Spyglass Design Feasibility for Economic and Educational Advancement of Women in Rural Locations

Dominic McGonegal, Dwayne Codding, Badah Badah,

Mohammad Alzaid, Mosab Alfailakawi

EGR 486C – Engineering Design

Instructor: Dianne McDonnell

Department of Mechanical Engineering

International Capstone

Northern Arizona University

Flagstaff, AZ 86011

Executive Summary

Access to education for young girls is limited in rural communities and in some third world countries. This is generally true due to education expenses being too high for low income households as well as cultural values placing young boys as a priority. Young girls are more likely to be raised at home with chores in place of education and this has an impact on career opportunities that are available to them.

In a specific case, the Maasai women of Lesoit Village in Tanzania are faced with these same cultural, academic, and economic barriers that prevent them from entering the workforce. This challenge arises from household expectations of women being the providers of wood, water, meals, and care for the elderly. Young girls are much more likely to drop out of school to either help the family earn money or to help with household chores. This collectively depletes time and energy for involvement beyond the home, which makes education and pursuit of a career very difficult.

The proposed solution to these barriers is the creation of locally made scientific tools such as a spyglass for observation of wildlife. This solution is meant to introduce low cost classroom tools that can inspire interest in professional STEM fields, especially if the costs are low enough be accessible for low income households. The main design under consideration is a 3D printed lens mount which can adjust for different spyglass housing options. The usage of local gourds and upcycled waste products like bottles, cartons, and cans can offer a low cost housing that can benefit the environment through a reduction of local waste.

The flexible design of the lens mount offers artistic opportunities for the housing to create desirable souvenirs for the local tourist industry. The option of providing locally made products that feature handmade patterns is a business opportunity that can have the flexibility of working around the busy lives of interested women.

The usage of 3D printing technology will offer skilled labor opportunities and possibly even educational workshop spaces for local students and community members. This technology will introduce a need for skills in CAD software, operation of manufacturing tools, and opportunities for programming projects. In the case of Lesoit Village, these resources will likely need to be set up in the neighboring city of Arusha for security and accessibility considerations for resources such as power, raw materials, and shipping advantages.

With products like the spyglass being made available in local schools, there is an opportunity to generate interest in STEM fields, especially when introduced in tandem with design challenges. Hands on involvement in a low budget design projects and rapid prototyping has a strong impact in generating interest for STEM fields. A small example of interactive education was conducted to engage a local group of students in rapid prototyping to demonstrate the possibility of a similar implementation in small group settings. The simulation was successful in generating quick ideas on improvements for a project like our own.

Additional benefits that come from introducing a small business operation in a small town if the opportunities for locals to receive hands on training on a variety of transferable business skills. Topics that can be explored in this setting include economics, supply chain management, and accounting.

Future considerations for this project include local applications in the city of Flagstaff as well developments of quicker manufacturing and additional design features.

Acknowledgements

Dr. Dianne McDonnell - International Capstone Instructor from Northern Arizona University

Ashwija Korenda - EGR476C Teacher Assistant from Northern Arizona University

Evalyne Long’arwa - Tanzanian Student from Northern Arizona University

Dr. Christopher Mann - Professor from physics department from Northern Arizona University

Todd Rossman - Elementary school teacher from De Miguel

Jon Helleson - Elementary school teacher from De Miguel

Sharna Beahm - Student from Northern Arizona University

Kristin Whitten - Local Artist Student from Northern Arizona University

Garin Slim – Lab Technician from Northern Arizona University

Coreen Walsh - Public Programs Manager for the Arboretum of Flagstaff

Table of Contents

1.0 Background

1.1 Technical

This capstone project was inspired by the Foldscope, a low cost optics education tool made from paper products. A research team at Stanford University designed the affordable, yet durable, design for a microscope that was meant to be implemented in third world countries. The Foldscope was successful in making real-world education and health evaluations attainable in communities that otherwise could not afford the lab equipment [FOLDSCOPE].

Our project aims to offer similar education opportunities for the community as well as providing a potential source of income through a product that could be assembled with technology found in the region. The ease of manufacturing should facilitate economic growth for the community. Resources that are prominent in small towns and third world countries that are worth consideration for this project are paper products and upcycled materials.

1.2 Cultural

Rural towns, both domestic and abroad, share similar cultural values in terms of prioritizing young boys when it comes to education and career investments. In the example of the Maasai people in Tanzania, rural communities such as Lesoit Village experiences high dropout rates and limited involvement of women in the reported workforce. These limitations exist as a result of 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 women in the job market.

In the case of the Maasai people, the culture 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. Chores take the form of gathering firewood and water as well as processing food crops and taking care of the sick. 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 responsibilities consume large amounts of time and energy. This is a barrier 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 manages 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].

In regards to high dropout rates, common factors were 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 women.

2.0 Problem Statement and Objectives

The education system in rural towns should prepare students for professional careers, including in STEM fields, regardless of gender or economic background. Additionally, women 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 local Tourism to offer new products and souvenirs that would impact the local economy.

Special circumstances in third world countries like Tanzania should also be considered. The current education system in Tanzania does face 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]. 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. These factors reveal the need for a flexible career options that can mobilize the unused workforce in the region.

A successful implementation should allow for new academic tools to be formed locally, offering better costs to schools and rural families. Interest within the community for involvement in such a product can improve educational resources, reduce dropout rates, and increase career opportunities for women.

3.0 Spyglass Design

3.1 Lens Modelling

The first step in designing the spyglass was to produce a lens model in order to determine the basic dimensions for the lenses and housing. We chose the Galilean telescope model as the basis for our design due to its versatility and relative simplicity. This design would allow for students or women of Lesoit to easily understand the physics behind the spyglass and modify the design for other applications. In order to create a lens model, some preliminary calculations had to be made to determine where to start.

First, a magnification factor had to be chosen along with our desired length for the telescope. The focal lengths could then be found by using the following equations relating them to magnification and telescope length.

$$L = f_o + f_e \qquad M = -\frac{f_o}{fe}$$

Equations 3.1.1 & 3.1.2: Spyglass length and Magnification [13a,14a]

Next, the diameter of each lens was chosen. These values, as well as the focal length and scope length, were then used to select a set of lenses from a database in order to test the chosen values for the telescope. After the lenses were chosen and entered into the modelling system, the length of the scope was fine-tuned to adjust for the differences between the lenses and the calculations, producing the spyglass in Figure A-#1.

With this baseline model we were able to select a set of premade lenses to physically test the design. In order to test multiple scope lengths and lens diameters, a range of lenses with varying focal length and diameter were ordered. After testing all of the lens combinations, the set that performed the best was an objective lens with a diameter of 7cm and a focal length of 16.8cm, and an eyepiece with diameter 2.1cm and focal length –1.5cm. This gave a total length of 15.2cm for the spyglass body.

3.2 Lens Mounts

With all of the dimensions known from the lens modelling and selection process, the lens mounts were designed using the Solidworks CAD program. The designs were first based around the assumption that the mounts would attach to the outside of the housing body. This made the designs overly complex, bulky, and took away from the artistic expression we wanted to emphasize with the gourd designs. After turning the focus to mounting the lenses inside of the housing body, the designs became simpler and more applicable to different housing shapes and sizes. The designs shown below were created to be resizable and used for both the objective lens and the eyepiece, all that was required is that three holes be drilled into the housing for the mounting of each lens.

The first models shown are the first iteration of the inside-mount design. It was based around the idea that we could print threaded bolts and nuts that could be used to secure the mount to the housing through the predrilled holes.

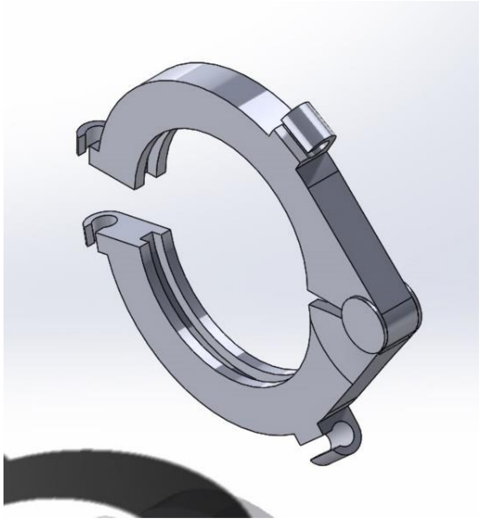
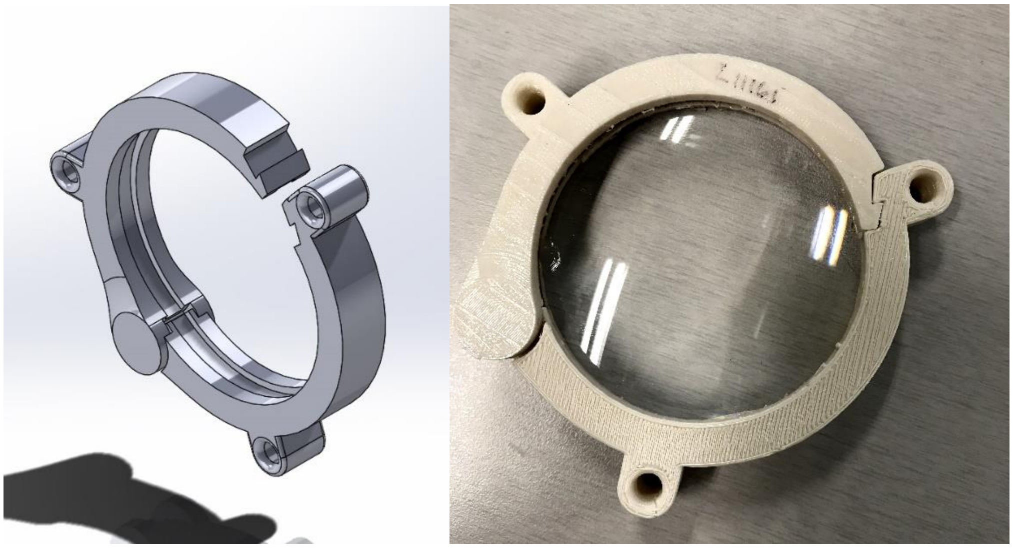


Figure 3.2.1: First Iteration of 3D Printed Lens Mount

Creating usable, 3D printed, threads proved to be difficult. So, instead of creating our own bolts and nuts, another design was created to work with store bought sets. The design below shows how the mount was modified to allow for the bolts to be slid through the inside of the mount and trap the head, but allow for a small degree of movement. The small amount of movement allowed was to provide some room for error when drilling the holes in the housing. This would make it possible to produce a scope without having to make exact measurements.

Figure 3.2.2: Second Iteration of 3D Printed Lens Mount

The final design was chosen after deciding that the bolts would be dangerous for children and would take away from the artistic expression of the housing. This led to the creation of a mount that allowed for string or twine to be used to secure the lens to the housing. The figures below model this design and show how the locking mechanism on the final product functioned.



Figures 3.2.3 & 3.2.4: Final Iteration of 3D Printed Lens Mount

3.3 Housing Options

Our design is meant to be compatible with various types of materials and dimensions for the housing. The intent of the flexibility is to offer artistic flexibility during assembly of scopes. We chose to focus on materials that either used local vegetation, repurposed waste, or low-cost paper products.

The consideration of paper products was due to direct inspiration from the Foldscope product that was developed by a research team in Stanford University. The benefits to a paper structure were through the affordability and the ease of transportation. Some drawbacks with this option include the fragile nature of paper as a structural component and as a surface against different weather conditions. However, this design would offer expendable tools that are easily replaced while offering opportunities for origami.

In contrast, gourds were an ideal choice due to the hard shells which offered a structural support for the end product while being readily available in the area. Gourds were also considered for the artistic opportunities they presented as they have a history for being carved or painted. This artistic consideration was important due to the unique opportunities that are present from the tourism industry in the area. Visitors that came from outside the country were considered likely to place a high value for products that showcased locally decorated gourds.

Waste products were considered a prime choice in material as they would offer environmental aspects to problematic trash build ups of discarded bottles, cartons, and tin cans. This variety in materials provided various surfaces which offered opportunities for artistic expression while maintaining a structural material that would be suitable for small optics products. Our design considerations focused on water bottles as a resource that is readily available. Regardless we attempted to maintain the flexibility in our design for other possible materials that may be considered.

Between the three material options, the waste products and gourds offer better structural support and better weather proofing. These products also offer decent surfaces for a variety of art styles, not being largely restricted to origami. Due to the feasibility of acquisition and manufacturing, waste products and gourds were deemed far better suited as housing options.

Figure 3.3.1: Final Prototype and Artistic Representations

3.4 Material Testing

In order to gain an understanding of how strong the printed product is compared to what was reported by the MakerBot group, a simple tensile strength test was done. This gave us the yield strength and modulus of elasticity for the stronger printing method where the grain of the print is parallel to the tensile force. From a MakerBot PLA strength datasheet, the expected tensile yield point is at 46.77 MPa [10a]. Figure 4.2.1 below shows that the experiment revealed a yield strength of approximately 11.4 MPa – much lower than the datasheet yield point. This difference could be due to the limitation of the testing equipment and future groups are encouraged to determine an experiment to test a variation in cross-sectional area to determine if this is a major factor in printed material strength.

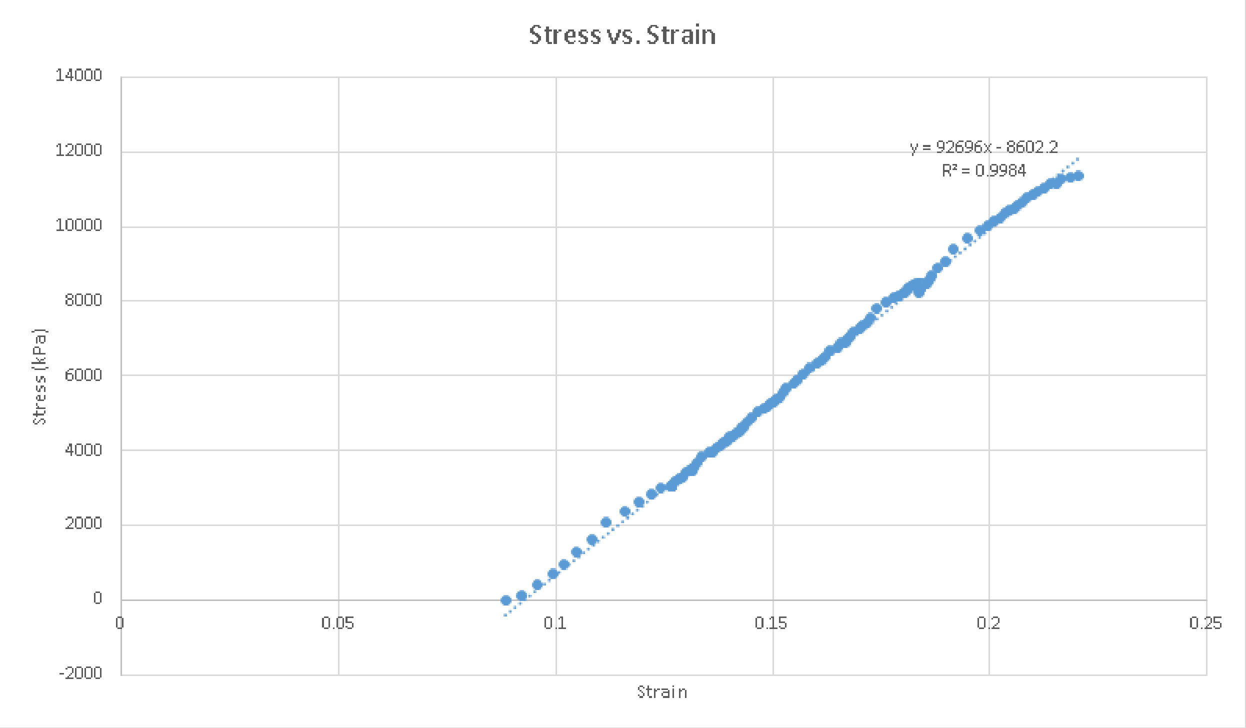


Figure 3.4.1: Stress vs. Strain Plot for MakerBot PLA Print

4.0 Educational Applications

4.1 Physics and Optics

The focus on developing a prototype based on a Galilean telescope model (Figure A-#2) was largely due to its applications in teaching children and young adults about physics and optics. The Galilean model is a simple design consisting of just two lenses, one concave and one convex. This could be applied in an elementary school level, allowing children to construct their own telescope given predetermined lenses and expose them to the fundamental ideas behind optics, concave and convex lenses, and magnification. The same telescope could be used with an older group to have them do the simple math behind dimensioning a telescope and selecting a set of lenses based on their calculations to construct the telescope.

High schoolers and young adults could use this model to create a coded program that, given the magnification, focal lengths, and lens diameters, could be used to determine the radius of curvature for each face of the lenses. The physical theory behind this project has roots in simple and complex mathematics that can be applied to many age groups, offering tailored learning experiences that are more enticing to all students.

4.2 STEM Prototype Challenge

We worked with an introductory EGR 186 engineering course to address the problem of building student interest in STEM fields for Maasai communities. The students in the EGR 186 course were tasked with a design challenge to develop a design proposal related to our spyglass product. Students were encouraged to create unique features or develop different approaches to the housing design. This challenge was in part a simulation of a potential education approach designed to raise interest in STEM fields for upcoming students.

Rapid prototyping was a key component for the design process as well as the development of interest from the students due to the hands-on approach. Prototyping was made possible with low cost resources such as cardboard, aluminum foil, and adhesives, shown in figure 5.2.1.

.

Figure5.2.1: Materials for Rapid Prototyping

4.2.1 Engineering Design Process

For this challenge, the announced need was to design a multipurpose housing option for a spyglass with some technical considerations. Any additional features aside from the basic functions of a typical spyglass were encouraged under the premise of making the product increasingly marketable. Each group was asked to design a product, build a prototype, and write a short brief describing their design process. The brief asked each group to share their design experience and provide future considerations for their ideas.

The physical constraints for the prototype process were only limited by the amount of supplies available. The team provided the students with different types of materials such as cardboard, duct tape, Popsicle sticks, A4 paper, string, paper clips, and similar items. No limitations were issued for any group in regards to dimensions or material usage. This freedom in material usage was meant to let the students create decent prototypes in a short period of time.

Shortly after being introduced to the challenge, students were instructed to work in groups of four to brainstorm possible designs. Teams began by creating sketches and communicating ideas to each other. Silent brainstorming sessions were also implemented where students were asked to communicate their ideas on sheets of paper that were passed around. This process was implemented to give a voice to all members without the risk of a single team member taking over the design. This process also works for shy students that may prefer a method that reduces chances for ridicule for ideas they provide.

Figure 5.2.2: Students started to brainstorm and draw their sketches.

4.2.2 Rapid Prototyping

After a final design was selected, teams began to create prototypes with low cost materials. Material selections for each team were made based on available resources and the design considerations that were made by each respective team. Teams made a use of low cost tools such as scissors and x-acto knives to create prototype components. Students were instructed to write informative briefs after each group was done with prototyping.

Figure 5.2.3: Students are prototyping their designs.

Some prototypes are highlighted below based on creativity and function of the spyglass. Figure 5.2.4 is the Storage Spyglass which includes a compartments that can store a survival kit. The structure of this design features potential origami elements and creatively implements low cost materials to give a structurally sound design. Figure 5.2.5 is the Eyewear Spyglass, which features a removable attachment for glasses. Applications include classroom visibility for lectures, spectator sports, and hands free bird watching. The third design is the Multi-Lens Spyglass, found in figure 5.2.6. This design features a rotating arm that contains covered lenses with variable focal lengths. The casing offers protection and the variable lenses offer variable applications.

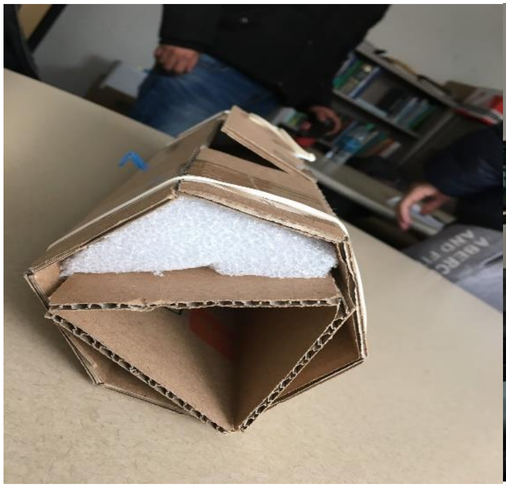


Figure 5.2.4: The storage spyglass.

Figure 5.2.5: the eyewear spyglass.

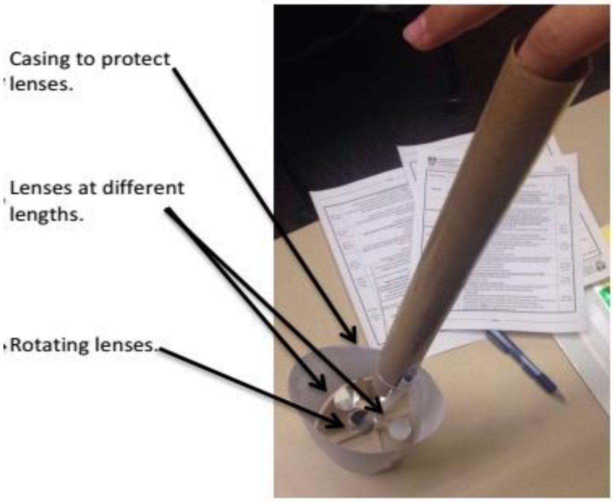


Figure 5.2.6: The multi lenses spyglass

4.2.3 The Significance of Rapid Prototyping

Rapid prototyping is a quick and rough process that allows students to visualize and communicate ideas without any major investment in time or money. This option for generating fast solutions helps test the validity of some designs in a shorter timeline and also engages students in connecting their education with a physical model. This process is proven to be effective in maintaining interest of students while offering skill sets for anyone interested in pursuing STEM fields professionally. Ultimately this process is meant to be iterative in creating new ideas, critical thoughts, and this is meant to convey that perfect products may be the result of several failed attempts that did not terminate the project.

5.0 Economic Application

One direct benefit of introducing a product and business plan for a small community is the hands-on opportunity for business education. The establishment of small businesses in rural communities offers special training options for locals that are interested.

Opportunities include education on various principles of economics in terms of supply, demand and the value of buying power for consumers in different regions. This translates to business decisions on where to attempt to make sales if different tourist attractions have varying amounts of interested consumers and varying ability to actually buy the product. Local research and recent experiences inform the business on how to adjust the distribution practices to draw up the most profit.

Another benefit from introducing a small business is the generated experience from supply chain management. Transportation considerations extend beyond determining the best regions for making the most sales. The additional considerations include the costs and risks from different travel routes and modes of transportation. Risks include regional weather or road conditions that may put harm on the people or the products, especially when they outweigh the possible rewards of making sales in any given region. Additionally, similar risks and costs would be regularly assessed for acquisition of raw materials such as lenses, 3D prints or filaments, and preferred housing options.

Another educational opportunity arises in the form of resource management and finances due to direct work on developing and distributing the product. One of the largest driving factors to a business of almost any size is accounting for fixed costs vs variable costs. Set expenses like the cost of rent and local taxes would be considered just as much as costs that vary by output such as the use of utilities and paint. Human resource management is another major consideration as one of the most impactful costs in many businesses comes from labor wages. In the case of the spyglass product, labor costs would be incurred in the manufacturing of the lens mount, the assembly and decoration of gourds, and the transportation of products and materials.

These benefits would all directly help train anyone involved with the small business and the benefits have the possibility of impacting the community as a whole. Many of these educational opportunities could be pursued as a whole or as a chosen specialty. After any given worker is trained, they now offer a skillset that can be applied to other careers in the area and the development of successful entrepreneurs is possible. These benefits would offer even greater opportunities if any small business works with local schools to impart these skill sets and interests to local youths.

6.0 Conclusion

Our product is primarily an education tool that introduces hands on applications for optics and observable sciences. The product is designed to be flexible for selection of materials and flexible with manufacturing time. The final product is reproducible with cheap resources once lenses are acquired, through manufacturing time is large due to the 3D printing process. Business opportunities emerge from the artistic contributions, especially in regions such as Lesoit Tanzania where tourism generates an interest for souvenir products.

A design challenge was issued to an EGR 186 class in the effort of engaging students into a hands on project to develop an interest in pursuing a STEM field such as engineering. This simulation is an encouraged approach to education in regions that are experiencing high dropout rates. In a similar fashion we expect hands on opportunities in business education and art styles will engage students into pursuing a desirable career.

7.0 Future Recommendations

The scope can be designed for specific applications such as the weather study project that is going to be conducted by the Arboretum of Flagstaff. This will call for additional features such as filters and possibly sensors that can measure the wavelengths and particles that may have a direct impact on plant growth in the region. Another specific application could be through generating a telescope version of our product.

Another option is to design a manufacturing process that is far more efficient with time and resources while still being reproducible with small town resources. Currently the product currently relies on bulk purchases for lenses to allow for affordability while 3D printers create the lens mounts. A recommended topic of research would be the consideration of combining a 3D printer with a mold process to cut on expenses. The implementation of a 3D printer would allow for custom designs and the mold process would cut down production and post processing time. This overall process is expected to be significantly faster and therefore affordable.

A multi-disciplinary group can design a program with a Raspberry pi to auto calculate recommended lens dimensions after desired inputs are considered such as focal length and housing dimensions. Additionally, a team can design methods or reinforcements for specific housing options such as upcycled materials.

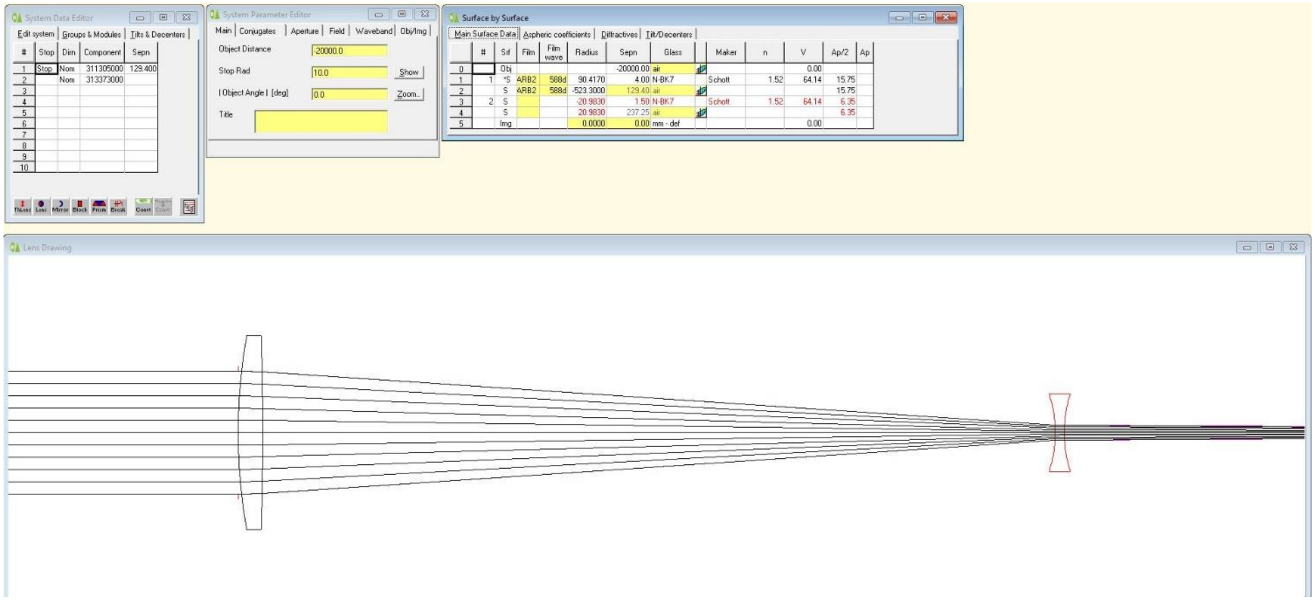
8.0 References

[10a] MakerBot, “PLA and ABS Strength Data,” datasheet. [Online]. Available: https://eu.makerbot.com/fileadmin/Inhalte/Support/Datenblatt/MakerBot_R__PLA_and_ABS_Strength_Data.pdf [Accessed: 25-Nov-2016].

[13a]"Telescope Equations", Rocketmime.com, 2016. [Online]. Available: http://www.rocketmime.com/astronomy/Telescope/telescope_eqn.html#Intro. [Accessed: 28- Apr- 2016].

[14a]"Radii of curvature for lenses", YouTube, 2016. [Online]. Available: https://www.youtube.com/watch?v=vSOdNf0Oh-Q. [Accessed: 28- Apr- 2016].

Appendix A



#	Stop	Dim	Component	Sepn
1	Stop	Nom	311305000	129.400
2		Nom	313373000	
3				
4				
5				
6				
7				
8				
9				
10				

Object Distance: -20000.0

Stop Rad: 10.0

| Object Angle | [deg]: 0.0

Title:

	#	Srf	Film	Film wave	Radius	Sepn	Glass		Maker	n	V	Ap/2	Ap
0		Obj				-20000.00	air				0.00		
1	1	*S	ARB2	588d	90.4170	4.00	N-BK7		Schott	1.52	64.14	15.75	
2		S	ARB2	588d	-523.3000	129.40	air					15.75	
3	2	S			-20.9830	1.50	N-BK7		Schott	1.52	64.14	6.35	
4		S			20.9830	237.25	air					6.35	
5		Img			0.0000	0.00	mm - def				0.00		

Figure A-1: CAD Lens Model (WinLens Free Software)

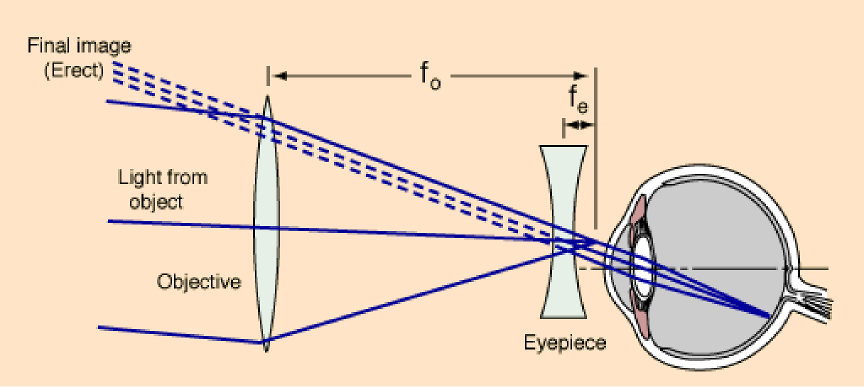


Figure A-2: Galilean Telescope Model

Appendix B

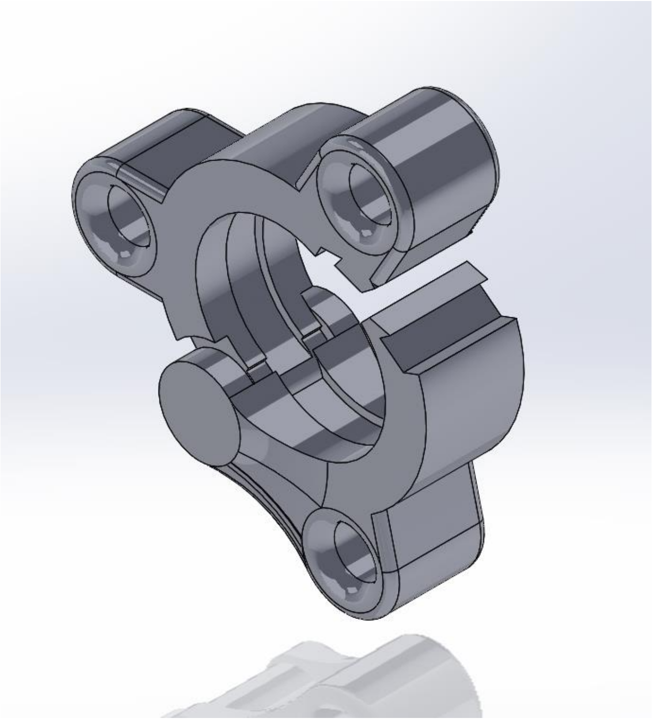


Figure B-1: Final Eyepiece Lens Mount Design

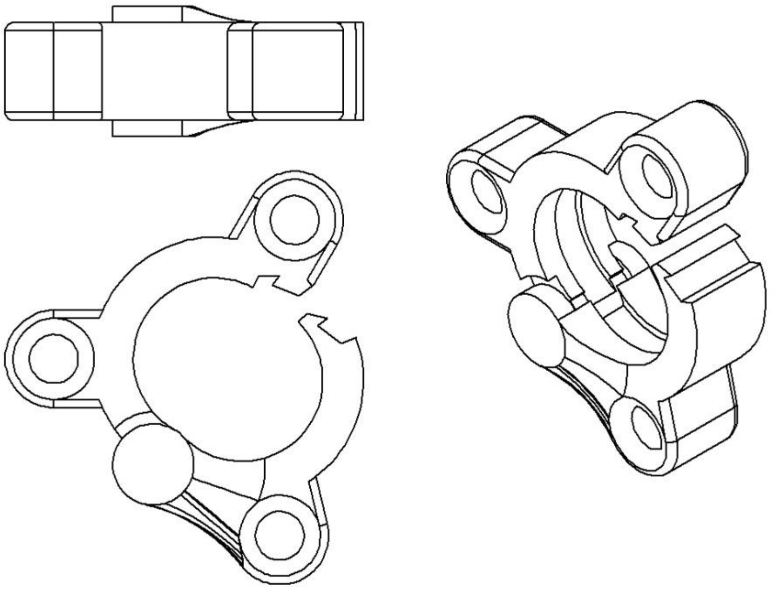


Figure B-2: Final Eyepiece Lens Mount Drawings

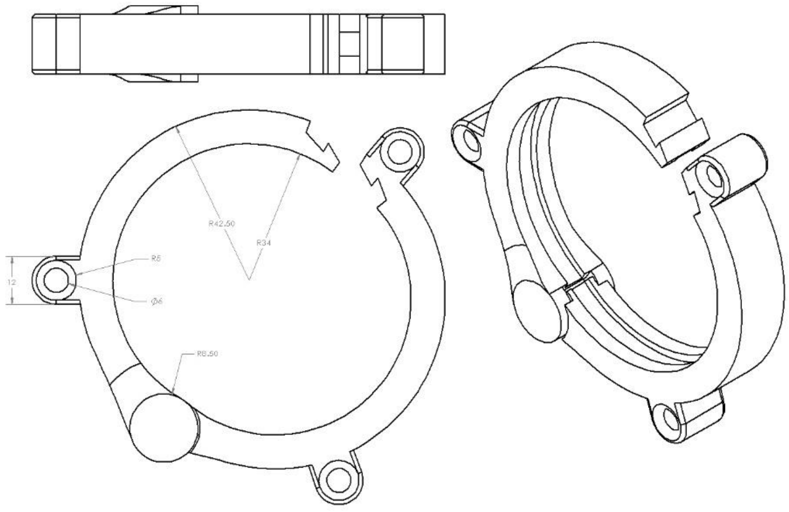


Figure B-3: Final Objective Lens Mount Drawings