SUNDIAL SQUARE BENCHES

Team Sunset Society

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Table of Contents

Table of Figures

1. Problem Formulation

1.1.Introduction

The problem formulation contains the objective statement and black box model for the design project. In the black box model shown in Figure 1-1, the explanation of the impact generated by the sundial square beautification is given.

1.2.Background

Catherine Zane Middle School in Eureka, CA is home to a diverse group of students whom follow a rigorous curriculum focused on STEAM (science, technology, engineering, art, and math). To promote STEAM education, the Environmental Resource Engineering department at Humboldt State University has been granted the opportunity to take on design projects to improve the school. A previous team built a human sundial on the foreground of the school; however the landscaping has since had some issues and an employee at the school, Trevor Hammons, is interested in improving and beautifying the sundial square area.

1.3.Objective

The objective of this design project is to construct a visually appealing first impression of Catherine L. Zane Middle School. The area surrounding the existing sundial will be aesthetically enhanced to encourage a welcoming environment for students and their families. We will utilize reused materials in order to encourage sustainability.

1.4.Black Box Model

2. Problem Analysis and Literature Review

2.1.Introduction to Problem Analysis

The problem analysis is a detailed summary of parameters considered during the design process for the sundial square beautification at Zane Middle School. This section details quantifiable and qualitative specifications and criteria, as well as considerations, usage, and product volume.

2.1.1.Specifications

Specifications are the guidelines that must be followed in order to fulfill the needs of Zane Middle School. The following list details those specifications.

- Location of the Square:

Catherine L Zane Middle School garden 2155 S St, Eureka, CA 95501

- The design must be suitable and safe for children.
- No wood may be used.
- Incorporate use of reused or sustainable materials in landscaping design.
- Must be a symmetrical design spanning over both rectangle plots.
- Rain resistant and durable.
- Should incorporate the spirit of the Zane Middle School Falcons.
- All plants must be raised at least 8 inches to 1 foot off the ground.

2.1.2.Considerations

The considerations consist of factors involved in the need for the project and are influenced by desires of the client. The considerations for this Sundial Beautification project are that it be aesthetically pleasing and enjoyable for the students and parents of Zane Middle School. Educational aspects and school spirit may also be included as we strive to achieve an improved first impression of the school.

2.1.3.Criteria

Criteria	Constraints
Safety	The design must comply with Zane Middle School safety standards and line of sight regulations.
Durability	Any plants or structures incorporated should be able to last through at least 10 years of foot traffic and usage by children.
Cost	Project should be completed with less than $400.
Aesthetics	Landscaping must be more aesthetically pleasing than the current desolate situation.
Mobility	Kids should be able to travel freely through pathways and plants.
Educational Value	An educational sign included in the design increases student knowledge about reused materials incorporated in project.

Table 1:Criteria and Constraints

2.1.4.Usage
The new pathways will be used to direct traffic at least 10 years to come, the pathways are to be utilized during all times of the day, as well as all seasons of the year. The main users of the square will be the staff and students of Zane Middle School. The seating, benches, and pathways will be used during school hours and any other scholastic event.

2.1.5.Production Volume
A singular sundial square needs beautification at Zane Middle School.

2.2.Literature Review
The literature review section is a collection of researched information regarding sundials and surrounding landscaping. Included are various sources with definitions and examples that directly correlate with the sundial at Zane Middle School. Topics covered are the previous sundial design project, client criteria, school landscaping, mosaics, and seating.

2.3.Catherine L. Zane Middle School

2.3.1.Introduction
Located near downtown Eureka, California, Zane Middle School attracts their students from a very diverse community. With its proximity to the ocean, Eureka is extremely humid and can have long periods of rain, with fog and wind present on many days. The beautiful redwoods on the outskirts of the town make Eureka a desirable place to live.

2.3.2.Mission Statement
Zane Middle School has a large student body and searches for ways to encourage learning, creativity, and sustainability. Zane's mission statement, found on their EurekaCitySchools website, is "to ensure that our students expand their knowledge and skills while enhancing their self-worth and personal responsibility within a nurturing environment that provides challenging learning opportunities tailored to the unique needs and interests of middle-level learners." Teachers at the middle school are dedicated to teaching using various methods to help engage the children during the learning process.

2.3.3.Partnership with Humboldt State University
Led by Trevor Hammons, Zane Middle School has partnered with Humboldt State University to create design projects. The Introduction to Design class at the university divides into teams and takes on various projects provided by school staff. This proves to be an effective way to give Humboldt State University students an engineering experience while focusing on engaging the kids at Zane in learning experiences using different materials and ideas.

2.3.4.Adolescent Learning
There is great importance placed on the learning process for students during the adolescent phase of their lives as this is when the frontal lobe is being developed. According the SPOTS manual about learning strategies, "The brain is social and requires interaction in order to develop properly" (Wolfe). During Middle School the social aspect can be an essential element on a student's path to success. Also detailed in this source is the fact that as humans, we take more information in through our eyes than any other method of learning. This encourages the importance of visual learning in school.

2.3.5.School Waiting Zone

One necessary aspect of a school is a safe area for students to wait to be picked up by their parents. While this area could be inside, outside interactive areas are also a possibility. A safe place to play while also being observed by faculty of the school is important. According to Trevor Hammons, at Zane Middle School the faculty have established the importance of a clear line of sight across the entire campus so that children are always under the watch of school staff.

2.4.Sundials

2.4.1.Human Fascination with Time

The origins of time telling consist of natural phenomenon and human curiosity, “strictly speaking the celestial bodies are not the firsts and original measures of Time; but rather those motions, which are observed round us by the senses, and which underlie our experiments” (Whitrow). The invention of the sundial came from the human desire to measure time passing and time ahead. Sundials went from simple sticks in the ground, to sculpted structures, and eventually turned into portable devices with magnets to accurately gauge the direction of the earth and sun.

2.4.2.Human Sundials

The sundial represents one of the oldest ways to tell time. Time of day is determined using the angle of the shadow created by the sun shining on the gnomon, the portion of the sundial extending straight up out of the ground (Carter). In a human sundial, a standing person’s body becomes the gnomon. A sundial is a very basic way to tell time when exposure to sunlight exists. The disadvantages of telling time with a sundial include the necessity of direct sunlight and the requirement of orienting the sundial’s complex angles during different seasons.

2.4.3.Interactive Sundials

Figure 1 – University of Wisconsin created an interactive sundial for local Elementary School students.

(University of Wisconsin)

UW Space Place designed an interactive sundial for a local elementary school with colored tiles representing the different months to stand on. This display created a fun outdoor activity, while

also educating the youth about the sun's orbital route. Painting the sundial a variety of colors and locating it near the playground encourage children to interact with the sundial daily.

2.4.4.Zane Middle School Sundial

A group of students from Humboldt State University designed a Sundial for Zane Middle School in 2017. Their mission was "to provide middle school students with an educational activity to emphasize the concept of solar time and the interaction between the sun and the earth in its orbital path." The main challenges of the Sundial design group included determining the angles of the sun in order to place the standing tiles for the months of the year in the correct location.

Figure 2 – A child at Zane Middle School uses the sundial installed by Humboldt State Students.

(Watson, Thomas, Gidanian, Gundert)

2.5.Outdoor Seating

Outdoor seating has great potential to succeed in schools where children gather in outside areas. The location of the sun dial beautification area is in front of the parking lot, making it a prime location for kids to congregate and wait for their transportation home. Outdoor seating will provide students with a comfortable place to do exactly that.

2.5.1.Lawns

A well-kept lawn can greatly improve the aesthetic appeal of any building. Grass, Sod, Astro turf, and greenery are all interchangeable words that define the contents of a lawn. Lawns provide a surface area of aesthetically pleasing landscape that have many uses. Lawns are the prime location to place a blanket on and relax for a few hours. Additionally, lawns are an effective method for preserving land. In order to construct any type of structure the beauty of the lawn must be disrupted turning the aesthetically pleasing surface area into something that is completely unrecognizable. Lawns do need to be regularly maintained in order to keep its aesthetically appealing presence. If it is not regularly maintained overgrowth may occur. This lack of attention causes the lawn to lose its aesthetically appealing presence. To implement SOD, a type of easily installed grass, previous greenery must first be removed. Second, make sure that the surface area that is being used is as close to even as possible. The level land will ensure that the roots of the SOD make their way into the earth. Third, amend the soil. Amending the soil will ensure that the SOD has the best environment to thrive and grow. After amending the soil ensure that the surface that you wish to place SOD on has no vegetation or rocks. Finally, plant SOD on designated surface area. Remember to maintain regularly.

2.5.2.Benches

Benches and forms are very similar but easily confused. A Bench is an elongated chair that is intended to seat multiple individuals but has a back rest and is free standing. A form is the same thing, but it is fixed to a wall. Benches have been common seating since the time that chairs were specifically reserved for the higher ups. Benches were derived from elongated joint stools. The implementation of benches draws positive attention to an area. It encourages individuals to idle for a while and take a seat on the bench. In a scholastic setting benches can act as a safe zone for students where they may be supervised by faculty. Bench's that don't have a back rest are the most versatile. This versatility is due to the design that allows pedestrians to approach the seating from the front or the back of the bench.

2.5.3.Picnic Table

A picnic table is an attempt to bring indoor dining and leisure to the outdoors. Picnic tables are used across the world. Parks, campsites, and some food establishments take advantage of picnic tables. Prior to the creation of picnic tables, whenever an individual wished to participate in a picnic, they would have eaten their meal on the floor with only a thin blanket to shield them from the dirt and small animals. With picnic tables individuals can comfortably sit and enjoy their outdoor meal because of the elevated seating and dining space.

2.6.Landscaping

Landscaping is the act of making an area of land more aesthetically attractive by enhancing the existing design or layout. Landscaping is not the repair or reinvention of an area of land.

2.6.1.Concrete

Concrete is a fundamental building material that can prove useful in any construction or beautification. Project. It has been used for centuries. It is a mixture of aggregate, cement, and dihydrogen monoxide. Different types of concrete are made with different ratios of these three components. Aggregate includes sand, crushed stone, gravel, broken blast-furnace slag, boiler ashes (clinkers), burned shale, and burned clay. Concrete is poured when used in a construction project. Aggregate, one of the fundamental components of concrete, is categorized as fine or coarse. Fine aggregate is distinguished by a size of .025 to 6.5nm. Coarse aggregate is distinguished by a size of 6.5 to 38 nm. The strength of concrete is measured in pounds per square inch. Many factors affect the strength of concrete such as temperature, components of mixture, and drying method. Since temperature is one of the factors, it is never poured in freezing temperature. To create different types of concrete all that needs to be done is changing the ratio of the concrete mixture. Concrete that is prematurely dried will result in a brittle, weak concrete.

2.6.2.Pathways

Pathways are effective at controlling foot traffic. They additionally give a nice aesthetic to the area in which they are placed. Pathways can be constructed from poured concrete, stepping stones, and or brick. With controlled foot traffic you can designate areas to be completely free of foot traffic. This will allow for the implementation of vegetation. Since the pathway controls the foot traffic and the vegetation will be left alone, it has a greater chance of thriving. Pathways can guide pedestrians around pieces of art such as a sculpture.

2.6.3.Rocks

Boulders are large scale rocks. Boulders can act as a barrier, seating, or stream control. The different types of boulder used in modern construction includes but is not limited to: windswept

mossy, Molalla, Santiam river, Idaho mountain, Montana rustic, Black basalt, Falls creek, Willamette Valley granite, and green glacier building. The combination of moss, rain, and lichen give windswept mossy boulders the aesthetic that it has been where it rests for ages. Molalla boulders are blocky or slabby shaped and they have a ledgy structure which allows them to be drilled into. They are brown with beige-gold accents. Santiam river boulders come from the heart of Willamette Valley. They have a variety of gray and buff hues. These boulders are effective for water features and dry creek beds. Idaho Mt Boulders have incredibly uniqe color and texture combinations. No two Idaho Mt Boulders are the same. The most common type are usually blocky which gives them the opportunity to be used as benches, landings, wall outcroppings, and even monuments. Montana rustic boulders come from the Ibex quarry in north west Montana. These boulders range from blocky horizontal structures to sculptural vertical structures. The best use for these boulders would be a back drop for lettering or numbering due to its flat surfaces. Black Basalt boulders are quarried in the southern Willamette Valley. Even though these boulders have a black hue they rarely look out of place. Falls Creek Bench boulders are warm beige-grey with some soft brown and gold. Willamette Valley Granite boulders are grey granite boulders. They have a subtle salt and pepper texture and make a striking contrast in any landscape. Green glacier boulders have an intense aqua-turquoise color. This particular boulder has many uses such as: benches, statuary pedestals, walls, or waterfall elements.

2.7.Designing Schools and Public Spaces

A school designers' job is to make optimal learning environments for the students. This entails several factors including collaborative spaces, spatial design, cultural values, and overall ambient qualities. (Lippman). When designing public spaces, it is crucial that the space appear safe and welcoming. Humans have developed a preference for spaces scaled for use by people. They are interpreted as, "cozy, intimate, or safe. We feel invited to spend time there" (Bain 5). Thus, if the area is more accommodating toward vehicles, and contains large empty spaces, the area becomes isolating and intimidating. (Bain 5).

The incorporation of nature into urban environments can enhance a positive atmosphere. Street trees for example facilitate improved mobility and often influence vehicles to slow down as they navigate through the street or parking lot (Bain 43). Likewise promoting a closer connection to nature has become increasingly important as we have entered the digital age. It establishes a foundational idea for our children that the environment is our responsibility and the value that it carries (Bain 50).

2.7.1.Sidewalks and Materials

Sidewalks can be made from several materials including concrete, asphalt, brick, and stone. During the design process a number of factors must be taken into consideration. They include accessibility requirements, be firm, stable, and slip-resistant surfaces. Specific to brick and stone, they can become slippery when it gets wet, making it not the optimal choice for high traffic areas (Bain 58). An alternative material made of recycled tires can be used for sidewalk pavers and tiles. They can be installed directly on prepared ground and have more flexibility to accommodate tree growth.

2.7.2.Interactive Outdoor Learning

An ideal Learning environment consists of open communal space where students can collaborate with one another and feel comfortable. Many studies show that learning in the outdoors improve creativity and reduces stress. It also allows for hands on learning in which students tend to be more engaged and perform better when tested (Minero). Education

architects say that theses environments should, “provide a fresh perspective for students who spend most of the school days indoors” (Lippman).

2.7.3.Rainwater Gauges

Rain gauges are a weather tracking tool that enable the rainfall in an area to be measured. There are two types: manual and automatic. Manual gauges have a simple design where a funnel pours into a graduated cylinder which is then measured. The automatic gauges allow precipitation to be tracked over longer periods of time and with significantly higher accuracy. Some designs employ a tipping bucket, in which a small seesaw-like container tips over once a pre-set amount of precipitation fills the container (University of Florida 2013). Once the water is decanted out it sends a signal that can be recorded electronically. In addition, there are weighing precipitation gauges that consists of a large storage bin. The tipping bucket method works better under intense weather; however, they are more expensive and require more maintenance (University of Florida 2013). Lastly there is an option of an optical gauge that contains a row of funnels. When enough water is collected to make a single drop, it falls into a laser beam path, and the amount is then transmitted.

2.7.4.Shadow Wall

In Texas, Daugherty Elementary School designed a shadow wall that teaches the students about the earth’s rotation. They used raised panels and created deigns that would shine through when the sun would pass over the school.

Figure 3- Shadow Wall at Daughtery Elementary School in Texas. (Emelina Manera)

2.8. Mosaics

Mosaics are types of art in which small pieces of colored glass, stone, or other materials are assembled into an image. This artwork can be made of pieces of colored stones, shells and ivory. Mosaics can be decorative, symbolic, or used to tell a story.

2.8.1.Grout

Grout is a mixture of water, cement, and sand used to fill gaps or used as reinforcement in existing structures. It is generally used for tiling, but the same concept can be used to build mosaics. Grout can be found at most local building material stores.

2.8.2.How to Grout Mosaics

To mix small batches of grout, a 5-gallon pail can be used. If a more fluid consistency is desired, add two thirds of the recommended water. Slowly add grout powder to water. Mix until it is a homogeneous doughy viscosity. Add additional water if needed and mix at medium speed for

five minutes to activate all ingredients. Do not exceed maximum water requirements stated on bag or overmix. Once the grout is ready use gloves to spread the grout over the pre-glued mosaic. Next, wipe off any excess grout with a sponge in a straight line and in one direction. Rinse the sponge after every wipe. Once it is completely cleaned off cover with sealer and plastic to avoid cracking.

2.8.3.Epoxy Resin Alternative

Epoxy Resin is made of an epoxy and a hardener. It provides a strong glossy coating, which works well with stained glass and porcelain tiles. It is a lower maintenance than standard grout because it is easier to clean. Epoxy-based grouts are exceptionally waterproof and have a porosity rate of less than 0.5%. Some drawbacks of using epoxy are that it develops a yellow tinge over time when exposed to sunlight and it scratches easily. These downsides make epoxy resin less suitable for high traffics areas.

2.8.4.Common Problems Faced While Outdoor Tiling

There are three conditions that can be attributed to the failure of outdoor tiling initial cracking, crack propagation, and crack widening. Initial cracking is caused by the shrinkage of the grout. Likewise, daily temperature changes cause thermal expansion and shrinkage adding to the cracking. Crack Propagation occurs when water infiltrates the system inducing swelling and further cracking. Repeated rain and dry seasons increase stresses and weaken the system. This study shows that overall grouts are zones of mechanical weakness. These issues can be counteracted by using smaller tiles and flexible grout can increase adhesion and save time. In addition, wetting the grout and then waterproofing the tiles will reduce drying shrinkage. Lastly, to reduce water infiltration, landscaping should be placed on a slope greater than 2% .

2.8.5.Sealers

Sealers are used to waterproof the mosaic and protect the mosaic. There are two types of tile and grout sealers: penetrating pore sealer, and coatings that form a membrane on the surface. The pore sealers leach into the pores of the grout and are typically made of latex and silicone. The combination of latex and silicone creates a hard-glossy finish on the surface.

2.8.6.Recycled Materials That Age Well

The following is a complied list of recycled material recommended online: old china plates, tea cups, seashells, beads, ceramic pieces and figurines, household tiles, used and stripped from walls or floors, scrap glass, broken mirror, bone, buttons, marbles, pebbles and beach stones, typewriter keys, jewelry, small metal tools, coins, bottle caps, nuts and bolts, dice, chandelier pieces, old watches, metal, glass and ceramic souvenirs

2.9.Plants

2.9.1.Eureka Yearly Climate

According to NOAA the average annual precipitation in the Eureka area is 42.9 inches. The rainy season typically begins in November and continues until April. The annual average high temperature is 59.6◦F and the average low temperature is 46.2◦F.

2.9.2.Shrubbery, Plants and Flowers

Different types of shrubbery and flowers can be used to improve the appearance of an area. Many of these plants only flower during certain seasons or not at all. Following are a few types of plants that flourish in the Humboldt area, and would be ideal should landscaping ever be desired in the rectangles. This list was recommended by Pete Haggard form the North Coast California Native Plant Society in Arcata, CA:

The following are Tough Herbaceous Perennials meaning they are non woody plants that can withstand harsher environments.

- Achillea millefolium
- Calamagrostis nutkaensis
- Fragaria chiloensis
- Grindelia stricta
- Iris douglasiana
- Lupinus rivularis
- Symphyotrichum (Aster) chilense

The following are tough woody perennials include evergreens and other shrubs that have a greater longevity.

- Berberis aquifolium
- Ceanothus thyrsiflorus “Skylark”
- Morella californica
- Pinus contorta
- Ribes spp.

3. Search for Alternative Solutions

3.1.Introduction to Alternative Solutions

This section includes the brainstorming process which led to the alternative solutions to fulfill the necessary requirements of an aesthetically appealing and efficient school foreground. The solutions are listed below and subsequently analyzed in more depth.

3.2.Brainstorming

Sunset Society's brainstorming happened as a group through the first month of the project. Working in person on the ideas being formulated as much as possible allowed us to give immediate feedback during meetings. The first brainstorming session was unstructured and used to generally organize our different ideas for possible solutions to the problems that Zane Middle School presented to us. The next brainstorming session was after we had met with the client and learned more about criteria of the client, so we were able to focus on aspects that included the client's vision more than we had in our previous brainstorming session. In our final brainstorming session, we talked about materials that we could use for the creation of the project. The following are designable solutions that we came up with during the brainstorming process:

- Raised Rocky Planters
- Trough Planters
- Wooden Benches
- PVC Benches
- Large Boulders
- Mosaic Pathways

3.2.1.Raised Rocky Planters

The raised planter employs recycled concrete slabs that are stacked into square formations which provide a barrier between the children and the plants. The planters have a height of 1 foot and are filled with the necessary amount of soil. To reinforce the structure the concrete is grouted together which increases stability. The external edges have potential to be painted and or decorated by students as part of a future art project. This design would meet both the durability and sustainability criteria.

3.2.2.Trough Planters

An idea the group came across on the internet involved converting old watering troughs into planters. This would raise the plants off the ground and protect them from traffic. The trough container would have holes drilled in the bottom for the purpose of drainage as the plants are watered. For this reason, any trough that was not in use anymore because of leaking issues could be used as a planter. Horse troughs are created to be durable enough for many years of use. The troughs pictured below are 2ft wide, 2ft tall, and 4 ft long. This limits the size of root system the plant inside would be able to have. Elevating plants is an effective way to increase protection while also ensuring that the plants get enough sunlight.

Figure 4 – The above image from Pinterest shows troughs in use as planters

(Langkamp)

3.2.3.Wooden Benches

To introduce seating to the project space benches constructed of wood are a choice. Wood is a very abundant resource in Humboldt county. Numerous designs for benches already exist there fore it would be a very simple and viable choice for seating.

3.2.4.PVC Benches

Using PVC pipes to make benches creates a modern artistic look for landscaping. The pipe would be glued together with PVC cement, which can be found at local hardware stores. This cement is used in a technique called Solvent Welding, in which a chemical essentially breaks down the pipe until it is pliable enough to meld with another portion of pipe (DeusXMachina). This process can be messy and difficult to time because of the quick-gelling nature of the PVC cement. The unique pipe material of this bench means that any shape necessary could be formed.

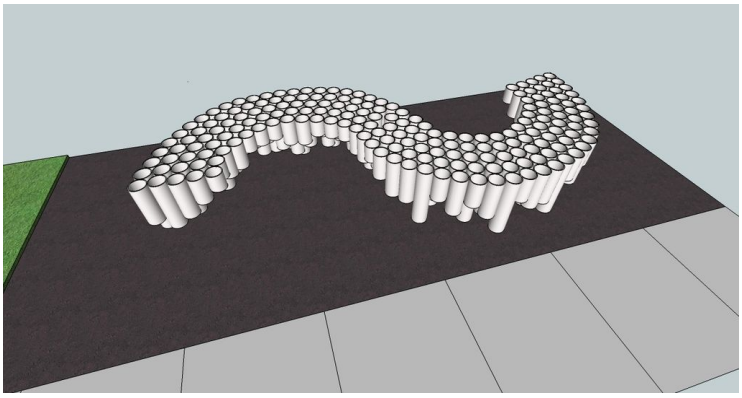


Figure 5 – A PVC bench placed in a rural area displaying the possibility of a curved design

(DeusXMachina)

3.2.5.Large Boulders

Large boulders provide a beautiful aesthetic structure that draws attention to any landscape they are used in. They are not cost affective and take mass amounts of labor to move. Large boulders provide a barrier from vehicle traffic.

3.2.6.Mosaic Pathways

The Mosaic Path implements recycled tiles of assorted sizes that are grouted into a concrete base. The tiles are arranged in an figure of a sun as seen in Image,, and utilizes red, orange, and yellow tiles that match Zane's colors. The decorative pathway directs traffic and prevents students from stepping on the surrounding plants. The mosaic provides a welcoming image as the students come to school. The path ways would either be oriented perpendicular to the parking lot or parallel.

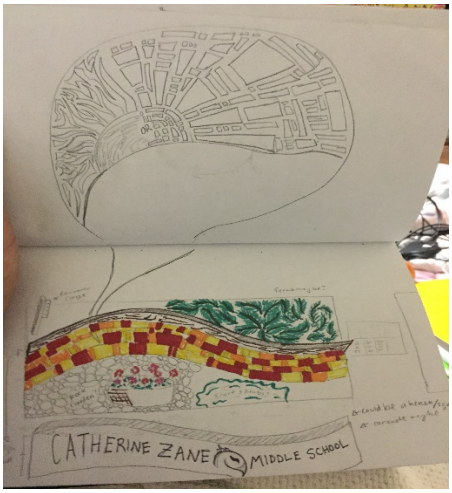


Figure 6-Mosaic Horizontal Pathway

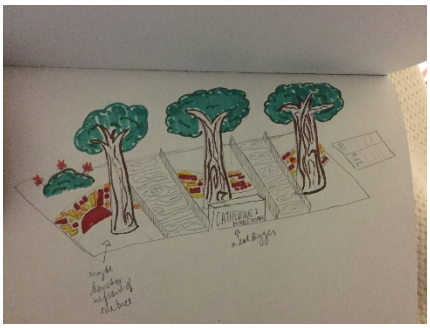


Figure 7-Alternate Vertical Mosaic Pathways

4. Decision Phase

Section 4 consists of analysis and comparisons of the various solutions that we have presented in Section 3. Elements including client feedback and criterion were taken into account to determine the best possible solution for the project. A Delphi matrix located in the Design Process section shows our different solutions and weights their importance. We used this chart and the assigned criteria weights to determine what design would satisfy client wishes and also be reasonable to build.

4.1.Criteria Definition

The criteria defined below are certain aspects that the project must satisfy. They are based on the specific parameters given by the client and were utilized to determine the final design.

- Safety- Unlikely to cause injury; the design must comply with Zane Middle Schools safety regulations and not obstruct the line of sight.
- Durability- How long the structure will last; any plants or structure must last for a minimum of 10 years.
- Cost- The amount that we will spend on materials; the project must not exceed $400.
- Aesthetics- The artistic value of the project; new landscaping must be more aesthetically pleasing than the current desolate state.
- Mobility- The ease of movement around objects in the landscaping; students must be able to travel freely through plant and pathways.
- Educational Value- The ability to learn something about the structure; an educational sign will be placed on site that educates students on the reused materials.
- Maintenance- The amount of work that goes into keeping the landscaping in good condition; the design must be suitable for the present landscapers to maintain and all plants must be evergreens.

4.2.List of Alternative Solutions

The following is a list of the alternative solutions that were presented to the client.

- Raised Rocky Planters
- Trough Planters
- Wooden Benches
- PVC Benches
- Large Boulders
- Mosaic Pathways

4.3.Decision Process

The decision process began with receiving feedback from the client regarding the six alternative solutions listed above. After the meeting, each criterion was given a specific weight of importance on a scale of 1-10, where 1 is least important and 10 is most important as seen in Table-2. The Delphi Model was then utilized to identify a solution that best meets the design criteria as a whole. It uses a scale of 1-50 with 50 being the most likely to meet the criteria. The values for each design were multiplied by their respective weight and then added at the bottom

of each column, with higher numbers signifying designs that were more likely to satisfy the design criteria. The completed Delphi matrix is shown in Table-3.

Table 2 - Criteria

Criteria	Weight (0-10 high)
Safety	10
Durability	8
Cost	5
Aesthetics	9
Mobility	7
Educational Value	2
Maintenance	8
Initial Labor	10

Table 3-Delphi Matrix

Criteria	Weight	Alternative Solutions					
	(0-10 high)	Raised Rocky Planters	Trough Planters	Wooden Benches	PVC Benches	Large Boulders	Mosaic Pathways
Safety	10	5 / **50**	25 / **250**	35 / **350**	45 / **450**	5 / **50**	45 / **450**
Durability	8	45 / **360**	40 / **320**	10 / **80**	20 / **160**	50 / **400**	30 / **240**
Cost	5	5 / **25**	25 / **125**	40 / **200**	40 / **200**	5 / **25**	10 / **50**
Aesthetics	9	45 / **405**	15 / **135**	30 / **270**	25 / **225**	35 / **315**	45 / **405**
Mobility	7	10 / **70**	30 / **210**	30 / **210**	30 / **210**	15 / **105**	50 / **350**
Educational Value	2	2 / **4**	35 / **70**	2 / **4**	35 / **70**	2 / **4**	35 / **70**
Maintenance	8	10 / **80**	10 / **80**	35 / **280**	50 / **400**	50 / **400**	40 / **320**
Initial Labor	10	30 / **300**	40 / **400**	30 / **300**	25 / **250**	30 / **300**	1 / **10**
	Total	**1294**	**1590**	**1694**	**1965**	**1599**	**1895**

4.4.Final Decision Justification

As seen in Table 3, the PVC pipe benches generated the highest Delphi score. The design meets most criterion well, except cost and aesthetics, which could be improved by modifying materials used in the project. Overall, the PVC benches are durable and require very minimal maintenance. Our client at Zane Middle School also appreciates the unique aesthetics and educational value upcycled PVC pipes will add to the project. The initial labor time that our group will need to apply to the construction of the benches is also reasonable.

To complete the large beautification project in front of Zane Middle School, we will be combining a seating option with the incorporation of plant and pathway landscaping. Both planter options scored decently on the Delphi chart, but lack ease of maintenance. The maintenance aspect led us to decide on planting a Native Species of plant in the ground as opposed to planters. We will be using a similar style of stepping stones to the ones in the ground left from a previous project to create paths for the students running to and from the courtyard and parking lot.

5. Specification of Solution

Section 5 includes details about our final solution for the Sundial Square Beautification project, the project hours, maintenance cost, and directions for use. The description of our final design is made up of multiple views of the project and shows the purpose of the solution. Also included is a table of costs detailing donations and the various products involved in the landscaping design. The costs are analyzed with respect to the project labor hours along with foreseeable maintenance time. Section 5 also details proper implementation and use of the landscaping design using pictures.

5.1.Solution Description

The final Sundial Square Beautification landscaping includes pathways made with a mold surrounding a PVC bench. There is one PVC bench in each square next to the piece of sidewalk with the sundial engraved on it. Each bench is made with a wooden frame that has a decorative PVC pipe skirt surrounding each edge. The pathways are strategically placed to prevent the ground from being worn in the areas where children will access the benches. The ground is also shaped in a way to prevent puddles from forming in the rectangles of ground.

5.1.1.Molded Pathways

Eventually surrounding each bench there will be red and gold pathways made from a 2'x2' mold. These will protect the ground from the high traffic that will result from the benches installed in the middle of each rectangle. The woodchips contained in each rectangle get tracked all over campus. This new design directs foot traffic toward the appealing pathways to minimize the spreading of woodchips. The pathways will contribute to school spirit as they are Zane Middle School's colors. As we run out of funding and time to complete the pathway, the below mold was left with Zane administration to complete the pathway design.

Figure 8 – Pathway Mold left with Zane administration

5.1.2.PVC Benches

There is one bench in the center of each rectangle, located on either side of the Sundial. Each bench has a top made from Trex planks and a decorative PVC skirt surrounding a wooden frame. These benches serve as a place to sit while the middle schoolers wait to be picked up by their parents. This area is also a gathering place for kids during lunch and recesses so the bench will be utilized during those times too.

5.1.3.Wooden Bench Frame

The frame and legs of each bench are made with 2"x4" wood sections, joined together with wood screws and wood glue. The legs will be concealed with the PVC skirt, which creates the illusion of the bench standing on the organ-inspired PVC design. The legs will be made of compressed and weatherproofed wood, which will meet our durability criteria.

5.1.4.Decorative PVC Skirt

The PVC skirt is designed to look like an organ shaped decorative edge. This design is included to add aesthetic appeal to our bench structures. The ends of the pipe are capped to prevent access to the inside of the pipe and to protect the bolts that will be holding the pipes together. The skirt design will be on all four sides of each bench.

Figure 9 – PVC Skirt in Progress

5.1.5.Securing Bench to Ground

Each leg of both benches is securely attached to a concrete pyramid using bolts. This strategy weights the bench down enough to prevent kids from being able to pick the structure up. The height of the pyramids also elevates the wood off the ground so it will be less likely to be exposed to rainwater collection and will be less susceptible to rotting, thus increasing the longevity of the design.

5.1.6.Concrete Underlay

Underneath the bench, there is a concrete slab that the pyramids holding the legs are submerged in. This slab is the same size as the frame of the bench, at 2’8”x6’4”. This slab will secure the bench, while also preventing weeds and plants from growing up through the ground underneath the bench. Our hope is to minimize maintenance required for the benches.

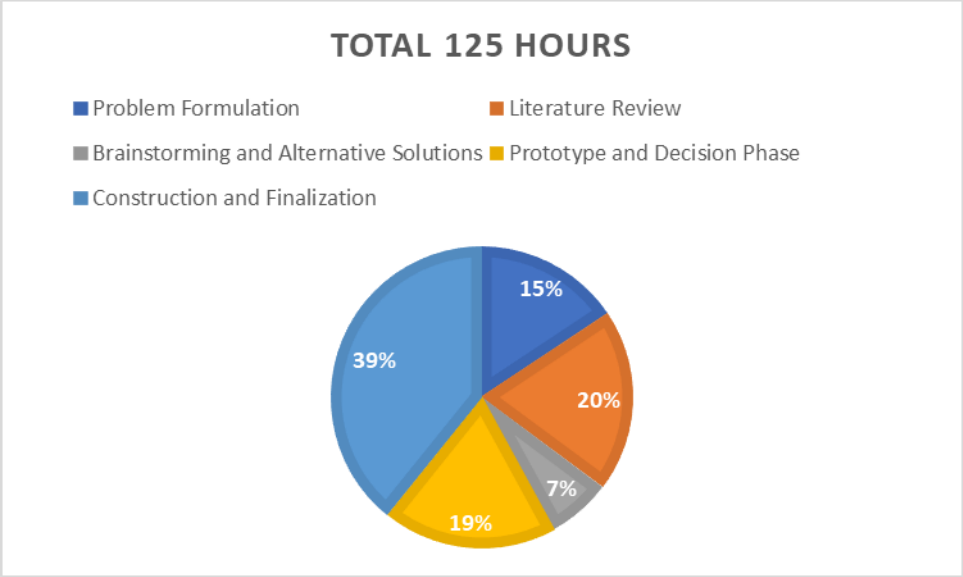
5.2.Cost Analysis

The following is an analysis of the total cost required to complete this project. It is separated into three categories: design, construction, and maintenance.

5.2.1.Design Cost

The design cost of the Sundial Square Beautification is evaluated by the amount of labor hours put into researching and constructing the project. The hours spent on this design are broken down by each phase of the project are sown in Figure- below.

Table 4- The cumulative labor cost in hours.



5.2.2.Construction Cost

The cost of construction includes the total monetary costs used to construct the benches and stepping stones. These costs total to $45.67 while the retail cost of the pendulum, without donated materials, totals to about $345.67. The breakdown of the total cost is shown below in Table 5-1

Table 5: Breakdown of all material expenses.

Materials	Total($)
Flat Wall Brush	$4.99
Oil Varnish	$7.99
2x4x8'(wood)	$22.96
Nuts and Bolts	$3.78
Street Signs	$20.00
Screws	$20.00
2x4's and 4x4 Presurized Wood	$64.56
Trex Decking Material	$180.00
5 ft of 2" PVC	$5.95
Feeling Groovy Stepping Stone	Donated
Quickcrete (50 lbs)	Donated
Potting Soil	Donated
Stepping Stone Mold	Donated
180 feet of 2 inch PVC	Donated
Total	**$330.23**

5.2.3.Maintenance Cost

The maintenance cost of this project is the estimated cost of maintenance of quality for the stepping stones and benches. The annual projected maintenance in cost is about 1 hour every month from the school grounds man to sweep of any bark or dirt on the stepping stones. Our benches have a minimum life expectancy of 30 years and the stepping stones will essentially last indefinitely. The project overall had very low maintenance.

5.3.Implementation Instructions

This section contains the implementation instructions for the construction of the PVC decorative skirt. The PVC skirt is constructed of a short side and a long side. Both sides are replicated twice creating the rectangle shape of the skirt. Therefore, instructions will be given for the construction of one long side and one short side.

5.3.1.Cut PVC

LONG SIDE

Cut the PVC so that you have Two: 20”, 18”, 17”, 16”, 15”, 14”, 13”, 12”, 11”,10”,9”,8”,7”, and 6” pieces.

SHORT SIDE

Cut the PVC so that you have Two: 20”, 16”, 12”,8”, and 4” pieces.

5.3.2.Bolt PVC to Frame

Drill evenly spaced holes along the frame. Make sure the holes are spaced enough so that when PVC is attached they sit side to side. Place a bolt in Hole so that the threads face inside of the skirt. Drill hole in PVC so that when attached to the bolt on frame it is flush with the top of the skirt.

LONGSIDE

Attach the PVC so that the lengths are in decreasing lengths of one inch from 20” until 5”. Then attach the PVC so that the lengths are increasing by one inch from 5” until 20”.

SHORTSIDE

Attach the PVC so that the lengths are in decreasing lengths of four inches from 20” until 4”. Then attach the PVC so that the lengths are increasing by four inches from 4” until 20”.

5.3.3.Assemble Skirt

To assemble the skirt remove all 20” pieces from the skirt frame. Place the short sides perpendicular and flush to the inside long sides of the skirt. Drill two screws through the long side into the short side for all four corners. The skirt is now ready to be attached to the legs.

5.4.Prototype Performance

The bench design is stable and durable. The prototype using bolts instead of the construction sealant adhesive was much more effective. The decision to use Trex instead of wood or signs as the top of the bench was more costly, but it will last longer.

Figure 10 – Fully constructed bench in front of Zane Middle School

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