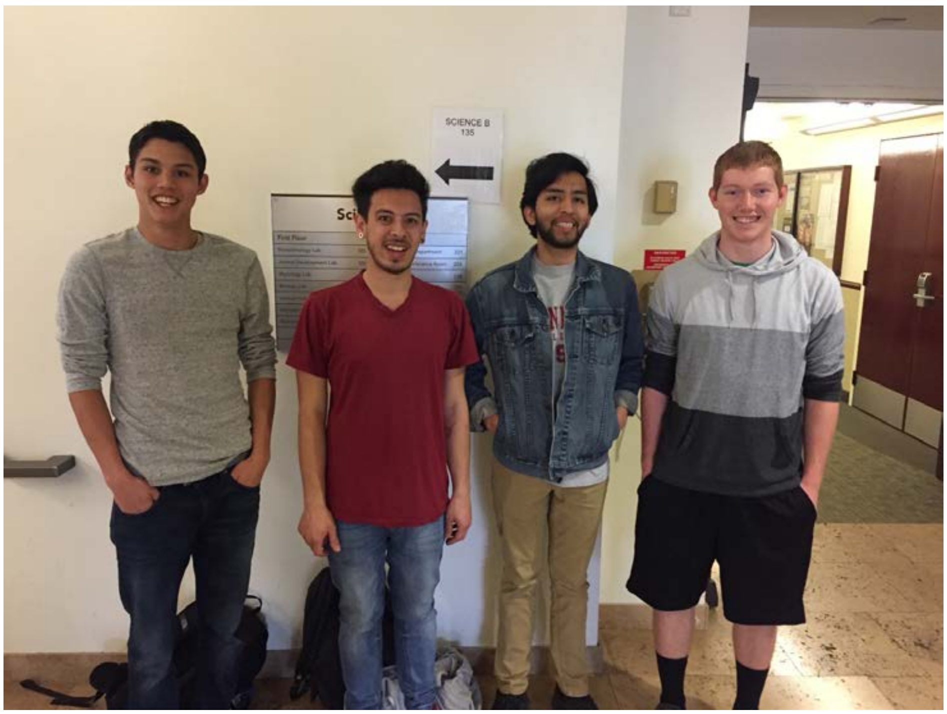
TEAM GIRL SCOUT COOKIES

Accordion Camera Obscura



Engr 215 Spring 2017

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1 Problem Formulation

1.1 Introduction

Section 1 contains the objective statement and the black box model for the Camera Obscura project. The black box model, Figure 1-1, shows an oversimplified overview of the design process for a problem presented by Zane Middle School on February 6, 2017.

1.2 Objective

Create a working Camera Obscura that teaches students at Zane Middle School point perspective and allows students to trace the images displayed.

1.3 Black Box Model

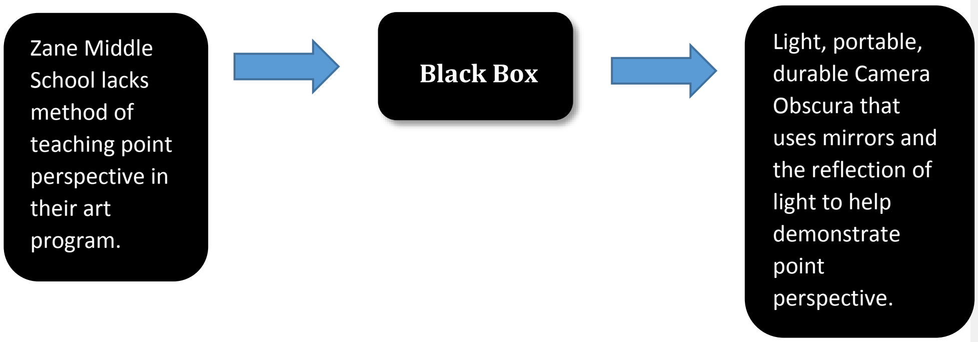


***Figure 1-1**: The black box model gives an oversimplified overview of what the design implementation will accomplish.*

2 Problem Analysis and Literature Review

2.1 Problem Analysis

2.1.1 Introduction to problem analysis

The problem analysis identifies the client's criterion and discusses the constraint associated with each criterion. The problem analysis includes: specifications and considerations, criterion and constraints, usage, and production volume.

2.1.2 Specifications and Considerations

Specifications and considerations are guidelines of the project based on the client criteria that have to be followed throughout the design process.

2.1.2.1 Specifications

Specifications describe the physical and functional characteristics of the project. These are the minimum requirements of the project. The specifications for the project are as follows:

- The camera is capable of displaying an image onto the viewing glass.
- The camera allows users to trace the images displayed on the viewing glass.
- The camera is durable.
- The camera can be easily stored and carried.
- The camera is aesthetically pleasing.

2.1.2.2 Considerations

Considerations are requirements based upon the outlined specifications in section 1.1.2.1 and general knowledge of the project. The considerations for this project are as follows:

- The camera's viewing glass is capable of withstanding a downward force of a person tracing on it.
- The camera is capable of withstanding wear and tear in a classroom environment.
- The camera can be stored on a shelf in the storage room.
- The camera can be carried by a middle school student.
- The camera is aesthetically pleasing towards young students.

2.1.3 Criterion and Constraints

The criterion and constraints help guide the design process to meet the client's needs. Criterion is an attribute of the design while a constraint is a condition that must be met by the design. Table-2.1 shows the criterion and constraints of the project.

Table 1:*List of client criterion and constraints*

Criteria	Constraint
Functionality	Middle school student is capable of using
Durability	Can withstand being in a classroom environment
Mobility	Can be easily moved by a middle school student

Aesthetics	More interesting than a plain camera obscura
Education	Meets or exceeds common core standards
Safety	Unlikely to injure a student
Cost	Less than $400
Wow factor	Greater than a textbook
Environmental Impact	Less than that of a commercial product

2.1.4 Usage

The camera obscura will be used to teach students about point perspective. The camera will also allow students to trace the images displayed on the viewing glass. The camera will be used twice a semester for a total of four times a year.

2.1.5 Production Volume

A single camera obscura will be produced for the students of Mr. Weiderman's art class at Zane Middle School.

2.2 Literature Review

The literature review section is a compilation of background research used to develop knowledge and generate ideas related to camera obscuras. This section includes research done on pedagogy, optics, materials, designs, and examples pertaining to camera obscuras.

2.2.1 Pedagogy

Pedagogy is the art, craft, and science of teaching. It deals with the best method of teaching. The project is designed for middle school students therefore a research on how they learn was constructed.

2.2.1.1 Common Core

Common core is the set of academic standards each student is expected to know by the end of each grade level. A state is not mandated to adopt these standards but a number of states have adopted the common core. In middle school, students are expected to have Examine art, photography, and other two and three-dimensional images. (CA Dept. of Education)

2.2.1.2 How children learn

Understanding how children learn is a way to help children become active learners rather than passive learners. Children are naturally curious about the way things work. They tend to gather evidence through observation and experience the most. Children are physical learners, they want to physically play with an item and try to figure out how it works. When children play with educational toys, they are actually creating a hypothesis, evaluating data, and coming up with conclusions (Kushnir, Cornell University).

Jan Hunt, an author and director of the Natural Child Project, came up with the idea of making children unschoolers. Unschoolers are those who learn directly about the world through experience rather than being taught. Jan Hunt used caterpillars to demonstrate physical learning. She stated that a child is most likely to take an interest in learning about caterpillars by physically observing it rather than reading a book about caterpillars. (Hunt, 2009)

2.2.1.3 Physical Learners

Physical learners, also known as kinesthetic learners, use movement and action to replace more passive forms of learning. Physical learners like to observe and experience the world. They learn best by combining their mind and body (Bucknell University, 2008). These learners are considered to be hyperactive and difficult but in reality they just learn differently. They learn best when they can move around rather than just sit and study. The best method to teach a physical learner is through in-class demonstration, field trips, and experiments (Bates and Wolfman).

2.2.2 Optics

Optics is the physical study of how light behaves, creates images and behaves with different types of matter. The type of optics dealt with in cameras is mostly geometric optics that treats light as rays, which make up waves, rather than the individual particles of light known as photons. Rays act differently in how they reflect and refract between different transparent medium, for example air and glass or water and glass. Reflection is when the rays of light bounce off a transparent object, whereas refraction is when the ray becomes transmitted through the transparent object (Young, 2012). Optics explains how this works with the use of an imaginary line perpendicular to the surfaces, called a normal line. When a ray of light hits the surface, called an incident ray, at a specific angle, the angle of incidence, compared to the normal line, it reflects back at the same angle on the other side of the normal line, as in Figure 1. Refraction on the other hand has the ray transmitted from the first medium to the second medium, where it bent at a different angle, called the angle of refraction that depends on the indices of refraction, which is different for specific mediums, as seen in Figure 2. Knowing the indices of refraction for both mediums and the angle that the ray hits the surface is also known, then Snell's law of refraction can be used to find the angle of refraction, $n_1 \sin\theta_1 = n_2 \sin\theta_2$ (Young, 2012).

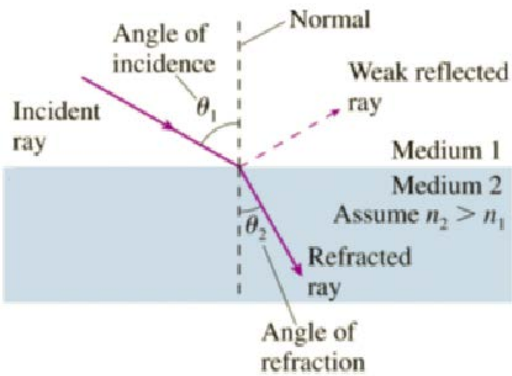


Figure 2-1: *Depicts the way that an incident ray is reflected and refracted with the use of Snell's Law ('Refraction and Lenses' 2014).*

Indices of refraction	
Medium	
Vacuum	1.00 exactly
Air (actual)	1.0003
Air (accepted)	1.00
Water	1.33
Ethyl alcohol	1.36
Oil	1.46
Glass (typical)	1.50
Polystyrene plastic	1.59
Cubic zirconia	2.18
Diamond	2.41
Silicon (infrared)	3.50

***Figure 2-2**:This table (on the right) shows the Indices of Refraction (n) for different mediums ('Refraction and Lenses' 2014)*

2.2.2.1 Lens Optics

Lenses are considered an optical system with two refracting surfaces, basically two spherical surfaces extremely close together. Converging lenses are studied specifically as rays of light waves are transmitted parallel to the imaginary perpendicular, or normal, line to the surface of the lens, they are refracted to a point on the other side of the lens, converging at a point where an upside down image can appear. This point, called a focal point is at a distance called the focal length away from the center of the lens. This normal line that goes through the lens, called the optical axis, is on both sides of it and has a focal point on either side of it, as seen in Figure 3 (Young, 2012).

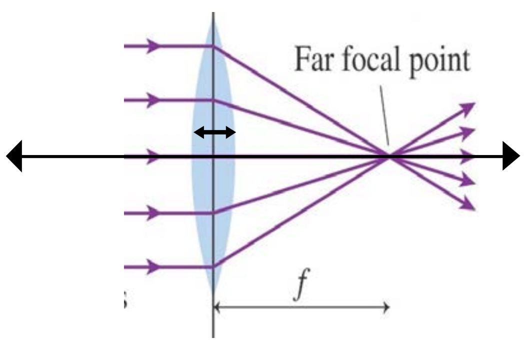


***Figure 2-3:** A converging lens with focal point the focal distance (f) away from the lens on the optical axis, which isn't labeled ('Refraction and Lenses' 2014).*

2.2.2.2 Camera Optics

Cameras are composed of a small box containing a photo-sensitive material, a converging lens and possibly a shutter to open the lens for a specific amount of time. Focusing the camera before taking a picture is required to take a picture with the sharpest image quality. The camera uses the properties of the converging lens to have the focal point at the photo-sensitive material, which records the focused image(Young, 2012). To get this focused image the lens is moved further and closer to the photo material, farther for nearer objects and closer for farther objects. With a longer focal length the angle of view becomes smaller, and a shorter focal length gets a much wider angle of view

To get the correct amount of light to the photo-sensitive material a specific light energy per unit area is needed and are usually controlled by a shutter and a lens aperture, that can be seen in Figure 2-4. The shutter controls the amount of time the lens takes in light to transmit to the photo material, while the lens aperture controls the effective area of the lens being used. All lenses have a specific f-number which is proportional to the focal length (f) and inversely proportional to the apertures diameter (D) and is the capacity for the lens to bring in light (Nave), as seen in Equation 2-1.

$$f - number = \frac{Focal\ Length}{Apeture\ diameter} = \frac{f}{D}$$

***Equation 2-1**: Equation showing how focal length is proportional to the aperture diameter (Young)*

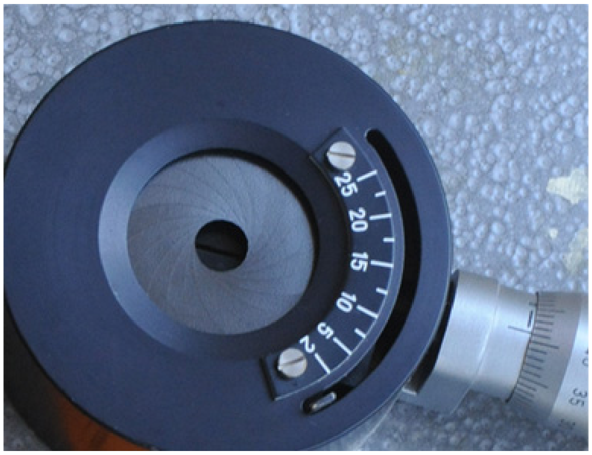


***Figure 2-4**:An image of a lens aperture in its smallest diameter (Nave 2017)*

2.2.3 Materials

2.2.3.1 Introduction

Materials that could be used to build the structure of a camera obscura are wood, metal, and plastic. This section will discuss the advantages and disadvantages of wood, metal, plastic, photography paper, hinge types, mirror types, and lens types as building materials.

2.2.3.2 Wood

Wood is, "The hard, fibrous substance consisting basically of xylem that makes up the greater part of the stems, branches, and roots of trees..." (*Merriam-Webster* 2017), and varies in size, color, shape, weight, and density. It can be divided up into two general categories, softwood and hardwood. Softwoods (fir, pine, or spruce) are conifers, while hardwoods (maple, oak, or rosewood) are angiosperms. Some softwoods can be denser than some hardwoods. Density is affected by, "Age, diameter, height, radial (trunk) growth, geographical location, site and growing conditions, sylvicultural treatment, and seed source" (Timell 1986). The closer the growth rings, the denser the wood. Growth rings vary upon seasonal patterns. In the spring the cambium, part of tree responsible for lateral growth, is more active and called earlywood, and in the summer its growth is slowed and called latewood (Figure 2-1). With softwood, "latewood tends to be darker, denser, and has smaller diameter tracheid's; earlywood is lighter, softer, and has larger diameter tracheid's" (Meier 2008). With hardwood, "latewood has smaller and less frequent pores; earlywood has larger, more numerous pores" (Meier 2008). Wood provides versatility and easy use as a building material, durability towards physical forces, and structural strength. The cost of wood is usually not cheap and wood does not fare well in damp conditions.

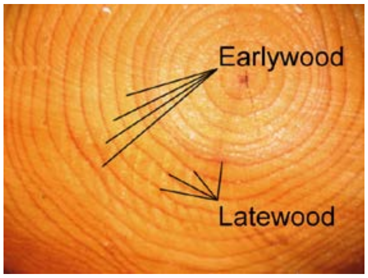


Figure 2-5: *Growth rings shown as earlywood or latewood. (Willem 2003)*

2.2.3.3 Metal

Metal is, "A solid material which is typically hard, shiny, malleable, fusible, and ductile, with good electrical and thermal conductivity" (Oxford 2017), and can exist as an element, compound, or alloy. The 91 metal elements on the periodic table are considered pure metals while compounds and alloys are a mix of different elements, but most metals do not form naturally and usually are found as compounds. Compounds are the mixture of two or more metal and nonmetal elements with a fixed composition and alloys are the mixture of various metals or a metal and an element with varying composition (Science 2017). Alloys are mostly man-made and created to have a metal with specific parameters. Copper and tin are mixed to create bronze which is harder than either metal alone. The hardness of a metal is not its density. Iron has a density of 7.87 g/cm^3 and steel has a density of 7.60 g/cm^3 (Macmillan 2010). On Mohs hardness scale (Figure 2-2) iron is 4-5 while steel is harder at 5-8.5 (Ted Pella 1996). Metals have high durability to both physical and elemental forces, provide structural strength, most often expensive, and heavy.

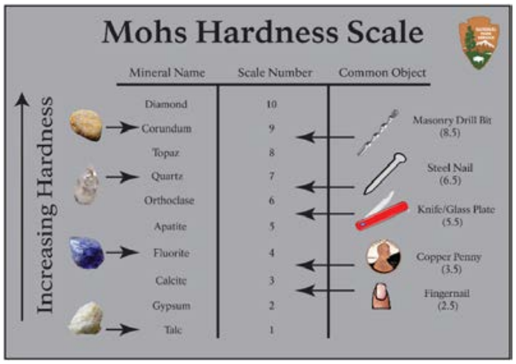
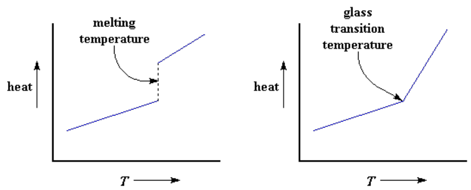


Figure 2-6: *Visual of Mohs Hardness Scale. (Mohs 2012)*

2.2.3.4 Plastic

Plastic is, "A synthetic material made from a wide range of organic polymers" (*Merriam-Webster* 2017). It is classified by if its thermoplastic, thermoset, biodegradable, elastomer, electrically conductive, structural, and by physical properties such as tensile strength, density, and glass transition temperature. Thermoplastic is a plastic that can be melted down and reused, thermoset can only be used once. Thermoset offers greater thermal stability and is hard and brittle. Biodegradable plastic can be broken down by water, wind, sunlight, bacteria, and enzymes. Elastomer is plastic that displays viscoelastic properties (if it is stretchy). Electroconductivity is the degree to which the plastic conducts electricity (Ensinger 2017). Structure refers to what group the plastic belongs, such as engineering plastics have more mechanical and thermal applications, and commodity plastic are cheaper and widely used. Tensile strength refers to the force required to pull something, density is the ratio of mass to volume, and glass transition temperature, Figure 2-2, is the temperature at which a hard, brittle object turns soft and rubbery (ScienceDaily 2016). These are all determined by the chemical structure of the polymer's backbone and side chains. Plastic can be used to build pretty much anything, is very cheap to build with, is water resistant, has a high environmental impact, and low durability.



A heat vs. temperature plot for an crystalline polymer, on the left; and a amorphous polymer on the right.

Figure 2-7: *Crystalline (not-brittle) vs. amorphous polymer (brittle) on a heat vs. temperature plot. (Crystalline 2003)*

2.2.3.5 Photography Paper

Photography paper is a, "light-sensitive paper on which photograph can be printed" (Farlex 2003), used for both film and photography. It is composed of a coating of a light-sensitive emulsion, usually consisting of silver halide salts suspended in colloidal material, and base material of baryta-coated paper, resin-coated paper, or solid polyester. The emulsion is sensitized to certain colors of light or wavelengths, in order to produce certain dye or protect the paper during processing, and both the emulsion and base material depend on what process is being used. All photography paper can be put into three processes: Negative to positive process where the colors are inverted during development, positive to positive process where the image is enlarged transferred from film to paper, and positive to positive process where the final image is the original film (Sowerby 1956). Baryta-coated paper or fiber-based paper (Figure 2-4) brightens the image and prevents absorbed chemicals from entering the gelatin layer. Resin-coated paper (Figure 2-4) improves dimensional stability and reduces developing time by making the paper impenetrable to liquids. Solid polyester increases the durability, because of its strong fibers and resistance to chemicals, and decreases developing time because it dries quickly (Salvaggio 2013). Photographic paper can capture an image, has low durability, and relatively high cost.

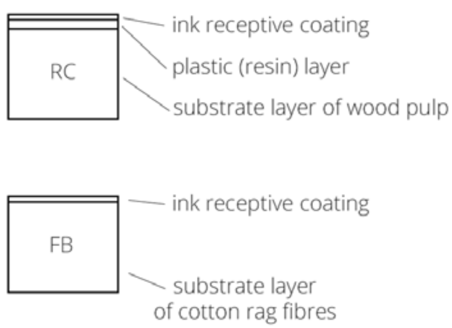


Figure 2-8: *Resin-coated and fiber-based photographic paper diagram. (Farrer 2015)*

2.2.3.6 Hinge Types

Hinges are, "a jointed or flexible device on which a door, lid, or other swinging part turns" (*Merriam-Webster* 2017). Cabinet, door, furniture, gate, shutter/window, and specialty hinges are a few categories they are broken up into. Each category contains different types, such as for cabinets there are blum, grass, European, semi-concealed, surface mounted, demountable, youngdale, overlay, wrap around, partial-inset, pivot, butt, and amerock hinges. Each hinge is good for different tasks. Factors such as which side (left, right, front, or back) the hinge is going on, direction the object is opening, and the thickness, weight, and clearance (lipped, overlay in Figure 2-5 and flush Figure 2-6) of the object are all essential to what hinge is selected (Philbin 2002). A hinge provides an axis of rotation and limits the space that object once attached.

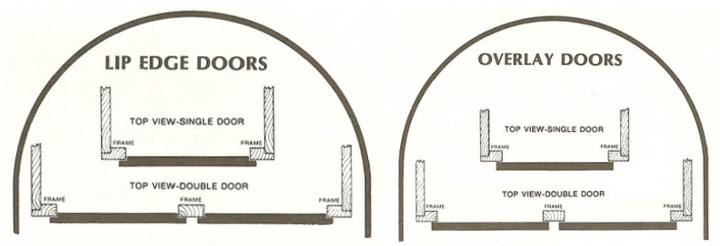


Figure 2-9: *Top view of lipped (left) and overlay (right) doors. (Philbin 2002)*

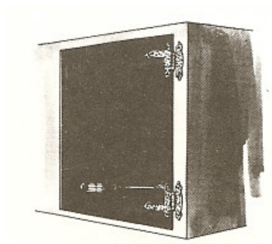


Figure 2-10: *Angled side view of a flush door. (Philbin 2002)*

2.2.3.7 Mirror Types
Mirrors are objects that reflect images. Commonly used mirrors are made up of plate-glass that is shaped, polished, and cleaned before being coated by a reflective substance, usually aluminum, resulting in it being called an aluminum glass mirror. A mirror can be either flat, reflect an image of the same size, convex, reflect an enlarged image, or concave, reflect a smaller, distorted image. One-way mirrors allow sight through one side, but reflect on the other. Silvered mirrors use a thin layer of metallic silver, which has the highest degree of reflectivity, to provide a high-quality reflective surface. Safety glass mirrors adhere a special protective film to the back to reduce the chance of injury when they break (Joyce 2015). A mirror provides a highly reflective surface and is easy to break.

2.2.3.8 Lens Types
Lenses are made out glass or plastic that is molded, ground, and polished into a desired shape. They come as a single piece of transparent material called a simple lens, which are used in products such as magnifying glasses, or as a group of simple lenses aligned upon a common axis called a compound lens, which are used in products such as cameras. Simple lenses, Figure 2-7, are either biconvex, plano-convex, positive meniscus, negative meniscus, Plano-concave, or biconcave. Biconvex, plano-convex, and positive meniscus lenses focus light behind them creating a real image, while biconcave, Plano-concave, and negative meniscus lenses diverge light behind them creating a virtual image. Compound lens use these simple lenses together to change, amplify, or reduce their individual optical effects (AZoOptics 2014). There are also fluidic adaptive lenses that can be tuned dynamically transform the lens properties and type by adjusting fluidic pressure (Zhang 2004).

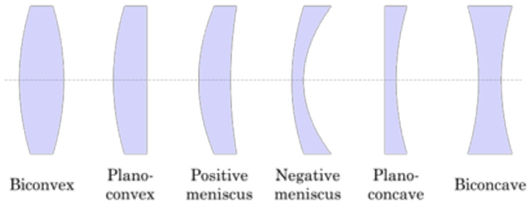


Figure 2-11: *Types of simple lenses. (ElfQrin 2001)*

2.2.4 Camera Obscura Designs

2.2.4.1 Boxes

Box designs are typically crafted out of wood, though cardboard is less durable alternative. Different box camera obscura designs can be split up into two categories, simple box and reflex camera obscura.

2.2.4.1.1 Reflex Camera Obscura

With this design, the image is first taken into the box through a reflex lens. The image is then reflected off an angled mirror to be project on a small viewing arear on the top of the box. The image, which is presented on a glass screen or photography paper, is upright but reversed. The mirror is placed at a forty-five-degree angle facing upwards to direct the image directly vertical. Often, designs such as this had another section of the box that was connected to the lens that could slide inwards and outwards. This was used to change the focus of the lens based upon how close an object is relative to the camera (Hammond 3-4).

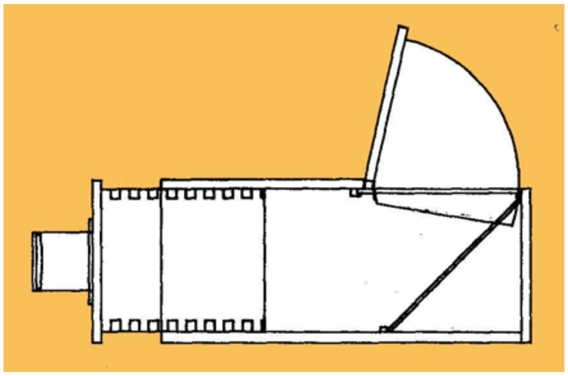


Figure 2-12: *Simple camera obscure box model with sliding focus feature (Hultman, 2003)*

2.2.4.1.2 Simple Box Camera Obscura

A common and more simple approach to crafting a camera obscura, the basic box design incorporates an opening to allow light into it (Balihar 2001). Often referred to as the “pinhole box” or “pinhole camera,” a small aperture allows light through which then presents an inverted image on the surface opposite the pinhole. The pinhole camera can also be used as an aid to drawing (Balihar 2001).

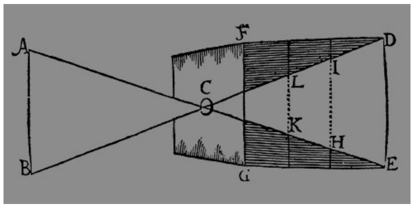


Figure 2-13*: Showing of inversion of light entering through a pinhole. (Balihar 2001)*

2.2.4.2 Darkrooms

A commonly constructed design in the 19th century, a camera obscura dark room utilized an entire room to display an inverse image on a wall. A lens set into one wall would take in the light and project it on the opposing wall. Alternatively, many architects and engineers designed camera obscuras which involved the lens taking in an image of the outside from the room or top of a building. This image was then reflected on a mirror towards the ground to present an image on a viewing table or surface (Hammond 1981).

2.2.5 Camera Obscura Examples

2.2.5.1 Clifton Observatory

The observatory utilizes a convex lens and mirror to project a panoramic view onto the floor of the dark room below. The actual panoramic image can be viewed on a circular metal table that can be rotated around by turning the mirror (Clifton Observatory 2015).

Figure 2-14: *An outside image of the darkroom camera obscura located within Clifton Observatory (Clifton Observatory 2015)*

2.2.5.2 Great Union Camera Obscura

The Great Union Camera Obscura, Figure 2-15, is unique in its design from any other camera obscura in the world. This specific design utilizes eleven separate lenses on the roof of the that reflect onto a series of mirrors to project the outside image into the darkened room ("Great Union Camera Obscura" 2017).

Figure 2-15*: Great Union Camera Obscura in Douglas on the Isle of Man ("Great Union Camera Obscura" 2017)*

2.2.5.3 Dumfries Museum

Originally a flour or provender windmill built in 1760, the Dumfries Museum, Figure 2-16, was converted to an observatory outfitted with a camera obscura provided by Mr. Morton of Kilmarnock. The camera provided was a size of seven and a half inches. Fifteen people at one time can view the outside image around the inset concave table that can raise and lower. The turret that has the lens on it can be rotated around to view the landscape at a 1.5X magnification (Hammond 1981). Other camera obscura's similar to this one include: the Clifton Observatory, Constitution Hill Aberystwyth, and the Santa Monica Camera Obscura.

Figure 2-16: *Dumfries Museum and Observatory (Dumfries Museum 2017)*

2.2.5.4 Pinhole Camera

This Pinhole Camera, Figure 2-17, was constructed using a cardboard box, black tape, photographic paper, and a tin can lid with a small hole in it. The tin can lid is attached to the outside of the bag over a small opening then taped over to keep light from getting in. The photographic paper is placed against the inside of the black box while in a dark room to keep from exposing the paper to light. When ready to capture an image, simply lift the tape for as long as one would want the photopaper or film to be exposed to the image (Balihar 2001).

***Figure 2-17**: Pinhole Camera (Balihar 2001)*

3 Search for Alternative Solutions

3.1 Introduction

Throughout multiple meetings and brainstorming sessions, six alternative camera obscura designs were created. The alternative solutions all meet the listed specifications and criteria; each satisfying all of the client's specified requirements to an extent.

3.2 Brainstorming

A total of two brainstorming sessions were conducted in the library with the use of paper and pencil to convey and record ideas. The purpose of these brainstorming sessions were to come up with at least six alternative camera obscura designs that met all the listed specifications and criteria, while remaining unique in some aspect. This includes different materials, additional parts, or alternative easy storage designs, which can be seen in Appendix A – Brainstorming Documentation.

3.3 Alternative Solutions

During the brainstorming session, six alternative solutions that met the set of design parameters were developed. Once developed, each alternative solution was depicted with a labelled illustration of the design and a detailed description. The six alternative designs are:

- Latched Camera Obscura
- 'I Can't Believe It's Not Wood' Camera
- Accordion Camera Obscura
- Shower Darkroom
- Dual Project-and-Capture Camera Obscura
- Strapped Curtain Camera Obscura

3.3.1 Latched Camera Obscura

The Latched Camera Obscura is a camera obscura design that relies upon hinges and latches for easy storage, Figure 3-1. The design has a lens, **B**, glass viewing pane, **E**, viewing pane cover, **F**, and mirror, **G**, like a standard box camera obscura. Four latches on both the front and back, **A,** allow both the front and back panels to be removed, opening up the back so that the mirror and glass viewing pane can be taken out. The two latches on the bottom, **D**, and the four hinges on the top and bottom, **C,** are placed so that the main box can be folded up, greatly decreasing the space it takes up.

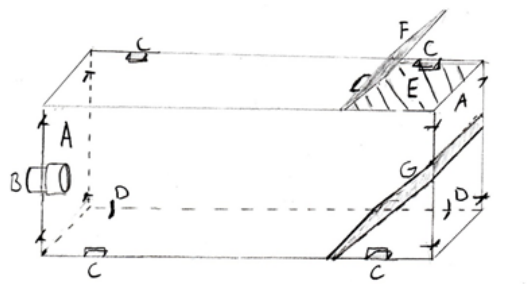


__Figure 3-1:__ The Latch Camera Design implements hinges and latches for easy storage. The letter labels represent the following: A, the four latches on the front and back; B, the lens; C, hinges; D, latches; E, glass viewing pane; F, viewing pane cover; G, mirror. (Image by Max Wrigley)

3.3.2 'I Can't Believe It's Not Wood' Camera

The 'I can't believe it's not wood' camera obscura is constructed out of Unplasticized polyvinyl chloride (uPVC). This material is rigid, durable, and can withstand high temperatures. In order to achieve a more vintage aesthetic, the plastic will undergo a process which would give it a more wood-like texture and look. The plastic will be scratched with a 100 grit sand paper and heavy metal file for texture. Then, it will be brushed with various shades of brown oil paints to give it a vintage wood-look. Figure 3-2 exhibits a labeled sketch of the design. **A** is a smaller compartment that allows the camera to extend or be compacted into the larger compartment **B**. This also allows the lens to be moved with respect to the focal point for focusing an image. **C** are rubber stoppers that increase friction between the camera and the table allowing a greater horizontal force to be applied upon the camera. **D** is the hinge that will allow the viewing glass cover to open. **E** is the lens that will be fixed in the center of the front side of the box.

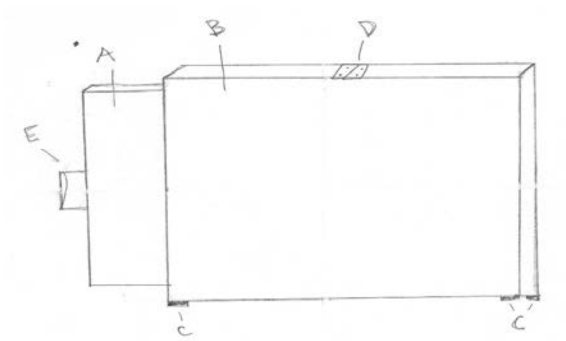


__Figure 3-2:__ 'I Can't Beleive it's not wood' Camera Obscura utilizes uPVC as the main material. The letter labels in the figure refer to the following: __A__, lens box; __B__, base box; __C__, rubber bumpons; __D__, hinges.(Image by Felix Chavez)

3.3.3 Accordion Camera Obscura

The Accordion Camera Obscura is an alternative solution which utilizes the concept of bellows. Bellows, shown as **A**, allow the camera to extend and compact allowing the lens to be moved with respect to the focal point for focusing images. The bellows are attached to the base box on one side and attached to the lens box which holds the lens, shown as **F**, on the other side. Rails, see label **B**, help keep the bellows at steady 180° angle and prevent the bellows from being over-extended. When the lens box is compacted into the larger base box, the cover (**C**) will close and straps on the side, shown as **D**, will keep the cover on when the camera is not in use. Figure 3-4 shows how the Accordion camera would look like when not in use. Rubber bumpons, shown as **E**, are located at the bottom of the camera to prevent the camera from sliding when tracing images. The combination of the bellows and stained wood give a vintage aesthetic to the camera.

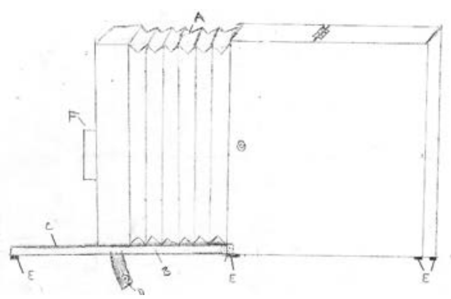


***Figure 3-3*:** *The Accordion Camera Obscura incorporates bellows in order to allow the manipulation of the focal length and for aesthetic purposes as well. The letter labels represent the following: **A**, the bellows; **B**, rails; **C**, front cover; **D**, straps; **E**, rubber bumpons; **F**, the lens. (Image created by Felix Chavez)*

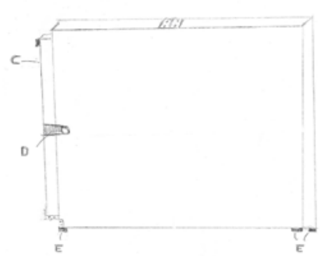


***Figure 3-4*:** *A view of the Accordion Camera Obscura when not in use. (Image created by Felix Chavez)*

3.3.4 The Shower Darkroom

The Shower Darkroom is a single user camera obscura. Seen in Figure 3-5, it utilizes a black curtain to shroud the user and a small viewing table to allow the image to be seen in complete daylight. The outside image is projected from a **convergent lens** located at the top of the structure, which is reflected directly downward onto the **viewing table**. Students can then see an image of the area outside the enclosed darkroom. The inside support frame, see label **PVC pipe frame**, is comprised of two circles of pvc pipe, one at the base, the other at the top, connected in between by four vertical columns of pvc to make the structure more durable. The lens and mirror are hoisted at the top of the darkroom inside a small enclosure, shown as **box mount**, and strung up along another set of pvc supports, around which a **dark curtain** is draped over to make the image easier to view for functionality purposes.

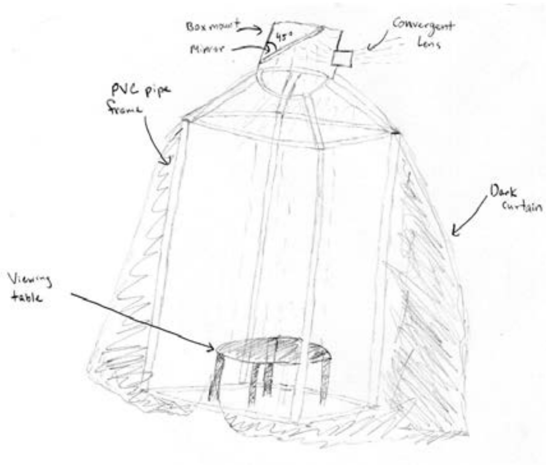


Figure 3-5: *The Shower Curtain Camera Obscura incorporates a small enclosed area that his completely dark save for the light streaming down from a lens and mirror that reflects an image downwards into the enclosure.**(**Image created by Gannon Carroll**)***

3.3.5 Dual Project-and-Capture Camera

The Dual Project-and-Capture Camera Obscura is a merging of both a photo paper and reflex camera obscura. In Figure 3-6, a mirror, **C,** will be placed at 45 degrees to reflect the light allowed in by the convergent lens, **D**, upwards towards a viewing pane, see label **B**. For taking pictures with photo paper, one will slide the compartment, **G,** out of the box on its tracks, shown as **E**. Photo paper will then be fit in the sliding compartments slots for holding paper, **F,** which is done in a darkroom to avoid risking exposure. The sliding compartment can also be left empty, without photo paper inside, to allow the light to travel all the way to the mirror and then the viewing glass, which allows for dual functionality.

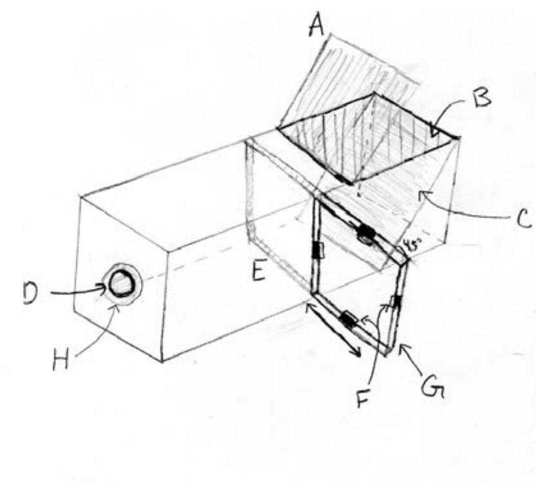


Figure 3-6: *The Dual Project-and-Capture Camera incorporates the addition of a function for capturing images with photo paper. The letter labels represent the following: (A) Glass pane cover (B) Glass viewing pane (C) Mirror (D)Convergent Lens (E)Sliding tracks (F)Holding slots (G) Sliding compartment (H)Lens cover. (Image by Gannon Carroll)*

3.3.6 Strapped Curtain Camera Obscura

The Strapped Curtain Camera Obscura is a camera Obscura design that incorporates a separate compartment that contains a curtain that acts as a portable dark room, seen in Figure 3-7. This camera design has a lens **A**, viewing window **B** and a mirror **C** like most of the other designs, but utilizes the curtain **E** in its own compartment **F**. The curtain goes over the user to have less light enter the camera through the viewing window for quality images. Having its own compartment for its curtain makes this design not only functional, but also more mobile as the curtain compacts when not in use. For even more mobility, this design has a leather strap **G**, that lets students easily carry the camera for long distances. Aesthetically this design incorporates faux leather on its exterior to exude an old-fashion feel.

Commented [1]: I have two figures for one of my suggestions so all figures after mine move one up. i changed this figure number already.

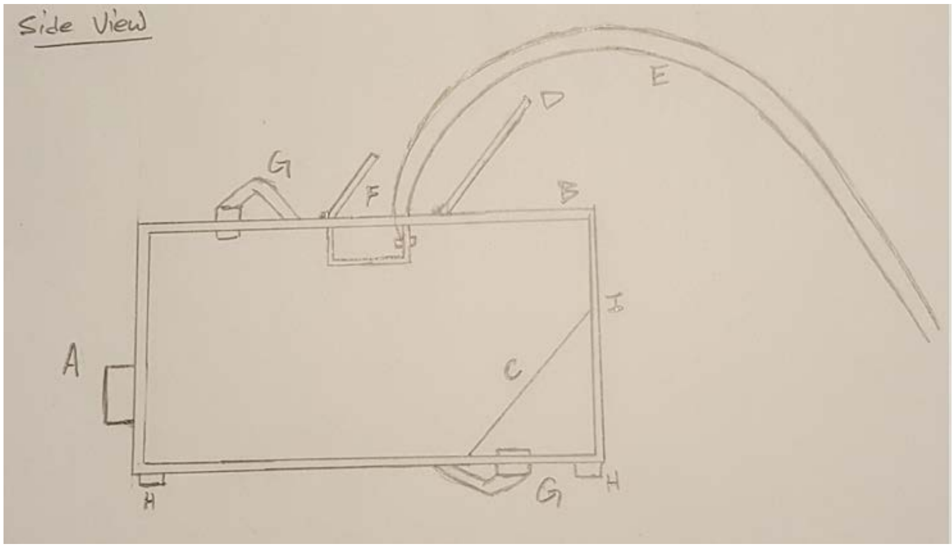


Figure 3-7: *The Strapped Curtain Camera Obscura integrates a curtain to cover the user. The letter labels indicate: A) lens, B) view window, C) mirror, D) view window cover, E) curtain, F) curtain cover, G) strap, H) rubber feet, and I) the faux leather exterior. (Image by Luke Pascasio)*

4 Decision Process

4.1 Introduction

Section 4 is the culmination of the problem formulation, problem analysis, literature review, and alternative solutions in order to produce the most appropriate design that meets the client's needs. The final design was chosen using the Delphi Matrix, which weights each alternative solution based off of how well each solution met the specified design criteria listed in Section 2.

4.2 Criteria

The following criteria, from section 2, were used to weight each alternative solution. They are defined as follows:

Cost- the total money used for all the materials used in the construction of the product, including maintenance costs. Also includes the total labor cost.

Durability- the products ability to withstand wear and tear in a classroom environment.

Mobility- the products ability to be easily stored and carried.

Aesthetics- the designs visual appeal.

Functionality- the ability of the product to serve its purpose while being practical.

Wow Factor- the uniqueness off the product.

Education- the products ability to teach students point perspective.

Environmental Impact- minimal amount of negative impact on the environment from the product

Safety- the product's unlikeliness to cause injury/danger to students.

4.3 Solutions

The following list is comprised of the alternative solutions, from section 3, being considered in the decision process. The alternative solutions being considered are:

- Latched Camera
- 'I Can't Believe It's Not Wood' Camera
- Accordion Camera Obscura
- Shower Curtain Darkroom
- Dual Project-and-Capture Camera
- Strapped Curtain Camera Obscura

4.4 Decision Process

The Delphi Matrix used during this process is shown in Table-4.2, the matrix was used to determine the most optimal solution for the final project decision. Before the matrix can be created, a list composed of criteria from Section 2 is to be weighted on a scale of 1-10 (Table-4.1), with 10 being of the highest importance. A group consensus determined the rating, on a scale of 0-50, for each alternative solution based on how it met each criterion. A 50 is given for a solution that best meets the criterion discussed. Once the group reached a consensus on the ratings, each rating was multiplied by the correlating criteria weight to receive a score. The sums of all of the separate criteria scores for the alternative solutions are then compared to determine the final solution.

Table 2: *Table of criteria listed by weight.(Image by Gannon Carroll)*

Criteria	
List	**Weight**
Functionality	10
Durability	9
Mobility	9
Aesthetics	9
Education	8
Safety	7
Cost	6
Wow Factor	6
Environmental Impact	4

Table 3: *Delphi Matrix used in the decision process. The Delphi matrix table includes the weighted criteria similar to Table4.1 on the left along with the ratings on the right. In the bottom, the total ratings are summed up and the alternative with the highest rating is chosen as the final design. (Table by Max Wrigley)*

Criteria		**Solutions**					
List	Weight	Latched Camera	Not Wood Camera	Accordian Camera	Shower Darkroom	Project-and-Capture	Strapped Curtain
Functionality	10	45 / 450	40 / 400	40 / 400	20 / 200	35 / 350	45 / 450
Durability	9	35 / 315	45 / 405	30 / 270	5 / 45	35 / 315	35 / 315
Mobility	9	45 / 405	35 / 315	35 / 315	5 / 45	20 / 180	40 / 360
Aesthetics	9	5 / 45	10 / 90	43 / 387	30 / 270	5 / 45	38 / 342
Education	8	25 / 200	35 / 280	40 / 320	25 / 200	40 / 320	25 / 200
Safety	7	25 / 175	40 / 280	30 / 210	41 / 287	25 / 175	28 / 196
Cost	6	30 / 180	20 / 120	30 / 180	10 / 60	15 / 90	30 / 180
Wow Factor	6	10 / 60	15 / 90	33 / 198	42 / 252	35 / 210	23 / 138
Environmental Impact	4	34 / 136	5 / 20	30 / 120	10 / 40	15 / 60	20 / 80
Total		1966	2000	2400	1399	1745	2261

4.5 Final Decision

The Delphi method concluded that the Accordion Camera alternative, from section 3.3.3, is the best fit for the camera needed for the students of Zane middle school. This model is on the more expensive side and has a greater impact on the environment, but it has the best aesthetics with its old fashion style which also brings the best educational capabilities of all the models. Educationally, the Accordion Camera offers a larger viewing window and better focusing for teaching point perspective.

5 Specification

5.1 Introduction

The purpose of section 5 is to give a detailed description of the final solution chosen in section 4. This includes a step by step instructions on how to implement and use the product. This section also contains a table of cost of materials, an estimated total design hours, and estimated time of maintenance.

5.2 Description of Solution

The final decision for the Camera Obscura was a standard box camera obscura with a few modifications. Various ideas were implemented upon the base, mirror, and glass to improve their overall aesthetic and functionality. The addition of bellows and a railing system allow for an extendable front that yields multiple advantages. The camera obscura is going to be 24” x 9.5” x 10” and made out of wood.

5.2.1 The Base

The base includes the viewport, lens box, and main box. It is made out of ¼” birch ply and is 24” x 9.5” x 10” including the length added by the bellows. Figure 5.1 shows that the viewport is built into the top as an 8” x 8” square that is hinged so it opens away from the lens. Figure 5.1 also shows the main box and its dimensions, 14.3” x 9.5” x 10”. The main is open on one of the 9.5” sides. The lens box is a 3” x 9.5” x 10” box with one of the 9.5” sides missing, and with the lense mounted 1.5” down from the center of the other side, as shown in Figure 5.2. The main box connects to the bellows in the front, which then connects to the back of the lens box. For functionality, rubber stoppers are going to be added to the bottom for traction. For aesthetics, oak wood stain is applied to the outside of the base so as to achieve an old-fashioned look.

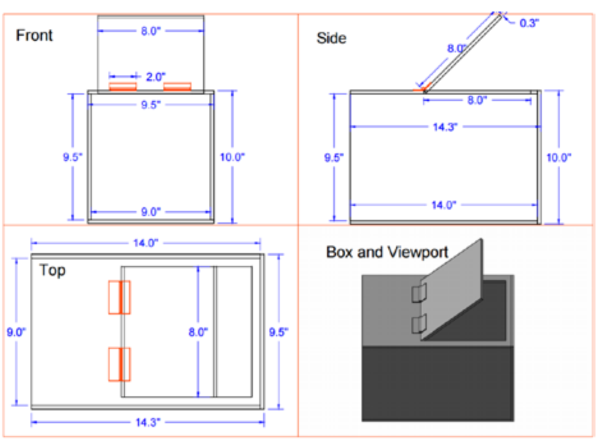


Figure 5-1: *Contains the views of the dimensions used for the final layout of base box and viewport (AutoCAD work by Max Wrigley).*

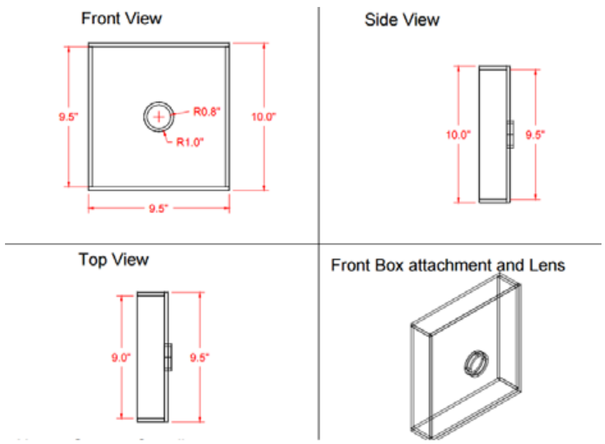


Figure 5-2: *Contains the views of lens and box attachment (AutoCAD by Gannon Carroll)*

5.2.2 The Mirror/Glass

The glass pane is located directly beneath the viewport, pressed against the top of the box frame, as seen in Figure 5.2-3. The glass pane is a ¼" thick for the intents and purposes of students using the glass as a surface to write on. The glass pane is 9" by 9" and 8" by 8" of the glass is displayed out of the viewing port. The mirror is a section that is 11.3" by 9". It is wedged in at a 45 degree angle, facing the bellows, and leaning against the back panel of the box base. This mirror angled at 45 degrees allows the light that is coming through

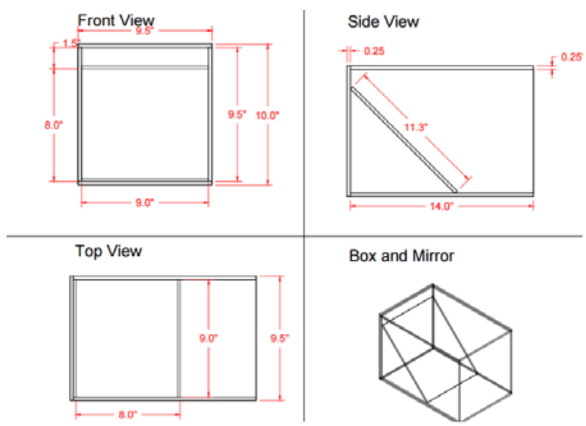


Figure 5-3: *Contains the views and dimensions of the Base Box and Mirror(AutoCAD by Felix Chavez).*

5.2.3 The Bellows

The bellows are attached to the front of the base box, to the open end, shown in Figure 5.2-4. The purpose of the bellows is to be able to move the front portion of the box to allow for focusing of the lens depending upon the distance of the image in view. The bellows are made of fabric that is coated with a polybond glue in order to hold the shape needed. The bellows are fit inside the front of the box to allow for full retraction length so the lens box and base box can fit together compactly.

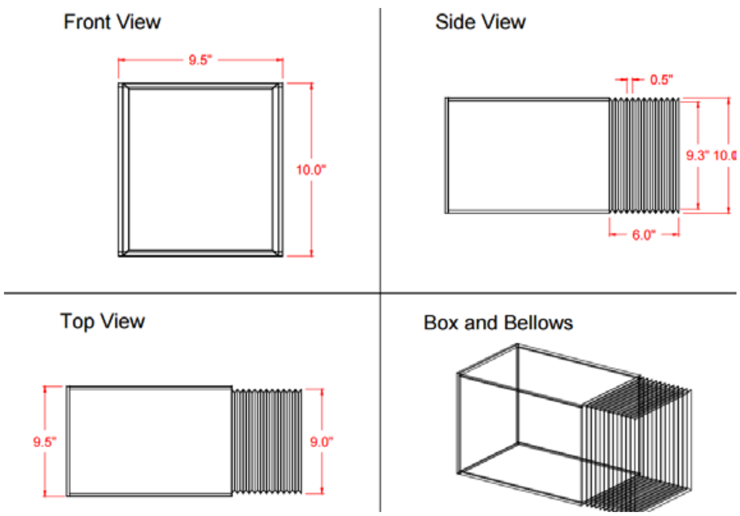


Figure 5-4: *Contains the views and dimensions of the Base box and bellows attached (AutoCAD by Luke Pascasio).*

5.2.4 The Railing System

The railing system serves two purposes in the design to keep the bellows straight at a 180°, and changing the focal length of the camera. The first purpose is to keep the bellows at a 180° angle from the base. This allows the lens to line up with the center of the mirror that an image can be displayed on the viewing glass. The second purpose of putting a railing system with a crank is to allow students to manipulate the focal point without causing damage to the bellows. Keeping the bellows on a railing system keeps students from over-extending the bellows, causing tears/damage to the bellows. The railing system is be attached to both the base and the lid. The lens box contains wheels allowing it to move freely on the rails.

5.3 Costs

5.3.1 Design Cost (hours)

Design cost shows the amount of hours Team Girl Scout Cookies worked on the project to create the camera obscura. Most of the design hours were spent on section 5, Design specifications, and a total of 126 hours were spent on the project, as seen in Figure 5.3-6.

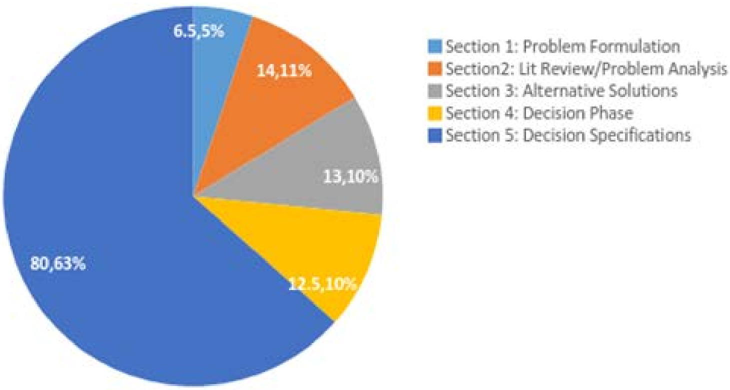


Figure 5-5 *:A chart depicting the distribution of team design hours (chart by Luke Pascasio).*

5.3.2 Implementation Cost ($)

The total cost of materials for the Accordion Camera Obscura is $46.00, as stated in Table 5.1. with the individual cost for each material used. A number of materials were donated to the team and kept the final total lower than what the total was projected to be.

Table 4: *Cost of materials for the Accordion Camera Obscura (table by Luke Pascasio)*

Cost of Materials			
Materials	**Use**	**Quantity**	**Cost**
Mirror	Inside Camera	1 9"x11.3"	$6.00
Glass	Viewing Window	1 9"x9.5"x0.25"	$14.00
Lens	On Camera	1	$2.54
Wood	Fram of Camera	4 9.5"x9.5"	Donated
Fabric (Black)	Bellows	37"x15"	$5.50
Canvas (White)	Bellows	37"x15"	$5.50
Polibond Adhesive	Bellows	3 oz. bottle	$6.99
Card Paper	Bellows	4 8.5"x11"	Donated
Spray Paint (Black)	Bellows	1 can	Donated
Wood Finishing	On Frame	1 can	Donated
		Total	**$40.53**

5.4 Instructions for Implementation

The model is used for in-class demonstration for students to learn point perspective. To operate the camera, the lid must be opened first by lifting the lid on the top revealing the viewing glass. The next step is to adjust the length of the bellows to focus the image that appears upside down on the viewing glass. The correct amount of light is required to get the best image displayed on the glass.

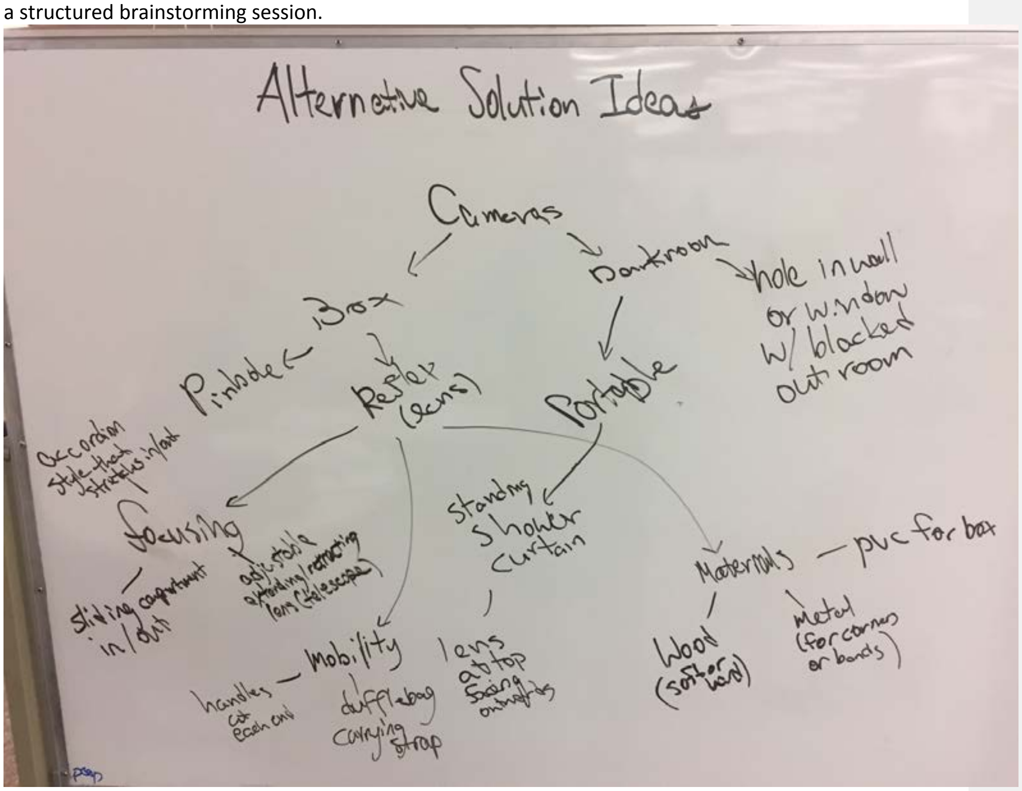
5.5 Results

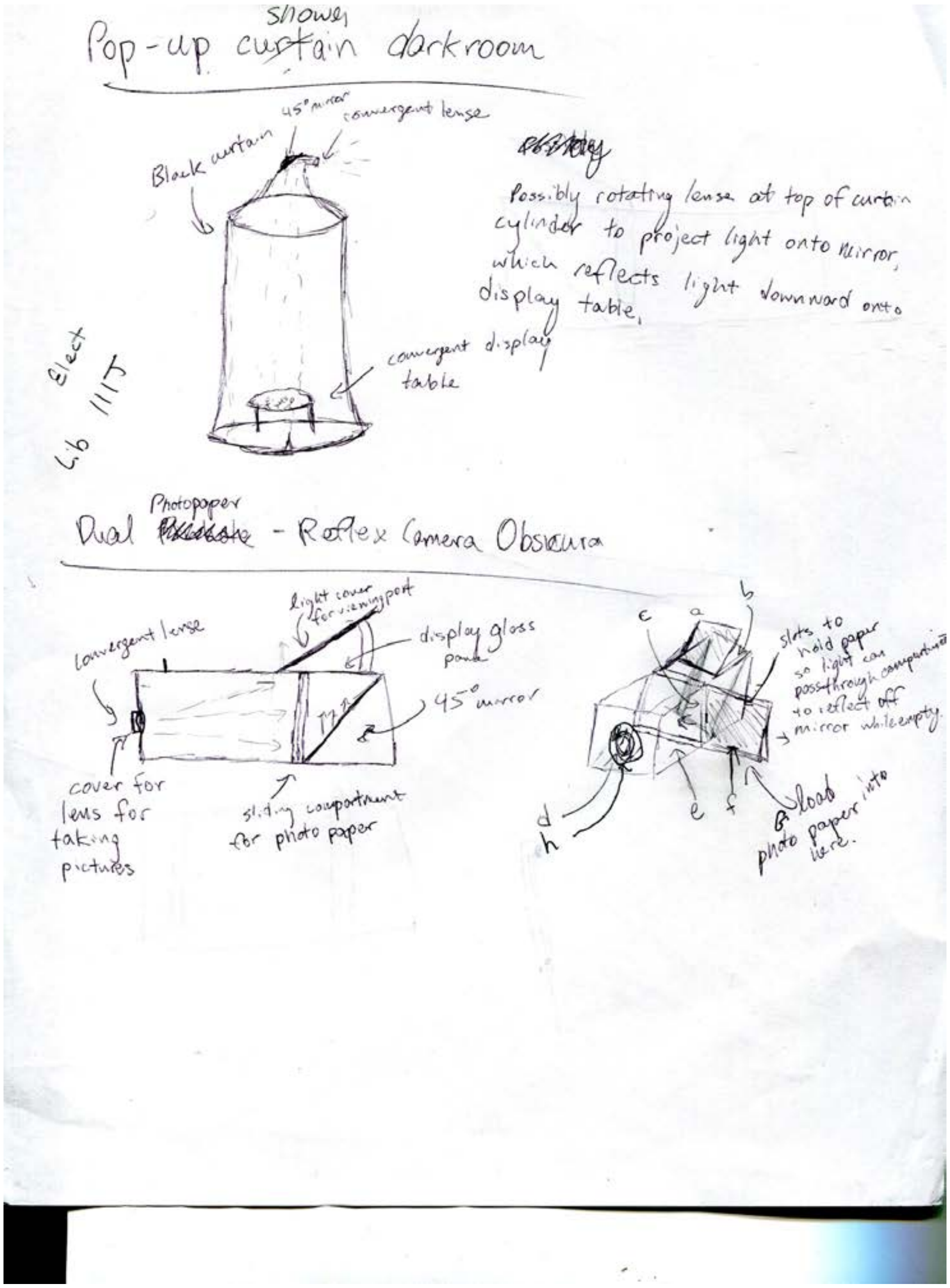
The results of the Accordion Camera Obscura, once built, conclude that it is an optimal design for teaching point perspective. The model provides a creative alteration to the general camera box design. This design might not have been the most efficient way to present the image, due to the necessity of a blanket to darken viewing port enough to see the image displayed, but once darkened, the image can be clearly seen (Figure 5-7). The thick viewing glass allows users to trace the images displayed onto paper, while the bellows allow for compacting and variable focal length. In addition, the bellows complete the overall old time aesthetic. The accordion model provides a durable solution that is able to be easily used by middle school students. It can help with showing perspective in art class, and is made usable and portable by the lighter weight but durable wood structure.

Figure 5-6: *Image displayed on the Accordion Camera Obscura viewport. (Image by Felix Chavez)*

Appendix A - Brainstorming Documentation

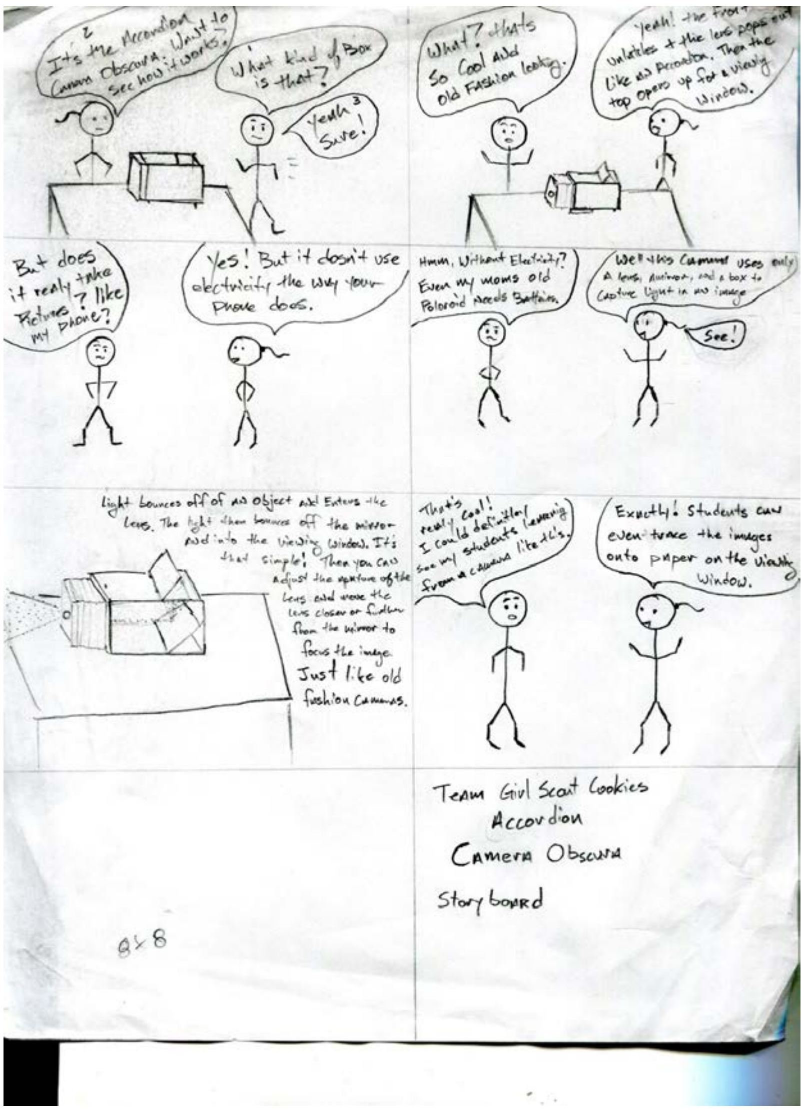
Of the two images included, the first is taken from an unstructured brainstorming session in the second floor of the library. The second image is scanned from sketches of a couple ideas that were discussed in a structured brainstorming session.




shower
Pop-up curtain darkroom
45° mirror
convergent lense
Black curtain
Possibly rotating lense at top of curtain cylinder to project light onto mirror, which reflects light downward onto display table.
convergent display table
Elect
Lib 111J
Photopaper
Dual - Reflex Camera Obscura
light cover for viewing port
convergent lense
display gloss pane
45° mirror
cover for lens for taking pictures
sliding compartment for photo paper
slots to hold paper so light can pass through compartment to reflect off mirror while empty.
load photo paper into here.

Appendix B - Storyboarding

A theoretical situation that could occur when presenting our solution to random citizens.



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