Spring 2014

The Songbird Refuge

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1. Problem Formulation

1.1. Introduction

The problem formulation consists of an objective statement which describes the assignment and a Black Box Model.

The client is Zane Middle School, home of the Falcons, in Eureka, Ca. The school is currently a part of the STEAM (Science, Technology, Engineering, Art, and Math) program and is looking for educational and engineering based ways to improve their school. Currently, Zane Middle School teaches sixth through eighth grade with approximately six hundred students. The seventh graders participate in the STEAM program and are who this project will be designed and built for.

The Applicateers are college students from Humboldt State University in the Environmental Resources and Engineering major assigned to assist Zane Middle School.

1.2. Objective

The objective of The Applicateers is to design and build song bird houses to take advantage of the migratory bird corridor on the lower end of the soccer field at Zane Middle School. These bird houses are made from up cycled materials and utilized by the middle school faculty to educate the students on the migratory birds. The bird houses provide a very hands-on learning environment not only for the children at Zane Middle School but the community as well.

The Black Box Model, as seen in Figure 1, shows the world as it is now in spring of 2014, the solution, and the world as it will be after May, 2014. It provides a brief and concise explanation of the overall goal of this project.

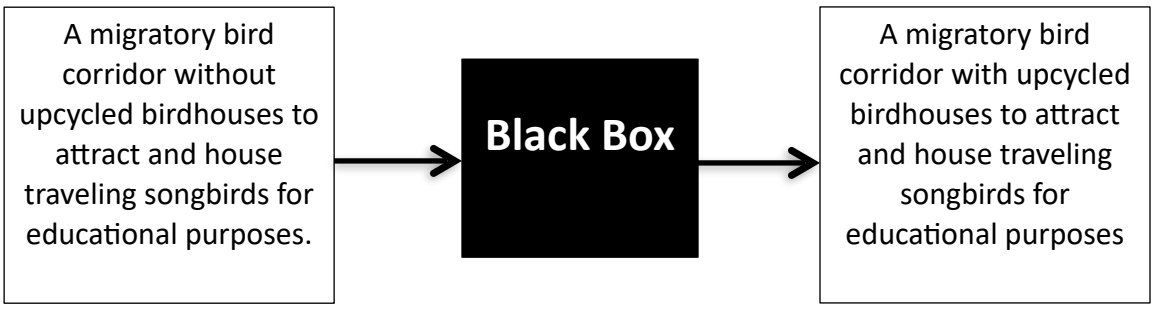


Figure 1 - A Black Box Model Describing the World as it is Now Without the Building and Design of Replicable Upcycled Birdhouses for Migratory Birds or Educational Purposes and as the World will be After the Solution is Implemented.

2. Problem Analysis

2.1. Introduction

The Problem Analysis applies and incorporates information from the client with the information found and decisions made by the team. Specifications and considerations of the client will help

guide the designing process, as will the approved criteria, to successfully meet the production volume and usage needs.

2.2. Specifications and considerations

Specifications and considerations are based off the wants of the client, Zane Middle School. These inputs allow the team to design solutions that will have the best chance of success under the client's expectations and predicted use.

2.2.1. Specifications

The client, Mr. Steve Wartburg, is a biologist that teaches science at Zane Middle School. His specifications ask for birds such as chickadees, nuthatches, wood ducks, and other similar songbirds that are native to Humboldt County and small in stature. He wishes for the project to be implemented at Zane Middle School near their future community trail.

2.2.2. Considerations

In designing this solution, the Applicateers are urged to consider the bigger picture of the solution. The songbird boxes will be the main attraction to a community trail that is going to be built behind Zane Middle School. Considerations also include that these boxes are expected to last as long as possible. Mr. Wartburg urges us to consider the possibility of this being a more experimental solution as opposed to a direct solution. This means that building the boxes using different designs to observe which traits about the bird boxes the birds are most attracted to.

2.3. Criteria

Certain aspects must be considered before possible solutions are developed and chosen. In order to create and select the best possible solution, a table of criteria and constraints was developed and approved by the client as shown in Table 1.

Table 1 - Criteria and Constraints for the Design and Building Process of Songbird Houses.

Criteria	Constraints
Aesthetics	Boxes will be neutral colors to blend in with the surroundings to avoid unwanted attention from predators.
Cost	The total amount of money spent will not exceed $450.
Diversity	There will be 3 mounting methods for the boxes; hanging direct, and by post. The boxes implemented will fit the nesting needs required by a variety of bird species.

Educational Value	1 educational sign per each box location.
Quality	Boxes will withstand any impacts by balls from the nearby sports field and will be fully and securely fastened to the mount.
Capacity	Each box will have at least one nesting section to allow for both solidary species and community nesting species.
Reproducibility	Each box will be reproducible by 2 students within 14 work hours.
Safety	There will be no chance of harming children, teachers, or community members whether by falling off of mount or by the transfer of the tetanus virus.
Sustainable Sourcing	All materials used will be renewable resources and/or up cycled to prevent waste.

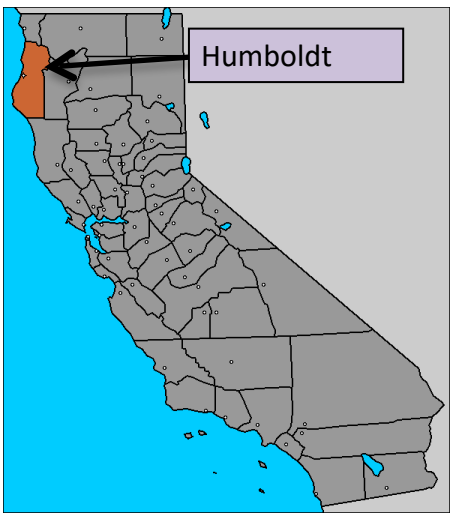
2.4. Usage

The bird boxes will be implemented at Zane Middle School near the soccer field. The boxes will be part of an interpretive trail that will serve students for educational purposes, as well as the greater community for recreational purposes. The boxes must be durable and sturdy enough to last for an indefinite amount of time, until the school administration decides to replace them, or until the interpretive trail is redeveloped.

Migratory songbirds will be using the structures primarily for nesting but also for shelter from predators and environmental dangers.

2.5. Production Volume

The production will consist of four or more birdhouses or bird boxes and these designs cater to a variety of species.



3. Literature Review

The purpose of the literature review is to provide appropriate background information for the design process. The following topics will be discussed: Environment of Humboldt County, Birdhouse Construction, and Birds of Humboldt County.

3.1. Environment of Humboldt County

This section provides regional information on Humboldt County. As shown in Figure 2, Humboldt County is located in the north-western part of California in the United States of America. Humboldt County contains about 2.3 million acres, or 3,568 square miles, of land but approximately 80 percent of the county consists of forest, protected lands, and recreational areas such as parks, beaches, and community forests (Prosperity 2013). Humboldt County's population as of 2013 was approximately 134,623 people and growing (WorldMediaGroup, 2014).

Figure 2 - Map of Humboldt County in CA. (Rosario 2013)

3.1.1. Topography of Humboldt County

Humboldt County is a mountainous coastal region with the Pacific Ocean on its western border. The county lies on the San Andres Fault Line which explains these physical features and the frequent earthquake activity (Lynch 2013). Humboldt County's elevation ranges from below sea level on the western coast to approximately 2,100 meters above sea level in the mountainous eastern region of the county (Humboldt 2014).

3.1.2. Climate of Humboldt County

The temperature of Humboldt County averages between 7.17°C and 17.17°C year round as seen in Figure 3. The climate is mild with a slight variation of temperature throughout the year. On average, Humboldt County experiences approximately 55.06 inches of rain per year. This is greater than the average annual precipitation of California with 22.97 inches and the entire U.S with approximately 38.67 inches of rain per year. Although Humboldt County does have a high amount of precipitation, the average annual snowfall is very low at 0.51 inches (WorldMediaGroup 2014). Humboldt County is a wet area but still experiences wildfires which are enhanced by the warmer and windier conditions of Northern California. There is an annual

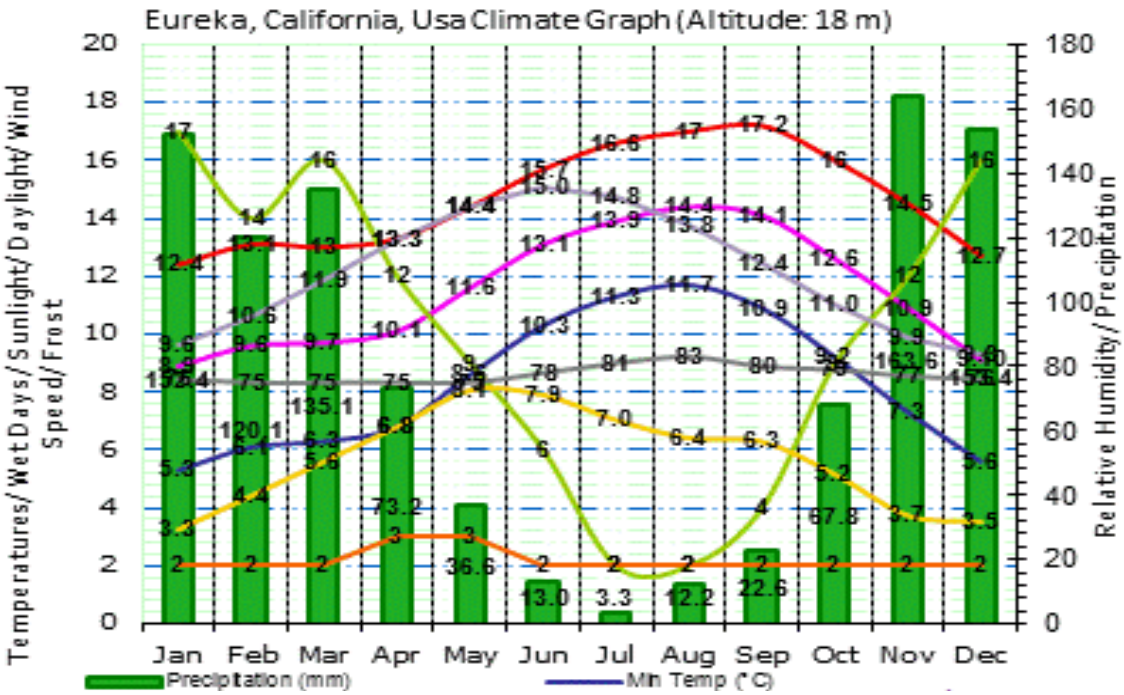


Figure 3 - Climate Graph for Eureka, Ca. Showing Precipitation, Temperature, Sunlight Amount, etc. (Climatemps 2013)

average increase of 114 wildfire escapes which threatens vegetation diversity, forest condition, and air quality (Fried 2004).

3.1.3. Plant Species of Humboldt County

Humboldt County is located in a temperate rainforest biome (Olsen 2001). A temperate rainforest biome receives about 60 to 200 inches of rain annually with mild temperatures. Figure 4 shows that fog is a commonality which helps provide moisture to the terrain and it's abundance of vegetation including, ferns, lichen and moss. These tend to grow in excess due Humboldt's wet and mild climate. The temperate rainforests main trees are conifers which are trees that grow cones and needles opposed to leaves. There are five types of conifers which predominantly grow in the temperate rainforest: Redwood Trees, Douglas Fir, Sitka Spruce, Western Hemlock, and the Western Red Cedar tree. Below these trees, shade-favoring trees grow such as dogwood and maple trees, as well as plants such as ferns and berry shrubs. Below these are lichen, mosses, fungi, and other miscellaneous small plants that thrive in wet and dark areas (Weir 2003).

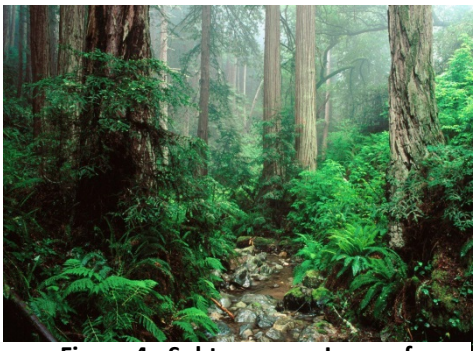


Figure 4 - Subterranean Layer of Temperate Rainforest. (WallSave 2012)

3.1.4. Pacific Flyway

Eureka, CA is located in the Pacific Flyway, a corridor that serves as both a year round residence and a migratory path for billions of birds. Species range from seabirds to songbirds, from smaller bushtits to larger long billed curlews (*Audubon* 2014). The Pacific Flyway stretches from Patagonia up through Canada and is inclusive of states as far east as Idaho and Utah (Barlow 2014).

3.2. Birdhouse Construction

This section addresses the construction of birdhouses. Many different aspects must be considered in the design and construction of environmentally sound birdhouses. These points of consideration include materials, structures and dimensions of the building. While the structure must be functional and sustainable, it is also essential to provide shelter and attraction for birds. This phase addresses important aspects of construction, providing information and examples of various techniques, designs, and materials implemented in different projects. Many of the materials and techniques discussed are very common in alternative home building, and can be applied on a smaller scale to produce unique and sustainably built birdhouses.

3.2.1. Materials

The materials used in the construction of these birdhouses are perhaps the most influencing factor in the environmental soundness of this project. Environmentally friendly materials can range anywhere from upcycled waste materials, such as boxes, recycled newspaper-maché, and water jugs to repurposed organic matter such as tree stumps, branches, and driftwood. What follows is an in depth discussion of various materials being considered for the construction of birdhouses.

3.2.1.1. Cobb

Figure 5 - Balls of Freshly Made Cobb (silverseedfarms 2014)

Cobb, as seen in Figure 5, is a building material made of completely natural materials including clay, sand water, and natural fibers such as grass or straw. Some advantages of Cobb include the accessibility of ingredients needed and the waterproof and sculpt-able properties it possesses. The disadvantages of using Cobb include a messy manufacturing process and a heavy product.

3.2.1.2. Wood

Figure 6 – A Log Cabin; Example of Wood Use (Wayside 2014)

Wood is a very common building material. It is abundant, sustainable, completely natural, and easy to manipulate into various structures. Figure 6 shows how wood can be implemented in buildings in a variety of ways, including timber framing, cordwood, and stacking. Although a structure made completely of timber susceptible to mold, leakage and rotting, wood can be an excellent component in any structure.

3.2.1.3. Earth

Figure 7 - Handful of Dirt (Families 2014)

Dirt, sand and loam, as seen in Figure 7, are all naturally abundant materials that can be used in sustainable building. Earth is very versatile because it can be easily moved and shaped. Downsides to using earth as a building material include its relatively low insulation, and difficulties associated with containing it in the desired shape and structure.

3.2.1.4. Repurposed Waste

Although solid waste is not produced naturally, implementing it into a useful structure is a great way to make use of what would otherwise be useless. Waste can include but is not limited to boxes, bottles, paper waste, disposable plastic bags, food containers, and much more. The advantages of building with solid waste include: cost- free materials, a wide variety of materials that can be used, reducing the amount of waste in landfills, instead being used in a positive and productive way. Furthermore, many forms of up cycled waste exhibit properties which are less prominent in nature, such as the waterproof properties of plastic, or the flexible strength of cardboard. Disadvantages associated with the use of waste include the aesthetics, and the potential odors that solid waste often possesses.

3.2.2. Building Techniques

This section covers the different building techniques utilizing the materials listed in Table 2.

Table 2 - Table Comparing Attributes of Materials for Songbird Houses

	Cobb	Wood	Earth	Upcycled

Accessibility	High Accessibility	High Accessibility	High Accessibility	High Accessibility
Waterproof	Moderate	Not Waterproof	Not Waterproof	Varies
Cost	Low	Medium	Low	Low
Weight	Heavy	Medium	Heavy	Varies
Flexibility	Flexible	Rigid	Flexible	Rigid
Durability	Durable	Perishable	Perishable	Varies
Aesthetics	Medium	High	Medium	Low

3.2.2.1. Sculpting

Sculpting a structure by hand is the most primitive and straightforward method of construction. Forming a structure out of a moldable material such as Cobb can produce very unique structures and aesthetics, but the product can be messy, lacking in structural integrity, and is difficult to build efficiently.

3.2.2.2. Bricks and Earth Bags

Forming materials into uniformly shaped and stackable pieces is an efficient method of construction that can produce strong, symmetrical structure. Casting molds of clay or Cobb can form bricks, or filling sacks with loose earth can create earth bags. Structures built from earth bags or bricks are strong and the building is a relatively organized process. The downside to building with these techniques is that small gaps can form between bricks or bags, resulting in poor insulation and waterproofing. This can be remedied by filling cracks with grout or Cobb.

3.2.2.3. Timber Frame

Timber framing is the technique used to build most modern homes. Figure 9 shows a timber-framed structure which consist of a wooden frame that upholds walls made of wood or bricks. An excellent alternative method of timber framing called Cordwood construction combines timber framing and Cobb to make a strong, insulated structure. This is achieved by filling the timber frame with Cobb and pieces of wood to form the walls of the building. Timber framing is advantageous because it creates a strong structure to uphold the walls.

A less traditional example of timber framing is a yurt, as seen in. A yurt is a type of tent in which textile is stretched over a wooden frame to create a structure with walls. Yurts have been used for centuries as practical and portable forms of housing

Figure 9 - Cobb Bricks Being Stacked as a Part of a Timber Framed Structure. (cobblerrockandstone 2014)

Figure 8 - A Yurt's Timber Frame (wikimedia 2014)

3.2.3. Design and Dimensions

The size and shape of a birdhouse depends greatly on the size, species, and quantity of birds that will inhabit the structure. The birdhouse should be just big enough for a nest; too big and too small of a space will both be unappealing to birds in search of a home. Birdhouses provide shelter from weather and predators, as well as a place for birds to nest, so a waterproof, ventilated and strong structure is essential, such as the birdhouse found in Figure 10. The entrance to a birdhouse should be big enough to allow birds to enter easily, but small enough to prevent predators from entering. Posts in front of the entrance are unnecessary, and only make it easier for predators to gain entrance.

Figure 10 - A Birdhouse Displaying Adequate Shelter and a Protective Entryway.

3.3. Birds of Humboldt County

This section talks about the Passeriformes, the order of birds selected for the design project that either live permanently or migrate through the migration corridor where our project is taking place. The birds are separated into families and then into species.

Passeriformes is an order of modern birds that pertains to over half of known bird species. Birds that belong to this order are commonly called perching birds or songbirds (Myers et al. 2014). Passeriformes are easily classified by the arrangement of their four toes, three oriented to the front and a fourth oriented to the back to allow for perching. Another defining feature of birds of this order is the defined voice box that allows for complex calls. This order has two clades, Oscines, commonly called Passeri, and Suboscines, commonly called Tyranni. Both clades have voice boxes, but the voice boxes found in oscines are much more complex. (Edwards and Harshman 2013).

3.3.1. Anatidae Family

Anatidae include ducks, geese, and swans. This family of birds tends to be monogamous and is generally herbivorous. Anatidae have a varying range of sizes but are known for having broad bodies, elongated necks, and strong colors. These birds are evolved for flying, floating, and diving and therefore are strong land walkers and swimmers. (Sibley 1961)

3.3.1.1. Wood Duck

The average length of a wood duck is 47 cm. These birds, such as the adult male pictured in Figure 11, are either found as residents along the west coast and the south east of the United States or as migrators, summering in the northern half of the United States reaching into southern Canada and wintering in the northern half of Mexico. Wood ducks are found along rivers, creeks, and ponds in wooded areas as well as marshes. Nesting habits include both natural tree cavities and

Figure 11: Male Wood Duck (Bartley 2011)

man-made nesting boxes which are found as high as 15 meters (*Audubon*, 2014).

3.3.2. Bombycillidae Family

This family of birds consists of Waxwings. There are three types of Waxwings, the Bohemian Waxwing, the Japanese Waxwing, and the Cedar Waxwing. All of these birds are defined by; their black "face mask", long crest on the head, and waxy-looking yellow tipped tail. They were named for the waxy looking droplets of color, attributed to their diet of fruit, on their tail and secondary flight feathers. (Sibley 1961)

3.3.2.1. Cedar Waxwing

This bird being one of only three in its family stands at 6 ½ - 8 inches tall with the Latin name *Bombycilla cedrorum*. Although this bird is only one of three species, its distribution covers most of the North American continent. Its breeding grounds are in the southern half of Canada and it migrates down to the southern half of the U.S. and Central America, although it can be seen year round in the northern half of the U.S. Demonstrated in Figure 12, cedar waxwings mainly feed on small berries and other fruit as well as insects. The reason they are seen so widely in the U.S. is because of their nomadic behavior. They travel in large flocks seeking food; once the food has been eaten they move on and search for more. Its habitat is mainly open woodlands or open fields with small shrubs and trees. They mainly nest in open woodlands avoiding forest type landscapes. Their nests are made from twigs and grass and placed in a tree that is in the open. (Witmer, Mountjoy, and Elliot 1997)

Figure 12 - Male Cedar Waxwing (NBS 2014)

3.3.3. Certhiidae Family

Certhiidae is a small family of the oscine clade and is made up of treecreepers. Located largely in North America, Europe, as well as small pockets of Africa and Asia, members of this family are known to inhabit forests, woodlands, parks, as well as gardens (*Audubon* 2014). This family is often associated with the Sittidae and Paridae families although behavior, coloring, and body structure differ, and is more closely related to the Troglodytidae family when comparing DNA (Harrap and Quinn 1996).

3.3.3.1. Brown Creeper

The average length of a brown creeper is 14cm. Brown creepers, such as the one captured in Figure 13, eat insects by systematically moving up tree trunks in a spiral to find bugs and larvae in the bark, using their tails for support. Both resident and migratory birds, the habitat range of the brown creeper covers the entire United States as well as southern Canada and bands of Mexico. Found in deciduous and mixed forests, brown creepers will nest by forming a cup-shaped nest between a peeling piece of bark and a trunk out of feathers, sticks, bark shreds, and moss (*Audubon* 2014).

Figure 13 - Brown Creeper (Bartley 2011)

3.3.4. Motacillidae Family

This family of birds includes Wagtails and Pipits, both of which are ground dwelling song birds known for their long legs, slender pointed beaks, and their high pitched flight calls. They forage for their food on the ground and in low laying shrubs and trees. (Sibley 1961)

3.3.4.1. American Pipit

Figure 14 - American Pipit (NBS 2014)

This 6-7 inch tall bird with the Latin name *Anthus Rubescens* inhabits the entire North American continent with breeding grounds in northern Canada. The American pipits, like the adult found in Figure 14, then migrate south for the winter in flocks and inhabit the lower half of the U.S. and most of Central America. Their diet consists of mainly insects and seeds. Their main habitat is Arctic and Alpine Tundra, while their migratory habitats are beaches, agricultural land, and open fields. They nest on the ground in shelters made of grass and twigs typically under rocks or shrubs (National Audubon Society 2014).

3.3.5. Paridae

Paridae is a large family of the Oscine clade which includes chickadees, tits, and titmice. Birds of this family are small, woodland birds that are found in large portions of Africa, Asia, Europe, and North America. Average lengths of these birds range from 7.5cm to 20cm. The diet of these birds primarily consists of insects and fruit (Encyclopædia Britannica Inc. 2014). Birds of this family have short, strong beaks which allow seeds to be incorporated into the diets; these birds commonly come close to human interaction due to the prevalence of birdfeeders. Members of this family commonly make nests in man-made nesting boxes. Parids do not migrate predictably, but they travel with various other Passerines such as nuthatches, kinglets, and vireos, and communicate throughout the community to avoid predatory attacks from birds of prey (*Audubon* 2014).

3.3.5.1. Black-capped Chickadee

The average length of a black-capped chickadee is 13cm. The coloring, which can be seen in Figure 15, is very distinctive and accounts for the name of black-cap. These birds can be found in deciduous forests, mixed forests, open woodlands, as well as suburban areas during the winter. Black-capped chickadees are very nomadic until the spring, when they nest in the woods to brood. Although black-capped chickadees will eat seeds from residential bird feeders, their natural diet consists of insects and larvae. When it comes to nesting, black-capped chickadees make their own cavities in rotted stumps, but are also known for accepting man-made nesting boxes if they are filled with sawdust. When brooding, 6 to 8 eggs will inhabit the cup-shaped nest made of grass, fur, moss, plant down, and feathers (*Audubon* 2014).

Figure 15 - Black-capped Chickadee (Bartley 2014)

3.3.5.2. Bushtit

The average length of a bushtit is 10cm. The coloring varies, depending on the regional environment. One of the possible colorings can be seen in Figure 16. Bushtits travel in flocks


Figure 16 - Bushtit (Steele 2014)

containing up to 50 birds and typically nest in deciduous forests and near streams. Any number between 5 and 15 eggs can be laid within the typically gourd-shaped nests that have an opening towards the top. Nesting material consists of lichens and soft plant fiber. Nests can be found suspended both in trees and in bushes (*Audubon* 2014).

3.3.5.3. Chestnut-backed Chickadee

The average length of a chestnut-backed chickadee is 12cm. They are found in pacific rainforests, particularly those containing conifers. Besides differences in coloring, shown in Figure 17, and their tendencies to feed in upper branches of conifer trees, chestnut-backed chickadees are very similar to their close relatives the black-capped chickadee shown in Figure 15. (*Audubon* 2014).


Figure 17 - Chestnut-backed Chickadee (Bartley 2014


Figure 18 - Mountain Chickadee (Audubon 2014)

3.3.5.4.Mountain Chickadee

The average length of a mountain chickadee is 14cm. Although mountain chickadees are typically found in high-altitude conifer forests, flocks can be found in conifers near sea level. Mountain chickadees behave similarly to other chickadees, but are not known for eating seeds, sticking to foraging for insects. Nests are located in old woodpecker holes or are excavated out of rotten wood (*Audubon* 2014).

3.3.6. Regulidae Family

Regulidae is a small family of the oscine clade which contains small, typically colorful birds with thin pointed bills. Due to their compact size, members of this family are able to extract very small insects and their eggs from within cracks in tree bark and even from coniferous needle clusters. Due to the specialization of this family's diet, members are able to be residential year round as long as food sources do not deplete (*Audubon* 2014).

3.3.6.1. Golden-crowned Kinglet

The average length of a golden-crowned kinglet is 9.5cm. Golden-crowned kinglets are named after their coloring which resembles a golden crown, displayed in Figure 18. These birds can be found in old conifer trees, as well as in thickets in deciduous forests during the winter. These birds can either be residential along the west coast of the United States or migratory, spending the summers in southern Canadian provinces and winters in the United States. Golden-crowned kinglets eat insects and larvae and are often found in feeding flocks with ruby-crowned kinglets, various nuthatches, and chickadees. Nests are found below


Figure 19 - Golden-crowned Kinglet (Small 2014)

60 feet in the air in conifer trees and are made into a cup shape with sticks, moss, lichens, plant down, and feathers (*Audubon* 2014).

3.3.6.2. Ruby-crowned Kinglet

The average length of a ruby-crowned kinglet is 10.5cm. Ruby-crowned kinglets are named for the ruby tuft of feathers seen in Figure 20. These birds nest in similar settings as their relatives, the golden-crown kinglets, but are less residential. These birds summer far into Canada and winter along the west coast of the United States, the southern half of the United States, and the northern half of Mexico. Since ruby-crowned and golden-crowned kinglets often are found in the same location, ruby-crowned kinglets feed in the lower half of conifer trees while hunting for insects and larvae. Nests are large mounds of sticks, moss, lichens, and plant down with a small cup at the top which is lined with feathers (*Audubon* 2014).

Figure 20 - Ruby-crowned

3.3.7. Sittidae Family

Sittidae is a family of the Oscine clade that contains the different subspecies of nuthatches. This family behaves very similarly to the family Paridae, apart from the scansorial feet, which allow them to climb trees, rock faces, and some buildings. The ability to climb is essential for eating habits as insects, seeds, and nuts are supplemented for larvae. The beaks of this family allow the birds to crack open hard shells and does so in order to feed, searching tree trunks and branches for insects and larvae (Harrap and Quinn 1996).

3.3.7.1. Red-breasted Nuthatch

The average length of a red-breasted nuthatch is 11.5cm. A large band stretching across the northern United States is home to resident red-breasted nuthatches, such as the specimen pictured in Figure 21, but some flocks will summer in southern Canada and winter in the entirety of the United States. Red-breasted nuthatches build their nests in conifer trees and hoard conifer cones elsewhere in preparation of food scarcity although their diet consists mainly of insects. The nests are made of sticks and lined with softer materials shaped into a cup and located in a tree cavity (*Audubon* 2014). As a defense mechanism, red-breasted nuthatches are known to smear tree sap around the entrance of their nest (Harrap and Quinn 1996).

Figure 21 - Red-breasted Nuthatch (Nadeau 2014)

3.3.7.2. White-breasted Nuthatch

The average length of a white-breasted nuthatch is 14cm. This subspecies of nuthatch can be seen in Figure 22 and is mostly non-migratory. White-breasted nuthatches are residential in deciduous and mixed forests in the majority of the United States and southern Canada. These birds mate for life and stay with their partners year round as they mix in with flocks of

Figure 22 - White-breasted Nuthatch (Wedge 2014)

various chickadees, woodpeckers, and kinglets. Nests are cup-shaped, made of sticks, grass, fur, and feathers, and can be found in a natural tree cavity, a newly excavated cavity, or nesting boxes (*Audubon* 2014). To prevent predators from invading their nests, white-breasted nuthatches will rub toxic-smelling insects around the entrance (Harrap and Quinn1996).

3.3.8. Troglodytidae

Troglodytidae is a family of the oscine clade and populates the western hemisphere. The long and thin bill structure allows for very precise movements to pluck insects and larvae from crevices. Members of this family live in a wide range of habitats and have been known to make nests in old boots, outhouses, and abandoned cars. Nest shapes range from a cup to a sphere, depending on the location (*Audubon* 2014).

3.3.8.1. House Wren

Figure 23 - House Wren (Bartley 2014)

The average length of a house wren is 12cm. House wrens are rarely residential, summering and breeding in southern Canada and the majority of the United States before migrating south to Mexico for the winter. The coloring of house wrens, such as the one shown in Figure 24, contains neutral colors to act as camouflage in wooded areas. As they travel between seasons, these birds will nest in residential areas, parks, farmlands, as well as along the edge of woodlands, making their temporary homes out of sticks and feathers in odd existent cavities including, but not limited to nesting boxes, flower pots, mailboxes, and the pockets of coats left on clotheslines (*Audubon* 2014).

3.3.8.2. Pacific Wren

The average length of a pacific wren is 10.5cm. These birds are mostly residential along the Pacific coast from central California up through Alaska, although some are migratory and will summer inland as far as Idaho and will winter in southern California. Similar to their relative the house wren, seen in Figure 24, the pacific wren's coloring acts as camouflage in wooded areas and can be seen in Figure 25. Their preferred habitats are dense thickets in both coniferous and mixed forests. Pacific wrens move along the forest floor and cleverly conceal their nests with sticks and moss with a lined side entrance (*Audubon* 2014).

Figure 24 - Pacific Wren (Yip 2014)

3.3.9. Turdidae Family

This family of songbirds includes Thrushes, Bluebirds, Solitaires, and Robins. Birds classified under this family tend to have longer legs with a blunt-tipped bill. They also tend to be more solitary birds with the exception of a few species that will form large flocks and search for food in the open (Sibley 1961).

3.3.9.1. American Robin

This bird is the most abundant, widespread, and largest of all in the Turdidae or Thrush family. The American Robin, as seen in Figure 26, inhabits almost all of North America with the exception of southern Central America. During the migration season in the winter they leave their breeding grounds in Canada and migrate through the U.S. down to northern Mexico and back up during spring. (Sallabanks and James 1999) This bird with the Latin name *Turdus Migratorius* stands at about 9-11 inches tall and builds its nests in mostly open woodlands, agricultural land, and urban areas. Its nests are made out of mostly mud reinforced with grass and twigs. (National Audubon Society 2014)

Figure 25 - Male American Robin (NBS

3.3.9.2. Swainson's Thrush

Figure 26 - Male Swainson's thrush (NBS

An English naturalist named William Swainson named this small, long legged bird, shown in Figure 27, that stands between 6 ½ -7 ¾ inches tall with the Latin name *Catharus Ustulatus.* Its' main habitats are coniferous forests and willow thickets (National Audubon Society 2014). During the winter this bird breeds in the Northwestern U.S. and part of Canada then migrates down between southern Mexico and northern Argentina where it spends the winter. During the spring they migrate back up the western coast of Mexico and the U.S. These birds generally leave their wintering grounds in early March to start migrating north for spring (Evans and Yong 2000).

3.3.9.3. Townsend's Solitaire

This 8 -9 ½ inch bird portrayed in Figure 28 with the Latin name *Myadestes Townsendi* is most commonly found on the western side of the U.S. year round with breeding ground in northwestern Canada and southeastern Alaska. For the winter season this bird tends to go more towards the Midwestern U.S. and down into northern Mexico. (Bowen 1997) This bird is solitary most of the time and is rarely found in open forests or woodland edges. Its preferred nesting areas are in steep dirt banks. This bird also looks very similar to a Mockingbird, mainly feeding on insects and berries. (Sibley 1961)

Figure 27 -

3.3.9.4. Western Bluebird

This 6-7 inch tall bird with the Latin name *Sialia Mexicana* tends to live in open areas next to woodlands or anywhere there are sparse trees that provide nesting. These birds also forage for food in small groups of about 10 looking for insects and berries. When beginning to foster young, the male birds use their vibrant rusty orange chest, as shown in Figure 23, to attract a mate that they often choose for life. These birds have a relatively short migration distance that involves more altitudinal change than latitudinal change. They can be found in the Southern Midwest of the U.S., Northern-middle Mexico, and most of the West coast of the U.S. (Guinan, Gowaty, and

Figure 28 - Male Western Bluebird (NBS 2014)

Eltzroth 2000)

3.3.10.Vireonidae Family

This family of small songbirds including all Vireo species generally doesn't have vibrant plumage and can be most easily identified by their "spectacled" pattern around their eyes. These birds are usually solitary or in pairs but will sometimes join flocks of other forest songbirds such as Chickadees and Warblers. (Sibley 1961)

3.3.10.1.Cassin's Vireo

Figure 29 - Cassin's Vireo (NBS 2014)

This bird with the Latin name *Vireo Cassinii* stands at about 5 ½ inches tall and is commonly found in the woodlands of the western U.S during the summer and the west coast of Mexico in the winter. (Sibley 1961) This bird is one of three sub-species that branched off from the bird formally known as the Solitary Vireo. A cassin's vireo can be seen perching in Figure 29. They nest in a similar way as the Hutton's Vireo, using bark strips and down feathers as the structure, hanging in the fork of a branch. Their main source of food is insects. They tend to travel in flocks with other songbirds as well. (National Audubon Society 2014)

3.3.10.2.Hutton's Vireo

This small 4-5 inch tall bird with the Latin name *Vireo Huttoni* has no migratory paths and can be seen year round on the West Coast of the U.S and in Central Mexico. The coloring, shown in Figure 30, is very similar to that of its relative the Cassin's Vireo, shown in Figure 29. Its habitat is mainly evergreen forests and the woodlands of western North America nesting in a suspended nest made out of twigs and moss, lined with feathers, hanging from small shrubs or trees. Their main food source is insects and sometimes spiders. These birds are mainly solitary but will sometimes join flocks of other small songbirds such as Ruby-Crowned-Kinglets (Davis 1995).

Figure 30 - Hutton's Vireo (NBS 2014)

3.3.10.3.Warbling Vireo

Figure 31 - Warbling Vireo (NBS 2014)

This bird with the Latin name *Vireo Gilvus* stands at about 5 ½ inches tall and is most commonly seen in large trees near water. This bird's distribution covers most of the North American continent with the exception of northern Canada. During the summer it is most commonly seen southern Canada and the northern half of the U.S. During the winter it migrates down to the west coast of Mexico. Figure 31 shows the similarity between the colorings among vireos when compared to relatives, Cassin's and Hutton's vireos, shown in Figure 29 and Figure 30, respectively. The Warbling Vireo's main food source is insects and grubs that it has taken from the treetops. Usually solitary, this bird can be most commonly identified by its pale white "eyebrow". (Sibley 1961)

4. Alternative Solutions

1. Introduction

During brainstorming sessions, alternative designs for Songbird houses to be implemented on the community pathway at Zane Middle School were created. Every alternative design created appeal to the criteria agreed upon by Steve Wartburg of Zane Middle School and the Applicateers. All options offer bird houses specifically designed for this project. A total of fifteen alternative solutions were created during brainstorming sessions.

2. Brainstorming

The purpose of these brainstorming sessions were to take four main bird house designs and create variations of each house to have a diverse group to choose from. Fifteen bird houses were designed and four were chosen to build for Zane Middle School. The four main different themes were traditional birdhouse, igloo, yurt, and teapot. The differing materials for each bird house were wood, cobb, and other various materials as described in the following alternative solutions.

3. Alternative Solutions

The following includes a detail list with descriptions of fifteen alternative solutions developed during brainstorming sessions. Sketches were drawn to provide a visual aid for each design and to clarify details expressed in written descriptions of each alternative solution. These alternative solutions will be weighed against each other using the criteria and constraints to evaluate the best solutions for the project.

3.1. Bird Bungalow

This sturdy wooden birdhouse houses between 8 and 12 birds in used painted cans covered by a thin sheet of tin, as seen in Figure 32. This birdhouse can be either: mounted directly to a tree, hung between branches or trees, or mounted to a pole that is stuck into the ground. As seen in Figure 32, the individual houses would be mounted on a circular piece of wood and covered by a cone shaped piece of sheet metal help up by a wooden frame. This birdhouse is designed to accommodate birds such as Nuthatches, Chickadees, and Bushtits.

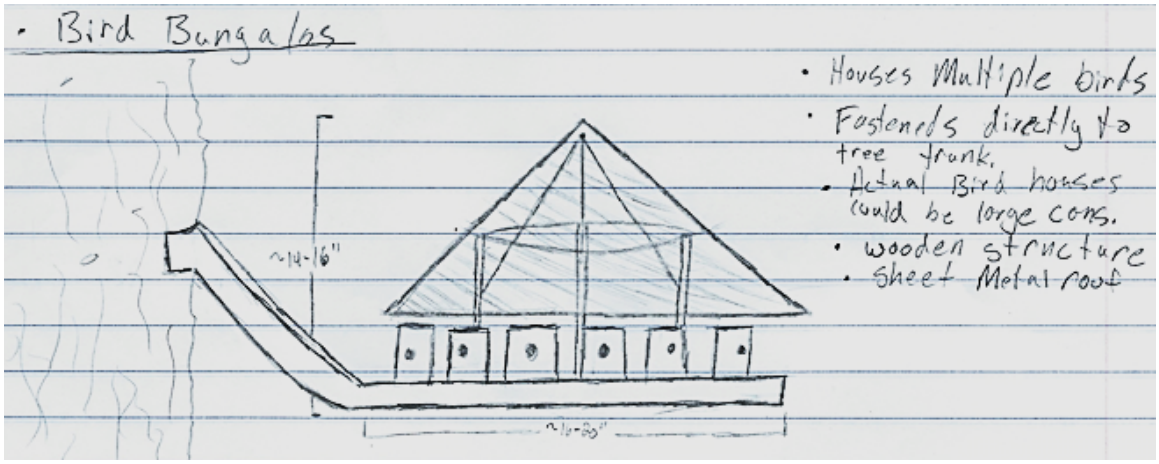


Figure 32 - Bird Bungalow Sketch by Ben Voelz

3.2. Cobb Cone

The Cobb Cone, like the name suggests, is made out of Cobb and is designed to be hung from a branch. A sketch can be seen in Figure 33. It is reinforced with a wire, wood, or bamboo (skewer sticks) frame. This design houses only one bird and is aimed toward birds such as Solitaires and Wrens. The Cobb is covered by a cone of sheet metal.

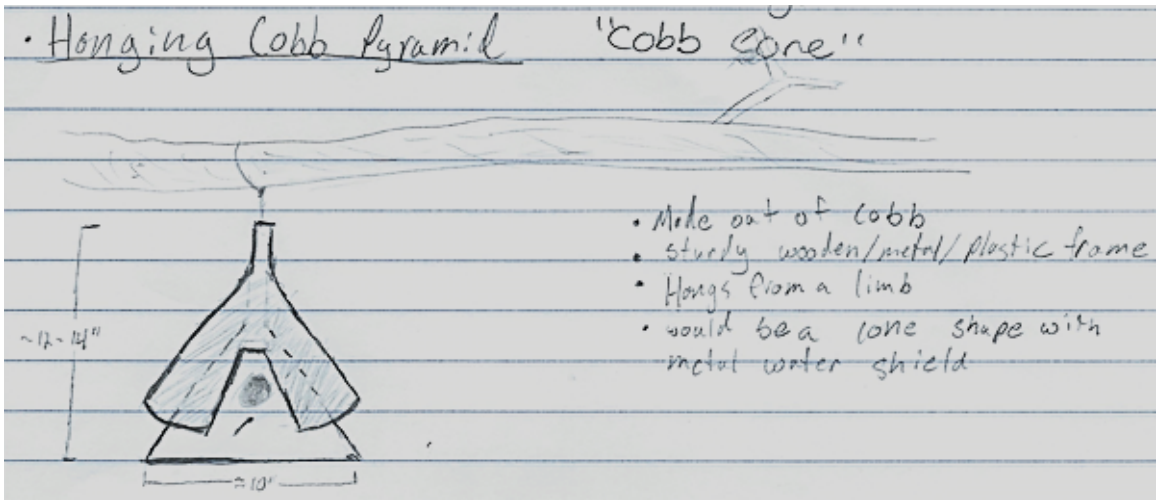


Figure 33 - Cobb Cone Sketch by Ben Voelz

3.3. Hydration House

The Hydration House is made out of a recycled plastic water jug and can be seen in Figure 34. It has been split up into three sections to house three birds. This design is aimed toward birds such as Chickadees, Wrens and Bushtits. This design can either be hung from a branch or mounted directly to a tree.

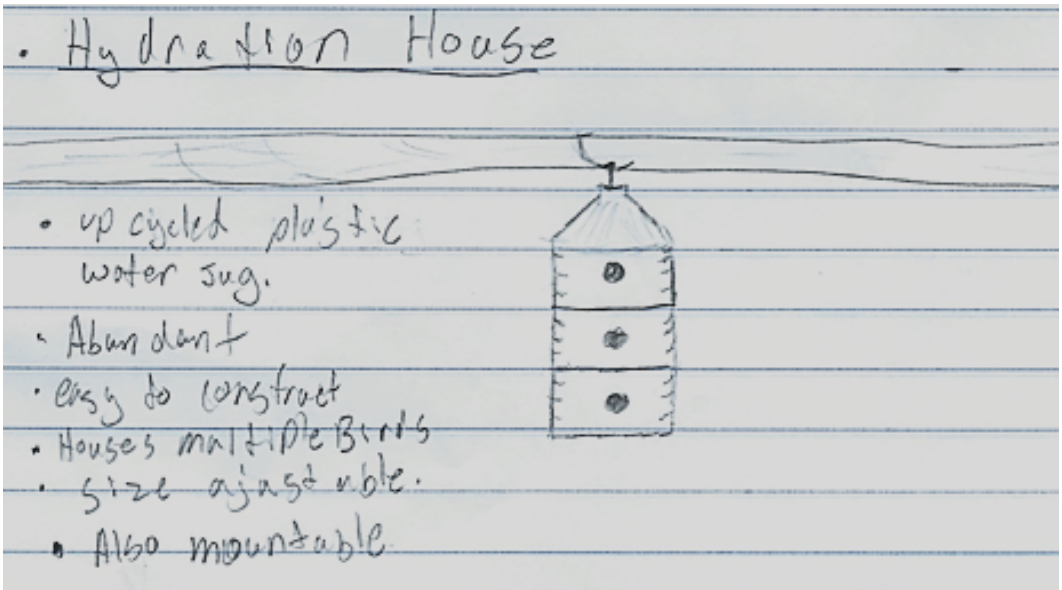


Figure 34 - Hydration House Sketch by Ben Voelz

3.4. Suspended Cup Condo

This design is meant to hang or suspend a plastic cup or bottle between two branches or a Y shaped branch, illustrated in Figure 35. The house would only house one bird and would be suspended using weather resistant chord. This design was aimed toward attracting birds such as Vireos or Thrushes.

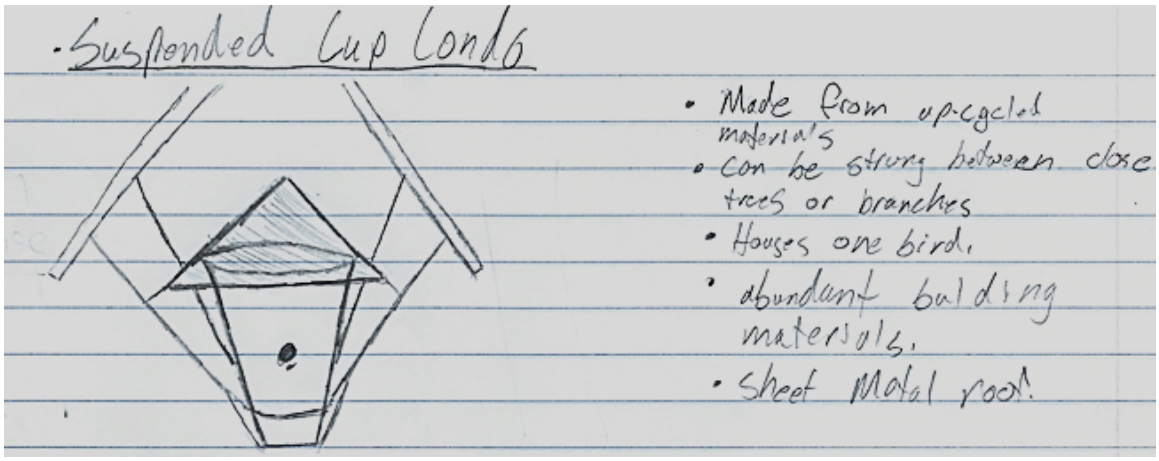


Figure 35 - Suspended Cup Condo Sketch by Ben Voelz

3.5. The Coffee Pot Cabana

This variation of the teapot design is a vintage metal coffee pot whose lid is fully secured by a chain attached to the lid and is hung from a branch as shown in Figure 36. An additional hole of appropriate size is cut out near the top of the coffee pot as an entrance. The spout is closed off to prevent rain from entering the nesting area.

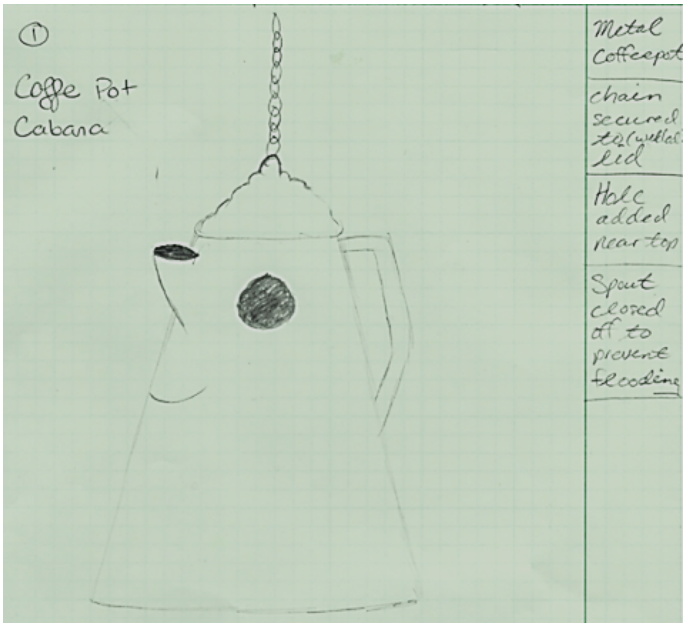


Figure 36 - Coffee Pot Cabana Sketch by Jennifer Warmack

3.6. Loft Pot

This variation of the teapot stem is mounted on two pieces of repurposed wood joined at a right angle to be directly mounted to a tree. The lid is cut in half to restrict the entrance to the nesting area in order to prevent predators from raiding the nest, illustrated in Figure 37. The spout is left open and pointing down to allow for drainage in case rain blows into the nesting area, and contains an additional support to help stabilize the pot. This support is only supplementary since the main point of contact is the base of the teapot, which is secured to the vertical piece of wood.

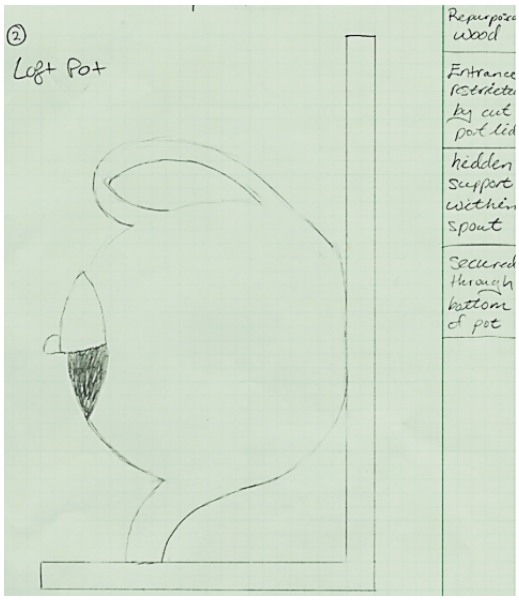


Figure 37 - Loft Pot Sketch by Jennifer Warmack

3.7. Don't Draw-Pot

This variation of the teapot design is nestled in a natural wood stained drawer to add aesthetics as well as reducing the chance of breakage. This design can either be hung from a branch or directly mounted to a tree. The teapot hangs from its handle off of the repositioned drawer handle, shown in Figure 38, and the base of the teapot is attached to the drawer to prevent swinging and brakeage. The lid is cut in half to restrict the entrance to the nesting area in order to prevent predators from raiding the nest. The spout is open and pointing down to allow for drainage in case rain blows into the nesting area.

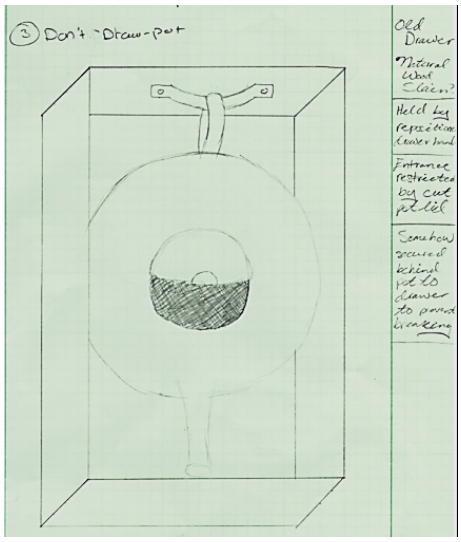


Figure 38 - Don't Draw-Pot Sketch by Jennifer Warmack

3.8. Chickadee Cottage

This is a very standard nesting box, whose design has been tested and guaranteed to attract nesting birds. A hole of appropriate size is located towards the top of the box, and there is an overhanging roof to prevent rain from entering the nesting area. A rough illustration of the Chickadee Cottage is displayed in Figure 39.

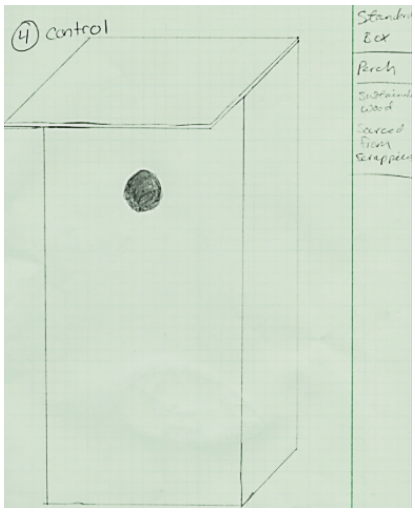


Figure 39 – Chickadee Cottage Sketch by Jennifer Warmack

3.9. The Bird Yurt

The Bird Yurt will be mounted onto a wooden platform that will be mounted horizontally onto branches on a tree. The frame will be made of upcycled chopsticks, straws, coat hangers, or popsicle sticks, and the fabric stretched over the frame will be a repurposed waterproof rain coat or processed, layered and heat-treated plastic bags and bubble wrap. The yurt, shown in Figure 40, will have a circular floor, houses 1 nest and can be adapted to various dimensions to accommodate an array of bird species.

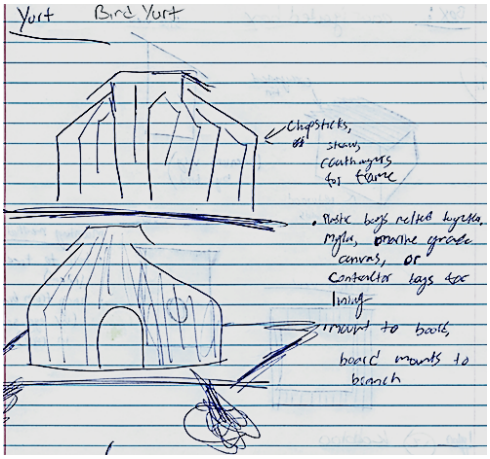


Figure 40- Bird Yurt Sketch by Christian Cota

3.10. Cobbloo

The Cobbloo will be an igloo-themed bird house made of Cobb supported by a wire frame as illustrated in Figure 41. The frame will be upcycled coat hangers bent into arches. The arches will be fed through small holes in the wooden base, and bent to support the base and maintain the shape of the arches. Cobb will be molded around the frame and treated with beeswax or some sort of natural waterproof coating to protect the Cobb from rain. The house will be attached to branches via twine that is attached to the point of the frame where all the arches intersect. The twine will be fixed before the application of the Cobb and the Cobb will be molded around the twine. This design houses one nest and can be adapted to various dimensions to accommodate an array of bird species.

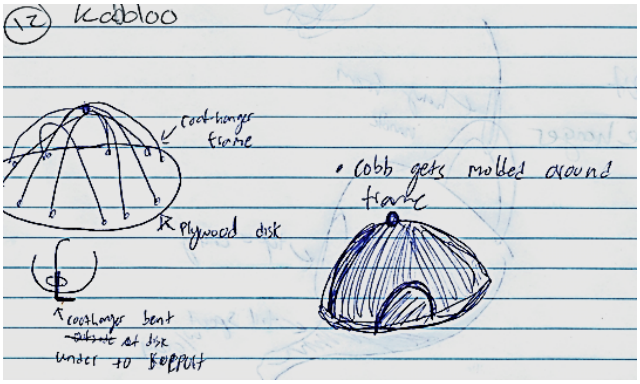


Figure 41 - Cobbloo Sketch by Cavanaugh Carter

3.11. Corrugated Bird Box

The control bird box will be made out of redwood boards for their rot and mold resistant properties and their vast availability and sustainable sourcing. The roof as shown in Figure 42 will be made of corrugated tin that will be tilted at a 30 degree angle towards the back of the birdhouse to redirect rainwater away from the box's opening. This design houses 1 nest and can be adapted to various dimensions to accommodate an array of bird species.

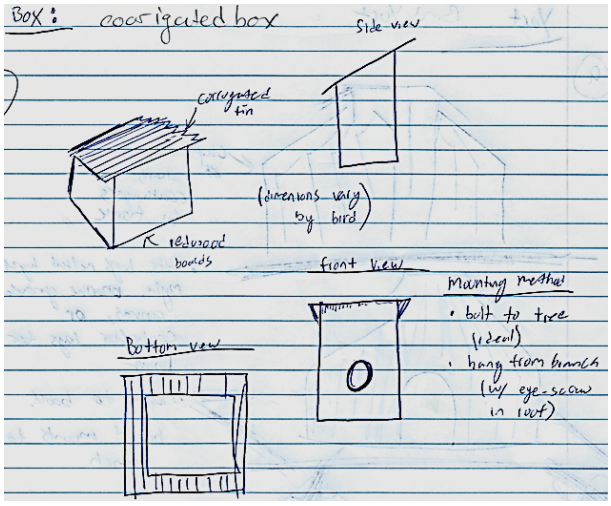


Figure 42 - Corrugated Bird Box Sketch by Christian Cota

3.12. DaVinci's Tent

DaVinci's Tent is a bird box that houses up to eight birds and their nests. It is designed for community bird housing with multiple compartments inside the box so birds have individual housing in a single section. The box itself is modeled after a yurt can be found in Figure 43. It will be covered in Marine Grade Canvas for optimal safety for the box's inhabitants and the children at Zane Middle School. The box will have a wire, wood, or bamboo frame. This design's dimensions can be easily manipulated to fit the requirements for various birds.

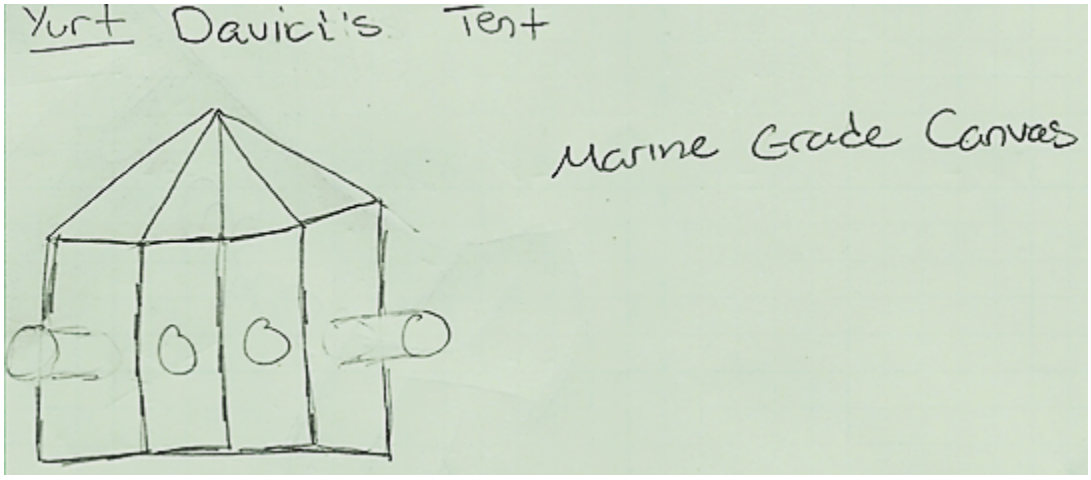


Figure 43 - DaVinci's Tent Sketch by Cavanaugh Carter

3.13. Bird-Loo

The Bird-Loo bird house is an igloo themed bird house. It has space for one nest and is made out of Cobb and wire. The flat base illustrated in Figure 44 is designed to be mounted on top of a post opposed to hanging from a tree.

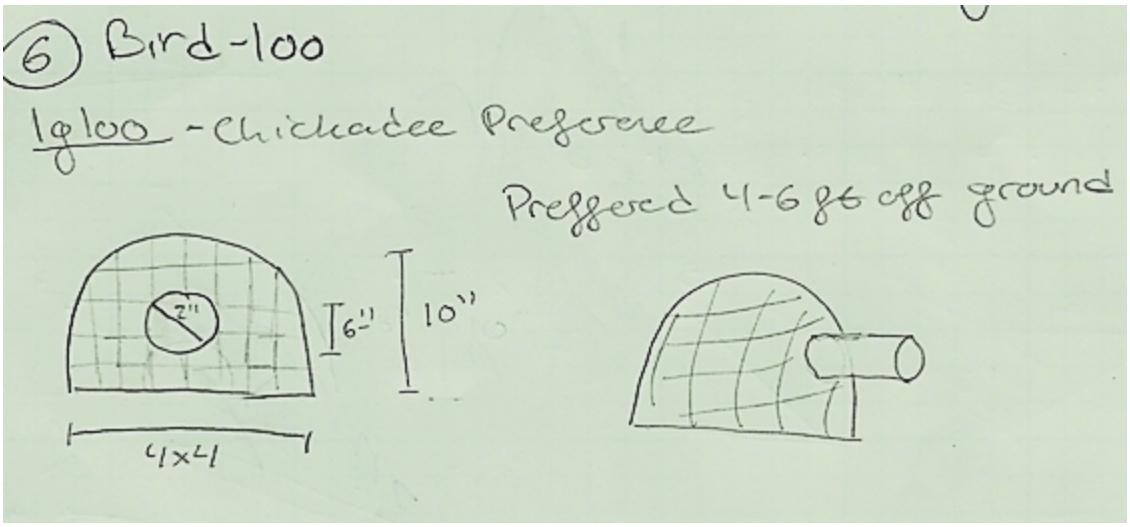


Figure 44 - Bird-Loo Sketch by Cavanaugh Carter

3.14. Wood Duck Inn

This control box is a standard nesting box made from wood, screws, and preferably mounted to a tree. This design, found in Figure 45, is specifically designed for a wood duck because they require special housing conditions similar to those of a wood pecker. This design is the desired size for a wood duck to have a single nest in. It is not built for multiple nests.

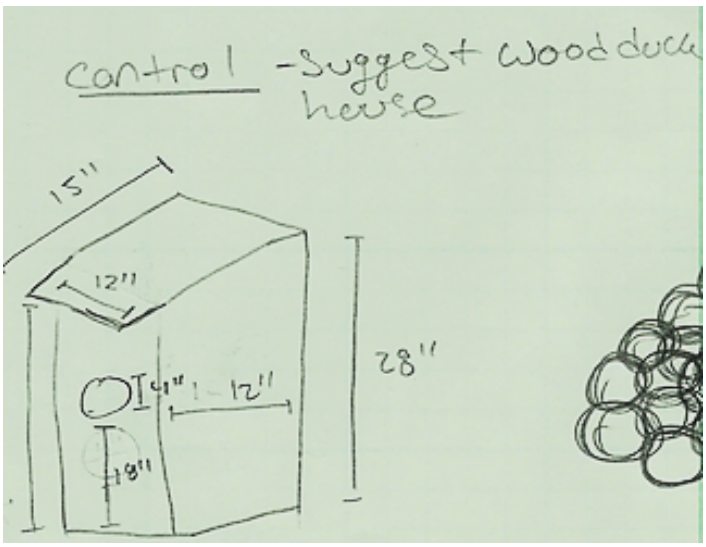


Figure 45 – Wood Duck Inn Sketch by Cavanaugh Carter

4.1.15.The Titt's Hotel

Titt's Hotel is based off of the yurt stem design, intended for bushtits which travel in very large flocks. The structure shown in Figure XX is divided into four individual nesting sections which allow for privacy and safety while still achieving a community nesting habitat. The main structure will be made of chicken wire and will be covered with gore tex material which will be derived from an old rain jacket. The sections will be divided by malleable plastic notebook covers.

4.1.16.Teapot Branch Tree Wire

Teapot Branch Tree Wire is a creatively named design based on its main features. The Teapot Branch Tree Wire birdhouse, as shown in Figure 46, is hung by a copper wire attached to its lid and mounted to a tree for added support. It can house one bird nest and is designed for bushtits, chickadees, wrens, and other similar small birds.

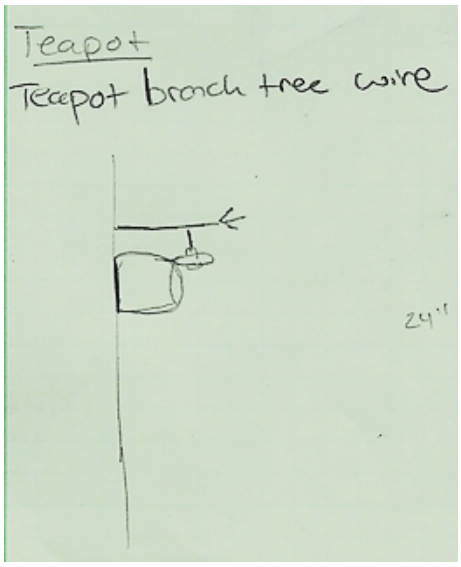


Figure 46 - Sketch of Teapot Branch Tree Wire by Cavanaugh Carter

4.1.17.Handle Hanger

The Handle Hanger as seen in Figure 47, is a teapot hung by a tree branch with copper wire. It's lid is removed for the birds to enter and spout filled with clay to stop items from falling out of the teapot. The Handle Hanger is designed to house one bird nest for birds such as chickadees, bushtits, wrens, and other similar small birds.

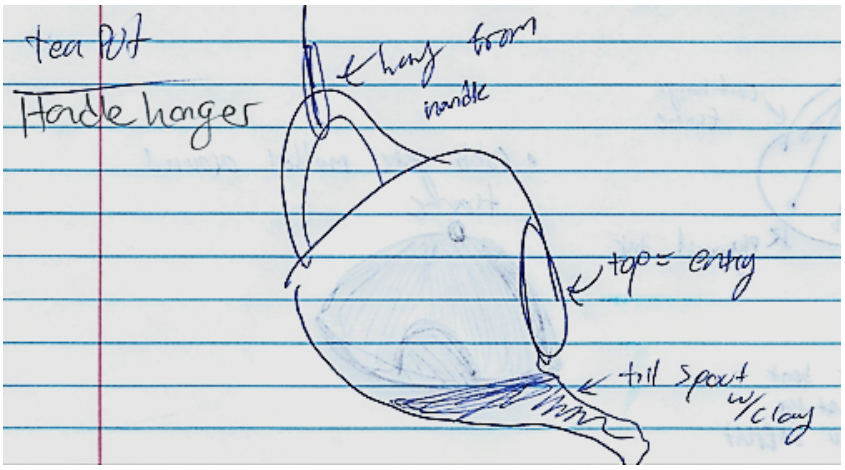


Figure 47 - Sketch of Handle Hanger by Christian Cota

5. Decision Process

1. Introduction

Section 4 explains and evaluates the decision process for the project. This section addresses the criteria, alternative solutions from Section 3 and decision process. This section also utilizes the Delphi Matrix to find the optimal final solution. The Delphi Matrix produces a final solution by weighing each alternative solution by how well it fits the criteria for this project.

2. Criteria

The criteria defined below were utilized during the decision process for choosing the final solutions. Each alternative solution is weighted by how well it meets the presented criteria.

Aesthetics: How the boxes look. Through constraints and discussions with the client, it was agreed that the boxes will be earthy, neutral colors to blend in with the surroundings and avoid unwanted attention from predators.

Cost: The total amount of money spent. The value will not exceed $450, the budget agreed upon in section II.

Diversity: The range of variety among the boxes. This variety is achieved through many aspects of the boxes. There will be 3 mounting methods for the boxes: hanging, direct, and by post. There is a combination of single dwelling boxes and communal boxes; and the boxes implemented fit the nesting needs required by a variety of bird species.

Durability: The ability to withstand any impacts by balls from the nearby soccer field and will be fully and securely fastened to the mount.

Capacity: The number of nests that are able to be built in the structure. Each box will have at least one nesting section to allow for both solidary species and community nesting species.

Reproducibility: The ease of reproduction in the classroom. Each box will be reproducible by 2 students within 20 work hours.

Safety: There will be no chance of harming children, teachers, or community members whether by falling off of mount or by the transfer of the tetanus virus.

Sustainable Sourcing: All materials used will be renewable resources and/or upcycled to prevent waste.

3. Solutions

The following list shows all alternative solutions created specifically for this project as shown in Section 3:

- Bird Bungalow
- Bird Yurt
- Bird-Loo
- Chickadee Cottage
- Cob Cone
- Cobbloo
- Coffee Pot Cabana
- Corrugated Box
- Davinci's Tent
- Don't Draw-Pot
- Handle Hanger
- Hydration House
- Loft Pot
- Suspended Cup Condo
- Teapot Branch Tree Wire
- Titts Hotel
- Wood Duck Inn

4. Decision Process

To come to a decision regarding the final designs, an entire week was spent considering the criteria and constraints for the project including the additional input received from the client. Each team member came up with 4 designs with each design sketched out with specific materials. A group meeting was held in which all the designs were presented and explained. Each design was evaluated based on our weighted criteria chart, Table 3, and assigned a score from 1-50 for each criteria, 50 denoting the most important. The weight of each criteria point was inputted into a Delphi Matrix, shown in Table 4. The Delphi Matrix was utilized to calculate the total score of each design. The highest scored designs exhibiting traits that most closely meet the project's criteria. In the end, the 4 highest scoring designs were chosen to be put into production.

Table 3 - Weighted Criteria

Criteria	
List	Weight
Sustainable	9
Quality	8
Cost	7
Diversity	7
Aesthetics	7
Reproducible	7
Safety	5

Capacity	3

5. Final Decision

The final decision includes four unique birdhouse designs. Table 4, which contains the Delphi Matrix concluded that the most effective birdhouse designs, in order form highest to lowest were “Titt’s Hotel,” “Cobbloo,” “Bird Bungalow”, and the control box, “Wood Duck Inn.” All four of these designs are innovative and cost effective. Most of the materials used to construct them will be upcycled or sustainable. The Wood Duck Inn will be used as a control box. This box has a more traditional design and has been proven to attract birds. However, after prototyping these four designs, it was made clear that Cobbloo and Titt’s Hotel were not practical choices due to the difficulty of construction and questionable lifespan. To replace these two birdhouses, “Don’t Draw-Pot” and a second smaller control box, “Chickadee Cottage,” were constructed.

Table 4 - Delphi Chart of Alternative Birdhouse Solutions

List	Weights (1-10)	Coffee Pot Cabana		Loft Pot		Don’t Draw-Pot	
Cost	7	35	245	30	210	30	210
Diversity	7	20	140	20	140	20	140
Quality	8	30	240	40	320	45	360
Capacity	3	10	30	10	30	10	30
Safey	5	35	175	15	75	20	100
Sustainable Sourcing	9	45	405	20	180	20	180
Asthtics	7	30	210	35	245	35	245
Reproducability	7	25	175	25	175	20	140
	Totals		**1620**		**1375**		**1405**

Wood Duck Inn		Titts Hotel		Davinci Tent		Teapot Branch Tree Wire		Cobb Cone	
35	245	40	280	10	70	40	280	30	210
0	0	30	210	35	245	20	140	35	245
45	360	20	160	40	320	20	160	30	240
10	30	50	150	50	150	10	30	10	30
35	175	35	175	50	250	10	50	30	150
30	270	45	405	0	0	20	180	40	360
20	140	25	175	40	280	35	245	30	210
45	315	40	280	15	105	20	140	20	140
	1535		**1835**		**1420**		**1225**		**1585**

Bird Yurt		Handle Hanger		Corrigated Box		Cobbloo		Bird Bungalo	
35		35		30		45		30	
	42		245		210		315		210
45		20		15		40		40	
	52		140		105		280		280
35		15		40		30		30	
	280		120		320		240		240
10		10		10		10		50	
	30		30		50		30		150
15		15		40		35		40	
	75		75		360		175		200
35		20		30		45		30	
	315		180		210		405		270
25		30		25		30		40	
	175		210		175		210		280
20		35		40		15		15	
	140		245		280		105		105
	1109		**1245**		**1710**		**1760**		**1735**

Hydration House		Suspended Cup Condo	
40		35	
	280		245
35		40	
	245		280
15		15	
	120		120
30		10	
	90		30
40		15	
	200		75
40		35	
	360		315
10		25	
	70		175
45		10	
	315		70
	1680		**1310**

6. Specifications

6.1. Introduction

Section 5 includes detailed descriptions of the four final birdhouses: Bird Bungalow, Don't Drop-Pot, Chickadee Cottage, and Wood Duck Inn. Implementation instructions, cost analyses regarding time and materials, and prototype results are also included.

6.2. Description of Solution

The Applicateers have four differing solutions as shown in the previous section. Bird Bungalow, Wood Duck Inn, Chickadee Cottage, and Don't Draw-Pot are all bird houses constructed in various ways and forms to house the differing birds' native to Humboldt County. Below are the construction summaries for each constructed bird house and it's more direct building

instructions and requirements. This section also includes an analysis of costs and its overall performance.

6.2.1. Bird Bungalow

The Bird Bungalow, found in Figure 48, is made out of an upcycled electrical spool, cans, and upcycled sheet metal. The base of the birdhouse is one, 14-½ inch diameter, circular, wooden end of the wire spool. Attached to the base are 4 recycled aluminum cans that have a 4-inch diameter and a 6-¼ inch height. In the center of the base is a pre-cut hole that was sealed with another piece of wood and has an 8-¾ inch long, one-inch diameter dowel screwed to it. The dowel serves to support the roof of the birdhouse. The roof is a recycled piece of thin sheet metal that is in the rough shape of an hourglass. The center of the sheet metal was marked and was screwed into the top of the wooden dowel at that point. The sheet metal was then bent down until it touched the sides of the circular base and screwed in at the touching points.

Figure 48 - Bird Bungalow before Implementation. (Picture by Ben Voelz, 2014)

Necessary Materials:

1. Aluminum Cans
2. Large Wire Spool w/ 16” (?) wood diameter
3. Sheet Metal for Roof
4. Pole for Mounting
5. 1-4’ length 1” dowel

For Base:

1. Separate spool into two wooden circles and plastic tube
2. Draw out placement of cans on wooden base (12” square containing 4 4” diameter circles)
3. Cut wood piece to cover hole in middle of wooden base
4. Use pre-existing holes to bolt wood cover on under-side of base
5. Measure height from top of hole cover in base to desire roof height (specific to house/ materials)

6. Cut 1 inch dowel to desired length
7. Fasten with screw from bottom up to wood hole cover
8. Cut desired entry holes in cans
9. Use silicon caulking/adhesive to adhere cans to previously drawn in locations

For Roof:

Step 1: Drill pilot holes in metal/top of wooden dowel
Step 2: Use 1" roofing screw to fasten sheet metal to dowel
Step 3: Bend sheet metal down until it touches the sides of the base
Step 4: Drill pilot holes in metal/side of wooden base
Step 5: Use half inch roofing screws on each side to fasten roof to base

6.2.2. Don't Draw-Pot

Don't Draw-pot, shown in Figure 49, is a variation of the teapot stem design and is nestled in a natural wood stained drawer to add aesthetic value as well as reducing the chance of breakage. This design can either be hung from a branch or directly mounted to a tree. The teapot hangs from its handle off of the repositioned drawer handle and the base of the teapot is attached to the drawer to prevent swinging and brakeage. The lid is cut in half to restrict the entrance to the nesting area in order to prevent predators from raiding the nest. The spout is open and pointing down to allow for drainage in case rain blows into the nesting area.

Figure 49 - Don't Draw-Pot after Implementation. (Picture by Christian Cota, 2014)

Necessary Materials:

1. Ceramic Teapot
2. Drawer
3. Drawer Handle

Building:

1. Locate center of inner drawer face and lightly mark both vertical and horizontal position, creating a cross
2. Place teapot with a handle facing the inner drawer, centering handle on vertical mark from step 1
3. Without shifting teapot horizontally, place drawer handle through teapot handle, center on vertical mark from step 1 and parallel to horizontal mark from step 1
4. Mark position of drawer handle on inner drawer face
5. Without shifting drawer handle at all, slowly shift teapot away from the inner drawer face to the point where the two handles are touching without pressure
6. Mark position of the teapot base on bottom of drawer
7. With drawer handle through teapot handle, attach drawer handle to inner drawer face
8. Lift teapot to reveal traced marking from step 5
9. Carefully apply superglue to inner half inch of marking from step 5 and return teapot to its intended position

6.2.3. Chickadee Cottage

The Chickadee Cottage, seen in Figure 50, is a small and sturdy bird box made of plywood with a sheet metal roof. The design is simple, yet functional, and easily reproducible. To begin building, acquire the materials specified Figure 51 below. All plywood pieces should be made from ½ inch plywood. Once all materials have been acquired, Figure 52 illustrates the building and installation of the structure. Drilling pilot holes is highly recommended before drilling the screws in. Designing the Chickadee Cottage was a fairly simple task. It is similar to many preexisting birdhouse designs. The correct dimensions for the house needed to be chosen, as well as materials. Once these elements were selected, the main crux of the design process for this model was encountered, which was making a plan on how to cut the materials and compensate for the thickness of materials, while still attaining the desired dimensions.

Figure 50 - Chickadee Cottage after Implementation. (Picture by Ben Voelz, 2014)

Please see Figure 51 and Figure 52 for dimensions and visualization of assembly

Necessary Materials:

1. ½" Plywood
2. Sheet Metal
3. 16 Wood Screws
4. 4 Eyehook Screws

Building:

1. Cut the required pieces of wood and metal as specified in the materials diagram
2. Mount the front piece (with the hole in the front) to the base piece (the square.) Secure the pieces with a screw at each corner where the pieces meet
3. Mount the back piece (the rectangular piece with no hole) to the bottom. Secure the piece with a screw at each corner where the pieces meet
4. Attach the two side pieces. The slanted sides should be o top. The taller corner should meet the back end while the shorter corner should beet the front end. Secure with a screw at each corner where the pieces meet.
5. Attach the metal roof with one screw at each corner. Drill 4 additional small holes along the roof to ensure that they will go through the wood.
6. In these holes, screw an eye hook into each hole.
7. Secure a 6" section of string to each of the hooks, ensuring that they meet at the ends. Tie the 4 sections together into a loop and hang the finished birdhouse from this loop.

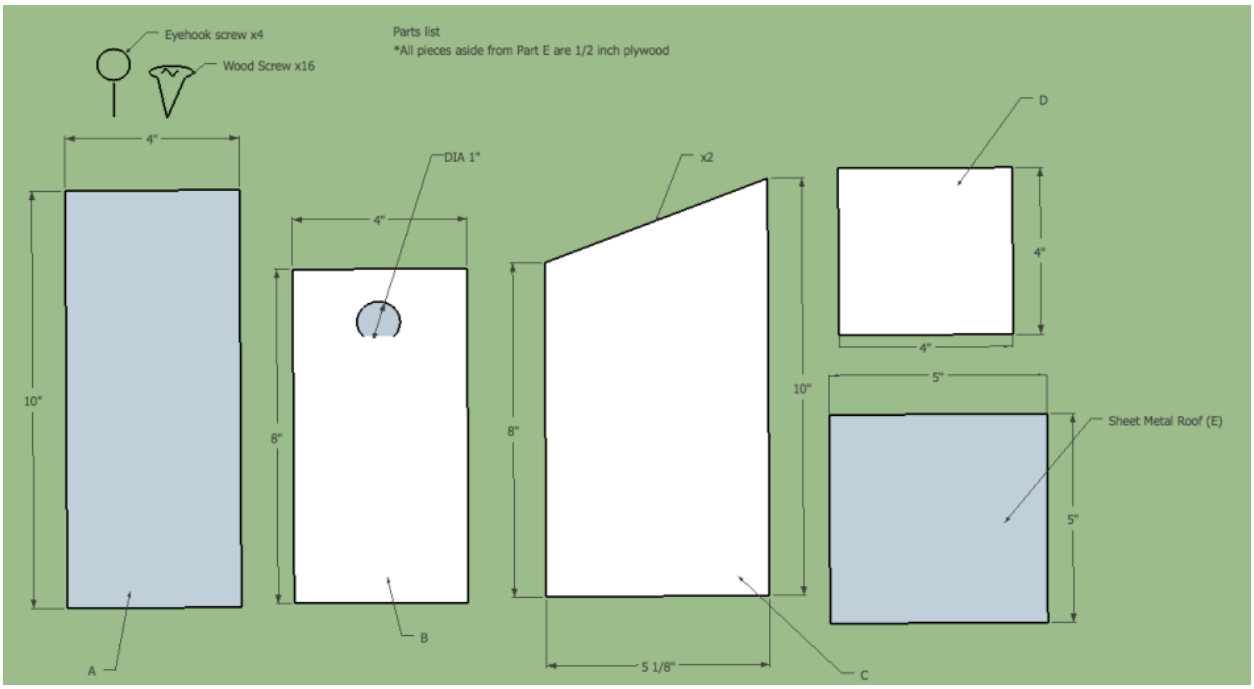


Figure 51 - Chickadee Cottage Diagram. (Picture by Christian Cota, 2014)

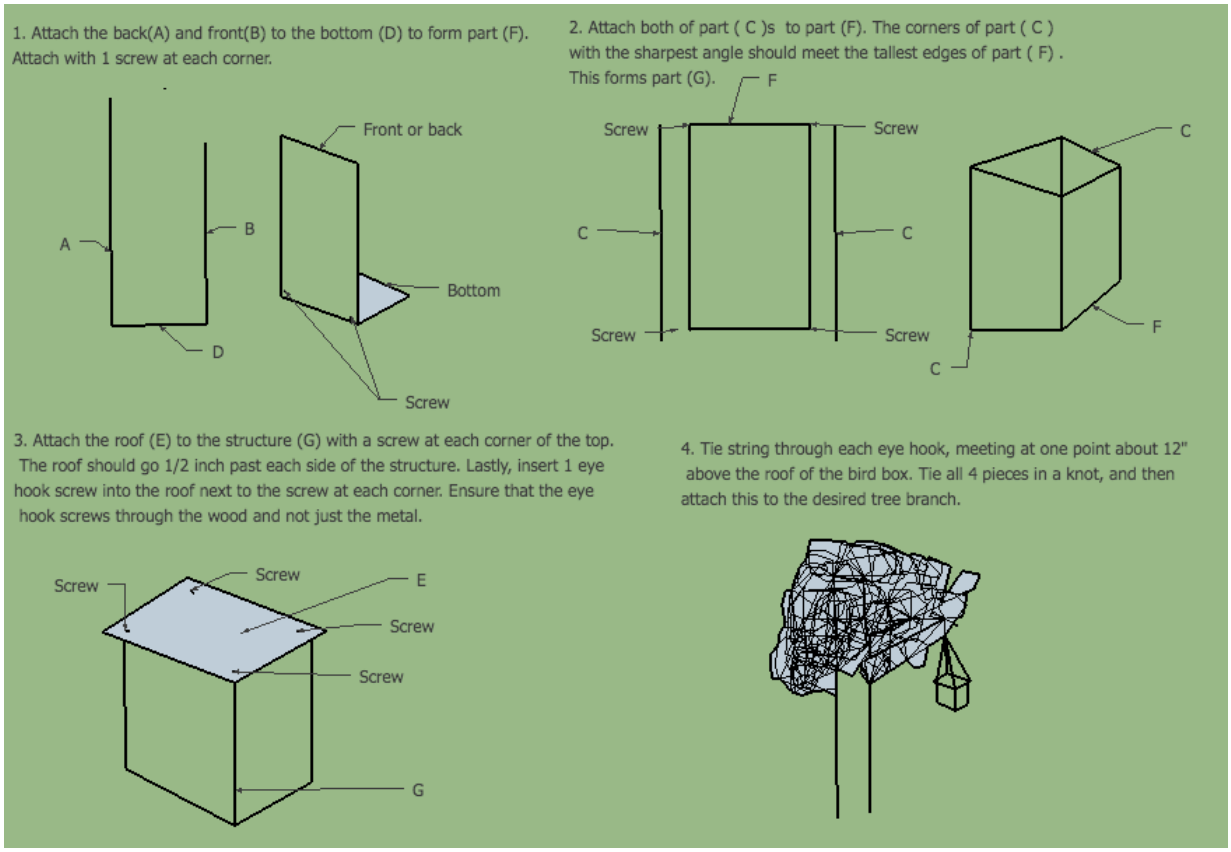


Figure 52 -Chickadee Cottage Building Process. (Created by Christian Cota, 2014)

6.2.4. Wood Duck Inn

The Wood Duck Inn, found in Figure 53, is a traditional wood duck nesting box. Built based on existent designs, such as Figure 54, this box is made of ½" plywood and sheet metal and is designed specifically for Wood Ducks.

Figure 53 - Wood Duck Inn after Implementation. (Picture by Ben Voelz, 2014)

Necessary Materials:

1. ½" Plywood
2. Upcycled Street Sign
3. 21 Wood Screw

Building:

1. Cut the required pieces of wood and metal as specified in the materials diagram
2. Mount the front piece (with the hole in the front) to the base piece. Secure the pieces with a screw at each corner where the pieces meet, as well as a screw in the middle along the bottom edge of the front.
3. Mount the back piece (the rectangular piece with no hole) to the bottom. Secure the piece with a screw at each corner where the pieces meet, as well as a screw in the middle along the bottom edge of the back
4. Attach the two side pieces. The slanted sides should be on top. The taller corner should meet the front end, while the shorter corner should meet the back end. Secure with a screw at each corner where the pieces meet, as well as screws in the middle of each, along the bottom of the side panels
5. Attach the metal roof with one screw at each corner and one screw between each corner
6. **Disclaimer: Consult with an arborist or tree climbing specialist to hang this box** the front panel must be removed so holes can be drilled through the back panel and into a

tree trunk. 3-5 screws should be used to secure the back panel to the trunk. Once the box is secure, reattach the front panel.

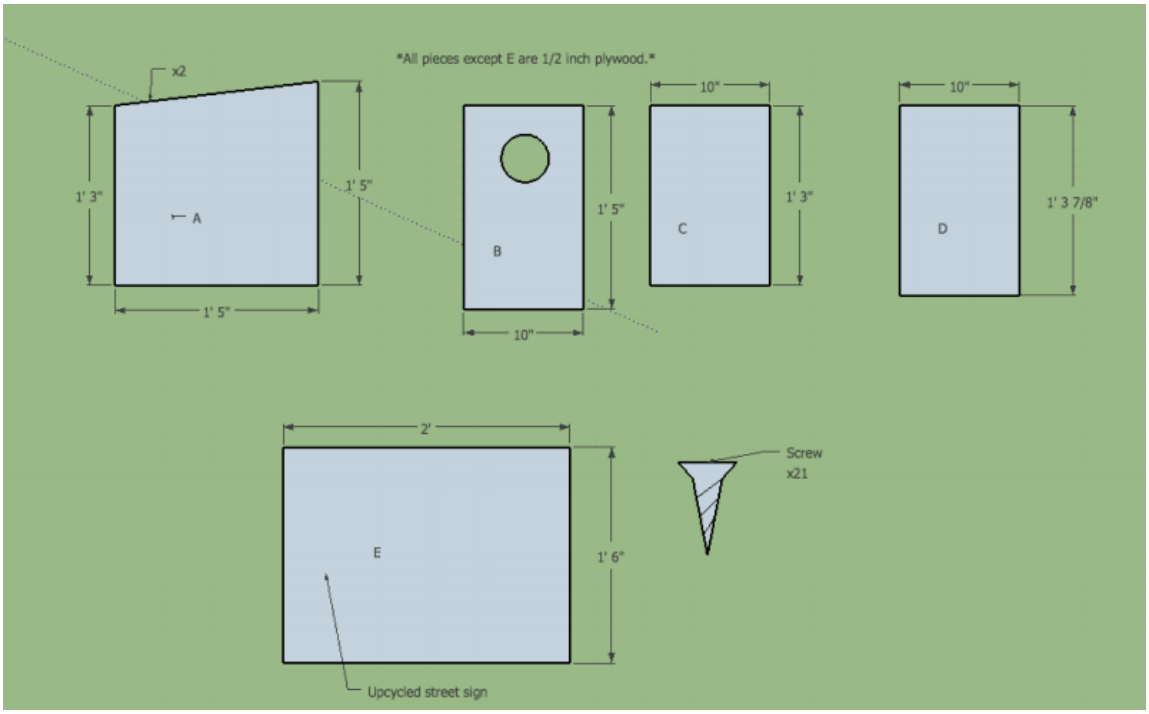


Figure 54 - Wood Duck Inn Building Process (By Christian Cota)

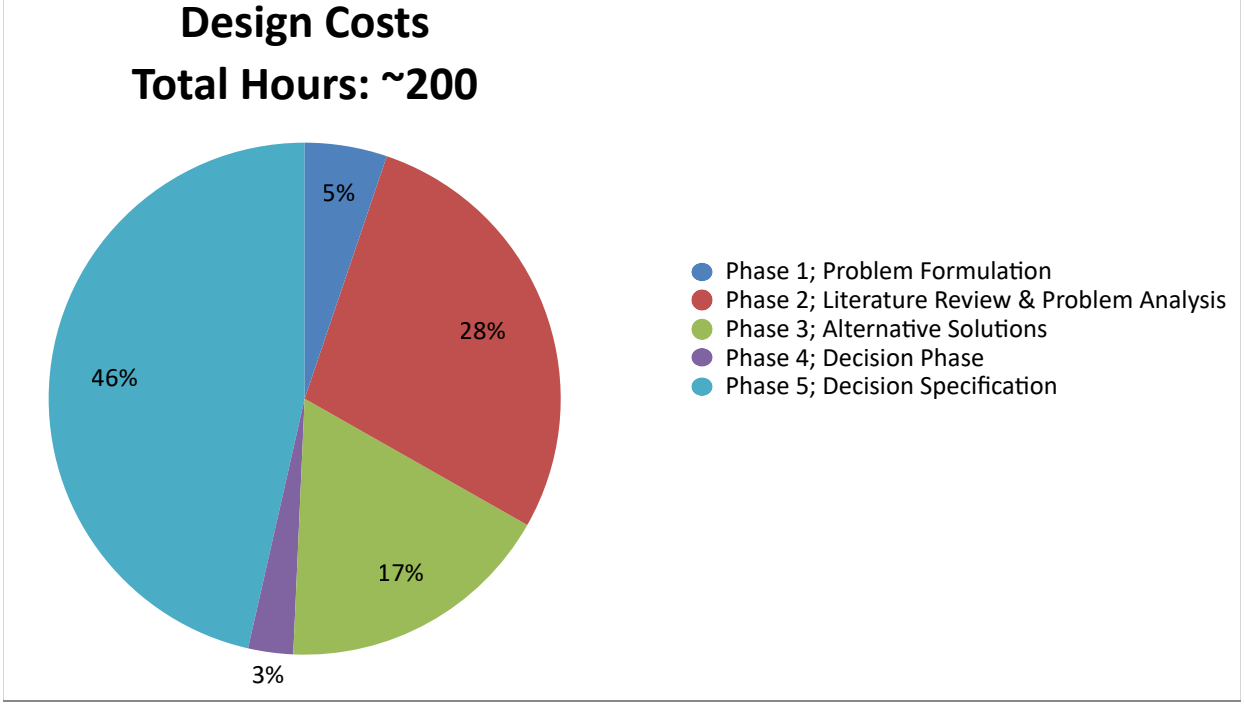
6.3. Cost

Analyses of costs regarding time and materials that were spent during the creation of the Songbird Refuge can be found below.

6.3.1. Design Costs

The design costs shows the total hours The Applicateers spent on this project of building Songbird houses for the community trail at Zane Middle School. Table 5 shows the total hours spent on each section of the design project. The total number of hours spent on this project was 197 hours where the majority of hours were spent on Section 5, the Decision Specification, with a total of 91.6 hours. The second most time spent was in Section 2; Literature Review and Problem Analysis with a total of 55.25 hours.

Table 5 - Design Costs Table Totaling all Hours Spent on this Project.



6.3.2. Maintenance Cost

The Applicateers Songbird Refuge does not require any regular maintenance but was designed to be replaced by the projects of future Zane Middle School children. Materials for all four bird house designs are shown in Table 6. These four songbird boxes are just the beginning of the rehabilitation of the migratory bird corridor and included nature area behind Zane Middle School. Students will replace and ultimately multiply these boxes throughout the years as a part of the developing curriculum. As the number of songbird boxes continues to increase, more and more songbirds will be attracted towards the school to further the educational opportunities associated.

Table 6 - Maintenance Cost Table

Quantity	Material	Source (Arcata)	Cost ($)	Total ($)
1	Aluminum Dryer Vent Pipe	Ace Hardware	4.99	4.99
5'	Chicken Wire	Ace Hardware	1.79	8.95
1	Drawer Handle	Ace Hardware	2.69	2.69
1	Fencing Concrete	Ace Hardware	3.54	3.54
10	Screws	Ace Hardware	0.09	0.90

1	PVC Pipe 4''x10'	Ace Hardware	29.99	29.99
1	Silicone Caulk Tube	Ace Hardware	4.99	4.99
1	Wooden Dowel	Ace Hardware	4.69	4.69
1	Teapot	Angels of Hope Thrift	2.63	2.63
2lb	Aluminum	Arcata Scrap & Salvage	2.00	4.00
6 lb	Stainless Steel	Arcata Scrap & Salvage	1.95	11.70
1	Desk Drawer	Free Wood Pile	Donated	Donated
2	Electric Wiring Spool	Free Wood Pile	Donated	Donated
	½" Plywood	The Mill Yard	Donated	Donated
4	Ravioli Cans	Safeway	2.95	11.80
			Total Cost	**$90.87**

6.3.3. Implementation Instructions

When implementing future birdhouses to the community trail follow instructions specified in section 6 under desired birdhouse design.

6.3.4. Prototype Performance

During the prototyping of the four highest scoring designs from the Delphi Matrix, it was evident that two designs, Titt's Hotel and Cobbloo, were not practical choices for the Refuge. These decisions were made at various levels of completion. Cobbloo was disqualified during the preparation of making the cobb because the weight of the cobb was heavier than anticipated. This additional weight would have warped the structure. Cobb is not highly weather proof, as well, which added to the decision to select a different design. Titt's Hotel was also disqualified, but much later in the construction process. It wasn't until the construction of the cover that this design was deemed impractical due to weather resistance and bird safety. The prototypes of the final four designs passed all tests, and were built in such a way that they were acceptable to be final products.

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7. Appendix

7.1. Group Member Project Hours

Cavanaugh Carter's Hours – Project Hours ENGR 215

Engr 215 - Intro to Design Time Sheet.

(Measurement in Hours)

Cavanaugh Carter - Applicateers

Date	Task Description	Course Time		Project Time		Total Course Time
		Task	Total	Task	Total	
02/14/2014	Excel 1	1.00	1.00	0.00	0.00	1.00
02/14/2014	Team Contract	0.00	1.00	0.66	0.66	1.66
02/14/2014	Self Trello Accnt	0.50	1.50	0.00	0.66	2.16
02/15/2014	Section I	0.00	1.50	0.83	1.49	2.99
02/15/2014	Group Trello Accnt	0.00	1.50	0.66	2.15	3.65
02/15/2014	Self Trello Accnt	1.00	2.50	0.00	2.15	4.65
02/17/2014	Team Contract	0.00	2.50	0.50	2.65	5.15
02/17/2014	Document	0.00	2.50	0.50	3.15	5.65
02/17/2014	Group Meeting	0.00	2.50	1.50	4.65	7.15
02/21/2014	Client Interview	0.00	2.50	1.50	6.15	8.65
02/21/2014	Client Interview	0.00	2.50	0.50	6.65	9.15
02/21/2014	Excel #2	1.00	3.50	0.00	6.65	10.15
02/21/2014	Word #1	0.50	4.00	0.00	6.65	10.65
02/24/2014	Group Meeting	0.00	4.00	1.00	7.65	11.65
02/25/2014	Section II	0.00	4.00	9.00	16.65	20.65
02/27/2014	Cad #2	3.00	7.00	0.00	16.65	23.65
02/27/2014	OpenProj	0.00	7.00	1.00	17.65	24.65
02/27/2014	Section II	0.00	7.00	1.50	19.15	26.15
02/28/2014	Section II	0.00	7.00	3.50	22.65	29.65
03/04/2014	Problem Analysis	0.00	7.00	1.00	23.65	30.65
03/06/2014	Word #2	0.50	7.50	0.00	23.65	31.15
03/06/2014	Team Meeting	0.00	7.50	1.00	24.65	32.15

03/09/2014	Bird House Design	0.00	7.50	0.75	25.40	32.90
03/10/2014	Bird House Dim.	0.00	7.50	1.50	26.90	34.40
03/10/2014	Team Meeting	0.00	7.50	1.00	27.90	35.40
03/11/2014	Midterm Writeup	2.00	9.50		27.90	37.40
03/11/2104	Section III	0.00	9.50	5.00	32.90	42.40
03/14/2014	Team Meeting	0.00	9.50	2.00	34.90	44.40
03/14/2014	MidT Eval Meeting	0.50	10.00	0.00	34.90	44.90
03/16/2014	Time Sheet	1.00	11.00	0.00	34.90	45.90
03/24/2014	Section IV	0.00	11.00	2.00	36.90	47.90
03/24/2014	Team Meeting	0.00	11.00	2.00	38.90	49.90
03/28/2014	Material Gathering	0.00	11.00	3.00	41.90	52.90
03/29/2014	Building	0.00	11.00	4.00	45.90	56.90
04/03/2014	Document	0.00	11.00	1.10	47.00	58.00
04/10/2014	AutoCAD 4	3.00	14.00	0.00	47.00	61.00
04/11/2014	Document 1-4	0.00	14.00	6.00	53.00	67.00
04/13/2014	Section V	0.00	14.00	3.00	56.00	70.00
04/13/2014	Design Costs (V)	0.00	14.00	2.00	58.00	72.00
04/16/2014	Section V	0.00	14.00	4.00	62.00	76.00
04/16/2014	Team Meeting	0.00	14.00	2.00	64.00	78.00
04/17/2014	Section V	0.00	14.00	2.00	66.00	80.00
04/17/2014	Presentation Pract	0.00	14.00	2.00	68.00	82.00
04/19/2014	TimeSheet	0.50	14.50	0.00	68.00	82.50
04/21/2014	Implementation	0.00	14.50	3.00	71.00	85.50
04/23/2014	Presentation Pract	0.00	14.50	2.00	73.00	87.50
04/23/2014	Presentation Pract	0.00	14.50	3.00	76.00	90.50
04/24/2014	Presentation Pract	0.00	14.50	2.50	78.50	93.00
04/24/2014	Presentation	0.50	15.00	0.00	78.50	93.50
04/24/2014	Section V	0.00	15.00	1.00	79.50	94.50
04/28/2014	Document	0.00	15.00	2.00	81.50	96.50

05/01/2014	Poster	0.00	15.00	1.00	82.50	97.50
05/03/2014	Time Sheet	1.00	16.00	0.00	82.50	98.50
05/03/2014	Document	0.00	16.00	5.00	87.50	103.50
05/04/2014	Time Sheet	0.50	16.50	0.00	87.50	104.00
05/04/2014	Document	0.00	16.50	3.00	90.50	107.00

Christian Cota's Hours – Project Hours ENGR 215

Christian Cota

Applicateers

(All time in hours)

Date	Task Description	Course Time		Project Time		Total Course Time
		Task	Total	Task	Total	
02/16/14	Timesheet	0.50	0.50	0.00	0.00	0.50
02/16/14	Trello Setup	0.00	0.50	0.50	0.50	1.00
02/16/14	Memo Edits	0.00	0.50	0.20	0.70	1.20
02/16/14	Contract edits/outline	0.00	0.50	0.50	1.20	1.70
02/17/14	Team Meeting	0.00	0.50	1.50	2.70	3.20
02/18/14	Literature Research	0.00	0.50	3.00	5.70	6.20
02/20/14	Literature Research	0.00	0.50	1.00	6.70	7.20
02/21/14	Team Meeting	0.00	0.50	0.50	7.20	7.70
02/23/14	Section II	0.00	0.50	2.00	9.20	9.70
02/24/14	Literature Formatting	0.00	0.50	1.00	10.20	10.70
02/26/14	Peer Rvw Sec II	0.00	0.50	1.00	11.20	11.70
02/27/14	Team Meeting	0.00	0.50	1.50	12.70	13.20
03/01/14	Autocad Assignment	2.00	2.50	0.00	12.70	15.20

03/02/14	Timesheet	0.50	3.00	0.00	12.70	15.70
03/03/14	Team Meeting	0.00	3.00	1.00	13.70	16.70
03/04/14	Criteria brainstorming	0.00	3.00	0.50	14.20	17.20
03/05/14	Client Meeting	0.00	3.00	1.50	15.70	18.70
03/06/14	Formatting with word	0.50	3.50	0.00	15.70	19.20
03/07/14	Design Brainstorming	0.00	3.50	1.00	16.70	20.20
03/08/14	Design Sketches	0.00	3.50	1.00	17.70	21.20
03/10/14	Team Meeting	0.00	3.50	2.00	19.70	23.20
03/11/14	Team Evaluations	0.00	3.50	0.50	20.20	23.70
03/12/14	Alt. Solutions Format	0.00	3.50	1.00	21.20	24.70
03/13/14	Team Meeting	0.00	3.50	1.50	22.70	26.20
03/13/14	Meeting with Lonny	0.00	3.50	0.50	23.20	26.70
03/14/14	Autocad #3	0.00	3.50	0.00	23.20	26.70
03/17/14	Team Meeting	0.00	3.50	1.00	24.20	27.70
03/19/14	Brainstorming	0.00	3.50	0.50	24.70	28.20
03/21/14	Team meeting	0.00	3.50	1.00	25.70	29.20
03/24/14	Team Meeting	0.00	3.50	1.00	26.70	30.20
03/27/14	Design	0.00	3.50	1.50	28.20	31.70
03/29/14	Build	0.00	3.50	3.00	31.20	34.70
04/03/14	Prototype and testing	0.00	3.50	2.00	33.20	36.70
04/04/14	Wood Collection	0.00	3.50	0.50	33.70	37.20
04/07/14	Team Meeting	0.00	3.50	1.00	34.70	38.20
04/08/14	Wood Cutting	0.00	3.50	2.00	36.70	40.20
04/08/14	Checking Materials	0.00	3.50	0.50	37.20	40.70
04/09/14	Grinding Sheet Metal	0.00	3.50	1.00	38.20	41.70
04/10/14	Team Meeting	0.00	3.50	1.00	39.20	42.70
04/11/14	Autocad #4	0.00	3.50	1.00	40.20	43.70
04/11/14	Poster design	0.00	3.50	2.00	42.20	45.70
04/13/14	Phase 5	0.00	3.50	1.50	43.70	47.20
04/13/14	Build	0.00	3.50	1.50	45.20	48.70

04/14/14	Team Meeting	0.00	3.50	1.00	46.20	49.70
04/14/14	Poster Design	0.00	3.50	1.00	47.20	50.70
04/14/14	Phase 5 revisions	0.00	3.50	1.50	48.70	52.20

Ben Voelz's Hours – Project Hours ENGR 215

Ben Voelz

Date	Task Description	Course Time		Project Time		Total Time
		Task	Total	Task	Total	
02/13/14	Writing Contract	0.15	0.15	0.15	0.15	0.30
02/15/14	Section 1 Writing	0.50	0.65	0.50	0.65	1.30
02/16/14	Trello Account	0.20	0.85	0.00	0.65	1.50
02/16/14	Time Sheet	0.45	1.30	0.00	0.65	1.95
02/23/14	Format w/ Word #1	0.25	1.55	0.00	0.65	2.20
02/23/14	Excel #2	0.75	2.30	0.00	0.65	2.95
02/25/14	Literature Review	0.00	2.30	5.50	6.15	8.45
02/27/14	ACAD #2	4.00	6.30	0.00	6.15	12.45
03/02/14	Time Sheet	0.25	6.55	0.00	6.15	12.70
03/03/14	Problem Analyisis	0.00	6.55	0.75	6.90	13.45
03/10/14	Brainstorming	0.00	6.55	2.00	8.90	15.45
03/12/14	Class Eval/Team Eval	1.50	8.05	1.50	10.40	18.45
03/12/14	Delphi Chart	0.00	8.05	3.50	13.90	21.95
03/23/14	ACAD #3	4.00	12.05	0.00	13.90	25.95
03/23/14	Timesheet #3	0.40	12.45	0.00	13.90	26.35
03/23/14	Sectoin IV Writing	0.00	12.45	0.60	14.50	26.95
03/28/14	Material Gathering	0.00	12.45	2.00	16.50	28.95
03/29/14	Prototyping	0.00	12.45	4.00	20.50	32.95
04/04/14	Material Gathering	0.00	12.45	0.50	21.00	33.45
04/06/14	Building	0.00	12.45	6.00	27.00	39.45

04/05/14	Timesheet #4	0.25	12.70	0.00	27.00	39.70
04/12/14	ACAD #4	3.50	16.20	0.00	27.00	43.20
04/12/14	Section V Writing	0.00	16.20	0.75	27.75	43.95
04/19/14	Implimintation	0.00	16.20	3.00	30.75	46.95
04/23/14	Took Pictures	0.00	16.20	0.50	31.25	47.45
04/23/14	PowerPoint Prep.	0.00	16.20	2.50	33.75	49.95
05/03/14	Final Document Edits	0.00	16.20	2.00	35.75	51.95
05/04/14	Final Time Sheet	0.25	16.45	0.00	35.75	52.20

Jennifer Warmack's Hours – Project Hours ENGR 215

Jennie Warmack

ENGR 215

Applicateers - Songbird Refuge

All Time in Hours

Date	Task Description	General Course Time		Project Time		Total Course Time
		Task	Total	Task	Total	
02/02/14	Excel 1	1.00	1.00	0.00	0.00	1.00
02/15/14	Team Contract	0.00	1.00	0.50	0.50	1.50
02/15/14	Section I Writing	0.00	1.00	0.75	1.25	2.25
02/16/14	Trello	0.00	1.00	0.50	1.75	2.75
02/16/14	Time Sheet 1	0.50	1.50	0.00	1.75	3.25
02/16/14	Section I Memo	0.00	1.50	0.50	2.25	3.75
02/17/14	Team Meeting	0.00	1.50	2.00	4.25	5.75
02/18/14	Lit Review Research	0.00	1.50	1.00	5.25	6.75
02/19/14	Lit Review Research	0.00	1.50	1.00	6.25	7.75
02/21/14	Lit Review Research	0.00	1.50	1.00	7.25	8.75
02/22/14	Lit Review Research	0.00	1.50	1.50	8.75	10.25
02/23/14	Lit Review Research	0.00	1.50	1.50	10.25	11.75
02/24/14	Team Meeting	0.00	1.50	2.00	12.25	13.75
02/25/14	Lit Review Format	0.00	1.50	2.50	14.75	16.25

02/25/14	Formatting 1	0.50	2.00	0.00	14.75	16.75
02/25/14	Excel 2	0.50	2.50	0.00	14.75	17.25
02/28/14	Gantt Chart	0.00	2.50	1.00	15.75	18.25
02/28/14	CAD 2	2.50	5.00	0.00	15.75	20.75
03/01/14	Time Sheet 2	0.50	5.50	0.00	15.75	21.25
03/03/14	Team Meeting	0.00	5.50	3.00	18.75	24.25
03/03/14	Section II Writing	0.00	5.50	0.75	19.50	25.00
03/04/14	Section II Writing	0.00	5.50	0.25	19.75	25.25
03/06/14	Designing	0.00	5.50	1.00	20.75	26.25
03/09/14	Formatting 2	0.50	6.00	0.00	20.75	26.75
03/09/14	Designing	0.00	6.00	1.50	22.25	28.25
03/10/14	Section III Writing	0.00	6.00	0.75	23.00	29.00
03/10/14	Team Meeting	0.00	6.00	2.00	25.00	31.00
03/11/14	CATME	0.00	6.00	0.50	25.50	31.50
03/11/14	Midterm Evaluations	0.00	6.00	1.00	26.50	32.50
03/13/14	CAD 3	0.67	6.67	0.00	26.50	33.17
03/13/14	Time Sheet 3	0.50	7.17	0.00	26.50	33.67
03/24/14	Team Meeting	0.00	7.17	2.00	28.50	35.67
03/26/14	Lit Review Research	0.00	7.17	1.00	29.50	36.67
03/28/14	Material Sourcing	0.00	7.17	1.50	31.00	38.17
03/29/14	Building	0.00	7.17	2.00	33.00	40.17
04/04/14	Material Sourcing	0.00	7.17	0.50	33.50	40.67
04/04/14	Building	0.00	7.17	2.00	35.50	42.67
04/05/14	Building	0.00	7.17	3.00	38.50	45.67
04/06/14	Time Sheet 4	0.50	7.67	0.00	38.50	46.17
04/09/14	Appropedia Pg Build	0.00	7.67	5.00	43.50	51.17
04/10/14	Appropedia Pg Build	0.00	7.67	1.50	45.00	52.67
04/11/14	Client Meeting	0.00	7.67	1.00	46.00	53.67
04/11/14	Site Survey	0.00	7.67	1.50	47.50	55.17
04/11/14	Building	0.00	7.67	2.50	50.00	57.67
04/11/14	CAD 4	0.00	7.67	1.50	51.50	59.17
04/13/14	CAD 4	0.00	7.67	1.00	52.50	60.17
04/14/14	Team Meeting	0.00	7.67	2.00	54.50	62.17

04/14/14	Document Format	0.00	7.67	2.00	56.50	64.17
04/15/14	Presentation Prep	0.00	7.67	1.00	57.50	65.17
04/16/14	Presentation Prep	0.00	7.67	1.00	58.50	66.17
04/17/14	Presentation Prep	0.00	7.67	1.00	59.50	67.17
04/18/14	Building	0.00	7.67	0.50	60.00	67.67
04/19/14	Appropedia Pg Edit	0.00	7.67	0.50	60.50	68.17
04/20/14	Building	0.00	7.67	0.33	60.83	68.50
04/21/14	Implementation	0.00	7.67	4.00	64.83	72.50
04/23/14	Appropedia Pg Edit	0.00	7.67	1.50	66.33	74.00
04/25/14	Document Editting	0.00	7.67	1.00	67.33	75.00
04/26/14	Document Editting	0.00	7.67	1.50	68.83	76.50
04/27/14	Appropedia Pg Edit	0.00	7.67	1.00	69.83	77.50
04/28/14	Document Editting	0.00	7.67	2.00	71.83	79.50
04/29/14	Document Editting	0.00	7.67	3.00	74.83	82.50
05/02/14	Appropedia Pg Edit	0.00	7.67	1.00	75.83	83.50
05/03/14	Appropedia Pg Edit	0.00	7.67	3.50	79.33	87.00

7.2. Brainstorming