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Trigo/πad™

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INTRODUCTION

This report describes the process our development team followed in the creation of the TrigoPad™. The sections of the paper followed the New Product Development cycle covered in the lectures and described in our readings. Each section will contain a description of the steps we took during each phase of the process and key learning we identified after working through the intended process.

TEAM FORMATION AND IDEA GENERATION

Our project team was formed during the initial class. It consisted of four team members, all of which had worked together on a previous team in ETM 520. We quickly determined that we would follow the same meeting schedule we used for our previous class and the existing Google group we used for group communication.

Unfortunately, one of the members of our team had to drop the class because of health reasons prior to the idea generation phase of the project. That left our team consisting of three members.

Our team struggled with idea generation. We initially came up with five or six ideas and we presented a couple of them in class. Although we liked the ideas most were determined to be too difficult for prototype generation so we went back to generate some simpler ideas. Some members of our team seemed to find it easier to generate ideas in our daily lives while others seem to struggle. The prototype development concern played a key issue even in simply identifying basic products that would be unique or we could compete against in the market place.

We finally determined that we would develop the TrigoPad™ primarily because we saw it as a simple product and one of our team members had substantial working knowledge of how this product could help our target market. Additionally, two-thirds of our team members had substantial mathematical knowledge and well as access to the target customers for discussions and user feedback.

PRODUCT PLANNING

We decided to form a company to provide mathematical educational tools. We developed the following Mission Statement for this project:

Product Description	Provide an educational tool to visually understand Trigonometry concepts
Primary Market	Students, Teachers
Secondary Market	Parents, Tutors, Educational Institutions
Assumptions	Small, Portable, Lightweight
Constraints	Affordable, Easy to manufacture
Stakeholders	Users, Retailers, Sales, Production

KEY LEARNING

We determined though the course of our concept generation steps, that the product description and target market were too vague. This caused issues when trying to formulate functional components of the product as well as identifying initial sales volume because the primary market was too vast and difficult to quantify.

IDENTIFYING CUSTOMER NEEDS

Our team did a good job at this phase of the development cycle. Because of a team member's access to customers in our target market, he was able to quickly setup discussions with them to capture customer statements regarding the functional need we were trying to fill. The initial statements were captured from six Portland Community College students taking Trigonometry. Our team member asked the questions regarding their needs for learning Trigonometry and what a tool if available would need to provide for it to be beneficial to their learning.

The statements were captured and then sent to the rest of our team via email for review. Each team member translated the customer statement into an underlying need based on their perspective of what the customer was saying. Our team met and wrote each individual need onto individual note cards. We then as a team grouped the cards into similar needs. Once grouped each team member then ranked the importance of each need based on our individual assessment. The groups and ranked needs were then captured in a spreadsheet for analysis and manipulation.

KEY LEARNING

The groupings that our team identified was focused more on the similarity of the need and not based on what the customer was stating were needed by the product. For example, we identified a group titled "User Friendly", when the actual need was "Easy to Visually Understand." The missed translation caused issues when we tried to create a functional diagram of the product later in the process.

The process of interviewing the customer individually and not as a team could have identified bias in the questions asked to the student. A theme we found very evident during the initial stages of the process was that a predetermined design of the product was already identified by our product champion based on his experience in tutoring these students. Although he tried to keep the questions from leading the students, review found that in some cases his enthusiasm for the product might have impacted the process.

We also did not create a survey to validate our needs groups and individual hierarchy. Although we did use surveys to capture customer feedback later in the process, validating our groups could have provided valuable insight into the importance of our criteria earlier in the process.

ESTABLISHING TARGET SPECIFICATIONS

Our initial attempt at determining specifications based on the user's needs statements was not adequate. This I partially because of the incorrect grouping of the needs into similar groups instead of actual user needs. Given our perceived id

CONCEPT GENERATION

Identifying an initial design of the product was not an issue for our team. Our product champion was quickly able to describe his idea of how the product should look and act to meet his perceived needs. The problem we had was pulling back to an abstract functional level to clarify the problem and identify the related functional composition.

FUNCTIONAL DIAGRAM

Our first attempt at building a functional diagram was too detailed. Given we already had a design in mind, the functional diagram was made more complex than needed by inserting design details into the diagram. The presentation of this diagram in our first team presentation elicited the feedback that indeed the diagram was incorrect. The team decided to revisit the functional diagram to redefine the functional composition in a way that would be beneficial to future stages of the product development cycle (see Appendix B). We also found this process helpful in breaking the functional problem into sub problems which clarified the important functional issues our design needed to address.

EXTERNAL SEARCH

Based on the functional problem our team underwent an external search for similar products in the market place. The search quickly showed that no working tool was available and the standard approach used to teach the Trigonometric concepts identified in our functional diagram was to use a unit circle diagram provided in most textbooks. This was very encouraging to our team. We decided not to undertake any additional searches like a patent search because we believed our concept was unique and would have shown up in initial external search. We also realized that we are working with known mathematical concepts which by themselves could not be patented.

INTERNAL DISSCUSSION/LEAD USERS

Within our team, we didn't have any problems with coming up with concept ideas to solve the functional problem we identified. In some ways, this was a hindrance to expanding our concept ideas because our product champion had a design in mind at the start of the project. Based on his ideas, initial discussions with lead users and team discussions we identified components of the product that would be needed to make it functionally helpful: unit circle, axis, movable radius and extendable arms. We determined that based on the needs assessment the product would need to fit the following criteria:

Need Statements
Easy to carry
Easy to visually understand
I can afford it
Can run on a digital device
Won't break
Explains all Trigonometry concepts

The team identified three different concepts models: paper, hard plastic and digital.

KEY LEARNING

We realized that to successfully complete the concept generation phase, having a product design already in mind was not beneficial in allowing us to examine potential concepts without being bias. We consistently needed to regroup and readdress steps in the process because we simply skipped over them given our design. We realized that in going back and breaking the concept into its functional components, looking externally for other products/ideas in the marketplace we gained a better picture of what our product needed to have to be successful in meeting our user's and the market needs.

CONCEPT SELECTION

The three concepts that we identified were simple products that we thought met the needs identified by our users. The outlier was the digital version which although it was specified as a need by some of the users we didn't think it was doable for this project. But we agreed that by keeping it as a potential product it could surprise us as we went through the screening process.

INITIAL CONCEPT SCREENING

Our team decided to use a decision matrix as our method to evaluate the initial concept ideas. We selected the following criteria for our comparison:

Selection Criteria
Ease of handling
Ease of use
Readability of settings
Accuracy
Durability
Portability
Ease of manufacturing

Based on these criteria we applied the simple rank of (+), (-) and (0); (0) signifying “better than”, (+) “same as” and (-) “worse than”. Our initial analysis showed that the hard plastic model scored highest with the paper model second and the digital model last.

CONCEPT SCOORING

During the initial concept screening, all of the criteria are assumed to have equal importance. Next we weighed the importance of each selection criteria based our group judgment and rated each model using a scale from 1 to 5. The weighted scores are calculated by multiplying the weighting percentage by the rating for each concept. Based on the weighting and ratings the outcome showed the hard plastic model ranked 1, paper model 2 and digital last (see Appendix F).

After our review of our concepts in our first presentation, we decided to revisit them to determine if additional concept options should be considered. We determined that based on our targeted markets, we should also consider a concept that is suitable to teaching professionals. We identified a teacher model as well as another model targeted at providing a product that would be “cool” in the eyes of our student market. We called this concept the origami model given it resembled the folding of an origami shape.

We added these models to our initial concept decision matrix and recalculate the results (Appendix X).

CONCEPT TESTING

Our team realized that the weighting we applied to the criteria could be different than how our users see the importance of each criterion. We felt it was important to try to evaluate each concept without our predetermined bias as well as try to determine product interest, concept selection, the interest in the purchase of any of these concepts, and price range.

We targeted two sets of groups for our survey. The first group was the original lead users interviewed to gather customer needs early in the process. The second set was Trigonometry students at Clackamas Community College. A team member had a contact in the math department and was able to deliver surveys to two separate classes to gather input.

The survey consisted of three pages. The first page was an explanation of how to use a graphical model of the product presented on the second page. The last page was the survey questions (see Appendix X).

We entered the customer criteria weighting into a spreadsheet and calculated the average. We then rounded up the percentage and used that as the basis for the customer weighted concept test. The survey weight results and concept test is found in Appendix X.

We found that the with a few exceptions, the weights that our team applied to the selection criteria was very close to those provided by the customers. The biggest surprise to our team was the difference in the importance of accuracy to the customers. We surmised that this might have been because the customers assume the tool will provide accurate data by the nature of its function. We were less surprised by the difference in the weights for durability after realizing the target market is students which typically have limited funds so purchases related to education need to be last through the duration of their use.

In addition to the criteria weighting we also gathered input regarding interest, pricing and need. The survey found that the average lowest price was $5.36, the average highest price was $23.36 and the average expected price was $11.22. These numbers were consistent with our initial targeted price of around $10.

The survey also showed 44% of the respondents were extremely interested and 36% were somewhat interested in the product with corresponding levels of need based on their interest. These values will be used to calculate expected initial production volume.

CONCEPT RESULT

Based on our decision matrix and input from the customers the team concluded to proceed with the hard plastic model as our concept to develop.

Concepts	**Teacher Model**	**Origami Model**	**Paper Model**	**Hard Plastic Model**	**Software Model**
Total Score	**3.1**	**3.25**	**3.0**	**3.35**	**2.70**
Rank	**3**	**2**	**4**	**1**	**5**
Continue?	**No**	**No**	**No**	**Develop**	**No**

KEY LEARNING

It was clear through this process that the preconceived design of the product influenced our decisions. The ratings applied to the concepts were generally pretty consistent which in reality there should have been more discussion and variation on them to more accurately differentiate between the models. Excitement around the origami model caused issue because it briefly derailed some team members from sticking to a single concept approach and considering a combined product offering. In the end, the difficulty in producing a prototype to reflect the origami model aided in putting all team members on a singular concept development track.

The surveys should have been distributed as a group instead of individually. Bias and excitement in specific concept types could have influenced responses by the customer base. Additionally, the timing of the surveys wasn't consistent with the product development process. In the end, the information was meaningful, but it might have been more complete if it was designed and delivered as a team.

PROTOTYPE PROCESS

After we finished the Conceptual Design document, our team examined the functionality in Phase 1. We ordered the subject areas and determined the user participants for each area. We then began to develop the materials we would need for the first prototyping session. We started by creating the Initial conceptual model consisted of foam board with a simple unit circle/axis diagram print out and taped to the board. We used a thumb tack and thin paper to represent the diameter, please see design in appendix" H" unfortunately the foam didn't work well as we expected, we had some issues such as keeping the arms secure on the foam board, but it didn't. We determined we needed thicker material, potentially clear plastic as the diameter.

After searching through a lot of materials, we determined we need a clasp that would be easy to attach the diameter to the base and secure the arms without falling off. We identified an eyelet as a possible solution. We searched many hardware stores and we were able to find eyelets for our prototype. Then we started our initial design by brainstorming and we tried to combine the unit circle into our base to save time and materials. We used a team member's contact who is a graphical designer to render an image (ID) and asked him if it was possible and what our options were. Josh at render an image said that it is possible and he was able to send us first images. Please see appendix "I"

After our initial design was already in process, we visited a company that creates signs to determine if it was possible to take the ID created by a graphical designer Josh and print it on a material suitable for the product. We chose two thickness of a sign material as potential options for the base. After a group discussion we determined the thinner material was better because of potential production issues attaching the diameter and the arms to the base.

Then a team member visited a local craft store to purchase eyelets and suitable tools for attaching the diameter to the base and the perpendicular arm to the diameter, we also found a suitable thin plastic to be used as the diameter.

PROTOTYPE

Our initial prototype consisted of printing the graphical image and gluing it to the sample base material we found and decided as our base. Through trial and error we were able to determine the best way to use the eyelets to attach the parts together. We picked up the final base created by the sign company and used for final prototype. A clearer plastic was chosen as the diameter. We ran to some issues while creating our first prototype such as: thicker plastic needs to be used for the diameter, a thinner plastic then used for the perpendicular arm. An eyelet with is an additional 1/8 inches deep should be used because the connection between the base and diameter is too tight to easily move. We put together all the materials purchased (eyelets, clear plastic arms, and plastic board with unit circle printed on) and created our prototype. Please (see Appendix "J")

KEY LEARNING

Prototyping is particularly helpful in order to provide a shared understanding of what the final learning is likely to be; it offers the development team a common background where many misunderstandings can be avoided. Our first prototype created an early iteration loop that provides valuable feedback on technical issues, creative treatment, and effectiveness of instruction. The design document itself is changed to reflect this feedback, and in some cases, a new prototype module is developed for subsequent testing of the refinements.

Some of the main learning key points and improvements we learned from our prototype are the following

1. We were able to reduce the prototype process time
2. We were able to reduce the development costs for DFM
3. We learned a lot from the user involvement in making our product fit's the customer needs
4. Developers receive quantifiable user feedback.
5. We were exposed to developers to potential future product enhancements.
6. Finally, our results ranked higher in user satisfaction.

PRICING

We initially considered two different ways to sell our product. Our first method was to sell it through a known, established website such as Amazon. And our second method was to sell it through creating our own website. But both options had pros and cons when it comes to shipping costs, fees, and profit. Although selling online is still quickly gaining popularity among Web users young and old. It is particularly appealing to people in remote areas who can now visit their favorite stores online with just the click of the mouse. Shopping online is fast, convenient and buyers can shop in the comfort of their own home. This is why both buyers and sellers are eager to get into shopping online. Based on our findings, we also considered that there are four basic components to a successful pricing strategy: First is Costs, which focus on our current and future, not historical, costs to determine the cost basis for our pricing strategy. Second is Price Sensitivity. The price sensitivities of buyers shift based on a number of factors and your pricing strategy must shift with them. Third is Competition, and finally, the product lifecycle. How we price, and what value we provide for that price, will change as we move through the product lifecycle. We chose to sell our product through our own website. But here are some of the Pros and Cons we ran into choosing this option.

Our own website Pros:

- Lower start-up costs
- Ubiquitous Web presence
- International customer access

- Business conducted 24/7
- Quick response to customers
- Lower overhead
- Lower product cost
- Work from home or remotely

Our own website Cons:

- No immediate customer visibility
- You can't physically see customers
- Constant need to maintain sites
- Late nights and long hours
- Lack of customer trust due to location
- Lack of immediate health care benefits
- Disruption of business and family privacy

SALES POTENTIAL

It was challenging to calculate the sales potential for our team as a new product producer. At the same time there was no product even close to TrigoPad™. So, after a lot of discussion we came out with C-definite and C-probability which was 0.25 based on our estimation. Indeed, we decided to measure these two values less than extreme and somewhat interest in our survey. So by having F-definite and C-definite based on our survey we got p=0.2. Also, we assume 20% for the potential customers who are aware the available product. First, we assumed the number of potential customer is 100,000. Based on these pre assumptions we found we need to produce 4,000 units (see Appendix G). But, later we did more research and we changed this number to a very reasonable estimation (we would explain about that later).

PRODUCT ARCHITECTURE

To determine the architecture to use for this product our team reviewed the functional diagram contained in the appendix. We originally thought that this diagram represented a product that could use a slot-modular architecture. The reason behind this was we determined that none of the components could be interchanged in their orientation on the product; and this definition matched the definition we found in the textbook. In hindsight, we realized that this was incorrect and the architecture for this product was not modular at all.

Based on this we redefined our architecture as integrated and developed the diagram in Appendix B. This shows that the components we identified do not have a one-to-one relationship with functionality of the product but in many cases interact to provide said functionality.

SCHEMATICS

Our next step was to break down the functional diagram into its constituent elements. We found this step relatively easy given the simplicity of the user interaction with the product (Appendix A).

The next step of clustering the elements based on geometric integration and functionality was again easy given the know user interaction but also because of the team preconceived design of the final product.

The hardest part of the schematic process was to identify incidental interactions between components. We struggled for quite a while but then realized that we were making this process much harder than it needed to be. The examples in the book represented complex devices that had electrical and mechanical components that by their nature would have numerous interactions; our product by comparison would only have a few based on stress and friction. The process was beneficial because it identified the importance of how certain components and their attachment to other components could cause quality issues if not addressed in the design.

DIFFERENTIATION AND PRODUCT PLANNING

Our team discussed if planning on delayed differentiation made sense for our product. Given the product is targeted at a specific market located in the US and that the product will not be available in different configurations we decided against that approach.

We also discussed if we planned on making this product part of a larger platform of products targeted at our market segment. Based on our concept generation and testing we realized that there is the potential of offering different products to meet the needs identified by the customer statements and their associated needs. The different concepts in most cases represented vastly different products so the design and manufacturing of those products would mean a complete new product development cycle. We determined that based on customer feedback if our initial product was successful, revisiting the development of alternate products might make sense but until that point we would not plan on additional products.

KEY LEARNING

It is clear that the steps of defining the architecture and associated schematics are an import part of the design process. Even a product with 5-6 parts requires considerable design and planning, much more than we thought at the onset of design after concept selection.

INDUSTRIAL DESIGN

The simplicity of this product posed the question in our group if we needed an Industrial Designer to work on the user interface. In our minds the product is straightforward but we realized that we need to assess the product not just on the interface but on other factors as well. We decided to look at both ergonomic and aesthetic factors and determine the importance of each and the impact on the product if we didn't take those factors into consideration.

- Ergonomic
    - Ease of use
    - Ease of maintenance
    - Number of user interactions
    - Novelty of user interactions
    - Safety
- Aesthetics
    - Product Differentiation
    - Pride of ownership, fashion or image
    - Team motivation

KEY LEARNING

The process revealed that ease of use and product differentiation was important factors for our product to be successful. Based on this we determined the need for an ID was important for the success of our product. Our team decided to reach out to a graphic designer to take our concept idea and make it a usable product.

KEY LEARNING

Industrial Design is not just User Interface Design. The importance of ergonomics and aesthetics go beyond the look and feel of the product and address how the user interacts with the product and how non-functional requirements play an important part in product design.

DESIGN FOR MANUFACTURING

Our team decided to concentrate on design for manufacturing by having a main goal to decrease the production cost by keeping production quality. Reducing the cost of assembly is one of the methods to achieve this goal. After a very long discussion, we found some integration between TrigoPad™'s parts. Finally, team considered the following questions for the Base, Axis, Unit Circle, Expandable Arm, & Perpendicular Arm: How many parts need to move on the device? Can we use the same material for all parts of the device? Do the parts need to be separated from the rest of the device to allow for assembly, access, or repair? After answering to those questions, team determined that design must be changed somehow to first, reduce the number of arms to one, second to exchange radius to diameter to eliminate expandable radius, and third, to combine base and unit circle to include axis and values on it. This helps to reduce the assembly cost. We calculate assembly cost before and after this design changes. The cost before change was about 13 cents and the cost after design change was 5 cents. That shows we could reduce the assembly cost by DFA (see Appendix L). Also, we calculated DFA Index for the both scenarios. DFA Index before DFA was calculated 0.3 and after DFA became 0.47 which shows we got some improvement by those design changes.

KEY LEARNING

Even though we could decrease the cost by DFA, later team found that its estimation for both was not realistic. So, we changed some time estimation. For example, we added 10 more second to the insertion time for each part during the assembly. This change increased the total assembly time to 59 seconds and assembly cost to 15 cents per unit (ten more cents per unit).

PATENT AND INTELLECTUAL PROPERTY

Intellectual Property (IP) is one of the most challenging sections through the all NPD processes. Fortunately, after we got a lecture about IP by Mr. Kevin S. Ross, a Patent Attorney, we found out that there TrigoPad™ has no need to apply for a patent. Indeed, this product needs to just get a copyright. That was an interesting idea. None of our team member was even thinking about a copyright instead of patent. This made our team happy because patent's application is much more expensive. Also, Ross confirmed the name TrigoPad™ as a trade market. Based on his suggestion, we started to use ™ everywhere we write our product's name to protect this name for our company.

DESIGNIG A LOGO

After IP, we asked a professional graphic designer to design a logo for TrigoPad™. He sent about 10 logos (See Appendix M) and we had to make a choice for just one of them. Based on the marketing aspects (color, catchy, and visual arts) we picked this one:

KEY LEARNING

After our team presented the logo, the instructor mentioned to a very important point. He asked, "Are you going to do this business in the U.S or in other countries?" Our answer could change the logo dramatically. Even though we did not think about this before, after his red flag, we decided to think about it more. The best example is Starbucks. They have been changing their logo several times. This process affects the business financially. Also, it's a bad sign for its consistency and reputation.

MARKETING STRATEGY

First, our team decided to have total two years marketing plan. For the first year we were going to concentrate just on Portland area and for the second your move to the national region by a trigonometry book publisher. After we talked to a professional marketer (MBA consultant), he changed our mind. He believed having just 2 years is not enough to be recognized as well as any publisher jumps on our product in a market. TrigoPad™ is a new product and needs more time to build its reputation. So we changed our marketing plan to three years period. First Year, we would market just in Portland area in Community Colleges book stores and our web site, second Year we move to Oregon Community Colleges book stores and we would expand our Online web site marketing, and third Year, we would expand the marketing to the entire of the United States by Trigonometry math book publisher partnership and shutting down the online marketing at all.

KEY LEARNING

Marketing strategy is a very complicated and critical subject. Getting advice from a professional marketer is always helpful. At the same time, there is no formula for marketing strategy. But whatever is the company's strategy, the road for marketing would be determined based on that. Indeed, marketing is moving with NPD all the time through the all processes.

MARKETING PLAN ESTIMATION

One of the challenging tasks for our team was how to determine the unit number which must be produced. Even though this number is estimation, NPD team must try to narrow it down and create more evidences and documents to show why and how they came out with this number. Also, as accurate as this number get calculated, at the end the company would find a better financial output. No one wants to produce the products and store them.

Through our first estimation we got a very unreasonable estimation for the unit which must be produced. Based on the formula Q=N*P*A, we assumed there are 100,000 trigonometry students and based on this assumption we got 4,000 for the unit which must be produced. After the presentation and professor's Khormaei's input we found out that first we need to concentrate on a specific region. Then we need to do some research on that region to find out proximately how many trigonometry students exist there. After talking with the chairman of Math department at Portland Community College we found about 560 students are taking Trigonometry just at Sylvania's Campus. We, found how many more campuses exist in Portland area, then added to other community colleges in this region and we estimate there could be about 5000 trigonometry students in Portland area each year. We already could estimate P (the probability) and A (the fraction of the potential customer). So, we could estimate all our marketing plans for the all three years:

- First Year
    - Geography: Portland, Oregon
    - Market Size: N=5000 trig students q=5000*0.2*0.2=200

We expected to sell 50% of q through our website. So we could add 100 units to the previous estimated units. By this way, the total Q becomes equal to 300 units. Then, we defined our Market Segmentation: Community College Students, Target Market: Portland Community College Students, Marketing Channel: Portland Community Colleges

Book Stores & Online (our website). Professor Khormaei mentioned that we had to use “Sales Channel” instead of “Marketing Channel” which was a very good lesson for us.

With the same way we came out with the second and third year marketing plan strategy. For the second year, we found there are almost 15 community colleges in Oregon State. So we multiple 15 by 5000 (the number of trig students in Portland) and the total Q for the second year became 4,500 (See Appendix N). Also, the research showed there are almost 1,800 community colleges in the U.S. So by multiple 1800 by 560 (the estimate number of trig student just in PCC) total Q for the third year became 200,000. (See Appendix O)

KEY LEARNING

We had a very reasonable estimation for the units which must be produced based on our research and etc. But our estimation for the units which we expected to sell through our website had no connection with our other estimation. That was a very important critical point which we figured out after our presentation when professor Khormaei’s gave us some notice.

ADVERTISING AND PROMOTION STRATEGY

For the first year, all that we need is designing logo and website hosting. For our company there is no ongoing marketing cost. Indeed, our sales cost is zero. One of our team members, Shahin, is a trained professional salesman who is willing to contact with the all community colleges and make a good deal to sell TrigoPad™ through their channels.

For the second year we would expand the internet marketing and we hope to sell more online. After one year experience in Portland area, there are more opportunities to get good contract with other community colleges in the entire Oregon State.

But for the third year the story is different. We decided to shutdown internet marketing at all and just concentrate on selling TrigoPad™ through the publisher channel. Our goal is to have a contract with a powerful publisher (distributer) who is publishing trigonometry books. We would sell them by discount and they can put TrigoPad™ and their book together, and then sell it as a package. This could be a win-win situation. We sell a huge number of TrigoPad™ by the publisher power and our product as a supplementary tool helps their book to be more useful. That’s how we can increase the unit of production (200,000) and decrease the marketing cost to zero, although we would give $5 discount for each unit which still looks profitable for us.

KEY LEARNING

All of these ideas look great, but when we started to calculate our profit and Net Present Value (NPV) by the spreadsheet, we found out that we planned to expend a lot for marketing in the second year. That strategy decreased our NPV dramatically. We would talk about later a little bit more.

TRIGOPAD™ PRODUCT DISCRIPTION

At this point, we were getting ready for the final presentation. We needed to prepare an informative product description. In appendix P, the product description is demonstrated. It explains when, where, and by whom the product was designed. Then there is a geometric integration details for each parts.

PRODUCT DEVELOPMENT ECONOMICS – MFC ESTIMATIO

Since we were introduced to Manufacturing Cost Estimation, our team understood this part of project is so challenging and complicated. We had to calculate all the cost in details based on our manufacturing, marketing, and advertising strategy. Until professor Khormaei gave us a magical spreadsheet which made our calculation much easier.

We calculated all the costs for three different years. The spreadsheet became a fantastic model for the manufacturing cost estimation. For the first year there was just two marketing cost: website cost and logo design. As we were told by Kevin, we just need to pay $35 for the copy right. For the parts we had different estimation. As the Volume of production increases, the cost for plastic based could get some discount. So, based on the information which we got from the supplier we got the first year MFC estimation and then we plugged it in the spreadsheet. Here is the estimation for the first year and its calculation in detail:

- **First Year MFC Estimation:**
    - Total Marketing Cost = $595
        - Website Cost = $95 , Logo Design = $500
    - Copyright = $35
    - Parts (50 units)
        - Plastic Base = $175 , Plastic sheet = $4.50 (diameter and arms)
        - Eyelets = $1.50 , Assembly labor = $60.00
        - Packing = $2.00 , Eyelet Puncher = $50.00
    - Total MFC = $1543.00
    - Unit Production Cost = $1543/300= $5.14

For the second year, we decided to upgrade our website and allocate $1,000 budget per month for internet marketing. The website costs us almost $2,000. The cost for plastic base got some discount and because the volume of production increased, we decided to buy more eyelet puncher and some extra equipment which could cost about $250. Here is the estimation for the second year and its calculation in detail:

- **Second Year MFC estimation:**
    - Marketing Cost = $2000.00 (new professional website)
    - Parts (50 units)
        - Plastic Base = $125.00 (volume pricing reduction)
        - Plastic sheet = $4.50 (diameter and arms)
        - Eyelets = $1.50 , Assembly labor = $60.00
        - Packing = $2.00 , Eyelet Puncher = $250.00
    - Total MFC = $17620.00
    - Unit Production Cost = $17620/4500= $3.92

For the third year as we decided to shutdown the online sales, we had no marketing cost and because we increased the production units to 200,000 the cost for the plastic based decreased again. Here is the estimation for the third year and its calculation in detail:

- **Third Year MFC estimation:**
    - Parts (50 units)
        - Plastic Base = $75.00 (volume pricing reduction)
        - Plastic sheet = $4.50 (diameter and arms)
        - Eyelets = $1.50 , Assembly labor = $60.00 , Packing = $2.00
    - Total MFC = $573,000.00
    - Unit Production Cost = 573,000.00/200,000.00= $2.87

As it's demonstrated, the unit production cost for the first, second and third year is $5.14, $3.92, and $2.87. Appendix Q shows the spreadsheet for the first, second and third year.

SENSITIVITY ANALYSIS

After implementing the given spreadsheet and play with its sensitivity analysis section, we found some interesting result about our product and project. We found that unit price is a very significant sensitivity factor in our project. We priced our product based on the customers' surveys. For any reason, if the price increases or decreases about 30%, the output which is NPV would change significantly. The discounted volume pricing for base in year three is a good example. If price is higher than expected, the profit would reduce the given discounted price to publishers. On the other hand, some factors like competition, free market, customer expectation, and etc could decrease the price less than what we expected. That would affect NPV dramatically. We also found more sensitive factors. Product simplicity, low development costs, and manual assembly are some of them (see Appendix R).

KEY LEARNING

So, we look at these different scenarios to be ready for any crisis or even good news. Sometimes we need to be ready even for good news. We always remember professor Khormaei's experience about his new product launch which he was not ready for a high volume market demand and this good news became a crisis for him.

CONCLUSION

No impressive project at all. We were not exited as much as our team had been feeling when we started this project. Period Cash Flow and Cumulative Discounted Cash Flow diagrams proved our feeling (See Appendix S and T). After three years the NPV became $97,000. We decided this project is not profitable anymore and we are not willing to do it. We were so disappointed. After all those hard work, following the NPD process, and listening to the professor Khormaei's lecture, the result was negative. Where we made mistake? What was wrong with our project?

KEY LEARNING

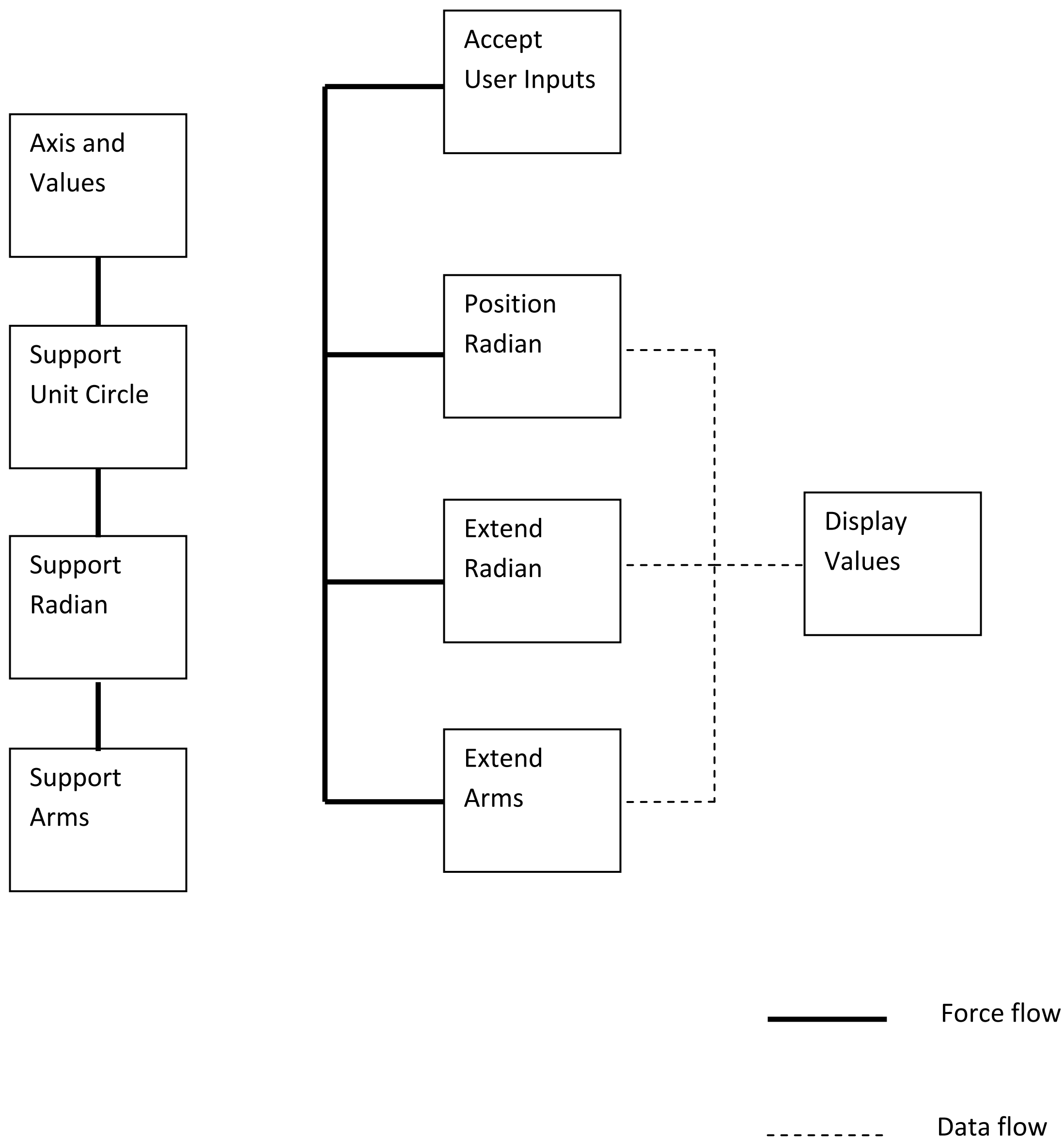
We were confused about "discount rate." We looked at this based on MARR which is minimum attractive rate of return. Based on the information from Advance Engineering Economic class, 10% is a conservative MARR for a company that doesn't know what its MARR is. Indeed, estimating MARR is more complicated and it needs some financial advisers input. But in this calculation discount rate is based on the opportunity cost for the investing money to compare with the interest rate in the bank if you want to borrow or for CD. While the interest rate for CD is almost 0.5% we have to think if we want to invest our money somewhere else, what the rate would be (of course it must be much more than 0.5%). Here, discount rate is the rate of return that could be earned on any investment in the market with same risk.

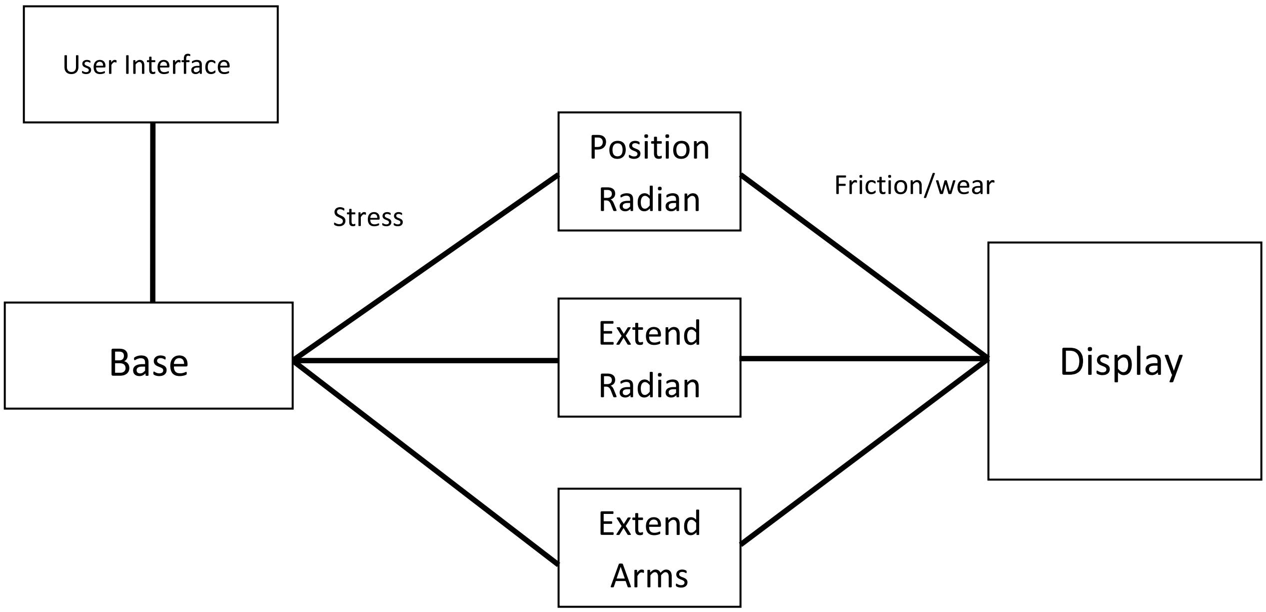
Also, we spend a lot of money for testing and development. That's why the cash flow diagram shows negative value for the whole first year. But if we cancel all those expenses although we get positive cash flow after the 7 month (who cares?), the total NPV doesn't get change dramatically (jump from 97,000 to 98,000).

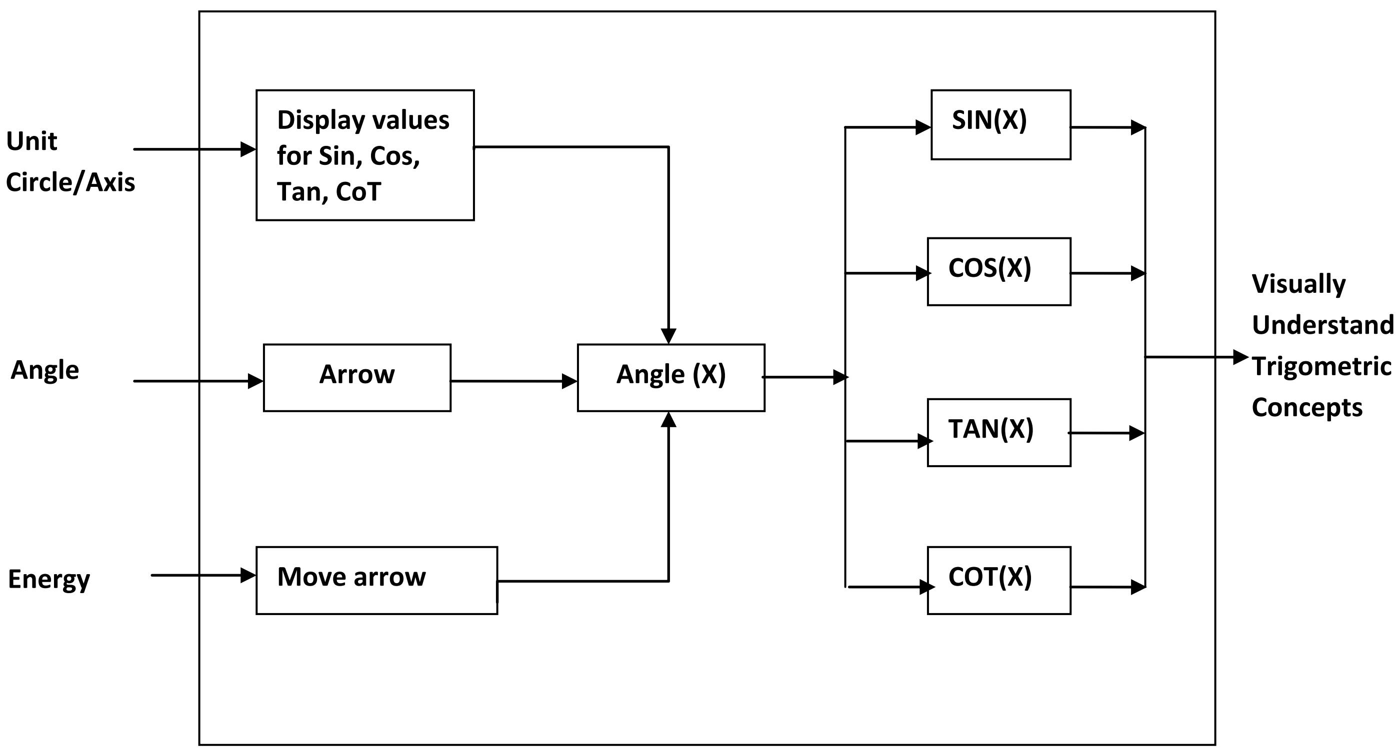
Do we really need to spend $1,000 monthly for internet marketing? But saving this money doesn't affect our NPV dramatically either. If we cancel this marketing investment even though we could save $1,000 per month and NPV increases from $97,000 to almost $99,000, there is big risk to have a lot of product which we can't sell. So we decided to not take this risk and stick with this ongoing marketing. But the spreadsheet is so sensitive to our discount rate. For example, if we change the discount rate to 7%, then NPV becomes almost $210,000 (for 5%, NPV becomes $358,000). So, if the discount rate for our company becomes less than 7%, the decision for our team would be changed.

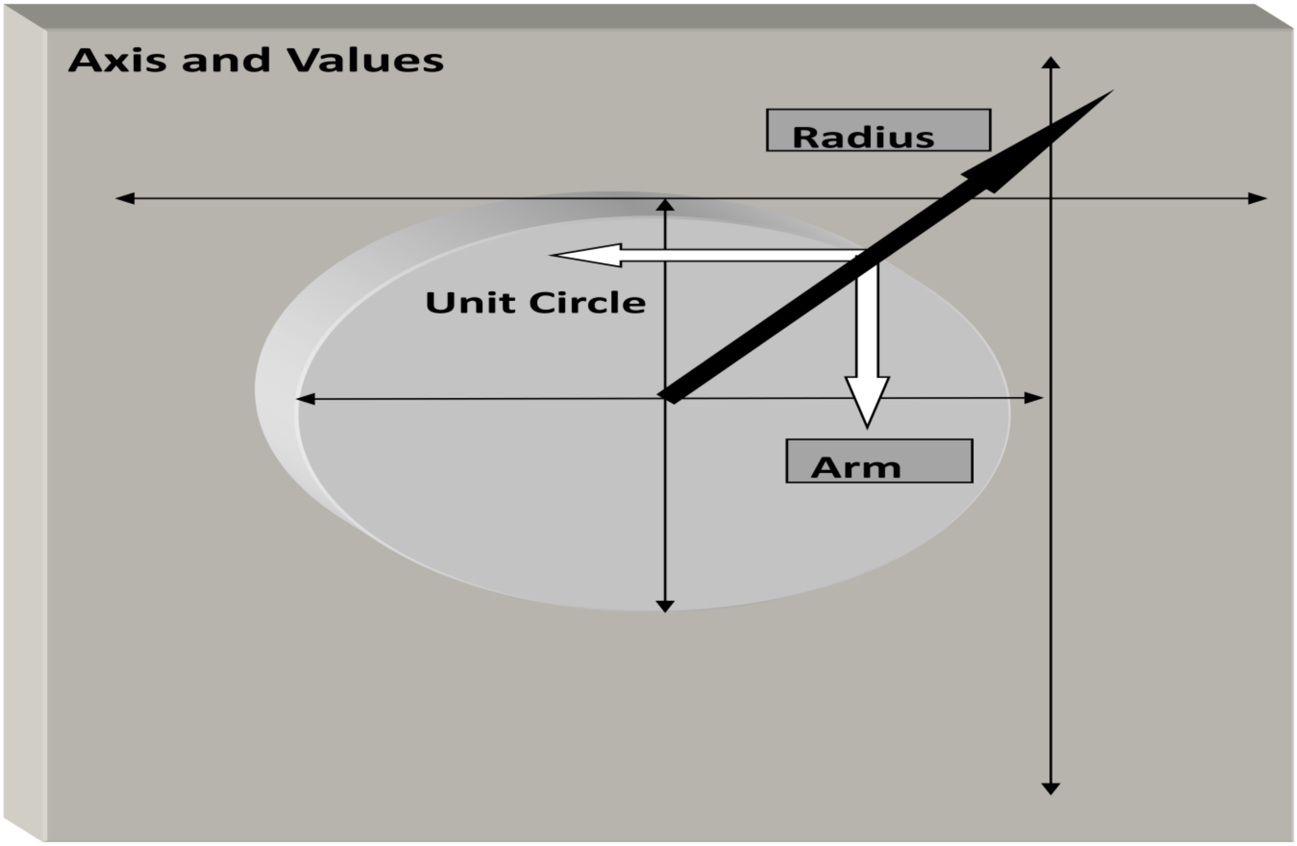
Through this project we learned how to move an idea from a basic raw idea to a real product before we spend a lot of money and produce the real product. Through these steps we can figure out the idea has the potential to get success in the market or not. Indeed, find the difference between an “invention” and “innovation.”

APPENDIX A- Schematics

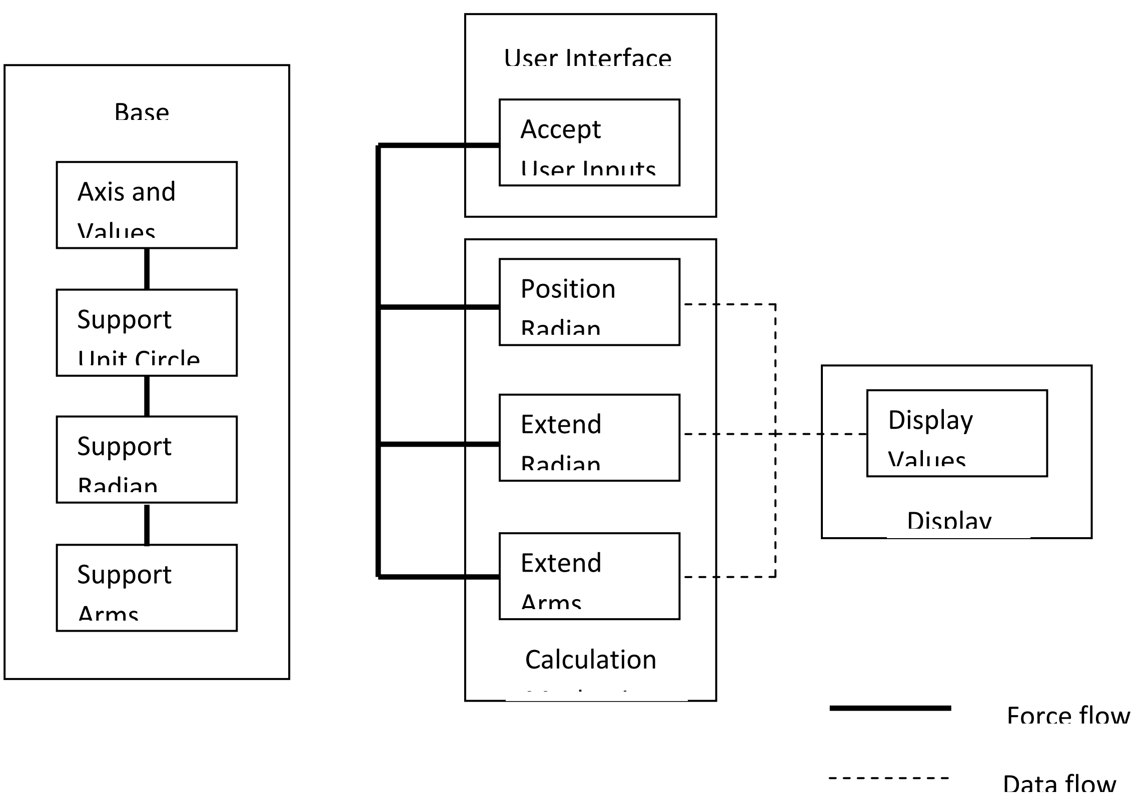



User Interface
Position Radian
Stress
Friction/wear
Base
Extend Radian
Display
Extend Arms


Unit Circle/Axis
Display values for Sin, Cos, Tan, CoT
SIN(X)
COS(X)
Angle
Arrow
Angle (X)
Visually Understand Trigometric Concepts
TAN(X)
Energy
Move arrow
COT(X)



APPENDIX B – Function Diagram- Product Architecture

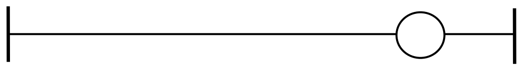
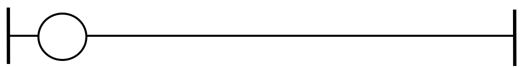
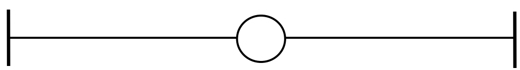
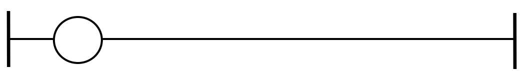
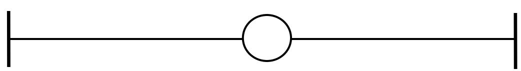
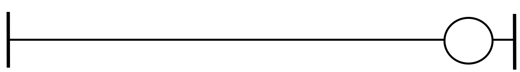
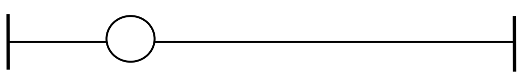
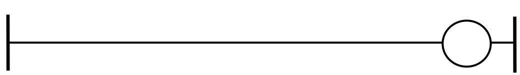


APPENDIX C – Initial Concept Matrix

Concepts			
Selection Criteria	**Paper Model**	**Hard Plastic Model**	**Software Model**
Ease of handling	0	+	-
Readability of settings	0	+	+
Accuracy	0	0	+
Durability	-	0	+
Portability	+	0	-
Attractiveness			
Ease of manufacturing	+	0	-
Sum +'s	2	2	3
Sum 0's	4	4	1
Sum -'s	1	0	3
Net Score	**1**	**2**	**0**
Rank	**2**	**1**	**3**

Concepts							
		Paper Model		**Hard Plastic Model**		**Software Model**	
Selection Criteria	**Weight**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**
Ease of handling	15%	3	0.45	3	0.45	1	0.15
Readability of settings	10%	3	0.30	4	0.4	2	0.20
Accuracy	30%	3	0.90	3	0.9	5	1.50
Durability	5%	1	0.05	3	0.15	4	0.20
Portability	15%	3	0.45	3	0.45	1	0.15
Attractiveness	20%	3	0.60	4	0.8	2	0.40
Ease of manufacturing	5%	5	0.25	3	0.2	2	0.10
			3.00		3.35		2.70
	Total Score		**3.0**		**3.35**		**2.70**
	Rank		**2**		**1**		**3**
	Continue?		**No**		**Develop**		**No**

APPENDIX D – Assessment of Industrial Design

Needs	Level of Importance	Explanation of Rating
Ergonomics		
Ease of use		It is important that the user can quickly understand the interface
Ease of Maintenance		This will require little maintenance
Number of user interactions		This will require a couple of simple user interactions
Novelty of User Interactions		User interactions are simple movements of product pieces
Safety		Few safety concerns except if pieces break off
Aesthetics		
Product Differentiation		Product differentiation and appeal important
Pride of ownership, fashion or image		Some users might take pride in product appeal
Team motivation		Team members feel this product has value

APPENDIX E – Second Concept Matrix

	Concepts				
Selection Criteria	**Teacher Model**	**Origami Model**	**Paper Model**	**Hard Plastic Model**	**Software Model**
Ease of handling	+	+	0	+	-
Readability of settings	+	+	0	+	+
Accuracy	0	0	0	0	+
Durability	0	-	-	0	+
Portability	-	+	+	0	-
Attractiveness					
Ease of manufacturing	0	-	+	0	-
Sum +'s	2	3	2	2	3
Sum 0's	3	1	4	4	1
Sum -'s	1	2	1	0	3
Net Score	**1**	**1**	**1**	**2**	**0**
Rank			**2**	**1**	**3**

		Concepts									
		Teacher Model		**Origami Model**		**Paper Model**		**Hard Plastic Model**		**Software Model**	
Selection Criteria	**Weight**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**
Ease of handling	15%	3	0.45	3	0.45	3	0.45	3	0.45	1	0.15
Readability of settings	10%	4	0.40	4	0.40	3	0.30	4	0.4	2	0.20
Accuracy	30%	3	0.90	3	0.90	3	0.90	3	0.9	5	1.50
Durability	5%	3	0.15	1	0.05	1	0.05	3	0.15	4	0.20
Portability	15%	3	0.45	4	0.60	3	0.45	3	0.45	1	0.15
Attractiveness	20%	3	0.60	4	0.80	3	0.60	4	0.8	2	0.40
Ease of manufacturing	5%	3	0.15	1	0.05	5	0.25	3	0.2	2	0.10
			3.10		3.25		3.00		3.35		2.70
	Total Score		**3.1**		**3.25**		**3.0**		**3.35**		**2.70**
	Rank		**3**		**2**		**4**		**1**		**5**

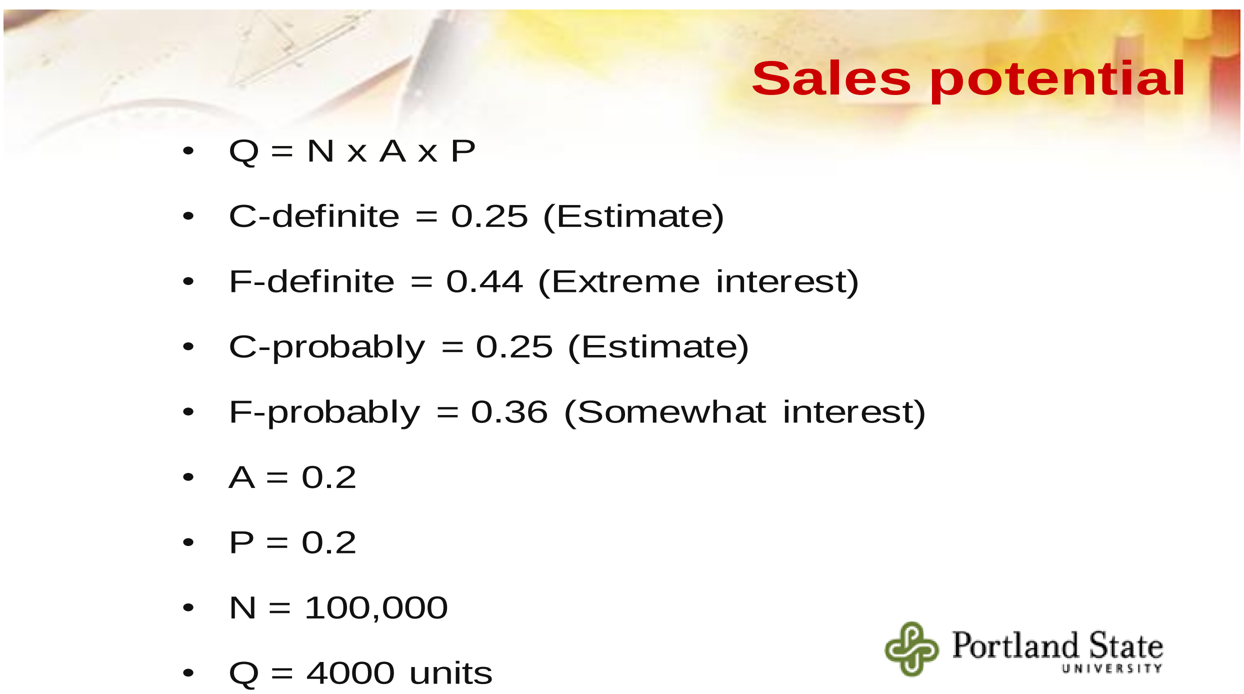
APPENDIX F – Customer Concept Matrix

Selection Criteria	Weight																									%
Ease of handling	15%	15	10	20	20	10	5	10	10	20	20	20	10	25	15	20	5	10	20	10	15	20	20	10	20	15
Readability of settings	10%	10	10	15	20	10	20	20	10	10	5	5	10	10	5	5	10	10	5	10	10	20	20	5	10	11
Accuracy	30%	20	30	0	10	40	20	10	10	20	20	10	10	10	20	10	10	25	10	20	10	20	20	30	20	17
Durability	5%	10	20	20	10	15	15	10	10	5	5	15	10	5	20	10	10	5	5	10	10	0	10	30	5	11
Portability	15%	10	10	20	20	10	35	10	10	5	5	15	10	20	20	25	10	10	20	10	20	20	5	5	20	14
Attractiveness	20%	15	10	5	5	5	0	30	40	30	40	25	40	25	15	20	50	40	30	30	35	20	20	10	20	24
Ease of manufacturing	5%	20	10	20	15	10	5	10	10	0	5	10	10	5	5	10	5	5	10	10	0	0	5	10	5	8
	100%																									100

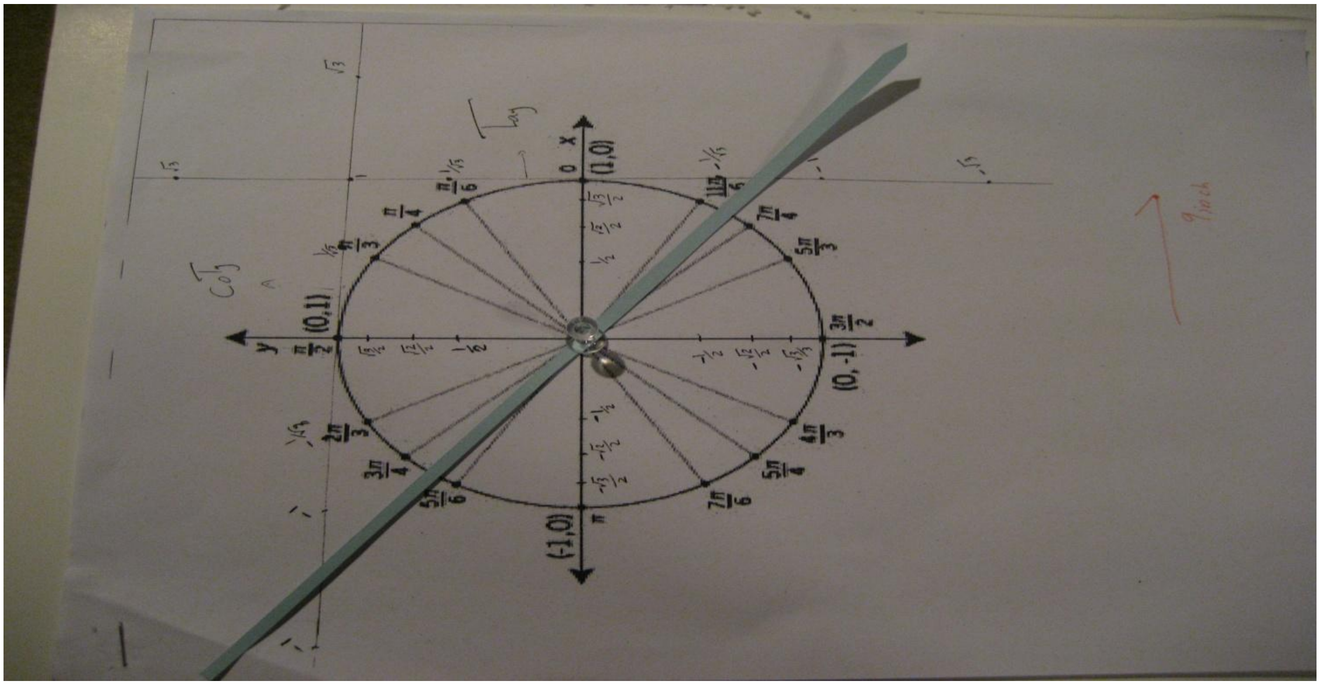
Concepts											
		Teacher Model		**Origami Model**		**Paper Model**		**Hard Plastic Model**		**Software Model**	
Selection Criteria	**Weight**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**	**Rating**	**Weighted Score**
Ease of handling	15%	3	0.45	3	0.45	3	0.45	3	0.45	1	0.15
Readability of settings	11%	4	0.44	4	0.44	3	0.33	4	0.44	2	0.22
Accuracy	17%	3	0.51	3	0.51	3	0.51	3	0.51	5	0.85
Durability	11%	3	0.33	1	0.11	1	0.11	3	0.33	4	0.44
Portability	14%	3	0.42	4	0.56	3	0.42	3	0.42	1	0.14
Attractiveness	24%	3	0.72	4	0.96	3	0.72	4	0.96	2	0.48
Ease of manufacturing	8%	3	0.24	1	0.08	5	0.40	3	0.24	2	0.08
			3.11		3.11		2.94		3.35		2.36
	Total Score		**3.11**		**3.11**		**3.0**		**3.35**		**2.36**
	Rank		**2**		**2**		**3**		**1**		**4**
	Continue?		**No**		**No**		**No**		**Develop**		**No**

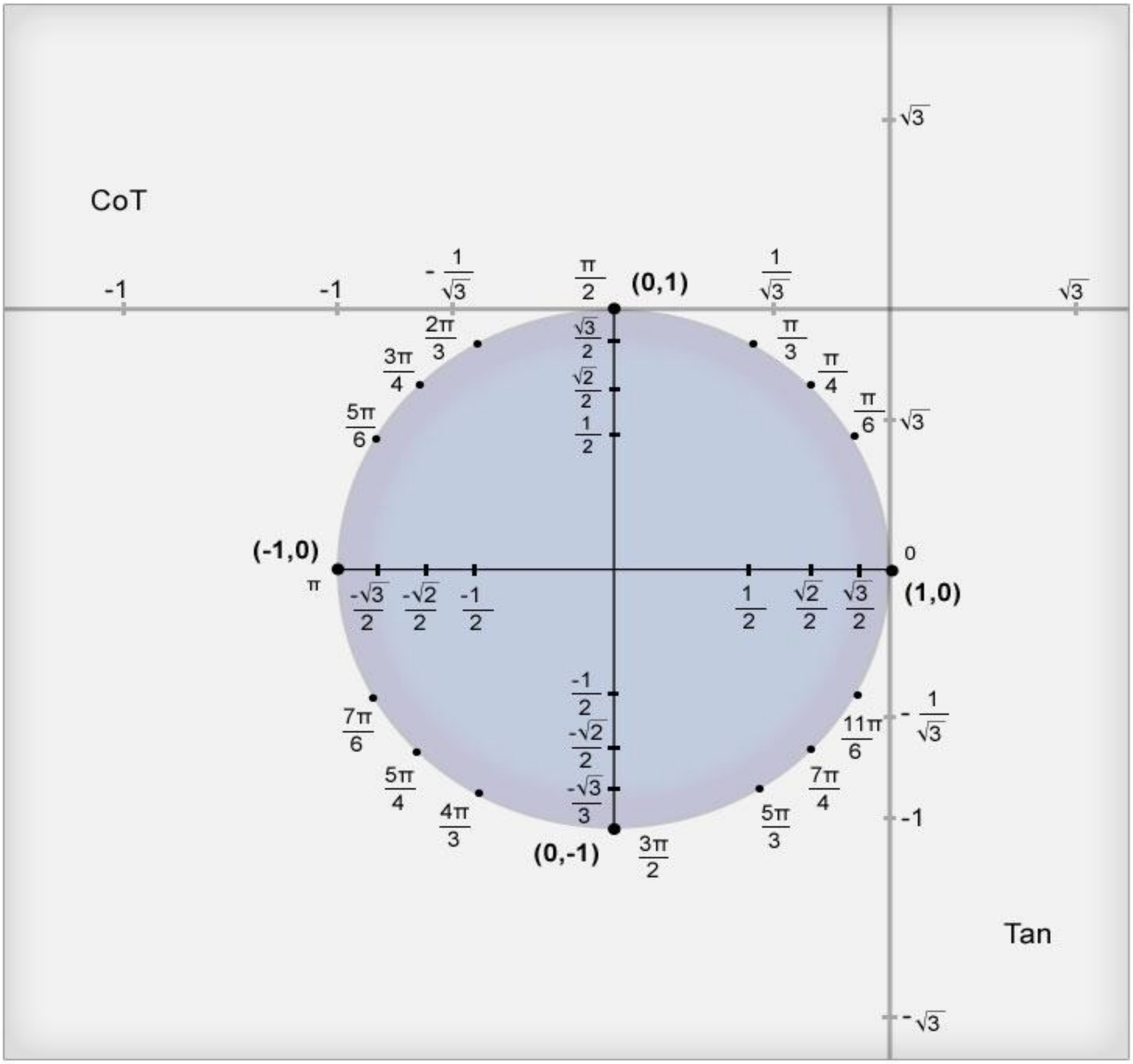
APPENDIX G – Customer Pricing, Need, Interest

Expected Price	Lowest price	Highest price	Need level	Product Interest
7.5	5	20	High	Extreme
15	5	25	Medium	Somewhat
10	5	20	High	Extreme
30	10	50	Medium	Somewhat
12	5	30	High	Extreme
0	5	10	None	Not sure
7	5	30	High	Somewhat
15	4	25	High	Extreme
5	2	10	Medium	Not very
15	10	20	High	Extreme
7	3	17	None	Somewhat



APPENDIX H – Initial Prototype





CoT
Tan
(0,1)
(-1,0)
(1,0)
(0,-1)
-1
-1
$-\frac{1}{\sqrt{3}}$
$\frac{1}{\sqrt{3}}$
$\sqrt{3}$
$\frac{\pi}{2}$
$\frac{2\pi}{3}$
$\frac{3\pi}{4}$
$\frac{5\pi}{6}$
$\frac{\pi}{3}$
$\frac{\pi}{4}$
$\frac{\pi}{6}$
π
0
$\frac{7\pi}{6}$
$\frac{5\pi}{4}$
$\frac{4\pi}{3}$
$\frac{3\pi}{2}$
$\frac{5\pi}{3}$
$\frac{7\pi}{4}$
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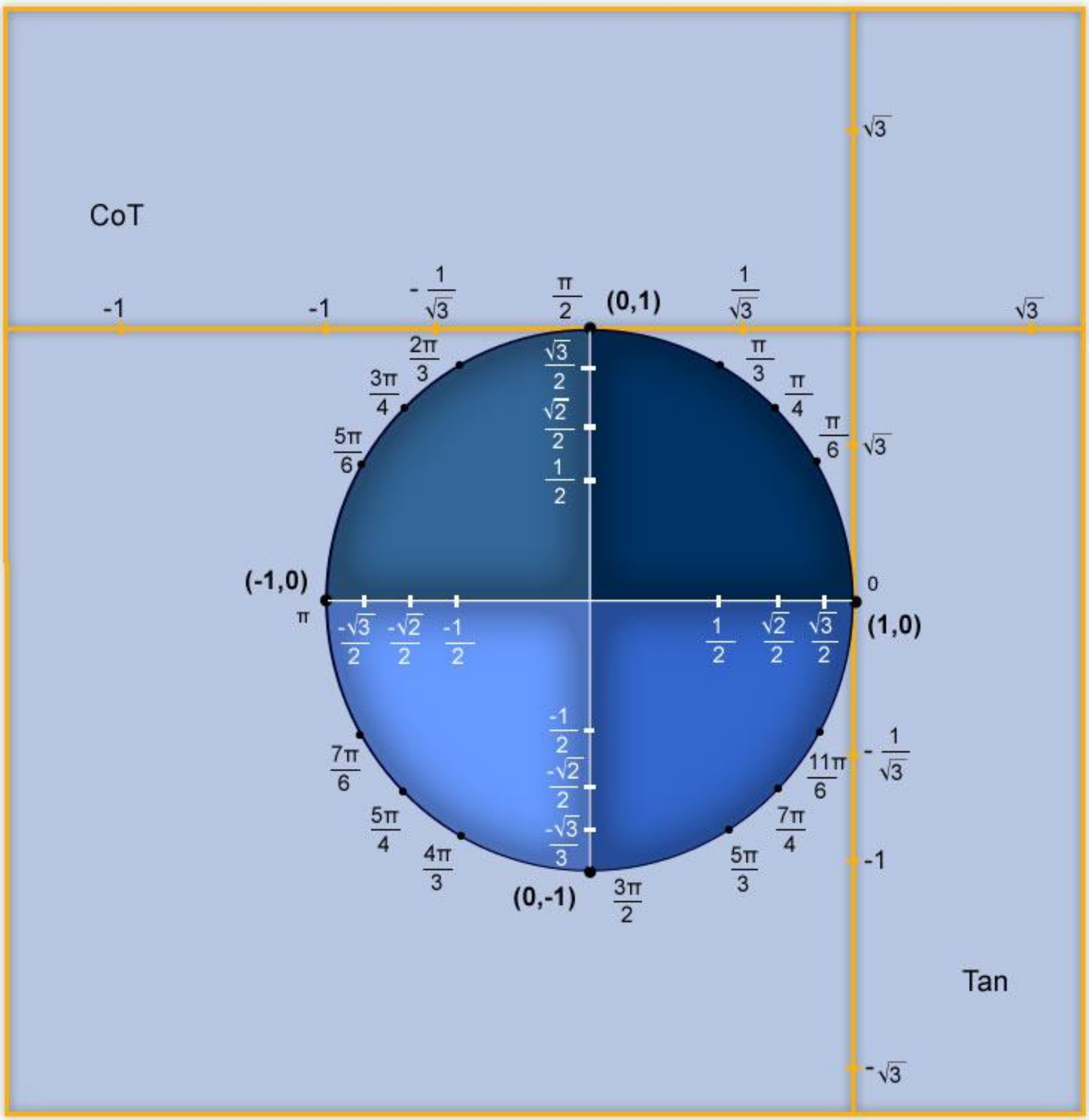
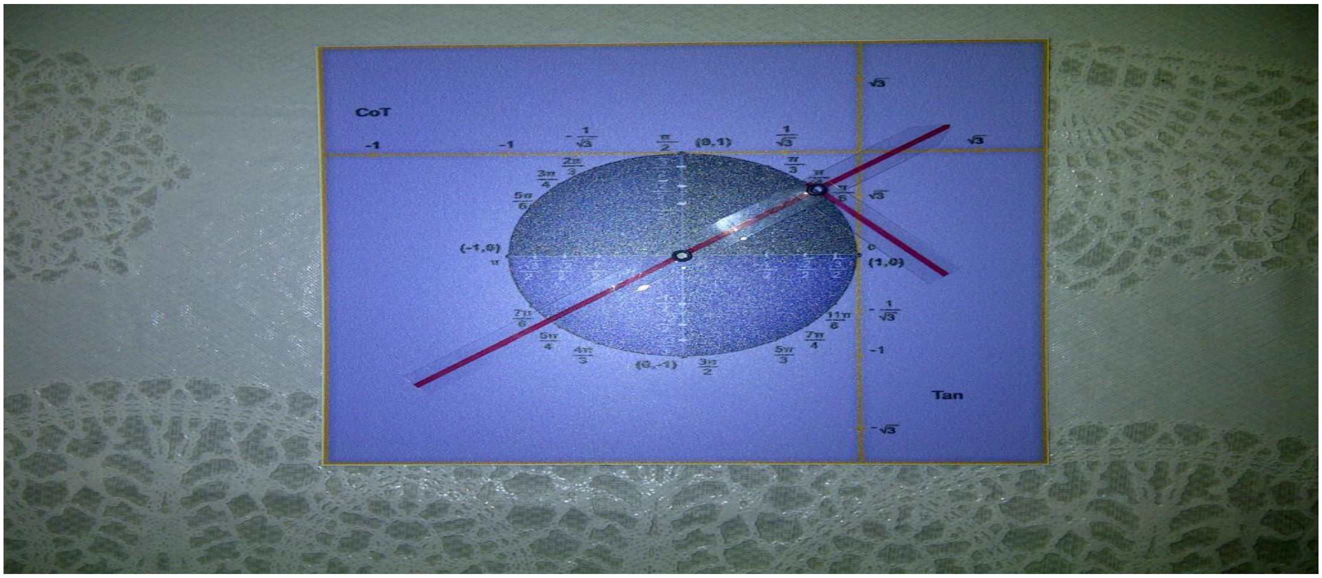
$\frac{-\sqrt{3}}{2}$
$\frac{-\sqrt{2}}{2}$
$\frac{-1}{2}$
$\frac{-\sqrt{3}}{3}$
$\sqrt{3}$
$\sqrt{3}$
$-\frac{1}{\sqrt{3}}$
-1
$-\sqrt{3}$

APPENDIX I – Concept Prototype



APPENDIX J – Final Prototype



APPENDIX K– ASSEMBLY COST ESTIMATIO BEFORE DFA

Component	Quantity	Handling Time	Insertion Time	Total Time
Base	1	3		3
Axis	2	3	5	16
Unit Circle	1	3	5	8
Ex-Arm	1	3	5	8
Pre-Arm	2	3	5	16
Total time (seconds)				51
Assembly Cost at $9/hour				0.13

APPENDIX L – ASSEMPLY COST ESTIMATIO AFTER DFA

Component	Quantity	Handling Time	Insertion Time	Total Tim
Base	1	3		3
Diameter	1	3	5	8
Small Arm	1	3	5	8
Total Time (seconds)				19
Assembly Cost at $9/hour				0.05

APPENDIX M – LOGOS

√TrigoPad™ √TrigoPad™

Trigo(Pad)™ Trigo(Pad)™

{Trigo√Pad}™ {Trigo√Pad}™

Trigo/πad™ Trigo/πad™

Trigo|Pad™ y x Trigo|Pad™ y x

APPENDIX N – SECOD YEAR MARKETING PLAN ESTIMATION

Marketing Plan Estimation

- Second Year
  - Geography: State of Oregon
  - Market Size:
  - N=15*5000=75000 trig students
    q=75000*0.2*0.2=3000
    expect to sell online; q2=0.5*3000=1500
    total Q=4500
  - Market Segmentation: Community College Students
  - Target Market: Oregon Community College Students
  - Marketing Channel: Oregon Community Colleges Book Stores & Online

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APPENDIX O – THIIRD YEAR MARKETING PLAN ESTIMATION

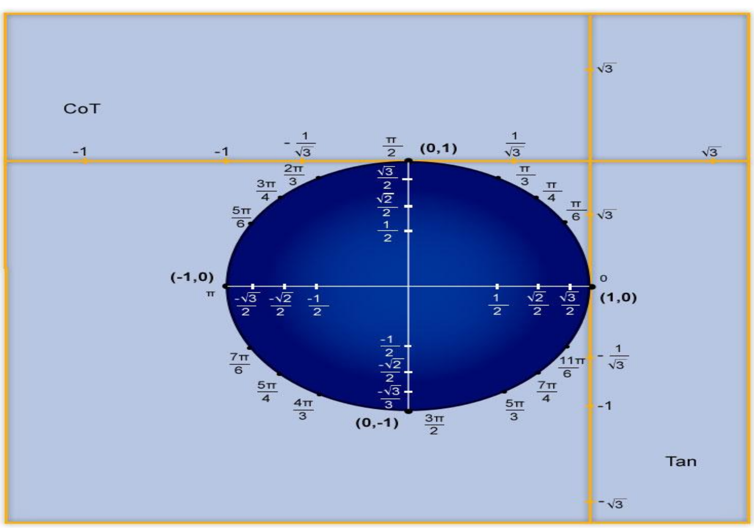
Marketing Plan Estimation

- Third Year
  - Geography: U.S.A
  - Market Size:
    - 1800 Community Colleges in the U.S
    - 560 trigonometry students at PCC per year
    - N=1800*560=1,008,000 U.S trig students
    - Expect to sell 20% to publishers Q= 1,000,000*0.2=200,000
  - Market Segmentation: College Trigonometry Students
  - Target Market: College Students
  - Marketing Channel: Publishers' distributers

TrigoPad™

APPENDIX P – TRIGOPAD PRODUCT DISCRIPTION

TrigoPad™



- Designed in 2011 by Graphical Designer for TrigoPad™
- Geometric integration:
  - Plastic Base
  - Unit Circle
  - Plastic Radius
  - Arms
  - Eyelets

TrigoPad™

APPENDIX Q –THE SPREADSEET FOR THE 3 YEARS

First Year - NPD Economics

Period	1	2	3	4	5	6	7	8	9	10	11	12
Development	-96	-500	0	0	0	0	0	0	0	0	0	0
Testing	0	-300	0	0	0	0	0	0	0	0	0	0
Tooling and Ramp-Up Costs	0	-50	0	0	0	0	0	0	0	0	0	-250
Market Introduction	0	0	0	-595	0	0	0	0	0	0	0	-2000
Ongoing Marketing Costs	0	0	0	0	0	0	0	0	0	0	0	0
Production Cost	0	0	0	-514	0	0	-514	0	0	-514	0	0
Product Revenues (wholesale)	0	0	0	1500	0	0	1500	0	0	1500	0	0
Unit Sales	0	0	0	100	0	0	100	0	0	100	0	0
Unit Price	0	0	0	15	0	0	15	15	15	15	15	15
Unit Production Cost	0	0	0	-5.14	-5.14	-5.14	-5.14	-5.14	-5.14	-5.14	-5.14	-5.14
Period Cash Flow	-96	-850	0	391	0	0	986	0	0	986	0	-2250
PV Time Period 0	-87	-702	0	267	0	0	506	0	0	380	0	-717
Cumul. Disc. Cash Flow	-87	-790	-790	-523	-523	-523	-17	-17	-17	363	363	-353

Second Year - NPD Economics

Period	13	14	15	16	17	18	19	20	21	22	23	24
Development	0	0	0	0	0	0	0	0	0	0	0	0
Testing	0	0	0	0	0	0	0	0	0	0	0	0
Tooling and Ramp-Up Costs	0	0	0	0	0	0	0	0	0	0	0	-1000
Market Introduction	0	0	0	0	0	0	0	0	0	0	0	0
Ongoing Marketing Costs	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000	-1000
Production Cost	-5880	0	-3920	0	0	-3920	0	0	-3920	0	0	0
Product Revenues (wholesale)	22500	0	15000	0	0	15000	0	0	15000	0	0	0
Unit Sales	1500	0	1000	0	0	1000	0	0	1000	0	0	0
Unit Price	15	15	15	15	15	15	15	15	15	15	15	15
Unit Production Cost	-3.92	-3.92	-3.92	-3.92	-3.92	-3.92	-3.92	-3.92	-3.92	-3.92	-3.92	-3.92
Period Cash Flow	15620	-1000	10080	-1000	-1000	10080	-1000	-1000	10080	-1000	-1000	-2000
PV Time Period 0	4525	-263	2413	-218	-198	1813	-164	-149	1362	-123	-112	-203
Cumul. Disc. Cash Flow	4171	3908	6321	6103	5905	7718	7555	7406	8768	8645	8534	8331

Third Year - NPD Economics

Period	25	26	27	28	29	30	31	32	33	34	35	36
Development	0	0	0	0	0	0	0	0	0	0	0	0
Testing	0	0	0	0	0	0	0	0	0	0	0	0
Tooling and Ramp-Up Costs	0	0	0	0	0	0	0	0	0	0	0	0
Market Introduction	0	0	0	0	0	0	0	0	0	0	0	0
Ongoing Marketing Costs	0	0	0	0	0	0	0	0	0	0	0	0
Production Cost	-143500	0	0	-143500	0	0	-143500	0	0	-143500	0	0
Product Revenues (wholesale)	500000	0	0	500000	0	0	500000	0	0	500000	0	0
Unit Sales	50000	0	0	50000	0	0	50000	0	0	50000	0	0
Unit Price	10	10	10	10	10	10	10	10	10	10	10	10
Unit Production Cost	-2.87	-2.87	-2.87	-2.87	-2.87	-2.87	-2.87	-2.87	-2.87	-2.87	0	0
Period Cash Flow	356500	0	0	356500	0	0	356500	0	0	356500	0	0
PV Time Period 0	32904	0	0	24721	0	0	18573	0	0	13954	0	0
Cumul. Disc. Cash Flow	41234	41234	41234	65955	65955	65955	84528	84528	84528	98483	98483	98483

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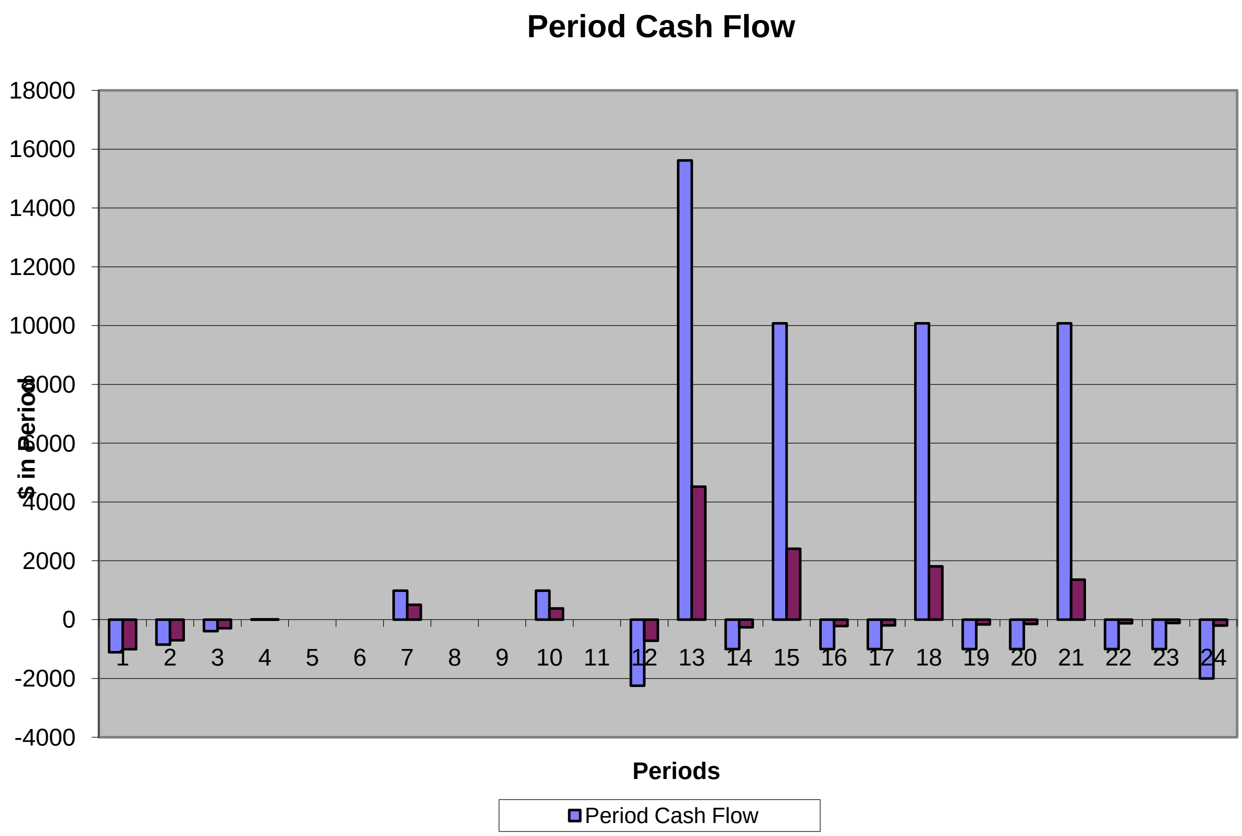
APPENDIX R– SESATIVITY ANALYSIS

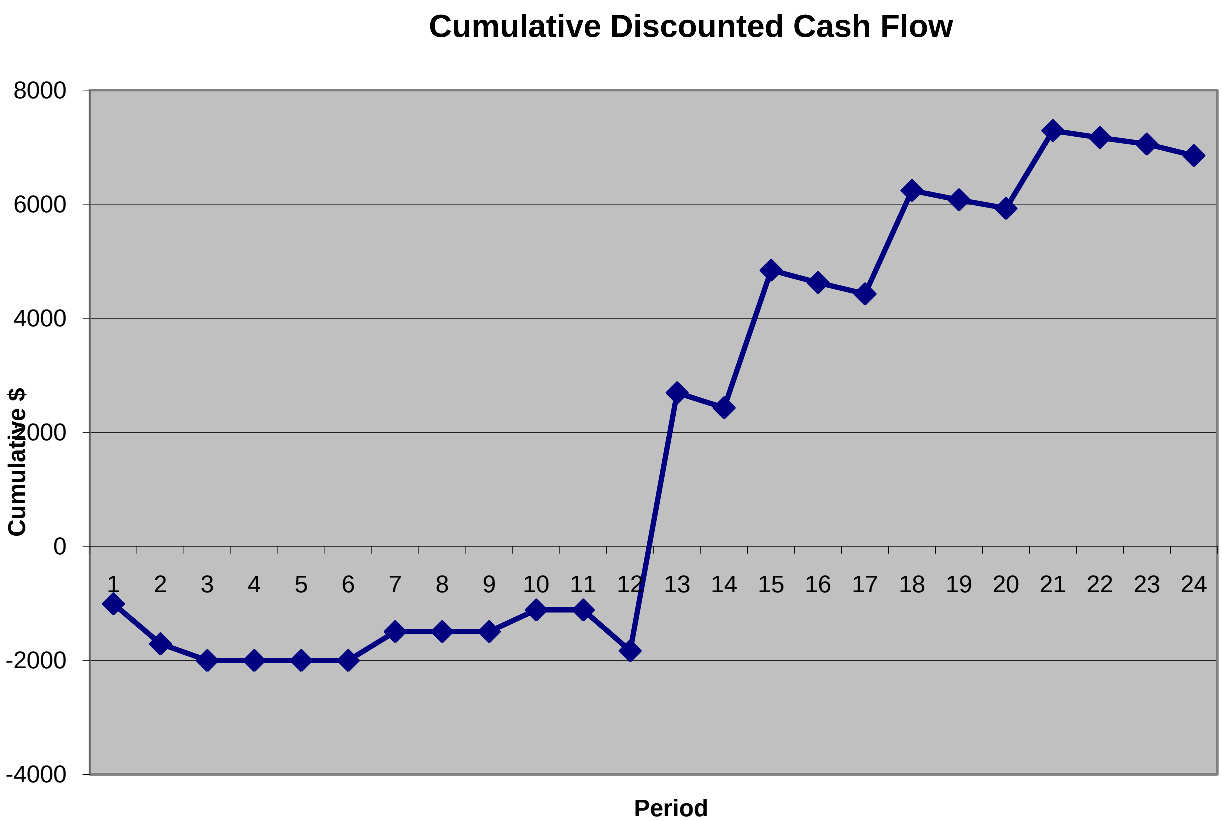
MODEL VALUES

	first	last	base burn rate	adjusted burn rate	%Δ from base value	$Δ from base value
Development	1	3	-598	-718	20.0%	-120
Testing	1	4	-300	-390	30.0%	-90
Tooling and Ramp-Up Costs	4	5	-50	-55	10.0%	-5
Market Introduction	4	5	-595	-774	30.0%	-179
Ongoing Marketing Costs	5	12	-10000	-11000	10.0%	-1000
Unit Sales	5	24	300	390	30.0%	90
Unit Price	5	24	15.000	19.500	30.0%	4.50
Unit Production Cost	5	24	-5.140	-6.682	30.0%	-1.54
Discount Rate (per time period)		10.00%				

APPENDIX S – Cash Flow Chart



APPENDIX T


Cumulative Discounted Cash Flow
8000
6000
4000
2000
0
-2000
-4000
Cumulative $
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Period