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Master Graduation Project

Geometry Appcessory for
Visually Impaired Children

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2017

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Geometry Appcessory for Visually Impaired Children

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Geometry Appcessory for Visually Impaired Children

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Abstract

Visually impaired children face challenges in learning spatial contents and materials, such as geometry. While many existing tools, such as string boards, or protractors with physical angle markers, can facilitate learning, these devices are highly specific: they tackle single issues and it can be hard to generalize the knowledge gained from their use into a broad understanding of the topic. This problem contributes to low levels numeracy in visually impaired individuals. Addressing these problems, this research presents Clicks, a digital manipulative product for visually impaired children that supports a range of geometry education tasks and ties physical adjustments to the device to a dynamic digital representation and additional audio feedback. Clicks comprises a construction kit of simple geometric primitives that snap together to produce a range of more complex forms such as lines, angles, triangles and rectangles. When placed on a tablet computer, the geometry of these objects is sensed (via the capacitive touch screen and electrodes embedded in the objects) and audio feedback is provided. This report describes the physical construction of the product and its accessories and use scenario for future software development.

After reviewing literature to understand first-hand the issues faced in the field of geometry by visually impaired children that makes it their least favorite, goals were set of identify a process that can enable us to make geometric shapes easily. Different methods were prototyped and we settled on a mechanism that uses magnets to join the different pieces together. The downside of the form was that we needed to have fixed lengths for the product and also a limited angle formation. Using this first prototype an interview with a visually impaired instructor was conducted to support formative studies. One of the major feedbacks from this study was that the product should be designed to support easy manipulation of the product as well as the tablet application as the use of technology can be challenging for visually impaired students. Progressing the project further, the form of the product was improved which supported the making of small angles.

The introduction of a conductive material around the perimeter also solved our problem of the product being recognized on the tablet, but to reduce cost of product, further iteration of form with mechanism was conducted. A 'circuit type' mechanism comprising of a conductive cap linked to a magnet (at one end) and a magnet connected to a rubber foot (at the other end that would be in contact with the tablet surface) with both ends connected by a copper wire was used. When the pieces are joined, it closes the circuit and touching the conductive cap makes the points recognizable.

The user interaction with the tablet saw the creation of hinged ‘buttons’ on the holder for the tablet to aid navigation of the application. A proposed interface flow of the software was discussed in this report using the Curriculum of Ontario and California Department of Education as reference. A prototype of the software was made with a UX web based tool Proto.io which gives first hand some of the processes of the use of the product.

Keyword; Innovation; Visually Impaired Educational Toy; Tangible Interface; Human Machine Interaction; Multimodal Interaction, Geometry

Table of Contents

1	2
Introduction	2
Background / Desktop Studies	2
Related Work.....	3
Visually Impaired and Technology	4
Project Scope	5
Design Goal	6
2	8
Product Development	8
Form and Mechanism exploration through prototyping	8
Working Prototype Design.....	9
User Study.....	10
Form Modification	11
Finalizing Working Prototyping.....	12
Package Conceptualization	13
3	17
Interface Conceptualization	17
Interface Scenarios.....	17
Interface Process	18
Use Scenario	22
4	25
Evaluation	25
Think Aloud	25
Interview	25
5	28
Conclusion	28
Main Project Findings.....	28
Expected Contribution	29
Reference	30
6	33
Appendix	33
Appendix 1 – Design Goals	33
Appendix 2 – Product development.....	34
Appendix 3 – Package Development	35

Table of Figures

Figure 1-Orion TI-84 Plush Talking graphing calculator	
Figure 2-Making graphs from pins and string _____	2
Figure 3-Audio Instructions guide the users to progressively construct the map. _____	4
Figure 4-Research Scope _____	5
Figure 5 - Initial prototypes of geometry making mechanism _____	8
Figure 6-Chosen prototype for further development _____	9
Figure 7- User has to touch various points for it to be read on the tablet _____	9
Figure 8- Conductive material around the perimeter of the product when clicked together _____	10
Figure 9- Prototype with conductive material covering the entire piece. _____	10
Figure 10-Form modification which still had restriction on the angle formation. _____	11
Figure 11-Another form modification that allowed the formation of very small angle. _____	12
Figure 12- Inner 'circuit view' of the connected pieces _____	12
Figure 13-Exploded view showing construction of a Clicks component. _____	13
Figure 14- Connected Pieces (working prototype). _____	13
Figure 15-3d representation of various shapes that can be constructed with the sizes _____	13
Figure 16- Package selected (left), the tablet holding plate (right) _____	14
Figure 17 - Tablet holder with a tablet and Clicks product _____	14
Figure 18-Base Package (left), product package (right) and the tablet holder with product on top. _____	15
Figure 19-A triangle made with clicks placed on a tablet in the holder. 오류! 책갈피가 정의되어 있지 않습니다.	
Figure 20-An example question in division 1 type of questions. _____	19
Figure 21-An example question in division 2 type of questions. _____	19
Figure 22- An example question in division 3 type of questions. _____	20
Figure 23- Interface to support the struts for easy manipulation by the child when game starts. _____	20
Figure 24-Game applications page on tablet	
Figure 25- Sign in page _____	21
Figure 25-Setting page to adjust based of varying types of visual impairment. _____	21
Figure 26-Choosing of level page with guardians help. _____	21
Figure 28-Use Scenario of Clicks _____	22

1

Introduction

- Background
- Related Work
- Visually Impaired and Technology
- Project Scope
- Design Goal

1

Introduction

This chapter will focus on the desktop studies conducted for the project which informed the first prototype making process to find the mechanism which could be used in making geometry shapes. The initial goals for prototyping and further developments are presented.

Background / Desktop Studies

Visual impairment can be described as both total blindness and varying degrees of residual vision. Some of the people who are visually impaired are born with vision difficulties and some have late-onset low-vision / blindness. The World Health Organization estimates that 1.4 million children under the age of 15 are irreversibly blind (World Health Organization, 2014). A wide range of specialized tools have been designed to cater to their educational needs. Many, such as the common corkboards that enable creation and exploration of lines and graphs from pins and strings (Fig. 1) (McGookin, Robertson, & Brewster, 2010) or the Orion TI-84 Plus Talking graphing calculator (Fig2.) (Orbit Research, 2011) that is capable of speaking or sonifying charts, focus on replacing traditionally visual STEM (Science, Technology, Engineering and Mathematics) contents with physical, tactile or audio equivalents.



Figure 1-Orion TI-84 Plus Talking graphing calculator

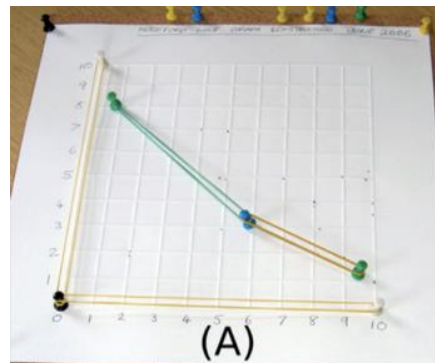


Figure 2-Making graphs from pins and string

This focus on technical education is critical as, given appropriate support, blind students are widely recognized to have the potential to meet the same learning goals as their sighted peers (Department of Education, 2010). Furthermore, educational achievement level of blind individuals has been linked to improved employment outcomes in later life (Bell & Mino, 2015). Developing tools to support the education of those with severe visual impairments, in order to offer them the same opportunities as those who are sighted, is therefore a societal imperative.

In addition, there is a longstanding research community dedicated to designing, developing and evaluating novel tools to support improved learning and developmental outcomes in children with severe visual impairment or blindness. For example, (McGookin, Robertson, & Brewster, 2010) explored how a tangible interface composed of easily manipulated physical objects could provide independent non-visual access to digital graph data and (Kim & Yeh, 2015) created story books with 3D movable pictures to encourage physical manipulation whilst the contents are being read.

This report contributes to this area by investigating the design space of a digital manipulative (Resnick, et al., 1998) – a tool to support playful exploration and learning that ties work with a physical artefact to dynamic digitally mediated responses – that aids blind individuals to understand basic geometric concepts. This report describes the background and motivations for the work and the design and fabrication of the physical prototype. It closes with a set of use scenarios and interface design prototype exploring how the system could be deployed to support playful and exploratory educational experiences.

Related Work

Students with vision impairments face major challenges in learning STEM contents compared to their visually able counterparts. There are many facets to this problem, such as a lack of suitable trained educators and the fact that the many traditional aids, such as charts and figures are predominantly visual. Geometry, falls in this category due to its high level of visual contents and most students express their dislike for mathematics and teachers point geometry out as a particularly difficult topic to teach (Klingenberg)

In elementary school, children's development of skills and understanding in many topics depend on their spatial sense (Klingenberg). Manipulation of objects in space also provides background for understanding algebra, trigonometry, calculus, and many topics in higher mathematics that require spatial thinking (Kennedy & Tipps, 1994, p. 387). Studies of human problem solving and language understanding have pointed out the importance of spatial representation and reasoning (Hobbs & Narayanan, 2002, p. 2). In addition,, according to (Jackson, (2002)), blind people learn geometry in a fundamentally different way than sighted people as they analyze information obtained through touch and hearing rather than vision. (Jackson, (2002)) argues the result is that blind individuals have a powerful spatial imagination and an increased ability to visualize spatial orientations that are difficult for sighted people to understand. Linda Bussell (Bussell, 2003), points out that haptic technology may hold potential for making mathematics more accessible to blind students.

Visually Impaired and Technology

ICT devices (e.g. computer games and toys, and its associated devices) which are now becoming an important part of the child and youth lifestyle in the developed world still has a restriction on its accessibility to the visually impaired (Archambault, Ossmann, Gaudy, & Miesenberger, 2007). This places an invisible gap between the visually impaired and sighted individuals, both socially and educationally (Celeste, 2006), (Archambault, Ossmann, Gaudy, & Miesenberger, 2007)).

However, Information and Communication Technologies (ICTs) are widely recognized to have substantial potential to bridge educational gaps between visually impaired persons and their visual counterparts by providing rich, interactive presentations of concepts in alternative modalities such as audio and touch (Clements, 2002), (McElligott, 2004). A broad range of research has been conducted on this topic and while there are many threads, most can be classified as focusing on presenting information through sound, through touch (or haptics), through an interactive tangible system (Ishii & Ullmer, 1997) or via some combination of these three approaches.

Audio is often used in the context of data sonification, a process analogous to that of visualization where data is rendered to an audio format designed to maximize comprehensibility. For example, (Brown, Brewster, Ramlohl, Burton, & Riedel, 2003) provided design guidelines for the audio presentation of data series more typically arranged as visual graphs and tables. Research on haptics follows similar approaches. For example, (Rouzier, 2004) noted that it is challenging to teach visual impaired students geometry and designed the SALOME system to address this problem. This system uses a force-feedback haptic device – to interact the user grips a stylus and the device can both sense the position of this device and apply physical forces to it. In this way, the system can create a dynamic virtual touch experience akin to exploring the world through the tip of a pen. SALOME focuses on presenting simple shapes to its users and the authors report that they were able to accurately assess qualities such as shape, line length and angle.

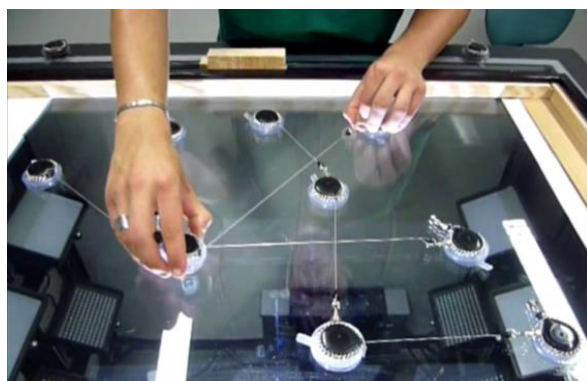


Figure 3-Audio Instructions guide the users to progressively construct the map.

Tangible systems offer a more natural experience. Typically involving a set of freestanding physical objects that are tracked by a digital system, they are capable of presenting dynamic cues as the objects are adjusted, manipulated or configured. Authors have deployed such systems to present graphs non-visually through the arrangement of thin stick-like objects (McGookin, Robertson, & Brewster, 2010)) or to allow visually impaired users to experience and recreate spatial data relating to maps (Ducasse, J-M Macé, Serrano, & Jouffrais, 2016)(Figure 3). This report argues that tangible systems have strong potential to support geometry learning in visually impaired students by combining natural physical manipulation of objects with digital feedback as to geometric state and forms of the objects. The remainder of this report describes research goals, and the design process for the design of a tangible system to achieve that objective.

Project Scope

The aim of the project was to look into the design of a tangible product that can work together with a tablet application (recognized when placed on a tablet) and also used to form basic geometry shapes like (triangles, squares, rectangle etc.).

The project began with a desktop study, followed by an initial goal setting which ended with the making of the first prototype. A qualitative research in the form of an interview was conducted which informed form of the product and the interface design. Finally, a product and a prototype of the software interface was made that achieved the aim of the project.

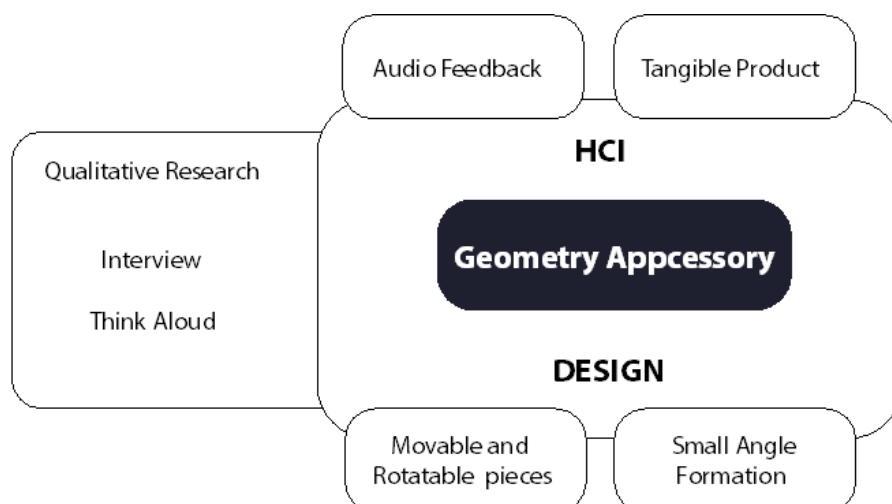


Figure 4-Research Scope

Design Goal

“Geometry as a school subject is a likely a challenge for students who are visually impaired and also their teachers” (Klingenberg). According to (Klingenberg), in some schools the students have special teaching arrangements in another room while in contrast some students have nearly no adjustment to teaching arrangements. Some go further to adjust the curriculum for the students while others still struggle with trying to teach the students the same thing as the students, who have sight. This can put stress on the child and cause some emotional issues as children at a stage in development seek independence (do things on their own).

I found that spatial relations and elements form the basis for understanding topics in algebra, trigonometry, calculus and many others in higher studies. Geometry, which focuses mainly on spatial representation is not an isolated part of the curriculum (Kennedy & Tipps, 1994). In addition, , “Classic geometry teaching is based on visual modality: drawings, graphs, lines, curves, etc., all of these being unavailable to blind people” (Rouzier, 2004).

I found (from (Klingenberg) (CHENG, 2013)) that it is not only students that find geometry challenging to learn/understand but teachers also find it difficult to explain the visual content to the students. Therefore, a device that will let the students through manipulation learn about geometry would go a long way to satisfy both parties. I also hoped the design of my product will encourage independence play in the children to alleviate any stress from trying to understand what is taught in class. They will learn through manipulation of the product.

The target group for our product was focused on visually impaired students in kindergarten to third grade which fell in the geometry concepts section which I wanted to cover for the project (California Department of, 2006) (The Ministry of Education, Ontario, 2005). It is hoped to give a basis for students to build on when they get to school. This product was also designed to be cost effective so that welfare centers that cater for visually impaired students can easily acquire the product for the students. (Appendix 1 goes into detail about design goals for the project)

2

Product Development

Initial conceptualization of the product and function design.

- Form Exploration and Working Prototype
- User Study
- Finalizing Working Prototype

Product Development

This chapter explains the initiation of the concept development. I looked at the context that this product should or can be used as well as the central goal the design revolves around. The initial goal started with the finding of a mechanism used to make the needed shapes (triangle, square, rectangle etc.). The criteria for this goal was to:

- Find a way to make small angles
- The product should have the ability to vary length
- The angles in the shapes formed should be varied
- The use of the product should make shape formation easy and intuitive.

This section also describes the form design and construction of the *Clicks* prototype in detail beginning from how the first working prototype was achieved.

Form and Mechanism exploration through prototyping

The initial design exploration took the form of prototyping of various forms with different mechanisms with the aim of making simple geometry shapes. I used laser cutting and 3d printing to achieve these various forms (Figure 5). Some of the forms incorporated affordance of how the pieces can fit together to make the projected shapes (triangle, square, rectangle etc.).



Figure 5 - Initial prototypes of geometry making mechanism

Aside the pieces being easy to connect together using the magnets, the points of clicking were easily rotated to form various angles. Some of the prototypes had the option of an extendible length but the outcome was not good and it had a limitation of how long it can be extended. (Appendix 2 shows into detail the various prototypes and their pros and cons).

After initial tests, I opted to pursue the development of the prototype that could also give room for the development of a mechanism to make it recognized when placed on a tablet. (Figure6). This was also chosen due to the fact that its static forms were unambiguous and simple to use, important qualities when designing tools for the visually impaired children. The use of static forms would also increase ease of fabrication and robustness of the prototype.



Figure 6-Chosen prototype for further development

Working Prototype Design

I found out that magnets could not only be used to make our product intuitive for the visually impaired children to use but also it could support the mechanism of our product being recognized on a tablet. In order to achieve this objective, I used a capacitive tracking system on a standard tablet (Chan, Müller, Roudaut, & Baudisch, 2012). I started prototyping the magnets with various materials to establish this connection using conductive fabric and the rubber foot of a phone pen. The rubber foot and the magnet proved to establish the best connection on the tablet and also protect the surface of the tablet and give the users a soft feel when they press on the product. This simply leverages the ability of modern multi-touch tablet computers to track not just fingers, but any conductive object placed firmly against their screen and in touch with a human user. This connection was however restricted to the points when the connection to the pieces were made and the child will need to touch the various points simultaneously to get it read on the tablet (Figure 7). This was inconvenient and went against our goal that makes playing easy for the child.

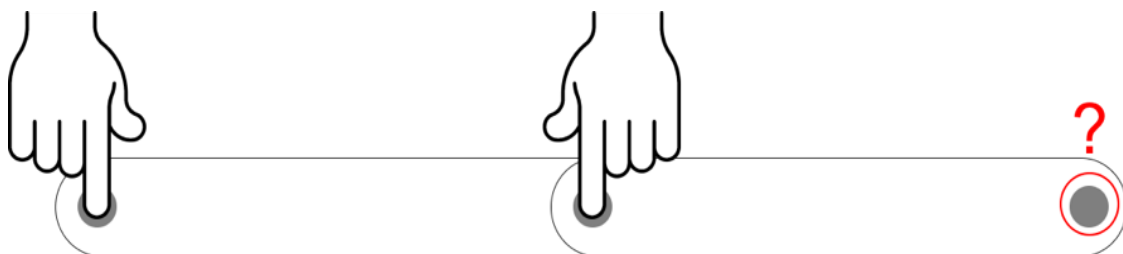


Figure 7- User has to touch various points for it to be read on the tablet

To figure out a way to make the points recognized without the simultaneous touch, a conductive material (plastic- 3d printed) was introduced around the perimeter of the product (Figure 7). This introduction made it possible to recognize the product when it was placed on the tablet and touched.

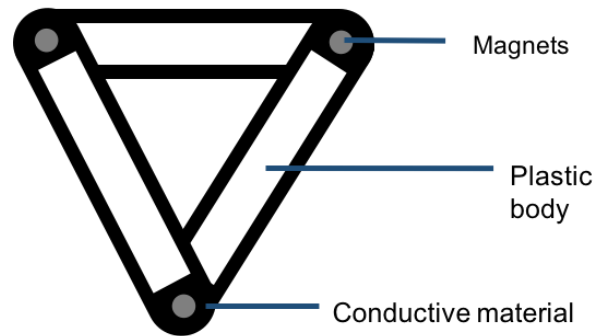


Figure 8- Conductive material around the perimeter of the product when clicked together

With this in place, the first functional prototype was achieved (Figure 9). This was done to facilitate the formative user study planned. This would help us to confirm that my background research was in line and what improvements were done to make our product more efficient.

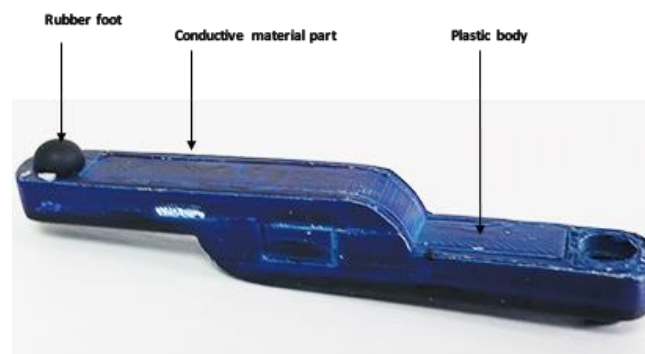


Figure 9- Prototype with conductive material covering the entire piece.

User Study

I conducted a formative interview session with a blind educator to inform our design. This individual has been blind since their childhood and has over seven years' experience teaching visually impaired children. The interview lasted 40 minutes. To get the most value from this session we finalized initial design decisions in order to present a high-level candidate system prototype for discussion. I prepared simple physical mockups of a strut based construction kit that would enable users to snap together a range of simple geometric shapes. We opted to use a standard tablet computer and capacitive markers as the tracking system (Chan, Müller, Roudaut, & Baudisch, 2012). In this stage, our entire system was neither functional, nor fully designed and the goal of preparing these materials was to better solicit criticism and comments.

A key result from this session was confirmation that visually impaired students struggle with geometry (and math in general). The interviewee reported that a high percentage of the visually impaired students he tutors gave up on learning mathematics early, particularly in the area of geometry which is primarily due to challenges in visualization of the concepts. However, in line with

formal statistics (Department of Education, 2010), he noted visually impaired students do have the potential to excel in this area. These comments validated our choice of application area.

Additional comments cautioned about the use of technologies such as touch-screen tablets, as these can be challenging for visually impaired students (in reference to the target group we chose) to operate. I interpreted this as supporting our design goal of an interactive system controlled solely by physical, tangible objects. In terms of the physical prototypes, feedback included physical markers on the objects so that learners would be able to easily and unambiguously identify them. For example, Braille text that describes each object on its surface. This comment highlighted the need to focus on a careful physical design of the tangible objects to maximize their comprehensibility. He suggested the form of the product also be improved making it less rigid, which I had already decided to do.

Form Modification

To continue the product development process, the form of the product was revisited first to improve the aesthetic quality, also the functional property and finally the ability of the product to make the smallest angle possible. I also found that the printed conductive material could be expensive therefore, placed around the perimeter of the product would make the final production of the product expensive. Therefore, the new form modification included finding a way to make the conductive material smaller but still achieve the goals set. This would also make it accessible to welfare centers that teach visually impaired children.

Also, referring to the user interview, I focused on making the product also easy to grab. Figure 10 and 11 had spherical point to incorporate the mechanism of its interaction with the tablet as well as make the user recognize the points on the shape that is made. This includes a curvature in the body (Figure 11) which allowed for the small angle creation (in the range of 20° to 30°). The conductive material was reduced to a cap at the top of the sphere with the introduction of a wire to connect the two ends of a piece.



Figure 10-Form modification which still had restriction on the angle formation.



Figure 11-Another form modification that allowed the formation of very small angle.

Finalizing Working Prototyping

Clicks, a digital manipulative for visually impaired children that supports a range of geometry education tasks and ties physical adjustments to the device to a dynamic digital representation supported by audio feedback, was designed. The tool is a construction kit of simple geometric primitives that snap together to produce a range of more complex forms such as lines, angles, triangles and rectangles. When placed on a tablet computer, the geometry of these objects is sensed (via the capacitive touch screen and electrodes embedded in the objects) and audio feedback is provided. In order to maintain a good connection, the pieces now worked as a circuit, each *Clicks* base assembly consists of a conductive rubber screen contact point and a magnet mounted above it. This is connected by a copper wire to the top assembly at the other end of the strut as shown in Figure 12. When *Clicks* is used, base assemblies are magnetically snapped to the top assemblies to make shapes. The magnets and wire serve to transmit touches to any of the conductive caps at the top, a *Clicks* shape of the whole screen makes contact points on the bottom. In this way, a tablet computer can sense a complete form, even when a user touches only one part of a shape.

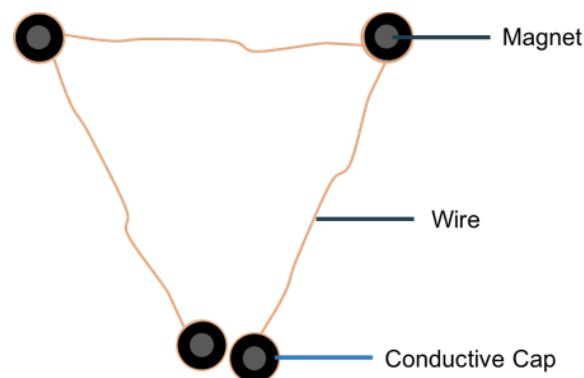


Figure 12- Inner 'circuit view' of the connected pieces

Construction and Functioning

Clicks is intended to operate in conjunction with a tablet computer capable of sensing the configuration of its parts – its geometric form. Figure 13 shows the exploded view of one piece of *Clicks*.

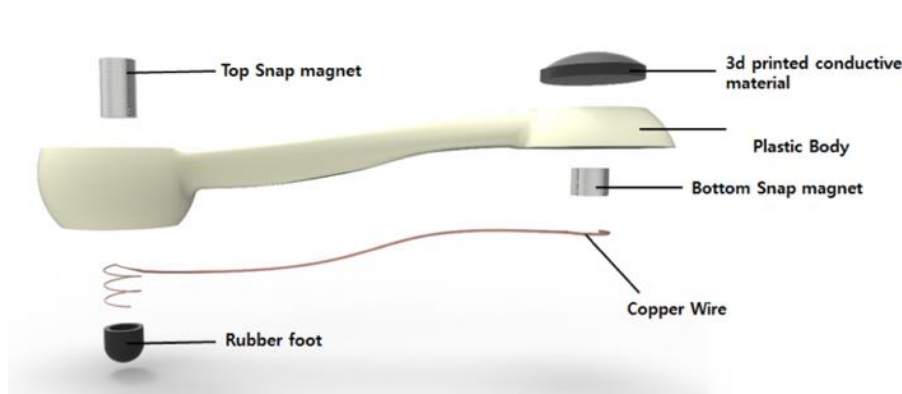


Figure 13-Exploded view showing construction of a Clicks component.

The body of the *Clicks* prototype is 3D printed in standard PLA while the conductive cap is 3D printed using a carbon impregnated PLA with a high resistance that is optimal for use with touch-screens. The current prototype is rendered in three lengths (6cm, 9cm, 10 and 12cm) capable of supporting construction of a range of different shapes (Figure 15).



Figure 15- Connected Pieces (working prototype).



Figure 14-3d representation of various shapes that can be constructed with the sizes

Package Conceptualization

Drawing from a comment in the user study which stated that the design of the product should encompass a system that will make the use of the technology (tablet) part of our system easy for the child to follow thereby making their playing enjoyable instead of stressful. In so doing, I looked at how the use of the package could make this possible and also support independent play as visually impaired students from my literature study, depend solely on their teachers/aid to understand the visual content in geometry study (Klingenberg). (Appendix 3 shows various package prototypes).

I settled first on a packaging which was to be made of wood with the sides chamfered to make it safe for kids to play. A holding plate was designed to hold the tablet with one side fitted with hinged pieces that is place on the tablet to go with the manipulation of the interface of the game (app) (Figure 16) right.



Figure 16- Package selected (left), the tablet holding plate (right)

This design however was found to be big in size and not cost effective. To reduce material size and improve the aesthetic quality of the product the packaging was reiterated.

A slender looking box was arrived in the box that had extrude-cut shapes to fit the pieces together. The rectangular plate that was initially holding the tablet was changed to 2 plastic bars, one having navigation hinges on the side. This navigation hinges (Figure 17) is covered in braille to make icons on the tablet whilst playing easy to identify. I proposed this will go a long way to ensure that the user doesn't need any help when playing has begun. Two package boxes were made with one acting as a base product (Figure 18). The idea was to give room for further design in this area for visually impaired children, example developing a set of measuring tools, puzzles and the like that visually impaired kids can play in conjunction with the tablet.

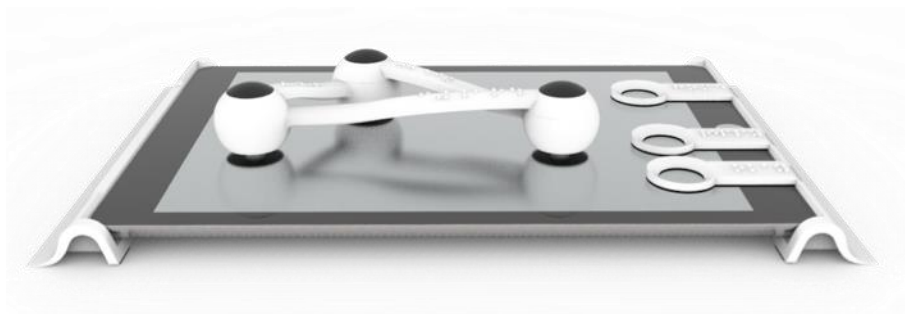


Figure 17 - Tablet holder with a tablet and Clicks product



Figure 18-Base Package (left), product package (right) and the tablet holder with product on top.

3

Interface Conceptualization

App interface prototyping based on curriculum from visually impaired schools.

- Interface Design
- Interface Process

3

Interface Conceptualization

This section explains the conceptualization of scenario of use for the product but first from its development through to the final outcome and reasons for that choice. The projected flow of the app which was made using the curriculum from (The Ministry of Education, Ontario, 2005) , (Ministry of Education, Province of British Columbia, 2007) and (California Department of Education , 2006) was explained. This section takes you through the interface flow projected for the app design. This ideation of the app stems from the goal to ensure an interactive and independent play for the visually impaired children.

Interface Scenarios

I have generated use scenarios that explored how *Clicks* could be used in a learning context. The target age group for these scenarios is from kindergarten to third grade. This is the age at which children are acquiring knowledge about shape identification and geometry. These scenarios also formed a basis for our interface software prototype. The core of our research focuses on the idea of a physical tool used in conjunction with a tablet with the ability to return audio feedback as the child plays and answers questions when asked by audio feedback.

The product which comprises of pieces that can be clicked together and a holder of the table with button rings with braille on the side which makes playing easier (Figure 18). This process however is limited to be used by the guardian that I proposed would set up the product for the child to play.

The interface is a blank space equipped with three buttons, one for going back to the home page to select a level, the second is to replay the question asked by the audio and the last one is pressed when the product is placed on the tablet to receive the answers from the audio feedback. This however poses a limitation of dynamisms in playing that would make the process a bit more fun.

Scenario 1 – Quiz. Using speech, the tablet computer pose challenges to the child, such as to make a particular type of isosceles triangle. In order to respond, the child uses *Clicks* to make a shape and place it on the tablet (Figure 19).

Scenario 2 – Measurement. In this scenario, the child uses the physical *Clicks* prototype to measure angles of a real-world object. By placing *Clicks* on the tablet, the child can hear the information about the measurements and shape of the object.



Figure 19-Clicks placed on tablet .

Interface Process

The quiz section is based on three levels;

1. Size identification and basic shape making.
2. Geometric terms identification and modification of shapes
3. Problem solving – Figuring out what is needed in the question and place solution on the tablet

Based on the three curriculums;

Kindergarten: Under Geometry and measurement; children should be able to compare length and weight and make comparisons. In addition, they should be able to identify and describe common geometric objects (California Department of, 2006) (Ministry of Education, Province of British Columbia, 2007) .

Grade 1: The students are to be able to compare the length, weight and volume of two or more objects and also they learn braille numerals (California Department of Education , 2006). Next they should be able to identify and describe and classify 2 –d shapes and 3-d figures by attributes, recognizing symmetry and relating shapes to other shapes (California Department of Education , 2006) (The Ministry of Education, Ontario, 2005).

Grade 2: They learn to distinguish between attributes that are geometric properties. Moreover, they can classify two dimensional shapes using geometric properties while composing and decomposing

the shapes (California Department of, 2006) (Ministry of Education, Province of British Columbia, 2007) (The Ministry of Education, Ontario, 2005).

Grade 3: According to (California Department of Education , 2006) (The Ministry of Education, Ontario, 2005) students learn by touch to identify the attributes of triangles and quadrilaterals (isosceles, equilateral triangle, right angle triangle, parallel sides for parallelogram etc.)

Under the first level, simple questions are asked where the child is required to identify the size of the strut needed for either three or four-sided shapes based on the audio feedback. Keywords like names of the triangle or four sided shapes are not included in this section questions but provided in the answer section when the child is able to make the shapes required. This is to help the child; especially ones not yet open the mathematics or geometry scene to gradually build the knowledge of how these shapes are made. Figure 19 gives an example of these questions and ensuing audio feedback.

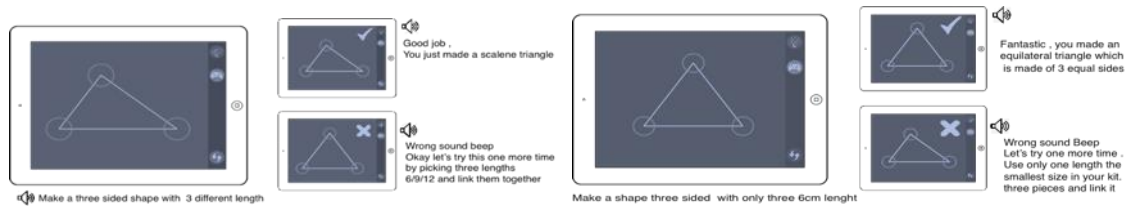


Figure 20-An example question in division 1 type of questions.

In the second level, the questions asked requires the kid to understand some geometry terms, like parallel, opposite, adjacent, parallel, equal angles, etc.. If the child had started from the first level, it is hoped that he or she would have gained the knowledge from the first level through the audio feedback interactions. Figure 20 presents example questions in this division.

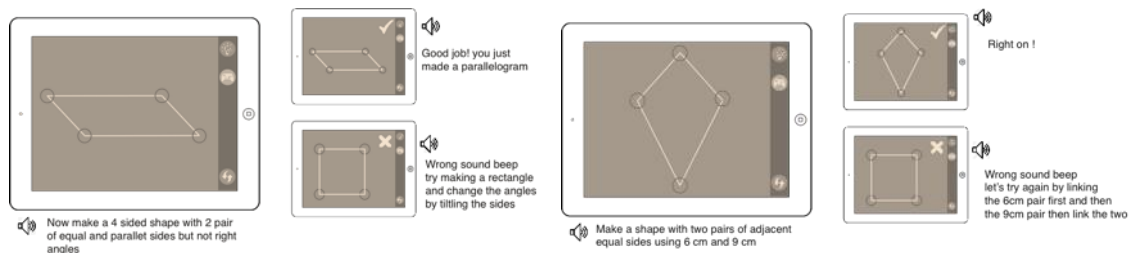


Figure 21-An example question in division 2 type of questions.

The final level takes a more advanced approach where problem questions are posed and the kid is to

work through the shapes and come up with a solution which is then placed on the tablet for a result declaration.

Figure 21 gives an example of some of the problem questions asked including a question like, what are the results when an isosceles triangle is cut with a horizontal line?. This needs a lot of imagination and understanding of some terms.

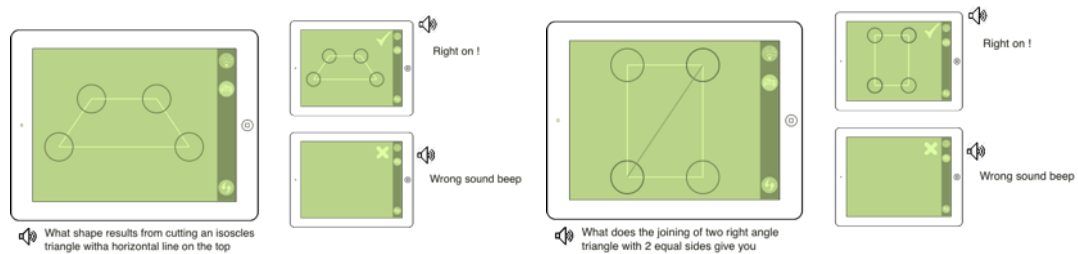


Figure 22- An example question in division 3 type of questions.

Using this scenario basis, a short working prototype of the interface (Figure 23) was made using a UI software (Proto.io) and a video was made to describe the working of the interface with the package and express the potential this product has when it is completed.



Figure 23- Interface to support the struts for easy manipulation by the child when the game starts.

Focusing on scenario one that is based on a quiz session, an app flow was created based on how the game is supposed to work. This also provided a framework which will provide a basis on how the application should be programmed (coded).

The application is to start with the clicking of the game icon on the application page of the game (Figure 24). It then moves onto the sign in page, (Figure 25), where the user's name is typed in, this is to help make the application more personal as the audio feedback will then be able to interact with the child like a form of personal AI.



Figure 24-Game applications page on tablet

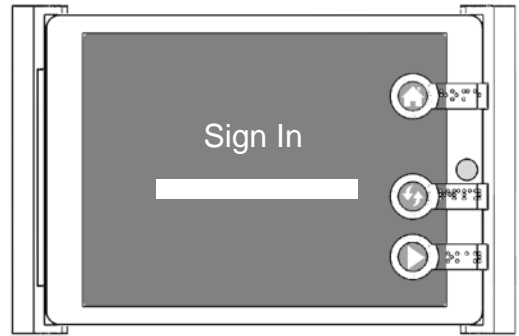
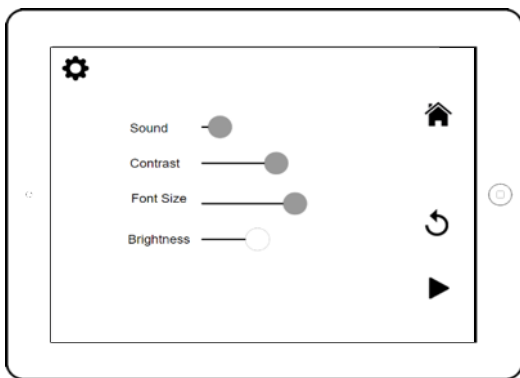


Figure 25- Sign in page



A setting page is also created with different menus (brightness, contrast, font size) to adjust, to cater for varying degrees of visual impairment (Figure 26) mainly to be done by the guardian that sets up the game for the kid.

Figure 26-Setting page to adjust based of varying types of visual impairment.

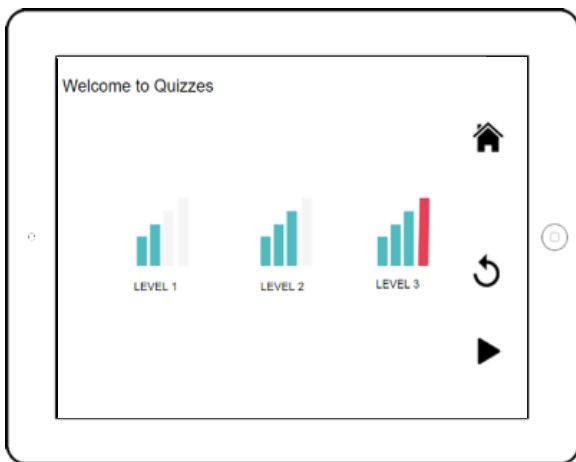


Figure 27, shows the different levels the game can be started from. This is decided by the guardian or the child with the help of the guardian. The levels of the game are divided based on the level of difficulty and certain particular characteristics or desires each level is to achieve. Each level was designed based on the curriculum from the California Department of Education (California Department of Education , 2006) and The Ontario Mathematics curriculum for Grades 1-8 (The Ministry of Education, Ontario, 2005).

Figure 27-Choosing of level page with guardians help.

Use Scenario

The process of the use of this product starts with the guardian of the child setting up the product for the child. When the quizzes start, the holder and the product encourages independent playing for the child. The braille on the product and holder makes for easy identification of the pieces and easy identification and movement through the app (now a prototype).

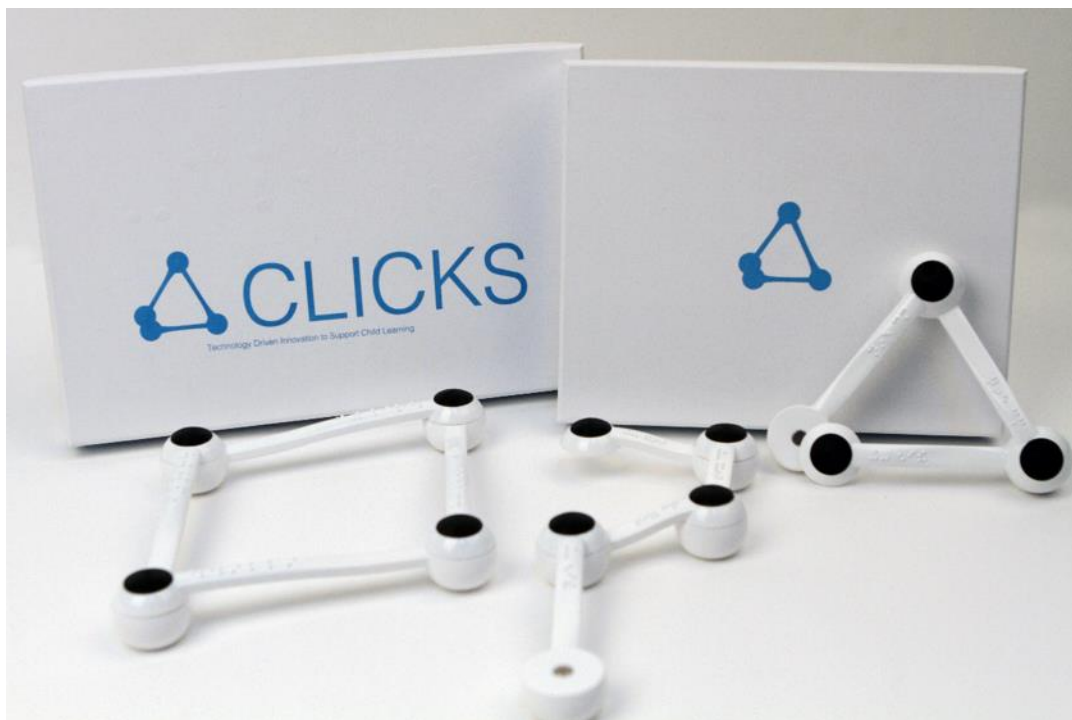
- This product can be purchased in the store by a parent or the welfare center. The box now comes in the base set and the *Clicks* set.
- On getting home, the guardian sets up the product pieces and places the tablet in the holder after the sign in page and level selection.
- From this point on the child plays on their own without supervision. The audio feedback starts asking questions based on the levels selected. The child then snaps the pieces together to produce the answer to what was asked by the audio. The answer is then placed on the tablet and the playing is navigated by pressing a button to solicit an answer from the audio feedback.



Figure 28-Use Scenario of Clicks



Child playing with clicks.



The Clicks product pieces.

4

Evaluation

- Think Aloud
- Interview

4

Evaluation

The chapter talks about an evaluation study that was conducted to conclude this phase of the project. A think aloud using the wizard of Oz technique (where audio was prepared to take the users through the task they were to complete). Next an interview with a blind instructor and one blind student was conducted, through observation and questions asking continuing goals were shortlisted.

Think Aloud

The think aloud was conducted with 3 individuals. I took them through the process of the software prototype and after asked them the process and its difficulties. They were blindfolded to give a role-playing sense as they complete the task.

I found that;

- The Braille on the product was a good addition although they couldn't read it, they believe it will make the intended user understand what piece they picked.
- After taking the pieces out of the box they found it difficult to locate where the pieces are easy.
- The software application should be more interesting (it is too simple).
- They couldn't find how to click the piece together on the first try and at other times as the magnet near the rubber foot interfered with that of the cap (end up clicking together)
- The navigation system is interesting and sure would encourage independent playing.

Interview

I had an interview session with one older blind student and the blind instructor I had the initial study with. The interview lasted for over 40 mins and I was able to shortlist things that needs improvement.

I found out that;

- The braille was a good addition. However, the spacing of the braille on the pieces makes its meaning different so it needs correcting. On the first try, it wasn't easy to find the right

position to read the braille writing but it couldn't be changed as English upturned doesn't read right anyway but the spacing would be revisited.

- When the software prototype was presented they loved the idea of the navigation system. They really appreciated the idea that the child can operate the screen without any help (play on their own). However, the replay braille should be rechecked just as on the pieces.
- The interviewees were able to follow the software prototype once the audio feedback had been translated to Korean.
- They suggested finding a way to make putting the pieces together more free than now (putting the pieces together was a little difficult sometimes because of the magnet in the foot area was clicking with the top of the conductive cap).
- There is also too much time spent trying to assemble the pieces into the shape needed (they suggested if the form or mechanism can be modified). This will make the process of playing from the beginning to the end a bit more fluid.
- Make the magnets firmer in place. (some of the finishing was loose).
- Make raised points (e.g. six dots for six centimeters) and also on the pieces for the students who don't read braille, so that they could also easily identify the pieces.
- Make the form thinner so that a kid can clutch more pieces and also we can add more lengths.
- Make the pieces more varied (different forms and shapes and more sections.). Make the shapes interesting.
- Have different levels for the game and have a timer included, which can train the kids to be faster at making the shapes as their levels progress.
- Instead of making this more educational we should make it more playful.
- Suggest thinking including a 3d section to the game (e.g. a car, a house – the dynamism would make a huge difference in making the game interesting)
- Suggest pushing the rubber foot in a little further to make the connected pieces rest more flat on the surface.

5

Conclusion

- Main Project Findings
- Expected Contribution

Conclusion

Main Project Findings

The main research question was to design a physical product that could be made with the ability of making simple geometry shapes (triangles, squares, and rectangles) and to have this product (shapes) recognizable on the tablet. Using a literature search, I investigated the difficulties visually impaired students had with geometry studies and analyze if technology could be introduced in solving the problems found in geometry.

I found out that indeed, visually impaired children face a lot of difficulties when it comes to the study of geometry. Additionally,, technology has been proposed as a solution to this problem but little of no research has been done in this stead. I concluded on the possibility of using a physical product in conjunction with a tablet (application) to better understand the basic geometric theories.

The main challenge was coming up with a simple method of creating the geometry shapes. I looked at a puzzle form which will be similar to some traditional toys already in existence. Through a series of prototyping I found that using magnets will not only make it easy to understand, for example, which piece went with what, but it was also the best method to get a rotating body in order to make angles. I also looked at some form that included extending the length of the product piece but realize the difficulty of prototyping outweighs the amount of length I could extend.

I discovered using magnets had the potential of making the product recognized when placed on the tablet. A rubber foot with a magnet mounted above it at one end and a magnet with a conductive 3d printed material mounted on the opposite side were connected together by a copper wire to produce a simple circuit which will make points at each end recognizable when placed on a tablet.

An interview was conducted which affirmed most of our discovery in the literature studies with a note to design not just the product but an experience that will make it easy for the children to be able to use the product in conjunction with the tablet technology.

With this in mind I went further to design a tablet holder that will allow for easy navigation of the application when it is completed and independent playing (the child can manipulate the application without the help of their guardian). The product and the tablet holder is equipped with braille to ensure easy identification of pieces as well as which navigation button should be pressed.

More work needs to be done on the development of the software and also on the product (making the form more interesting, and thinner).

Expected Contribution

This research was conducted with the aim of contributing to the field of HCI (Human Computer Interaction) and research. It hopefully able opens up a bit further the research into technological approaches to learning for visually impaired children. I found geometry was just one of the areas of difficulties and the scope of our research touched on is only the basics of geometry.

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6

Appendix

6

Appendix

Appendix 1 – Design Goals

Product piece Goals

- The product should have the ability to make the smallest angle possible and also make varying angles.
- Due to the changes in length in certain parts of geometry concepts, the product should have the ability to vary in length.
- The technical composition of the product piece should make the process of playing easy and simple.
- The mechanical make-up of the piece should make it immediately recognizable when placed on a tablet.
- The product should have indicators (like braille) to make it easily recognized.
- The product should be durable.
- The form and size of the product should be comfortable to be held by the child.

HCI (Human Computer Interaction) Goals

- The interaction between the product and the tablet should be fluid.
- The product should offer a way to make the child playing on their own without asking for help from anyone
- Make the interface simple enough for playing but not too simple as not to be interesting.
- The software process should be smooth so the child doesn't get confused
- The interaction between the child and the computer should be able to achieve the goal of understanding the basic concepts of geometry.

Safety and Material

- The material to be used should be affordable but also durable.
- The mechanism to make the shapes should be safe for children.
- Materials used in the product should be safe for children (not harmful even if product is put in the mouth of the child)
- The details on the product should be legible for the children.

Appendix 2 – Product development

Table 1-The first prototypes made to investigate the mechanism of making simple geometry shapes



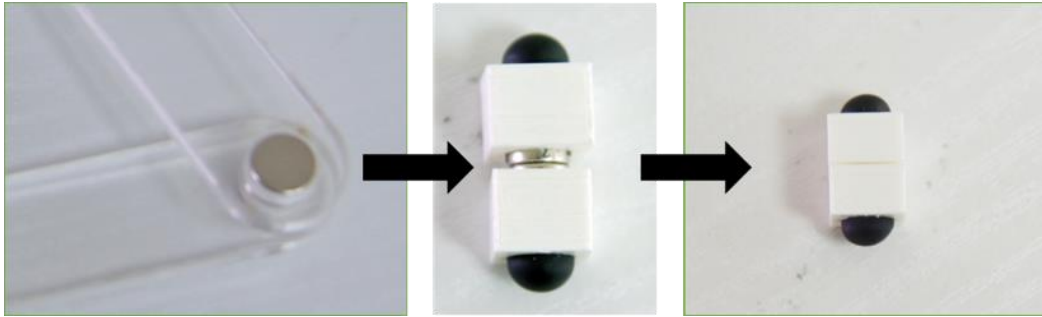
	<p>Pros</p> <ul style="list-style-type: none"> • Easy to make • Clips easily
	<p>Cons</p> <ul style="list-style-type: none"> • Not working on the tablet • Have to hold all three points to get it to work <p>Pros</p> <ul style="list-style-type: none"> • Rotates easily • Extends to a certain length <p>Cons</p> <ul style="list-style-type: none"> • Connection to pieces is poor • Extension is limited • Problems with extender

Table 2-Second phase of prototyping still focused on mechanism finding

	<p>Pros</p> <ul style="list-style-type: none"> • Elevated to give room for the tablet mechanism • Good connection <p>Cons</p> <ul style="list-style-type: none"> • Limited length • Limited angles making
	<p>Pros</p> <ul style="list-style-type: none"> • Rotation center <p>Cons</p> <ul style="list-style-type: none"> • Complicated connection



Magnets size and height finding

Appendix 3 – Package Development



Various form of packages that was looked at

Various forms of packaging were iterated and found to be too large when put in final print. A solution was found in the form of using the package (case) the product will come in, to support the interface of the tablet, to help keep the tablet in place for playing and to make it simple to use