

Origami Spyglass Design Feasibility for Economic and Educational Advancement in Lesoit, Tanzania

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Executive Summary:

The focus of this project is to present the community of Lesoit, Tanzania with a product whose main function is to help facilitate economic and educational development within the community. This product is to be an origami spyglass incorporated into an educational booklet which focuses on wildlife education. The spyglass is intended to be assembled from a single pre-cut page of the booklet and folded into the three-dimensional scope to be used for viewing the local wildlife that is described within the booklet. A lesson plan will also be created in addition to the booklets to ensure more of a mentorship-type environment, which has been shown to increase student interest and reduce student dropout rates. This design is to be constructed in such a way that the women in the village of Lesoit will be able to manufacture these booklets and market them to nearby other communities boost their local economy. The design is also intended to be modified for tourism applications as well, since recent studies have shown that the tourist population and spending has increased by 122% and \$27.5 million respectively.

The manufacturing process of these booklet will involve a laser cutting printer to speed the process of cutting pages for the housing of the spyglass, as well as a clear-resin 3D printer that will be used to develop lenses for the spyglass. These production options have proven to be the simplest, most cost effective, and versatile products compared to processes which would use recycled materials and plastic/glass molding techniques. To meet the power need of the manufacturing machinery, the Maasai community will need to set up a small workspace in the nearby city of Arusha. After production is completed, sets may be brought back to the village to assemble and distribute the booklets.

After initial prototype testing, the Tri-Hex design is the best rigid structure so far that offers several contact points for lens attachment. This design is constructed from a single sheet of paper with minimal cuts, meaning the space between the lenses has minimal interference from ambient light. Future plans for mechanical testing will determine if the product needs to be reinforced through supplemental supports like an internal truss system.

Future plans for the project will include coordinating with other school departments to allow for outsourcing of specialized tasks such as graphic design, business planning, and lesson plan design. Testing and redesign of the spyglass will also be conducted in future iterations of this product.

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1 TABLE OF CONTENTS

| | | |
|-------|--|----|
| 2 | Background..... | 6 |
| 2.1 | Technical | 6 |
| 2.2 | Cultural..... | 6 |
| 2.3 | Problem Statement and Objectives | 7 |
| 3 | Spyglass Design..... | 8 |
| 3.1 | Options for Manufacturing..... | 8 |
| 3.2 | Design..... | 9 |
| 3.2.1 | Educational Booklet..... | 9 |
| 3.2.2 | Paper Housing | 9 |
| 3.2.3 | 3D Printed Lenses | 9 |
| 4 | Lens Calculations | 10 |
| 5 | Housing Designs and Prototyping | 12 |
| 5.1 | Housing Designs | 12 |
| 5.2 | Fastening Designs | 14 |
| 5.3 | Design Selection for Prototype Phase | 15 |
| 5.4 | Prototyping..... | 15 |
| 5.4.1 | Material Performance Comparison | 19 |
| 5.4.2 | Fastener Design and Performance | 20 |
| 5.4.3 | Results and Recommendations | 21 |
| 6 | Business Model..... | 21 |
| 6.1 | Operation Guide | 21 |
| 6.2 | SWOT Analysis..... | 22 |
| 7 | Recommendations | 23 |
| 8 | Future Work..... | 23 |
| 9 | Conclusion..... | 28 |
| 10 | References..... | 29 |
| 11 | Appendices..... | 29 |

List of Figures:

List of Tables:

2 BACKGROUND

2.1 TECHNICAL

FIGURE 1: Foldscope Microscope Design

A research team at Stanford University had designed the Foldscope, a low cost, durable design for a microscope that could be implemented in third world countries. The product made education and real-world health applications to be both affordable and attainable in communities that otherwise could not afford attaining and maintaining lab equipment [FOLDSCOPE].

The foldscope design inspired this capstone project, where a low cost, optics education tool could be created through simple assemblies of paper products. However, instead of focusing solely on educational benefits for the community, our project aims to design an easy-to-manufacture product that could be assembled in a third world country in order to facilitate economic growth for the community.

The original foldscope design is a microscope that is made out of paper and small lenses that can be assembled in multiple configurations depending on the application. Similar to the foldscope, we would apply elements of optics to create an education tool, though we would pursue a spyglass design instead of a microscope. Our product will be designed to be assembled from pre-cut paper housing designs that can be folded into a rigid body with secured lenses.

In addition to creating a paper spyglass, the project plan is to incorporate the spyglass into an educational booklet focused on wildlife education in order to reduce dropout rates and increase interest in the region. If the village of Lesoit would like more economic opportunities, the educational design could be adapted to more lucrative applications like tourism. The foldscope design is the basis of our project, but we are taking the idea and applying it to a different field of education while also allowing the involved communities to build income by marketing this product.

2.2 CULTURAL

The Maasai people in Tanzania have rural communities such as Lesoit Village where education and professional opportunities are limited for women. These limitations exist through several barriers within the culture, geography, and economy in these communities. These barriers prevent female students from pursuing higher education and professional opportunities for fields in Science, Technology, Engineering, and Mathematics (STEM). There is a need for creating accessible education for young children in rural communities and providing an improved outlook for Maasai women in the job market.

Maasai culture in Tanzania is driven by gender roles that place limitations on the education and professional development of women. These limitations often take the form of expectations such as chores and financial burdens that are exclusive to women in most households. This

cultural outlook has an impact on young Maasai girls as households are less likely to invest in schooling or training for females [A. ELLIS].

Household chores for Maasai women that consume large amounts of time and energy can range from gathering firewood and water to processing food crops and taking care of the sick. These responsibilities are barriers for business oriented women that are seeking to earn a living wage. These barriers are even harsher when there are children involved as opportunities for daycare are expensive.

Any women that manage to earn a wage tend to earn 3.5 times less than men, regardless of qualifications. In spite of this, the bulk of household expenses are proportionally affected by how much is earned by women in a household [A. ELLIS].

Common factors that prevent young students from pursuing opportunities in schooling and training tend to be related to economics and geography. Many rural communities have a single school available which can be physically distant for some families. This distance can serve as a deterrent for children that walk to school. Additionally, low income households face difficult financial decisions that impact access to education. Expenses related to education create a strain for these families. Children sometimes drop out from school to cut these expenses while being put to work to help support their families [ALARMING DROPOUT RATES].

These geographic and economic barriers create a need for affordable education that can be accessible to low income households in rural communities. This need is emphasized for female students as cultural norms reduce opportunities for young girls and have professional impacts for Maasai women.

2.3 PROBLEM STATEMENT AND OBJECTIVES

The education system in Tanzania should prepare students for technical careers in STEM, regardless of gender or economic background. Additionally, the women of Tanzania should have professional opportunities to earn income in a workplace that is compatible with cultural norms in their community. Designs for academic tools should offer affordable accessibility to education beyond the existing opportunities found in rural schools. Designs should also take advantage of the Tourism industry to offer new products and souvenirs that would impact the local economy.

However, the current education system faces dropout rates throughout all levels of primary school, going as high as a 7% drop out rate for the graduating 5th grade class of 2009 [2]. The cultural norms currently place a higher value in educating young boys instead of girls as grown women are defined by household responsibilities instead of professional development. Current job markets offer women work in agriculture and unpaid labor with a higher frequency while men have better opportunities in pursuing manufacturing and other technical jobs [1]. These current trends show that less resources are invested in a viable workforce than can be found in Maasai women.

By introducing manufacturing technologies such as 3D printing and a laser cutting printer, new job opportunities can be introduced for rural families. Sustainable business opportunities

can then rely on these manufacturing technologies as well as the local Tourism attractions. Proposed designs for new academic tools can then be formed locally, offering better costs to schools and rural families. These solutions can improve educational resources, reduce dropout rates, and increase career opportunities for women.

3 SPYGLASS DESIGN

3.1 OPTIONS FOR MANUFACTURING

Many different materials and manufacturing processes were researched to determine the best methods for both lens and housing production. Lens molding was the first manufacturing process to be ruled out during the research phase due to the amount of high precision post-processing that had to be done to obtain usable lenses [CITE TEKRON?]. Recycled materials were also the first to be ruled out because of the number of contaminants in both recycled glass and plastics [5 (from GP)]. Since these materials and processes were not usable for the spyglass application, research focused on the possibility of 3D printing lenses which led to the discovery of the Form 1+ printer. This printer uses a specific laser printing process that allows for up to 4 times the resolution of heated filament 3D printers and also has the capability of printing using a clear, acrylic resin [FORMLABS].

Figure 2: Form 1+ 3D Printer

As of now, this 3D printer is the best option for lens manufacturing, although the village of Lesoit does not have electrical energy available, so the printer would have to be used in a small workspace in the nearby city Arusha. The housing production research started by looking at the foldscope production equipment, which was an industrial sized laser cutting printer. Since this project is focused more around creating a pilot business and up-scaling in the future, the industrial capabilities were unnecessary. Looking toward more personal laser cutting printers, the Glowforge printer was found and was determined to be the best option due to its size, price, ease of use, and versatility.

Figure 3: Glowforge Laser Cutting Printer

The Glowforge has the capability of cutting through other materials like leather which would also allow the local women to use this equipment to produce more retail products in the future [CITE GLOWFORGE]. After researching other local production methods in Tanzania, it was determined that the Form 1+ and the Glowforge printers are the most feasible approach at this point.

3.2 DESIGN

3.2.1 Educational Booklet

As mentioned earlier, the spyglass design this project is focused around is to be contained in an educational booklet based on local wildlife. This booklet will house information on a variety of wildlife that is known to inhabit the regions applicable to the region where the booklets are being produced. It is planned that the engineering department will partner with NAU art and education departments to develop this booklet and provide meaningful information as well as interesting and accurate artistic representations of the animals discussed. The spyglass is to be installed in the back of the booklet, where the housing can be removed from a single page and one of the final pages is cut to safely carry the 3D printed lenses.

3.2.2 Paper Housing

The main function of the spyglass housing is to provide a sturdy, durable structure for the 3D printed lenses. The housing is also to be cut from a single page of the booklet and perforated to make the intended folds easy to reproduce by any child 8 years of age or older. These criteria are applied to the housing prototype testing, outlined later in the report, in which a final design is chosen based on its performance in these fields.

3.2.3 3D Printed Lenses

The lenses are the most crucial part of the spyglass assembly simply because they are what provides the magnification needed to examine wildlife from a distance. The proposed magnification of the spyglass is to be between 10 and 20 times magnification. This range will allow for the determination of the focal point of the lenses and provide the dimensions required to run optical simulations in the Zmax program and test different magnification values.

4 LENS CALCULATIONS

The team chose the Galilean telescope because it is easy to construct and build, so the kids could build it by their own. Because the focal point is going to be the eye itself, it will help us with the calculation.

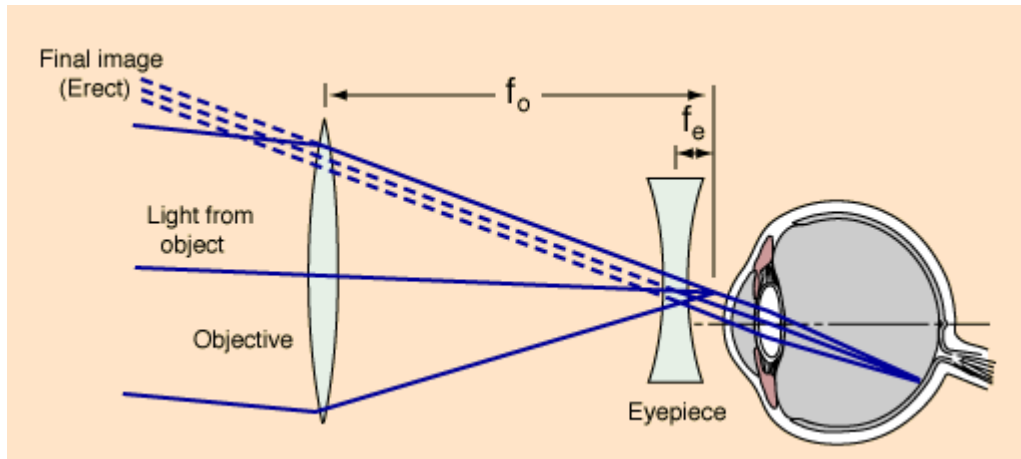


Figure 1: Galilean telescope [1]

Galilean telescope has two lenses one is convex which is going to be in the front of the telescope, and the other one is concave, it is going to be in the back of the telescope as shown in figure 1 above [1]. The lens sets on the either side of the telescope such that the focal point of the eyepiece lens is the same as the focal point for the objective. The Galilean telescope was determined as the first telescope can be expand the range of magnification, and it has more the 3x magnification. A thing considered to be a problem or a disadvantage of the Galilean telescope that it has a small field of view [2].

In order to design a lens we need to assume some value, the team came up with some values as the length of the telescope and magnification.

The team used three equations in order the design the lens theoretically [3,4].

$$1/f = (n-1)(1/r_1 - 1/r_2)$$

This equation is the focal length equation, and it is only applied for one lens, where

f : The focal length

n : The material refractive index.

r_1 : The outer radius of curvature.

r_2 : The inner radius of curvature.

For the material refractive index for photopolymer which is the material provided from the 3D printer.

$$L = f_o + f_e$$

This the length of telescope equation, where

L : The length of the telescope.

f_o : The focal length of the objective lens.

f_e : The focal length of the eyepiece lens.

This equation allows us to determine the focal length of the objective and the focal lens of the eyepiece lens.

$$M = -f_o/f_e$$

This equation is the magnification equation, M represents the magnification, and this equation allows us too to determine the focal length of the objective lens and the focal length of the eyepiece lens.

The table below shows the values the team chose for the length of the telescope and for the magnification, and it shows the values after the team did the calculations.

Table 1: values predicted and calculated for designing the lens

| Lens Properties | Current values |
|---------------------------------------|----------------|
| Material Refractive Index (n) | 1.514 [5] |
| Length of Spyglass (L) | 15 cm (chosen) |
| Magnification (M) | 10x (chosen) |
| Objective Lens Focal Length (F_o) | 16.67 cm |
| Eyepiece Lens Focal Length (F_e) | -1.67 cm |

5 HOUSING DESIGNS AND PROTOTYPING

5.1 HOUSING DESIGNS

Square Cross-Section

This design was created with the intention of keeping the assembly and blueprint design as simple as possible. The design's simplicity would allow for young students to assemble the spyglass with minimal or no help from the class teacher. It would also help the women who are responsible for manufacturing to learn how it was designed and facilitate the creation of their own designs/modifications for the spyglass product.

As seen in the figure below, the housing is a simple, tapered rectangular prism. This shape requires only three main folds and can be secured using paper tabs, which are shown in the Solidworks rendering of the housing.



Figure 1: Square Cross-Section Solidworks Model

Tri-Hex Cross-Section

The 'Tri-Hex' design focuses more on the structural integrity of the housing more than simplicity. Having a triangular prism for the exterior and a hexagonal interior creates a type of truss system which would resist deformation or crushing and provide better lens protection. Unlike the square cross-section design, this design will require many more fastening points in order to keep the hexagonal interior from shifting inside the triangular body and provide the needed structural support.

Theoretically, any of the fastening methods covered in the next section could be used to secure this housing. The method that appears to be the simplest however, is the folding tab method which was designed specifically for this housing model. This method would require a

total of six tabs, three for each end of the spyglass, and would allow for a stable link between the two cross-sections without obstructing the view inside of the hexagonal lens housing.

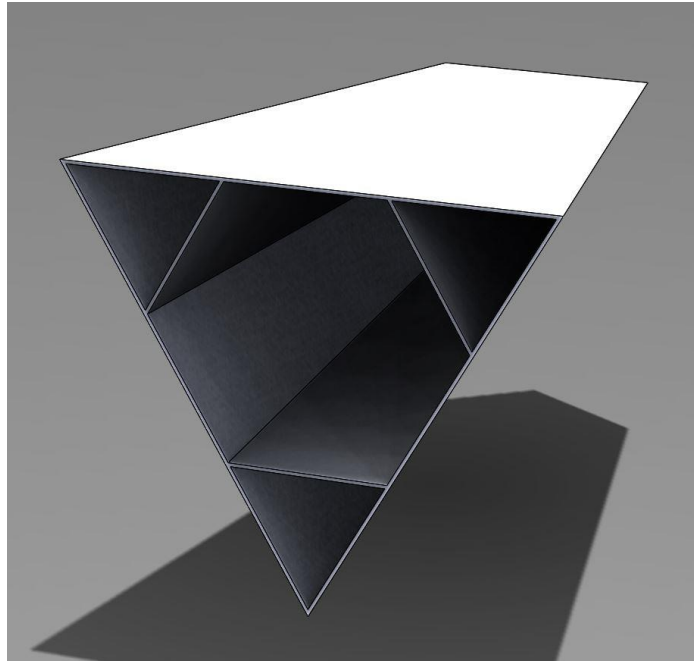


Figure 2: Tri-Hex Cross-Section Solidworks Model

Accordion Design

As seen from the next figure, this design proved to be a rough concept of a possible design direction. The main consideration for this concept was the ability to adjust the distance between the lenses to modify the focus of the image. It was decided that the assembly would be too difficult to carry on with, although the idea of focus compensation is important to this project and will need to be addressed when the final prototype is developed.



Figure 3: Accordion Concept Physical Model

Circular Cross-Section

This design was the only of the four physical models to require the use of tape to achieve the desired shape, although, like the accordion concept, this also addressed the possibility of changing distance between the lenses to adjust focus. Because the circular shape does not provide an easy method for securing lenses to the body, this design was excluded from the candidates to move on to the prototyping phase.

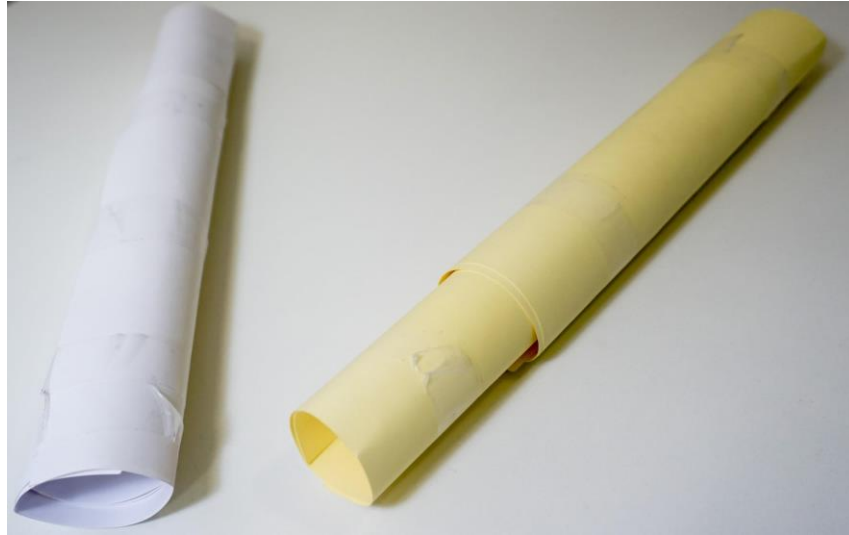


Figure 4: Circular Cross-Section Design Physical Model

5.2 FASTENING DESIGNS

Single Tab

The single tab method is the simplest of the four methods that were introduced. The method uses a single tab which runs the length of housing and effectively secures only the ends of the housing. The disadvantage to this design is that the housing will be free to warp and bend throughout the mid-section due to a lack of contact points. This method would be ideal with extremely rigid paper, but the multi-tab design solves this problem by using many smaller tabs to create a higher number of contact points.

Multi-Tab

The multi-tab method uses the same concept as the single tab design and applies the technique with many smaller tabs along the fastening edge. This method creates a strong edge with many contact points which prevent bending or warping along the distance of the housing. This fastening method is expected to be used in the final product because of its simplicity and functionality.

Hook-Tab

Hook-tabs are also a good fastening option because they provide the most contact area between the tab and the housing, better supporting the fastening corner. The disadvantage to this method is that there is a large gap that allows for light to enter through the fastening edge which could obscure the view of the user.

Folding Tab

The folding tabs were introduced after the prototyping phase, but have been added here because they are theoretically the most viable option for securing the Tri-Hex design easily. These tabs would protrude from each end of the hexagonal body along the axial planes which are in contact with the triangular planes. They are designed to fold at each end of the housing and securing the hexagonal body to the triangular with tabs that will be inserted into the small triangular spaces in each corner. This allows for rigid body using no adhesives and the tabs do not penetrate the interior lens housing so there is not view obstruction.

5.3 DESIGN SELECTION FOR PROTOTYPE PHASE

The final designs chosen for prototyping are the square and Tri-Hex cross-section designs based on their simplicity and structural integrity, respectively. These designs will also be tested using the multi-tab and folding tab techniques to determine the difference in difficulty to assemble. Of these two designs, the Tri-Hex design is expected to be the final product because it is the most structurally sound and the fastening method does not penetrate the portion of the housing containing the lenses. If simplicity is the ultimate goal for the product then the square cross-section design is expected to be the optimal choice because of the ease of design and assembly which also benefit the students as well as the manufacturers.

5.4 PROTOTYPING

Square Cross-Section Design

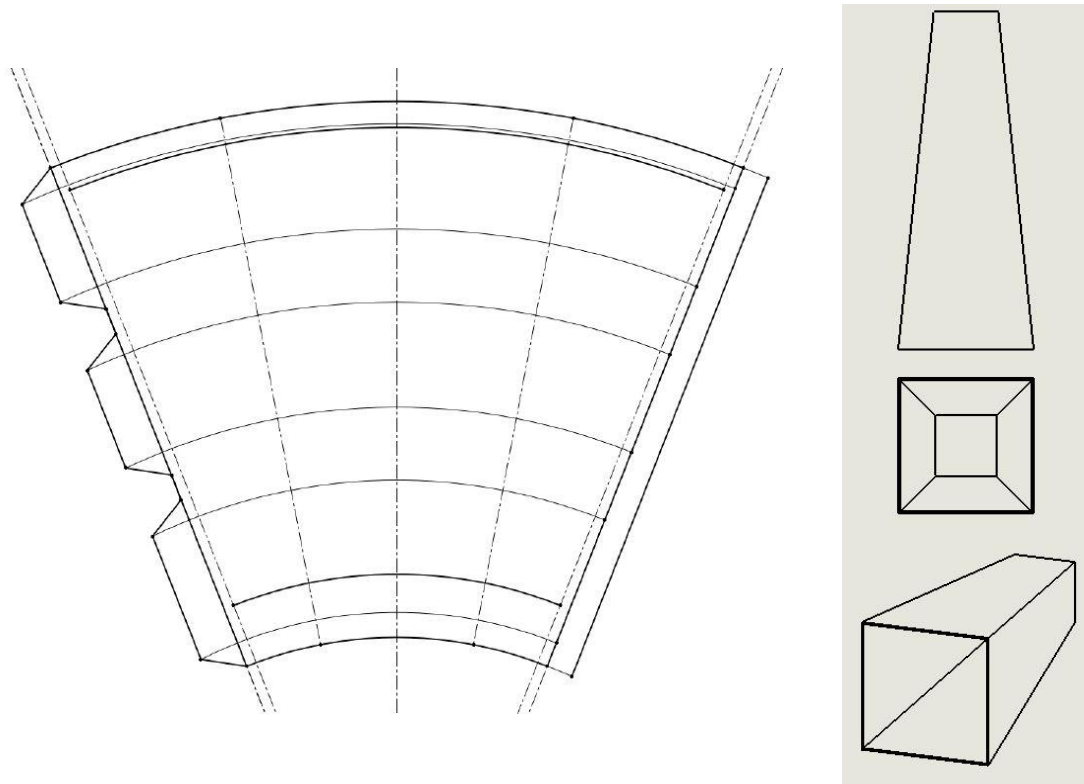


Figure 1: Solidworks Blueprint and Drawings for Square-Profile Design

The square-cross section design focuses on making a simple, easy to assemble housing whose blueprint can fit on a single page. As shown above, the housing is a tapered, rectangular prism based around the dimensions of the lenses, which are 2cm and 4cm in diameter, as well as a chosen housing length of 10cm.

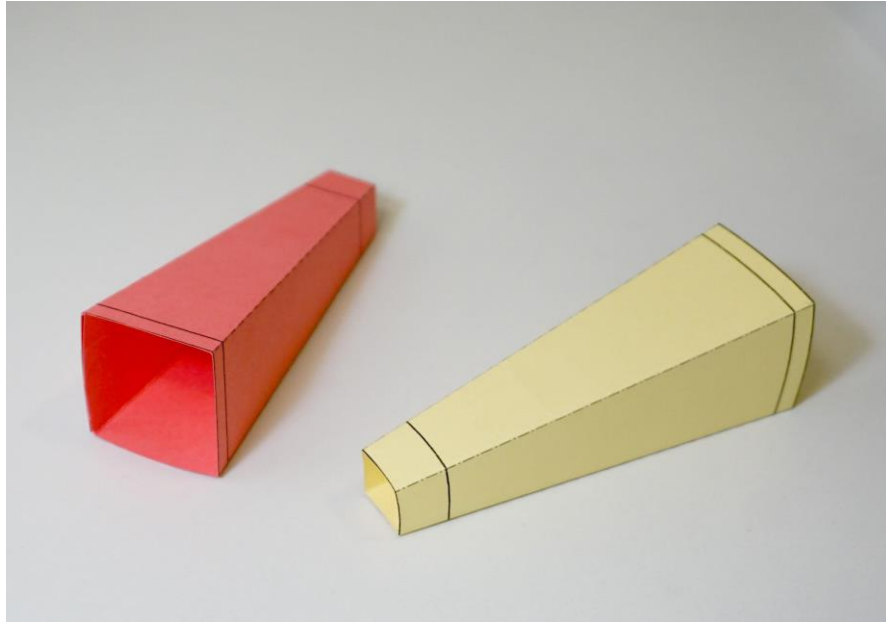


Figure 2: Square Cross-Section Construction Prototypes

The physical model of this design proved that the housing construction is the simpler of the two designs tested. The design requires only 3 main folds and fastens along a single edge, which made for quick, simple assembly. A main drawback to this assembly, and possible future problem for the project, is that any fastening method used for this design penetrates the viewing space and could obstruct the light moving through the telescope.

Due to the design's simplicity, the housing is not a rigid body without the lenses acting as supports inside the assembly. The housing alone is simple to collapse and will fold flat along the two folds which are opposite each other. A proposed idea to fix this design in the future is to create some sort of 3D printed support structure to fit inside the housing to increase rigidity, as simply using a thicker paper will not solve the problem.

Much of this design's durability is determined directly by the paper used in construction. The structure is easy to bend and manipulate, allowing for the housing to deform even when the lenses are inserted, meaning dropping the housing could seriously impair its function. Using thicker paper would help to prevent this issue, but this design is relatively fragile compared to the Tri-Hex.

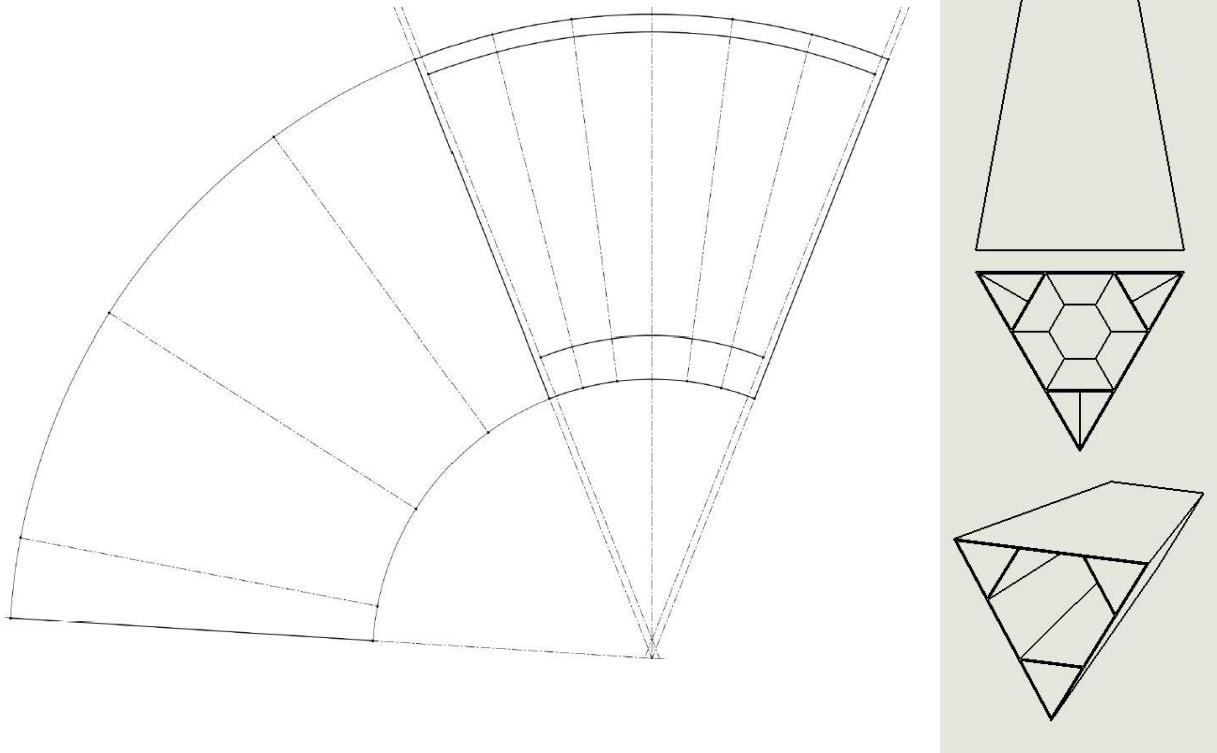
'Tri-Hex' Design

Figure 3: Solidworks Blueprint and Drawings for 'Tri-Hex' Design

The Tri-Hex design is the more robust design out of the two that were tested. As shown above, the exterior of the housing is a tapered, triangular prism, which provides better rigidity to the overall structure. Using the triangular profile prevents the assembly from folding flat when crushed, like the rectangular design, offering better lens protection. A hexagonal cylinder is used to reinforce the triangular exoskeleton and allow more points of contact to secure the lenses within the housing.

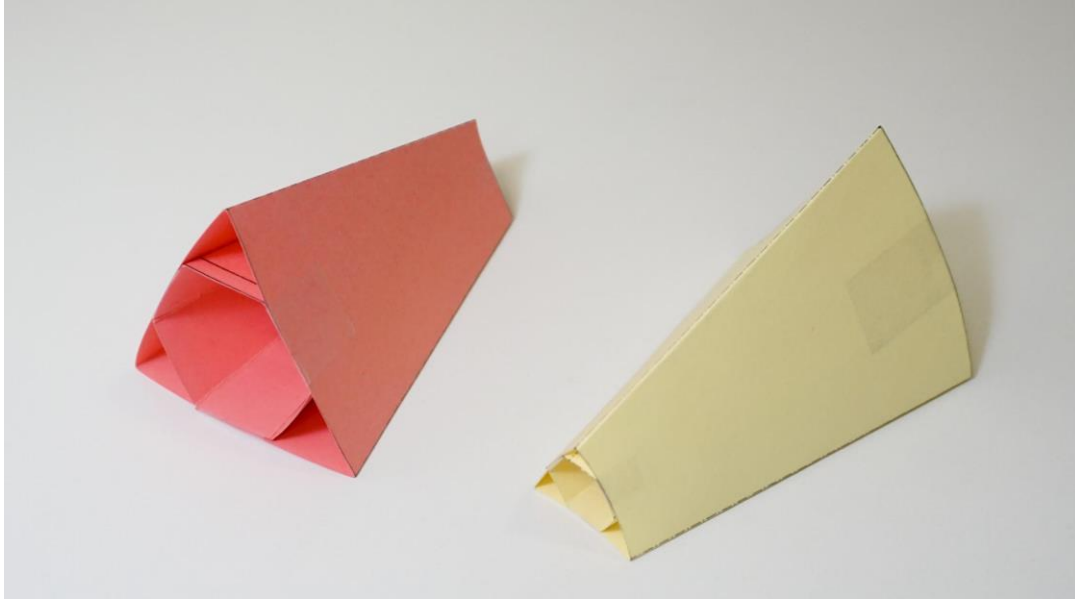


Figure 4: Tri-Hex Construction Prototypes

The physical prototype of the Tri-Hex method revealed that this design assembly is slightly more complicated than the square design, simply because of the increased number of folds and fastening points. With the fastening methods proposed, there is no single step in the assembly that is more complicated than those of the square design.. Using a laser printer to create perforations along fold lines is expected to keep the assembly process simple and comparable to the square method and minimize any confusion that the added steps may create.

Although this design is still simple, it has proven to be a much more rigid structure than that of the square prototype. The hexagonal shape enclosed within the triangular exterior acts as a truss system, preventing the triangle's faces from collapsing. The triangular shape also secures the hexagonal interior and prevents any deformation. Of the two designs, this is the most promising for structure. Using this design would eliminate the need to investigate the use of 3D printed supports, saving on material costs.

The design durability depends on the type of paper used, but the construction allows for a substantial amount of torsional and crushing forces without permanently damaging the housing. The triangular exterior also acts as a safety measure when the scope is dropped, the design allows for the housing to be damaged without as high a risk of lens damage. Using thicker paper for the housing as well as adjusting the cuts of the triangular exterior may allow for greater lens security, increasing overall durability.

5.4.1 Material Performance Comparison

Table2: Material Comparison

| Paper Type | Pricing [1] | Weight (per ream) | Stiffness | Durability | Construction Difficulty |
|-------------------|--------------------|--------------------------|------------------|-------------------|--------------------------------|
| Printing paper | \$10.29 | 20-32 lb | Low | Low | Medium |
| 67lb Weight | \$12.99 | 67 lb | Medium | Medium | Low |
| 110lb Weight | \$14.19 | 110 lb | Medium | Medium | Low |

As shown in the table above, the three construction materials that were tested were copy paper, 67lb weight paper, and 110lb weight paper. Of the three tested, the copy paper was the weakest material, while the 67lb and 110lb papers were nearly identical. It was observed that the 110lb paper held a better fold than that of the 67lb paper, which is the main differentiating factor between the two. Although, since the two weighted papers are nearly identical in performance, the 67lb paper would be the most feasible option due to its price per ream. If the housing is required to be stronger in the future, it is recommended that the paper weight be more than doubled to exhibit any noticeable difference. At this time, it has been decided that the mechanical and elementary class testing done next semester will be done with 67lb paper.

5.4.2 Fastener Design and Performance

Single Tab

The single tab method was the simplest of the three fastening designs that were tested during the prototyping phase, although it offered little structural benefit. Due to the fact that the only two contact points between the tab and the connecting edge of the housing were at each end of the assembly, the fastener edge of the housing could warp easily. It was determined that more contact points must be needed to maintain a strong fastening edge, which led to the design of the multi-tab method below.

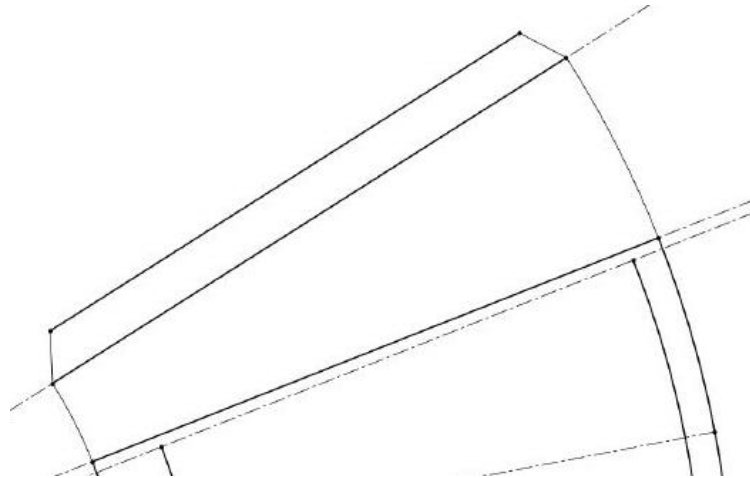


Figure 5: Single Tab Blueprint

Multi-Tab

The multi-tab method is currently the most promising fastening method. The increased number of contact points creates a strong fastening edge that is still simple to assemble. Of the three methods tested, this method performed the best and is expected to be used in the assembly of the final product with some minor changes to the tabs to greater simplify the construction process.

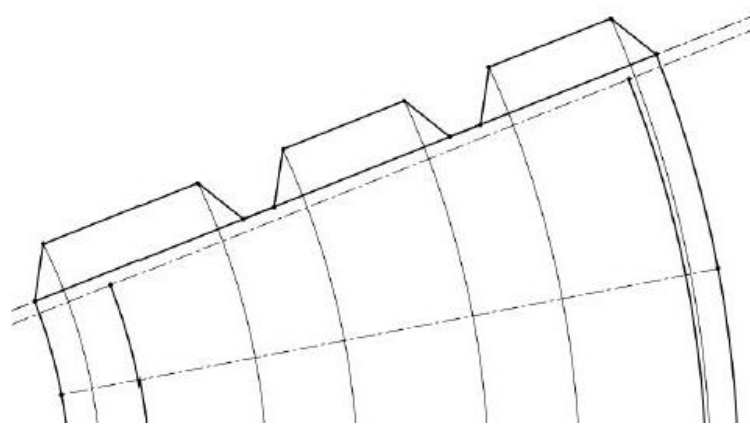


Figure 6: Multi-Tab Blueprint

Hook Tabs

Hook tabs are a possible solution for the fastening of the hexagonal and triangular bodies in the Tri-Hex design, but are not practical for the square design compared to the multi-tab method. When tested with the square design, because the cuts on the fastening edge of the housing have to be offset to the hooks, there were large openings along the fastening edge which would allow for light to penetrate into the lens space. Since the lenses we will be creating will not be perfectly clear, this could create glare and obstruct the viewer's vision. Because the hexagon assembly is completely contained within the triangular exterior however, this could be used to fasten parts of the Tri-Hex housing if it proves to be more feasible for the final assembly.

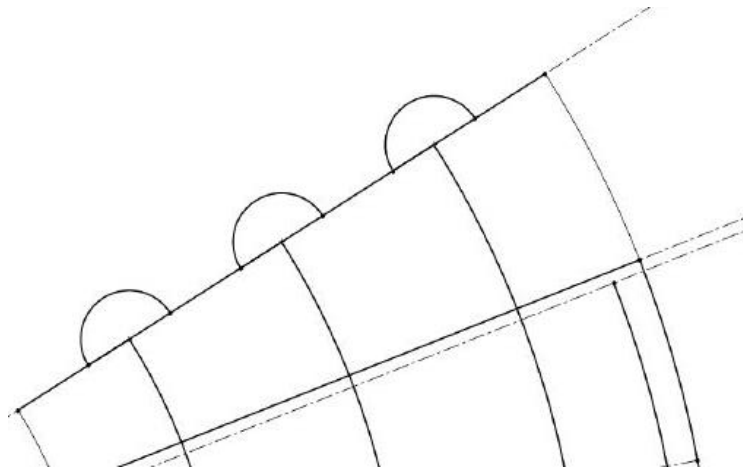


Figure 7: Hook Tab Blueprint

5.4.3 Results and Recommendations

Of the two main designs tested, the Tri-Hex design is recommended as the final design to carry through to next semester's mechanical testing. This decision is based on the fact that the Tri-Hex model was much more structurally sound and offered a greater durability due to its structure. It is expected that the fastening points on the Tri-Hex assembly will all be multi-tab connections, however the Tri-Hex model has the capability of utilizing the hook method if that is determined to be the best solution. Finally, if the mechanical testing proves that the housing is not strong enough to serve an adequate lifetime, then a stronger paper must be selected and tested as well and should be approximately 200lb paper for a noticeable difference in performance.

6 BUSINESS MODEL

6.1 OPERATION GUIDE

The expected labor force for this business would include a couple people operating the manufacturing machinery and the rest accommodating for post processing and transportation needs. A single person should be able to operate the 3D printer at any given part of the day and at least one person would be needed for the laser cutting printer. The bulk of the labor force

would likely be assigned to polishing printed lenses and assembling the educational booklets. Such a labor force would be estimated based on the amount of printing machines attained. For every 3D printer, we would expect 2 to 3 employees would be needed for the polishing process. Similarly, for every laser cutting printer, we would expect 2 to 3 employees would be needed to assemble the booklets. This booklet assembly would include the binding of pages as well as the inclusion of polished lenses and pop out parts for the foldscope. Labor force devoted to shipping would depend on the resulting production volume, the amount of demand, and the frequency of travel.

6.2 SWOT ANALYSIS

Table #: SWOT analysis

| | | |
|--------------------------------------|---|---|
| I N T E R N A L | STRENGTHS | WEAKNESSES |
| | <ul style="list-style-type: none"> • It's dependent project that pay itself. • Creation of new jobs. • Economic growth in rural communities. • Unique technology in the area (3D printer) offers products that can't be easily replicated. | <ul style="list-style-type: none"> • Limited manufacturing technologies impact production volume. • Retrieving new materials are subject to shipping and handling expenses. • High need for training the people how to build the foldscope • CAD software training needed before printer can be utilized beyond the creation of lenses for the foldscope. |
| E X T E R N A L | OPPORTUNITIES | THREATS |
| | <ul style="list-style-type: none"> • Local Tourism offers a market to sell new products to. • Untapped job force of Maasai women that are seeking additional income. • Valuable assets are provided at the expense of NAU, not the business. • Initial designs provided by NAU engineering students. • Supplemental products like the educational booklet will be designed by NAU students from specialized departments. | <ul style="list-style-type: none"> • Weak economy in rural communities limits the market. • Cultural norms value having women in the household instead of workforce. • Resources limited to Arusha and surrounding communities. • Transportation is heavily dependant on the existing infrastructure. |

7 RECOMMENDATIONS

Our current recommendation for the design project is to use the Tri-Hex design to build the spyglass housing. This design has a rigid triangular structure and will have the advantage of being an easy to assemble product. Unlike other designs, the Tri-Hex design meets requirements of securing space between the lenses that doesn't allow for ambient light.

8 FUTURE WORK

For manufacturing in Tanzania, there will be a need for a workshop to manufacture the booklets. This workspace will provide a safe environment for the workers and prevent any kind of theft that could affect the production and job security for this product. Future coordination with business students will help us design an ideal work environment that will offer high productivity and ideal working conditions for the female workforce. We expect to implement a product tracking and reporting system to prevent any type of complacency in the work.

For next semester, we expect to further develop the lens dimensions, which in turn determine the housing dimensions. Our priority for next semester is to finalize these calculations. Further tasks will include design for the educational booklet through outsourcing with complimentary departments at NAU.

8.1 FALL SCHEDULE

| Key Tasks | Allocated Time (days) | Deadline | Team Member Assignment |
|--|-----------------------|-----------|------------------------|
| Interdepartmental Outreach | MILESTONE | Aug 30th | - |
| Education (Lesson Plan): Make an appointment with the education department to discuss the project and lessons we want to use in it | 5 | | Badah |
| Graphic Design (Housing): Contact the graphic design department to discuss the housing design | 5 | | Dominic |
| Business (Business Plan): Contact the business department to discuss the business plan | 5 | | Mohammad |
| DeMiguel (Schedule Testing dates): Contact the teachers from the school department to discuss the design testing | 5 | | Dwayne |
| Prototype 1 | MILESTONE | Sept 6th | - |
| Paper Housing Design: Finish the housing design prototype | 3 | | Badah |
| Laser Cutting (3rd party): Buy the cutting printer from Glowforge | 2 | | Mosab |
| Assembly Testing at DeMiguel: Test the prototype in the local school | 2 | | Dwayne |
| Lens Calculations: Finalize the lens calculations and dimensions | | | Dominic |
| Presentation 1 | MILESTONE | Sept 20th | - |
| Design Summary: Summarize the design and be ready to present it | 2 | | Mosab |
| Environmental Analysis: An environmental analysis is to be done for the product and presented | 3 | | Dominic |

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| DeMiguel Results: Present the prototype testing results from the local school | 6 | | Dwayne |
| Testing (Plan Update): The prototype design testing results | 5 | | Badah |
| Outreach Summary | 2 | | Mohammad |
| Paper 1 (Prototyping) | MILESTONE | Sept 27th | - |
| Load Bearing testing: Report about the load testing results | 2 | | Mohammad |
| Twisting Testing: Report about the twisting testing | 2 | | Mosab |
| Bending Testing: Report about the bending testing | 2 | | Dominic |
| Sweat, Dirt, Water (Nature Testing): Report about the nature testing | 4 | | Badah |
| Prototype 2 | MILESTONE | Oct 11th | - |
| Paper Housing Redesign: Fix what was wrong in Prototype 1 | 4 | | Dominic |
| Durability Testing at DeMiguel: Test prototype 2 in the local school after adding the improvements | | | Badah |
| SolidWorks Lens Design: Create digital graphic sketch of the lens using solidworks software to | | | Dwayne |
| 3D Printer Testing: test the 3D printer for the lenses | 6 | | Mohammad |
| Presentation 2 | MILESTONE | Oct 18th | - |
| Prototype Testing Results: (test the prototype and make sure its work. | 1 | | Mosab |
| DeMiguel Results: let the children test the project. | 1 | | Dwayne |

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|---|-----------|----------|----------|
| Lesson Plan Update: finishing the lessons that we want to include in the booklet | 2 | | Badah |
| Graphic Design Update: get the design for the booklet done from one of the students in that department. | 1 | | Dominic |
| Business Plan Update: Update the business plan and insert it into the powerpoint | 1 | | Mohammad |
| Paper 2 (Schedule of Materials) | MILESTONE | Oct 25th | - |
| Material Costs: get the cost for the materials for the stable store or online. | 4 | | Mosab |
| Projected Labor Costs: Research about the labore cost and mak a table and options. | 4 | | Dwayne |
| Installation and Shipping Costs: figure out the total price with the shipping. | 3 | | Mohammad |
| Presentation 3 (Practice for final) | MILESTONE | Nov 15th | - |
| Background and Problem Statement: doing the introduction for the practice presentation. | 1 | | Badah |
| Design Summary (Final): describe the final design. | 1 | | Dominic |
| Manufacturing Summary: Present the manufacturing process | 1 | | Dwayne |
| Business Model Update: update the business model and put it in a good format | 1 | | Mosab |
| Lesson Plan Summary: summarized the lesson plan and apply them into the booklet. | 1 | | Mohammad |
| Future Recommendations: make a recommendation for our future project so people can work on it and improve it in the future. | 1 | | Badah |

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| Final Report | MILESTONE | Nov 29th | - |
| Design and Test Summary: summarized the design and write up the description. | 1/2 | | Dwayne |
| Final Business Model | 1/2 | | Mosab |
| Final Economic and Environmental Analysis | 1 | | Badah |
| Final Product | MILESTONE | Dec 1st | - |
| Final Graphic Design Update: take the final design from one student from that department. | | | Dwayne |
| Laser Cutting (3rd party): work on the lenses and print them via the 3D printer. | | | Mohammad |
| 3D Printing (Final Lenses): print the lens and get it done for the final design. | | | Dominic |
| Assembly (Scope and Lesson Plan): make sure everything is good and work. | | | Mosab |
| UGRADS | MILESTONE | Dec 2nd | - |
| Final Editing of Presentation: format the final presentation and make it ready to present. | | | Dominic |

9 CONCLUSION

The design of a low cost education tool can be achieved through the addition of laser cutting and 3D printing technology. The selection of the Form 1+ printer is largely based on the high resolution that is achievable through this technology. The Glowforge laser cutter is beneficial in cutting down assembly time and offers lucrative opportunities for the community to create souvenirs from paper and leather products. The final product will consist of an educational booklet which will contain a precut assembly of a spyglass housing with attachable lenses. This product will be provided in an alternate format to accommodate the tourism industry as well as the classroom. Package offers for schools will include a supplemental lesson plan that will encourage the development of STEM topics through wildlife education. Final housing design is a Tri-Hex cross-section design until future testing calls for reinforcement or new design considerations. Future plans will include outsourcing with other school departments for specialized tasks such as graphic design, business planning, and lesson plan design.

10 REFERENCES

LENS CALCULATION REFERENCES

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11 APPENDICES
