tool that trains computer programming competences in children between 6 to 8 years old. The playful experience consists on adopting an explorative and experimental approach to composing sounds and music through the Beatwheel. This use context goes from a) a first-time use of the Beatwheel where users get acquainted with the core functionalities of the product by following a walk-through tutorial, to b) a play-time use of performing live music once users are familiar with the basics of sound computing and the pieces' dynamics on the Beatwheel.

Ill. 80: 'First use case: play-time use'

EDUCATIONAL PROGRAMS

Research showed that the toy industry was moving towards supplying equipment for educational programs of Science Technology Engineering Arts and Maths ranging from mainstream schools to specialized tech and coding courses for children. The educational experience consists on a set of introductory sessions to advanced computer languages in hands of a facilitator by using the Beatwheel as a platform to teach computation of sounds and writing computer programs. This use context goes from a) getting started with the Beatwheel software by coding melodies and beats, to b) training writing arguments, boolean operations and data structure in sound and music programming.

Ill. 81: 'Second use-case: Education time'

PLAY-TIME USE CASE

To build the use cases the project group utilized the Service Design tool: Customer Journey Map [Morelli 2002,2006]. This use case includes the first-time use and the performing live music by exploring the product. 'Illustration 82' shows the user's journey in this regard by identifying what they do in a time-event, which rewards they get, what the Beatwheel and hardware do, together with the sequences in the Software. This tool is useful to plan and design the overview of before and after situations for further specification and development.

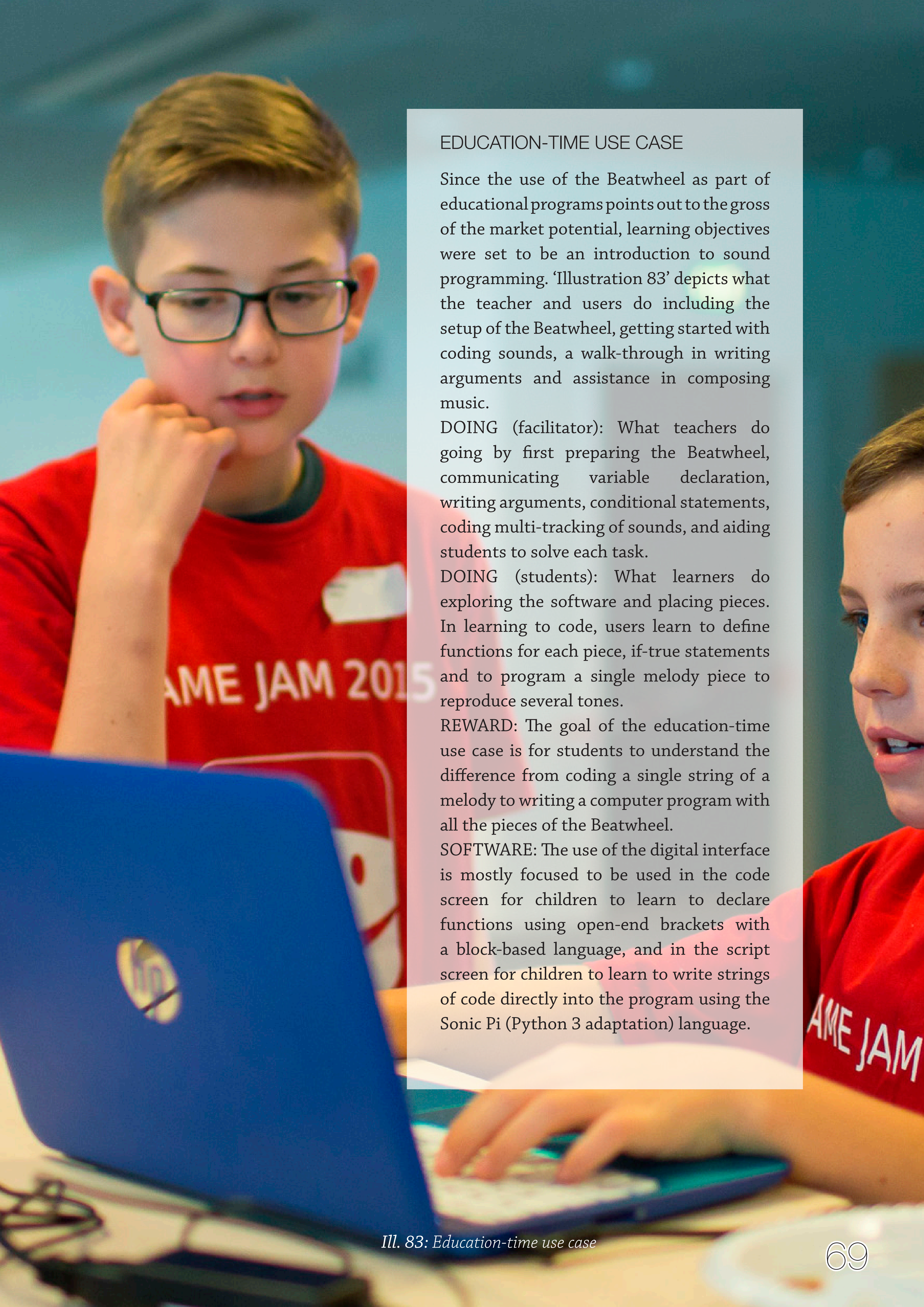
DOING: What children do going by first, turning on the beatwheel and following up the software walk-through, then experimenting with the software/hardware inverse communication, for after playing by manipulating time and synchronizing pieces while performing live.

REWARDS: the goals the user achieves while exploring with the Beathwheel, that goes from becoming aware of the device immediate feedback to composing original pieces of music.

BEATWHEEL: along each time-event the device and its internal hardware process the arrangements made by the user in the platform, recognizing the pieces and display their code layout in the computer.

SOFTWARE: the digital interface is divided in three main screens accompanied by an intro tutorial that includes a step-by-step instructive of each function.

Ill. 82: Play-time use case



EDUCATION-TIME USE CASE

Since the use of the Beatwheel as part of educational programs points out to the gross of the market potential, learning objectives were set to be an introduction to sound programming. 'Illustration 83' depicts what the teacher and users do including the setup of the Beatwheel, getting started with coding sounds, a walk-through in writing arguments and assistance in composing music.

DOING (facilitator): What teachers do going by first preparing the Beatwheel, communicating variable declaration, writing arguments, conditional statements, coding multi-tracking of sounds, and aiding students to solve each task.

DOING (students): What learners do exploring the software and placing pieces. In learning to code, users learn to define functions for each piece, if-true statements and to program a single melody piece to reproduce several tones.

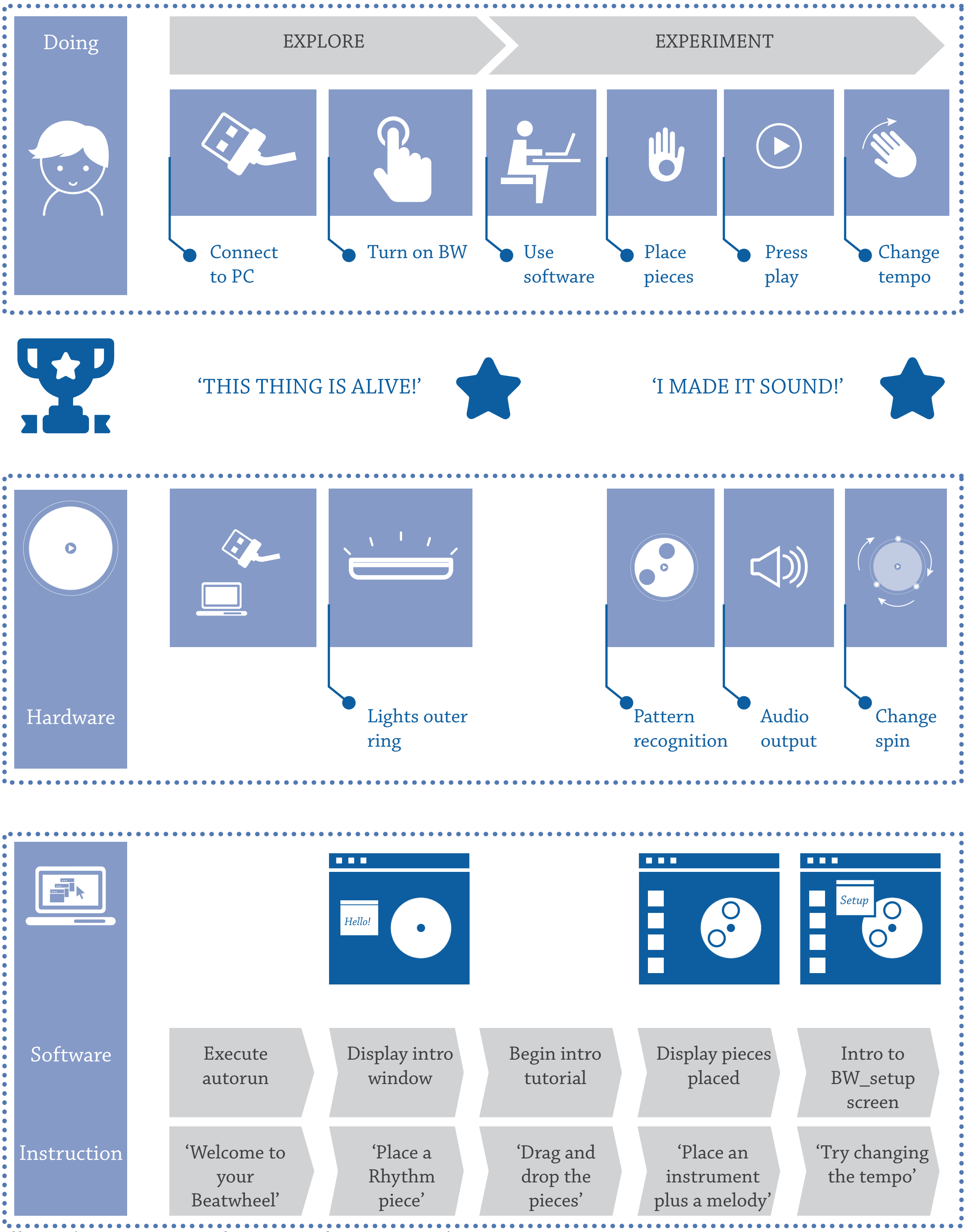
REWARD: The goal of the education-time use case is for students to understand the difference from coding a single string of a melody to writing a computer program with all the pieces of the Beatwheel.

SOFTWARE: The use of the digital interface is mostly focused to be used in the code screen for children to learn to declare functions using open-end brackets with a block-based language, and in the script screen for children to learn to write strings of code directly into the program using the Sonic Pi (Python 3 adaptation) language.

Ill. 83: Education-time use case

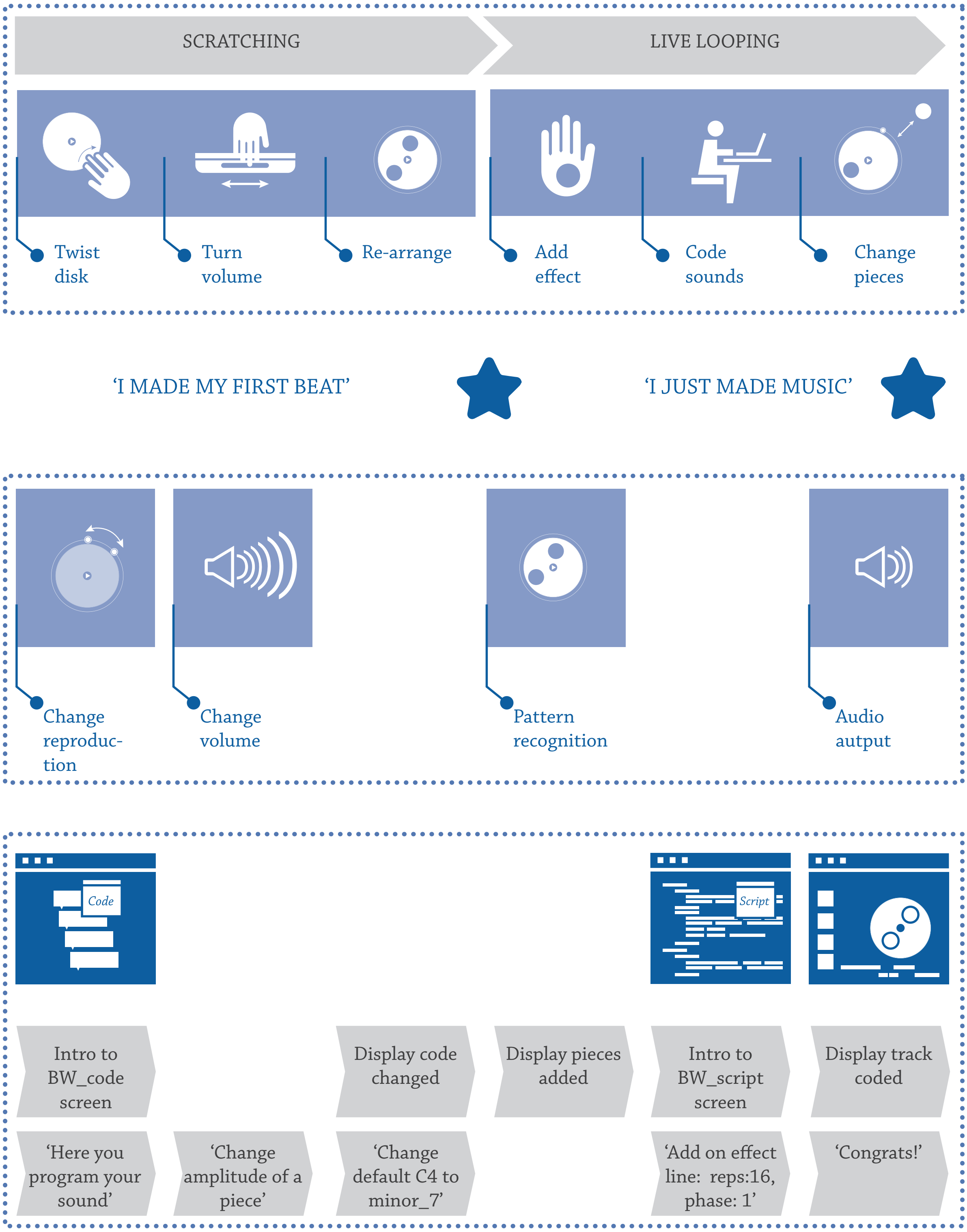
USER'S JOURNEY: PLAY-TIME

The diagram describes user's tasks, rewards, Beatwheel hardware and software operations.



Ill. 84: 'First use case diagram: Play-time use'

USER’S JOURNEY: PLAY-TIME

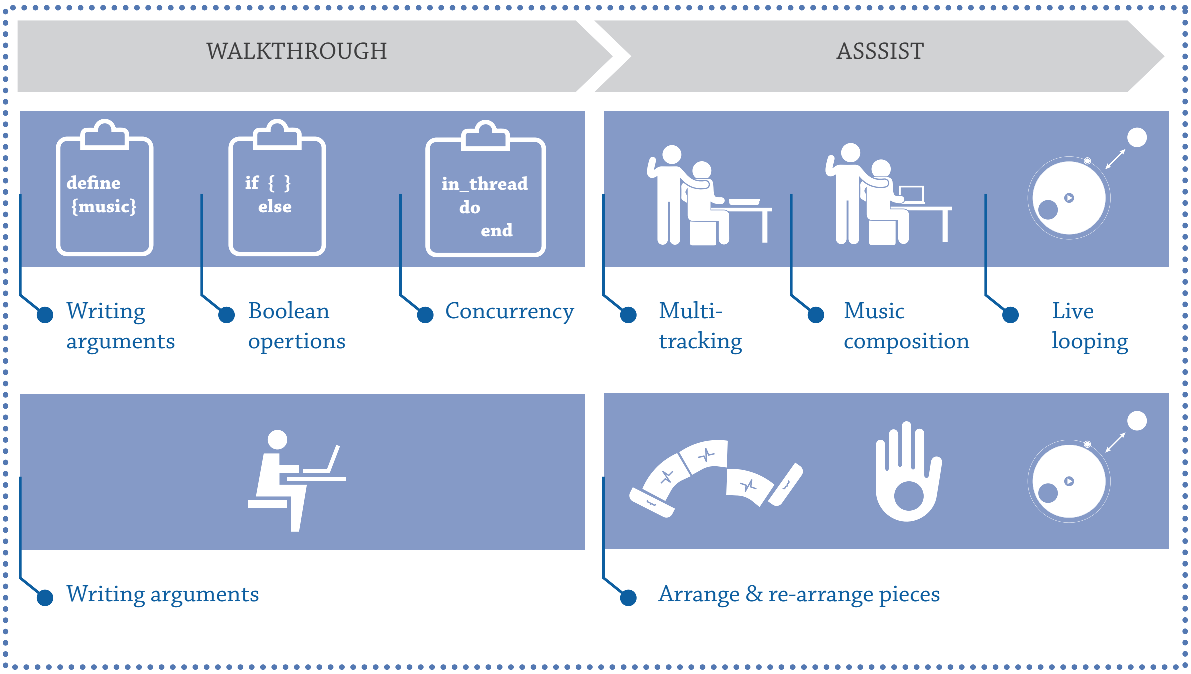


USER'S JOURNEY: EDUCATION

The diagram describes teacher and student tasks, learning goals, Beatwheel and hardware operations, together with the core functionalities of the software.

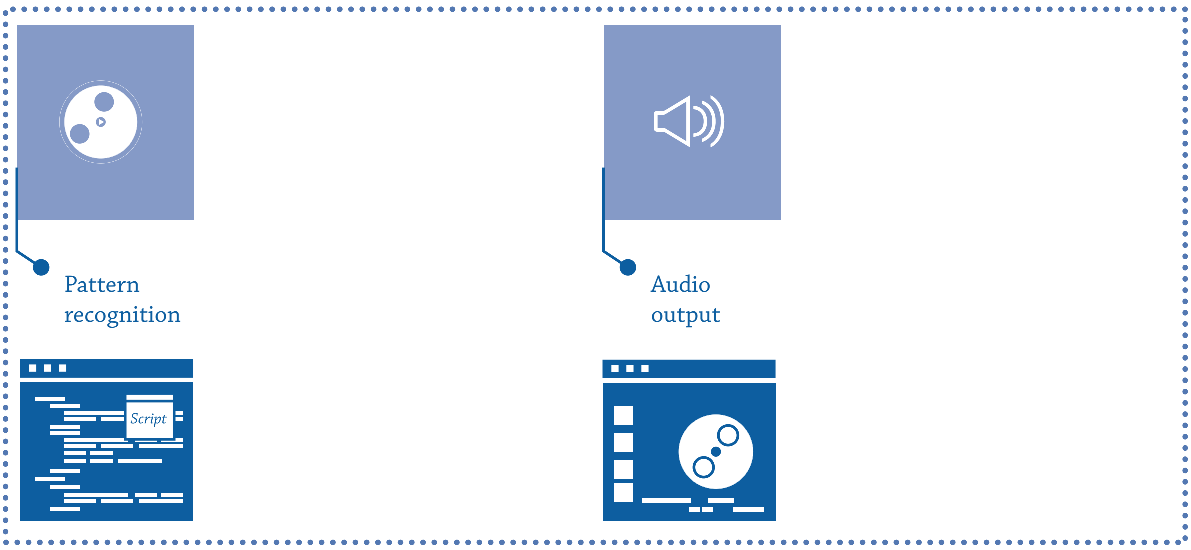
Ill. 85: 'Initial code interface sample'

USER'S JOURNEY: EDUCATION

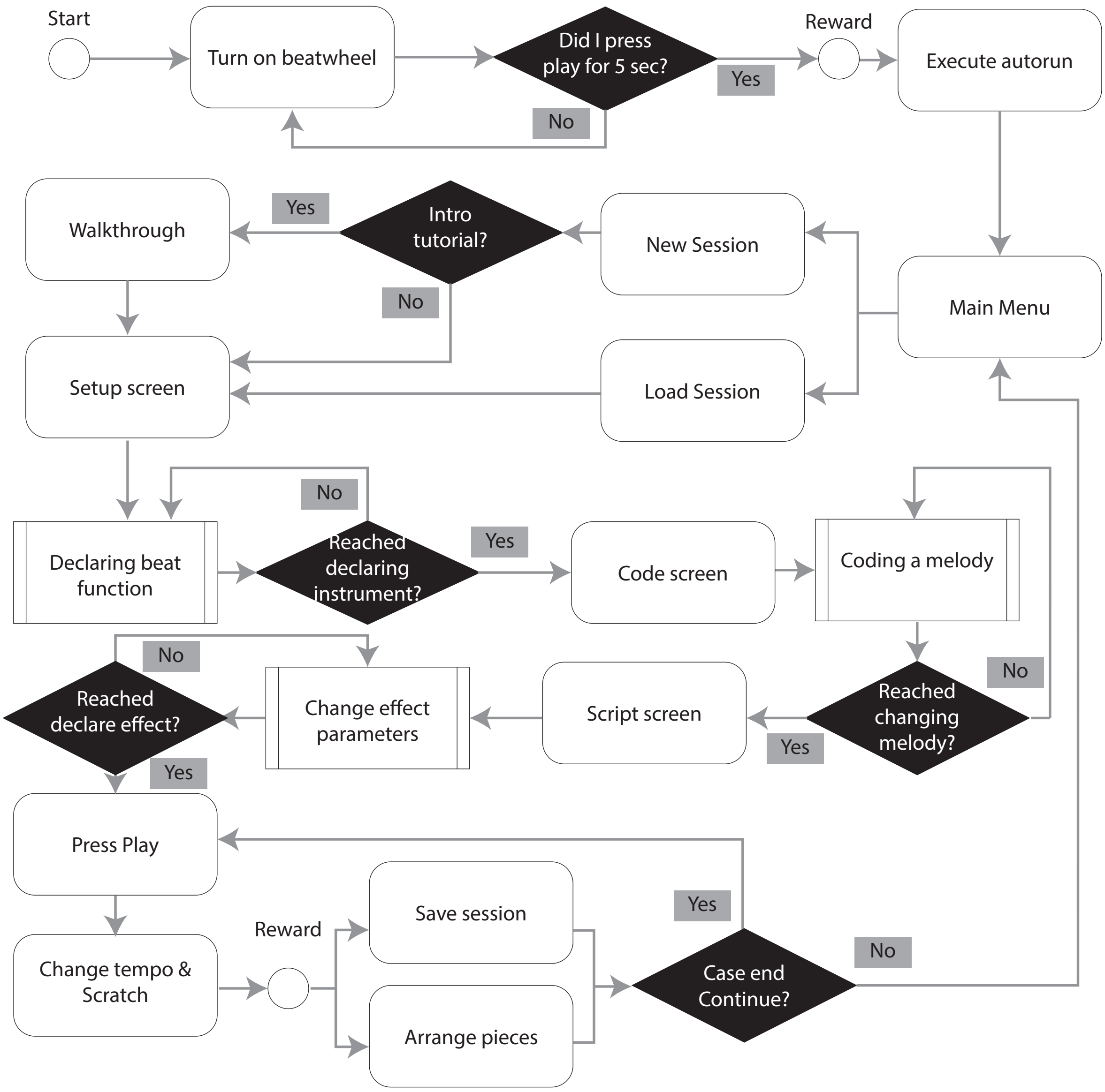


'I MADE MY FIRST COMPUTER PROGRAM'

'I JUST MADE MY OWN MUSIC'



INTERACTION FLOW



Ill. 86: 'Interaction flowchart: Play-time use case'

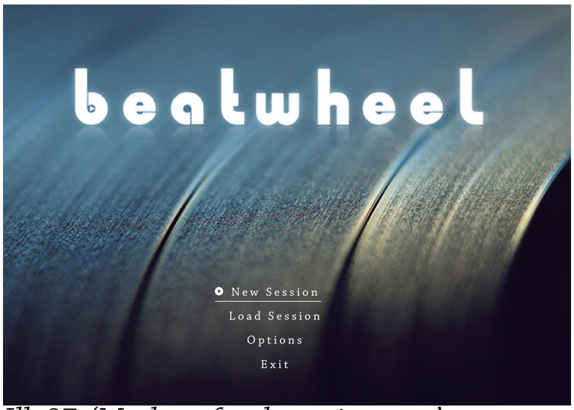
The project group decided to develop the first use case since it consisted on the base for the educational use case, therefore was identified to be a crucial aspect to solve for children to understand intuitively the interaction between the Beatwheel and the computer software. The project group modelled the interaction flow as being developed for a software engineering brief that should be deliver to a software development department, as well as the use cases to develop the system design. 'Illustration 84' was built under assessment of a Software Engineer, user tests and results from previous iterations and shows the use of the beatwheel in the first use case.

SOFTWARE DESIGN

Under assessment it was found that it would take six month for a one-person team to develop the full product and three months for a proof of concept. Therefore, the project group developed the system architecture, the use case, the interaction flowchart, and the screen mock-ups with the functionality of core buttons as requirements for delivering a software engineering brief. The project group decided to focus the interaction between the Beatwheel and the computer in the System Architecture, delve into the graphics of the main menu, the setup, code and script screen depicted in the interaction flow. The sub-tasks of declaring a beat function, coding a melody and change the effects parameters can be accomplished in two ways: either selecting and placing them in the software that highlights the positioning of the desired piece or by arranging the pieces directly in the beatwheel. This sub-task requires to place a piece (melody, beat, sound effect) place the brackets (musical instruments), define the duration (displace the brackets), change the respective parameters and press play.

MAIN MENU

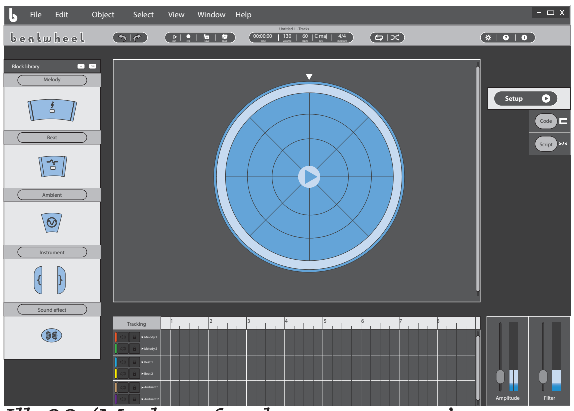
Once the Beatwheel has been turned on, the auto-run will be executed to start the download and installation of the software. The main menu is opened with the brand image of the Beatwheel and buttons that give users the choice of starting a new coding session, load a saved session, select options (resolution, language, sound settings) and to exit the software.



Ill. 87: 'Mock-up for the main menu'

SETUP SCREEN

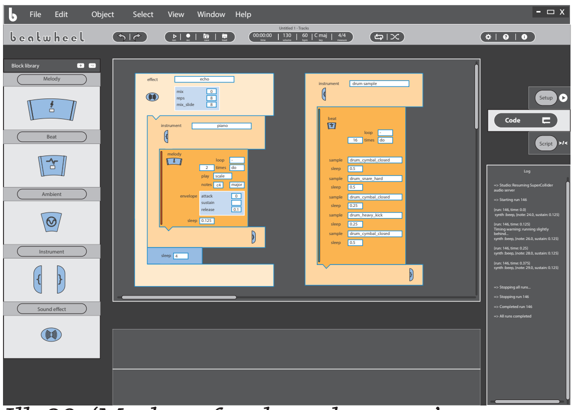
The setup screen visualizes the pieces that have been read by the hardware of the Beatwheel. Users can drag the pieces in the block library menu (left) and drop them on the platform (centre) that displays their position. It includes a reproduction time-line, saving variables, track information, screen shifting buttons, and sound filters.



Ill. 88: 'Mock-up for the setup screen'

CODE SCREEN

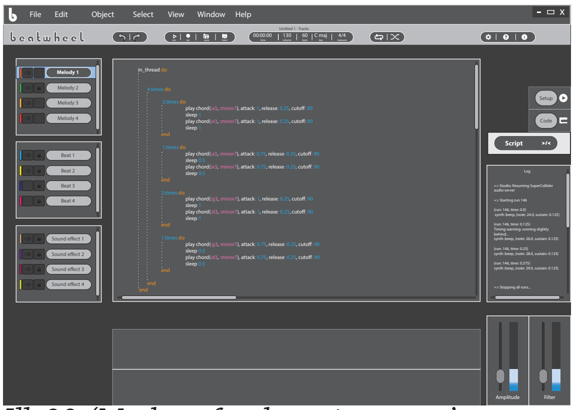
Users click on the second screen shifting button that goes to the code screen. This screen visualizes the code of each piece through a user-friendly interface corresponding to a block-based computer language (Scratch) where users can easily see the variables, tasks and numerical values of each function. It includes a sound visualization box and a live coding record.



Ill. 89: 'Mock-up for the code screen'

SCRIPT SCREEN

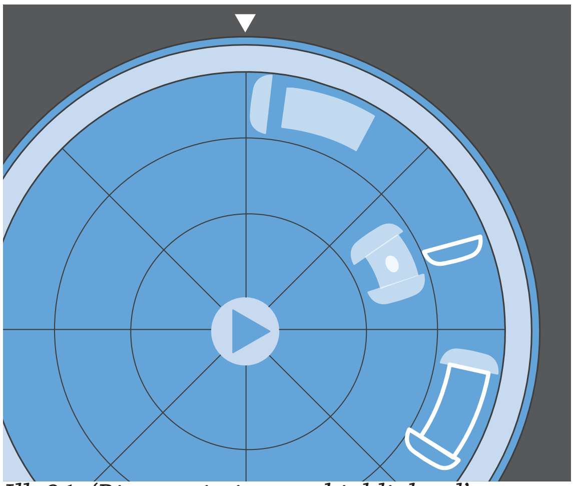
By clicking the third screen shifting button the script screen shows up. This screen visualizes the strings and lines of code in Sonic Pi language that previously were in blocks (Scratch). It includes sound layers where the pieces are ordered per function (left) and it deploys the code in the workspace as they are selected. If a sound filter is applied then the values are shown.



Ill. 90: 'Mock-up for the script screen'

BEATWHEEL SETUP WINDOW

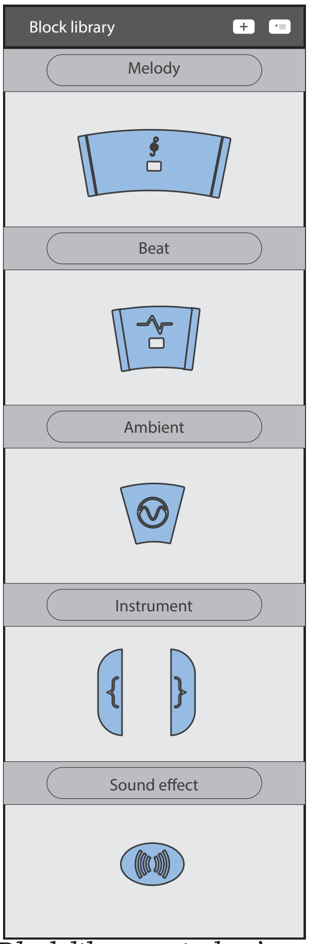
In the setup screen the workspace shows a view of the Beatwheel that once the user places a physical piece on the platform, the software indicates them with a transparent colour while, when the user drag and drop a piece it shows where the piece is missing in the Beatwheel. If a bracket piece is missing to declare a melody with an instrument the Beatwheel will not recognize the piece and therefore it will not sound since a function is absent.



Ill. 91: 'Pieces missing are highlighted'

BLOCK LIBRARY WINDOW

In both setup and code screen the pieces are disposed in a window with the buttons of each block. Here, users can select and drag the desired melody, beat, sound ambient, instrument or sound effect and place them in the BEATWHEEL SETUP WINDOW. In the block library window, users can add more pieces and deploy special functions such as 'hide piece', 'duplicate layer' or 'delete piece'.



Ill. 92: 'Block library window'

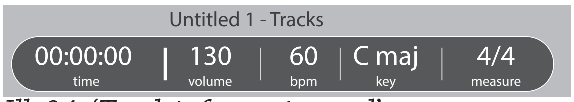
LAYERED REPRODUCTION TIME-LINE

With each piece that is added or placed, the software includes a window that locates them as tracks on layers which visibility or toggle lock can be changed. Together with this the window displays the reproduction of each track layer on a time-line that users can modify according to the beats per minutes, meter and overall duration.

Ill. 93: 'Layered reproduction timeline'

TRACK INFORMATION TOOL

In the upper part of the screen, the software displays in numerical values: the duration length of the musical track, the volume, beats per minutes, piece's key and measure.



Ill. 94: 'Track information tool'

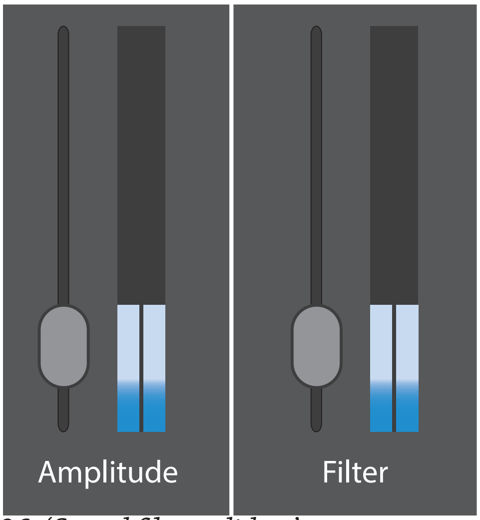
SAVING VARIABLES TOOL

Users can load a stored session, save the current session, record their music and pause or play their loop when coding in the script.

Ill. 95: 'Saving variables tool'

SOUND FILTERS WINDOW

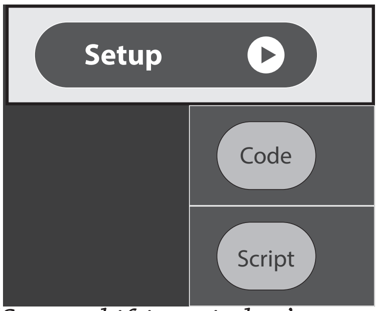
In the lower right corner there are located two master filters that regulate the amplitude of the pieces and a low/high-frequency pass that can be modified by moving up and down sliders affecting all the pieces placed on the Beatwheel. By clicking on them, users can modify special functions such as 'select type of filter', 'filter options', or 'cross-fader'.



Ill. 96: 'Sound filters sliders'

SCREEN SHIFTING BUTTONS

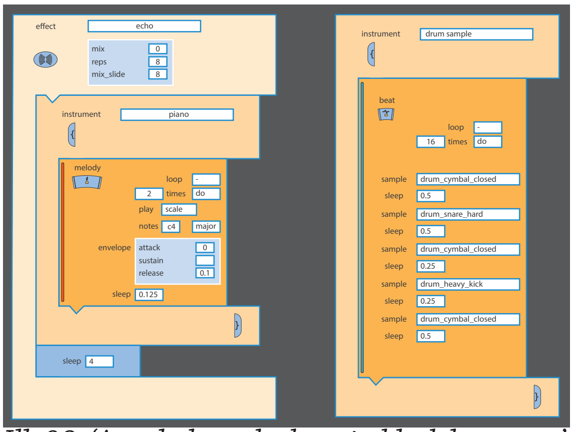
For switching between setup, code or script screen there is a window with buttons corresponding to the respective screens that users press to open them.



Ill. 97: 'Screen shifting window'

BLOCK BASED CODE

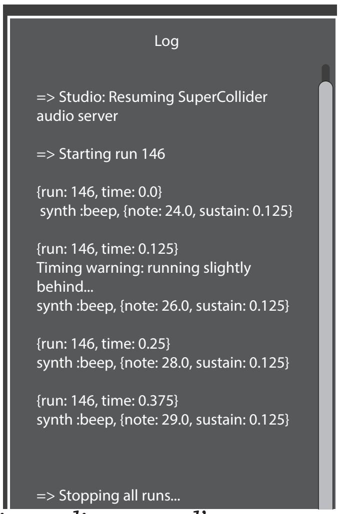
In the code screen, the workspace deploys each piece's code as they are disposed using an event-driven programming with multiple active objects representing the pieces' function separated by coluors and enclosed by blocks. For developing this, a plugin is applied to the computer language Scratch.



Ill. 98: 'A melody and a beat in block language'

LIVE CODING RECORD

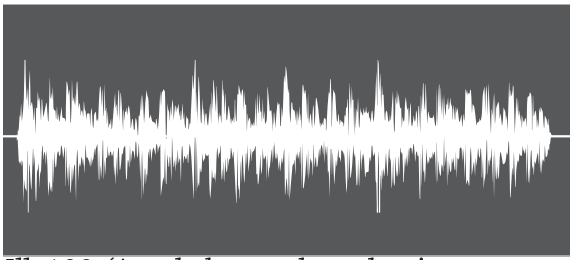
The code and script screen are showing live the compilation of the code as a history where users can see which function is running at what time.



Ill. 99: 'Live coding record'

SOUND VISUALIZATION BOX

The code and script screen include a box showing the development of the sound waves coded with the pieces.



Ill. 100: 'A melody sound envelope'

MATERIALS & PRODUCTION

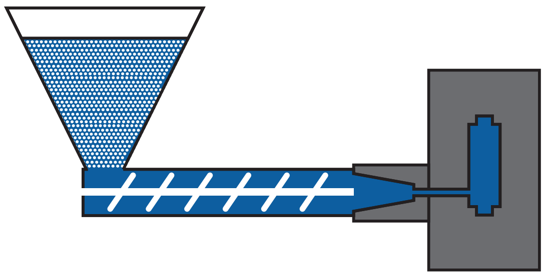
The project group has looked into materials and production methods for the finalised Beatwheel based on commercial use, availability and functional properties. Different plastics were chosen as mass production and production possibilities combined with light weight and optimised characteristics.

PLASTIC

Acrylonitrile Butadiene Styrene(ABS): For the shell of the platform ABS durability withstands some abuse as the main users are to be children who will not always remember to take care of it.
Polypropylene(PP): For the pieces the material will not need to be as durable as the shell. PP is a commercial wide spread material that can help give a lower price than ABS while not restricting the look and feel of the pieces.
High Density Polyethylene (HDPE): For the scratch ring, low friction and low price is the characteristics being looked for. HDPE was chosen as it is a self-lubricating material while still being a cheap material.

INJECTION MOLDING

For producing the beat wheel, it was considered that it will be purchased individually. With the shell, pieces, and scratch ring being made out in plastic, there are two main production methods for creating a shell form: injection moulding and compression moulding.
Compression moulding is the best solution in low production numbers, as the moulds and machines are not as expensive as for injection moulding, but it does not have the same capabilities for mass production. Injection moulding have its strength in the possibility of creating cheaper parts with a high part count. It was decided on injection moulding as it is assumed the market can sustain an amount of Beat Wheels to make injection moulding the cheaper option.



Ill. 101: 'Diagram of injection molding method'

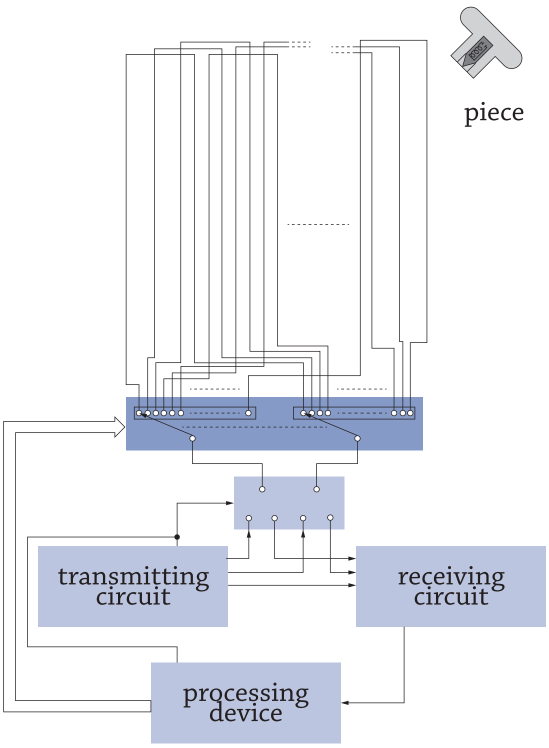
PIECE IDENTIFICATION

For having the pieces identified by the Beatwheel each piece will have a passive RFID tag in each with a reader placed in the Beatwheel that reads what the next piece added is and then pass on this information. By having a passive RFID tag in each piece they will not require any other type of technology inside, and being able to be read by a program with an individual identification for each type with the possibility to add future types of pieces with a cheap starting technology. RFID is also preferable because it can be invisible implemented a it functions using radio waves that can power up a small tag with a coil that can send it information back at the reader thereby telling it what type of piece it is.

Ill. 103: 'Piece identification method'

TOUCH SCREEN

For making it possible to implement the freedom of piece placement a passive way of reading each piece is needed. For this, electromagnetic resonance digitizing will be used. It works in similar fashion to RFID though it uses a double layered perpendicular grid with one reading the x-coordinate and the second reading the y-coordinate. It provides freedom in choosing a piece material as it is a component inside each piece that tells their position and not the bottom surface. Therefore, a secondary RFID chip would not be needed as it would be part of the positioning and because of its simple construction a cheap unique grid would be possible without a big extra cost added.



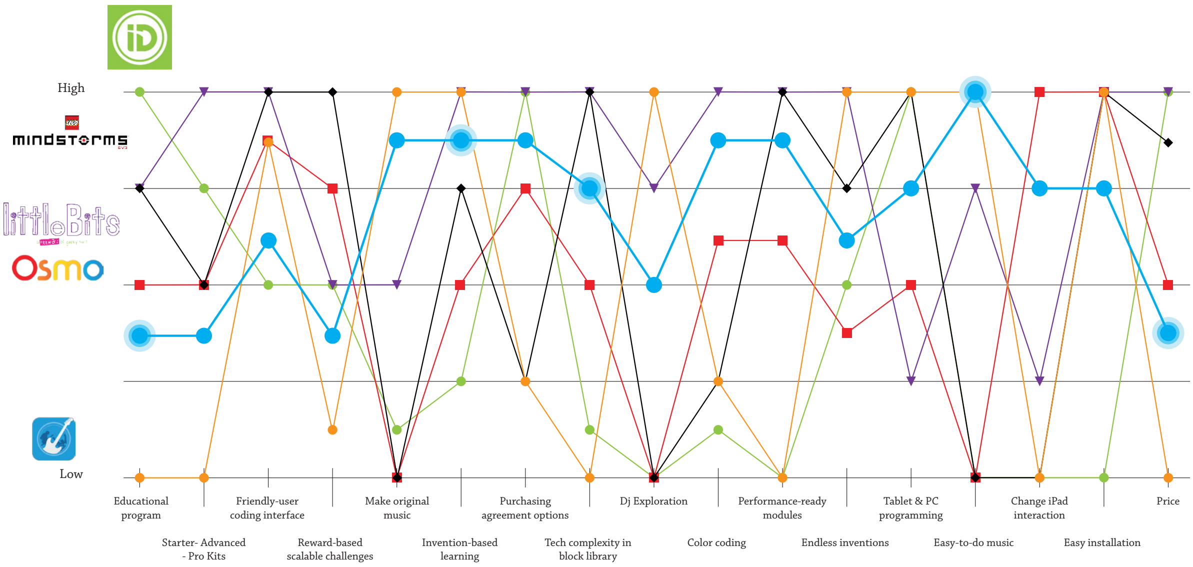
Ill. 102: 'Touch screen circuitry'

BUSINESS ASPECTS

For introducing Beatwheel to compete into the market, differentiate from competitors and reach the project's end-users the project group used the methods of Blue Ocean Strategy Canvas [Chan 2006], Business Model Canvas [Osterwalder, 2010] and Cost-Benefit analysis.

BLUE OCEAN STRATEGY

For developing a strategy that allows to reach an opening into the market of programmable musical devices as a way to create value for our buyers, end-users and influencers. The objective of this strategy consisted of identifying unique selling points of the Beatwheel through external and internal analysis for designing a business plan.



ANALYSIS

The toy industry was analysed concerning products and service systems in strategic groups such as: coding camps for children (ID tech), gaming accessories for digital devices (OSMO), easy-to-use electronic modules (Little bits), easy-to-program robots (LEGO Mindstorm), and mobile applications (Walk band) for deriving the parameters [WS_XX].

The parameters from the analysis correspond to the products performance on educational programs, starter-pro kits, friendly-user interface, reward-based challenge, make original music, invention-based learning, purchasing agreements options, tech complexity in block library, dj exploration, colour coding, performance-ready modules, endless inventions, tablet and computer programming, easy-to-do music, change iPad interaction, easy installation, and price accessibility.

Ill. 104: 'Blue ocean graphic'

UNIQUE SELLING POINTS

Due to the previous analysis, from 'Illustration 102' it can be observed that Beatwheel strategic strengths in respect of its competitors are the following.
Educational programs: The solution serves as an introductory platform to STEAM learning in coding and computation oriented to sound programming for young children between 6 to 7 years old.

Invention-based learning: The product encourages children to invent-while-coding through offering live performance.

Easy-to-compose music: The kits of the solution train skills of sound programming and music composition by offering tangible modules that can be easily programmed and re-arranged.

Tangible interface: Interactive modules have a user-friendly interface with an immediate feedback for kids to facilitate the technical behind lines of code and their physical translation into sound.

Block library: Pieces with specific functions and default code allows an easy expansion and diversification of the solution's flexible identity.

Price accessibility: Purchasing agreements offer an accessible price that range from acquiring a single product, to a complete set for coding courses and retailers.

Ill. 105: 'Unique selling points'

BUSINESS ASPECTS

BUSINESS MODEL CANVAS

Once unique selling points of the solution were defined, the value created from insights with key social agents were used to build the business model.

KEY PARTNERS

- Manufacturing bodies.
- Coding courses.
- Technology sponsors.
- Toy retailers.
- Technology retailers.

KEY ACTIVITIES

- Update programs.
- Fit purchase order with logistics.
- Supply courses with software.

RESOURCES

- 'Buy one, fund a course' agreement.
- Touch screen and ID recognition.
- Sound library.

VALUE PROPOSITION

- Invention-based learning.
- Easy-to-do music.
- Tangible sound interface.
- Block library.
- Artistic coding.
- Price accesibility.

CUSTOMER RELATIONSHIPS

- Automated on-line shops.
- Personalized purchase orders.

CHANNELS

- Shipping.
- Wholesalers.
- Web stores.
- Web press.

CUSTOMER SEGMENTS

- Retailers.
- Public institutions.
- Volunteering coding courses.
- Paid tech camps.
- Projecting parents.
- Schools.

COST STRUCTURE

- Software, hardware development.
- Manufacturing and assembly chain logistics.
- Agreements with Retailers, Governments and sponsors.

REVENUE STREAMS

- Sales from softwares.
- Sales from retailers and wholesalers.
- Sales from online shopping.
- Sales from 'Buy one, fund a course' purchase agreement.

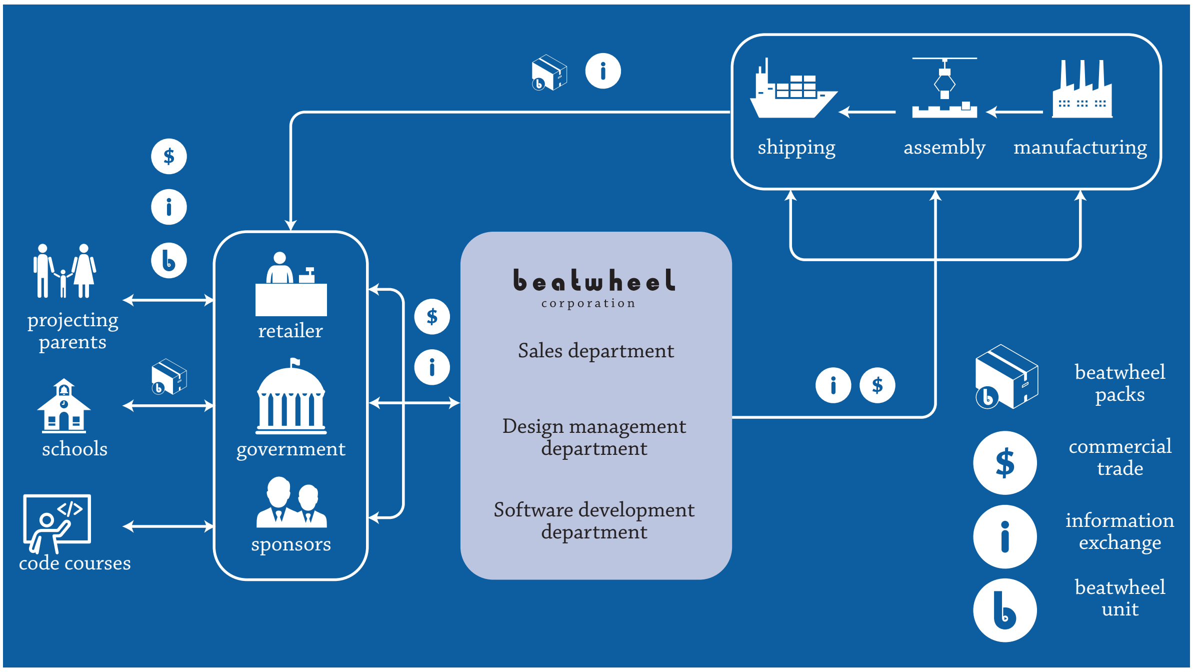
Ill. 106: 'Business model canvas'

The core competences of Beatwheel are 1) the invention-based learning by live looping possible with the immediate feedback between the device and the computer to the changes the user make arranging pieces; 2) the block library embodied by a tangible interface for conveying both computer programming and music composition principles; and 3) easy-to-do music with performance-ready pieces through a plug-and-play product using cheap technology makes it possible to formulate personalized purchase agreements such as 'Buy a Beatwheel, fund a course' that per 2 units sold part of the sales revenue can be negotiated with sponsors to support an allied volunteering coding camp. This means that key partners and activities are based on alliances with technology sponsors such as Google or Microsoft and alliances to outsource the manufacturing logistics to ensure the optimal amount of pieces. Also a core competence of the Beatwheel is to develop a software that supports an easy-to-code music as a way to provide coding courses and schools with the appropriate equipment under frames of STEAM education.

BUSINESS ASPECTS

INFORMATION FLOW

To accommodate the project's fit into the market and to provide the foundation for an investment and a business plan, an information flow chart was developed by identifying the internal activities of Beatwheel Co., an external layer of manufacturing logistics, an external layer of partnerships with wholesalers, and an external environments of buyers.



STRATEGY

Beatwheel Corporation has its Headquarters located in Denmark divided in three main departments: Sales and Marketing, in charge of handling brand image and direct contact with clients; Software and Hardware engineering, in charge of developing connectivity, digital, and electronic solutions; and Design Management, in charge of handling business operations together with product design and development processes. Beatwheel Co. maintains close outsourcing partnerships by affording information exchange and commercial trade with manufacturing, assembly and shipping bodies to carry out the product manufacturing and deliver them to the wholesaler layer. In the other hand, Beatwheel corporation mantains a personalized contact with sponsors and governmental institutions to expedite the delivery of the product to the hands of our end-users, therefore sustaining information exchange and commercial trade. This alliance is agreed upon forming economic collaborations within this layer as well as the manufacturing logistic layer.

Ill. 107: 'Business plan and strategy'

BUSINESS ASPECTS

To fund the project, the project group suggests to mantain agreements with sponsors as potential investors. For this purpose a business case was developed identifying the market share, investment for development, product prices and a break-even analysis.

MARKET SHARE

As an initial market targeted with project, it contemplates coding clubs in the national and international territory, and children in Denmark between six and nine years old for producing an initial production of 15.000 units of the Beatwheel. These figures were taken from the Coding Pirates web site, Code Club World and Statistik banken.

Market	Beatwheel units
Coding clubs and courses	
Coding pirates	93
International	12500
End-users	
6-9 years old (DK)	10678

Ill. 108: 'Initial market share'

DEVELOPMENT INVESTMENT

For developing this amount of units it was considered on each item the Salary per hour, number of employees, the time needed, the manufacturing of the platform and the pieces with a quality check in hands of the Design Management department. The price range was calculated considering production, sales and retail price.

Software development	kr. 450000
Hardware development	kr. 216000
Design management	kr. 900000
Prototyping	kr. 21915
Advertisement	kr. 250000
Total investment	kr. 1.837.915

Ill. 109: 'Beatwheel development investment'

PRICES

Item	Production price	Sales price	Retail price
1 Beatwheel	kr. 659	kr. 844	kr. 1899
1 Platform	kr. 328	kr. 444	kr. 999
6 of each piece	kr. 332	kr. 400	kr. 900
6 pieces	kr. 71	kr. 80	kr. 180

Ill. 110: 'List of prices per Beatwheel'

BREAKEVEN ANALYSIS

The break-even point of the initial investment is achieved at the third year, while at the fourth year the goal of 15000 units sold is achieved. Note this calculation is an estimated of the initial Beatwheel kick-off budget whereas an optimal of 50.000 units sold will increase the contributions up to 40%, therefore the revenue streams depends on the maturity of the agreements with the sponsors.

SALES BUDGET					
	Year 1	Year 2	Year 3	Year 4	Total
Beatwheel sold	1802	3593	9539	14990	29924
Turnover	kr. 1,520,888	kr. 3,032,492	kr. 8,050,916	kr. 12,651,560	kr. 25,255,856
Variable cost	kr. 1,188,234	kr. 2,369,215	kr. 6,289,992	kr. 9,884,367	kr. 19,731,807
Contribution margin	kr. 332,654	kr. 663,277	kr. 1,760,924	kr. 2,767,193	kr. 5,524,049
BREAKEVEN ANALYSIS					
Investment	kr. -1,837,915	kr. -1,505,261	kr. -841,984	kr. 918,940	
Contribution	kr. 332,654	kr. 663,277	kr. 1,760,924	kr. 2,767,193	
Remaining	kr. -1,505,261	kr. -841,984	kr. 918,940	kr. 3,686,133	
KEY NUMBERS					
Return	kr. 3,686,133				
CMR	22 %				
Rate of Investment	201 %				

Ill. 111: 'Cost-benefit analysis table'

CONCLUSION

From this calculations the price of the Beatwheel is kr. 1899 with the software and the product, prices of plastic pieces were calculated by price per gram, while standard components where found online. The reason for calculating a kick-off budget of 15.000 units was considering only 25% of coding clubs (national and international) and 4% of children . It is believed that increasing the reach of the project to more coding clubs would reduce the production costs

Ill. 112: Onward

ONWARD

CONCLUSION

The final solution incorporates tangible interfaces in order to offer a creative interaction so intending to accomplish an introduction point to learning coding languages and the computational programming thinking.

The solution combines computer programming thinking in the way pieces are added to the platform while giving freedom to the user in what they would like to create. Beatwheel's use of music as the output for the code have created a simple bridge between the thought process of programming and arts.

With the chosen way of modifying each piece it is only the simplest form of the programming language that have been taken out of the computer. As the more complex modifications of each piece is only possible on the computer and not done directly with the pieces and the platform.

This have led the Beatwheel to become a two-fold solution in the regard that the tangible interface is responsive and intuitive with the placement of pieces. However, the software part of the solution can easily become complex and might lead some users to never go beyond the standard piece setting.

Though this duality is also the Beatwheels's strength as the adding of pieces to the platform is a playful experience and with the varying degrees of complexity in the software it could lead to a natural introduction to programming with a scalable and steady progression curve. This should lead users to become content creators and not just content consumers.

Though by having the computer write the code for the user with the adding of each piece the code can easily become a complex line of text that is hard to fully understand thereby not fully conversing the beauty of simplicity and readability of the code as computer and machine language.

REFLECTION

The initial focus on the social construct of gender-stereotyped play patterns enforced by modern toys made it possible to visualize a societal issue in respect of narrowed business approach reflected in design products. The project group attempted to approach this by pivoting into a focus on lowering the complexity bar for computer programming through the tangible interface solutions as a manner of tackling stereotypes in science and technology by maximizing the audience learn-ability.

PROCESS REFLECTION

The findings done throughout the project when specifying learning computer language as an artistic technique could have led the project in many directions with completely different outcomes. For managing these divergent points the project group decided to converge the critical factors by following a structured decision making process in ideation solutions by separating insights and combining them with the knowledge acquired through the Master's programme. This was not a bad approach as the findings had multiple variable directions therefore structuring the decision making to make sure that no choice was made on loose whims. The solution's viability was supported by only 2 teachers, 3 children, 1 parent and 9 test subjects therefore not being a representative testing, however they were enthusiastic about the solution and each had a take on how they could see themselves using the solution.

PRODUCT REFLECTION

Although the Beatwheel's focus is on easing the learning curve for children to learn how to code, its strongest selling point might be its functionality as a programmable musical instrument and a practice tool rather than a coding tool. The chosen production method of injection moulding is viable, however for the prototypes and first set it might be better to go with compression moulding, though this have to be consulted with the production facility to make the final choice.

FURTHER WORK

The EMR technology that is being used for detection and recognition of each piece has some mayor drawbacks in form of not supporting finger touch, and not easily supporting orientation of each piece. The orientation problem can be worked around with either having two chips in each piece making it possible to track its orientation, or make an algorithm that calculate this. However, the inclusion of finger touch and maybe even a display would make it more accessible to include changes to the pieces outside the computer program. Leading to the next solution should include finger touch, visual displays, motion graphics and movement sensors as a way to explore the maximum the potential of the project.

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WORSKHEET OVERVIEW

WS_001: Assumptions Brain Map Documentation.
WS_002: Mapping the tendency of toys and games.
WS_003: Types givers and Offerings.
WS_004: Gender development and differences of a boy and a gir
WS_005: GirlsWhoCode.
WS_006: Toy design tendencies.
WS_007: Lead user insights.
WS_008: Problem mapping.
WS_009: Sub-Product Categories.
WS_010: Target Sub-Group.
WS_011: ProblemOpportunity detection.
WS_012: Problem and mission.
WS_013: Artistic coding context.
WS_014: Requirements from previous worksheets.
WS_015: Ideation.
WS_016: Initial requirements.
WS_017: Interview with coding pirates.
WS_018: Workings of the beat wheel.
WS_019: Iterations on product semantics.
WS_020: Iteration 2 on product semantics.
WS_021: Iteration 3 on bracket semantics.

ILLUSTRATION LIST

ILLUSTRATION LIST