Rain Garden Project

WPI

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An Interactive Qualifying Project submitted to the Faculty of Worcester Polytechnic Institute.

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Project Advisor: Elisabeth Stoddard
Project Sponsor: Turn Back Time Inc.

Abstract

Turn Back Time Inc. is a nature-based learning institution that was facing a flooding problem on one of their main walkways. We sought to build a rain garden in an area that would help drain excess water to make traversing the farm easier for students and teachers. After researching rain garden designs, native plants, and conducting many interviews, we created a rain garden on the property that addresses the flooding issue, serves as an educational tool for the children, and adds visual appeal to an otherwise uninteresting space.

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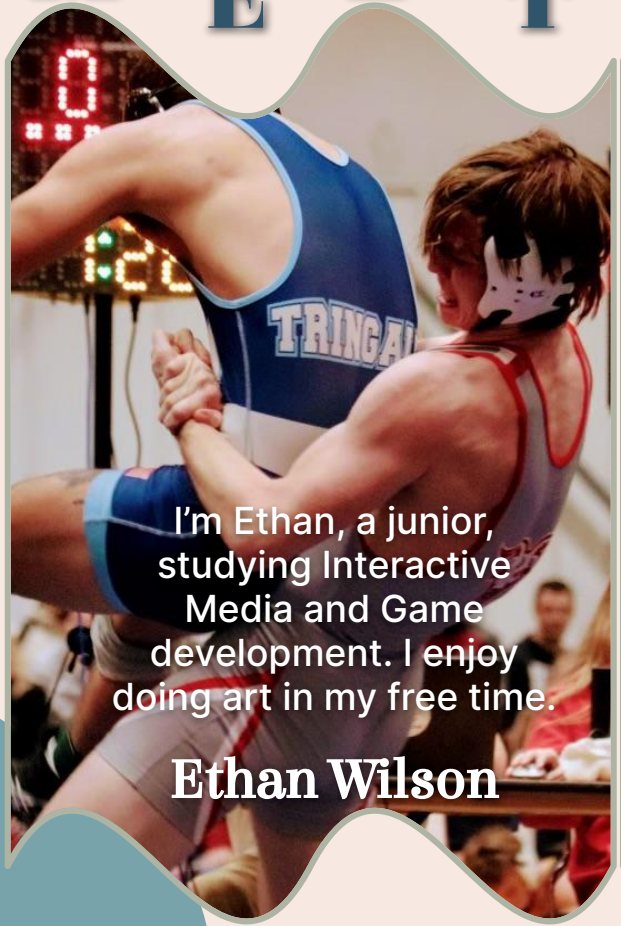
MEET THE TEAM

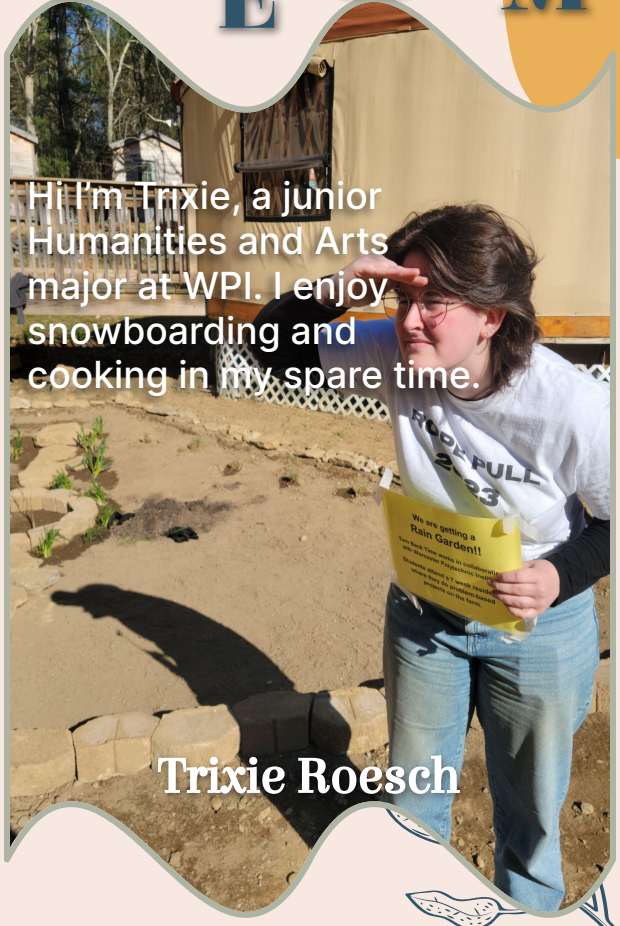


I'm Ethan, a junior, studying Interactive Media and Game development. I enjoy doing art in my free time.

Ethan Wilson

Hi! I'm a junior studying Mechanical Engineering at WPI. I enjoy spending time in nature, games, and rollerskating.

Ligia Portugal



Hi I'm Trixie, a junior Humanities and Arts major at WPI. I enjoy snowboarding and cooking in my spare time.

Trixie Roesch

01

Introduction

Figure 1: An overhead view of Turn Back Time taken via drone

Project Overview

Where?

- Turn Back Time Inc. Farm located in Paxton, Massachusetts

Problem?

- Stormwater runoff and snowmelt
- Caused by yurt installation

Rain Gardens?

- Type of green infrastructure
- Increased water retention
- Specific flora required
- Education opportunity

Green Infrastructure

Typically, when the problem of stormwater flooding is brought up, the most environmentally friendly solutions point toward the usage of **green infrastructure**. Green infrastructure uses plants, soil, and other natural materials to **filter stormwater and absorb it back into the ground**. A great example of green infrastructure is the image on the right - a garden on the roof of a building in Chicago that was designed to mitigate rainwater runoff caused by the addition of the building. Our team seeks to utilize green infrastructure in the form of a **rain garden** at Turn Back Time which would not only **mitigate the flooding problems they're facing**, but also serve as a source of **curriculum for children** who attend school there. By including the right types of plant life, the garden will be efficient in **attracting local wildlife**, which can then be worked into a curriculum focused on the surrounding environment.

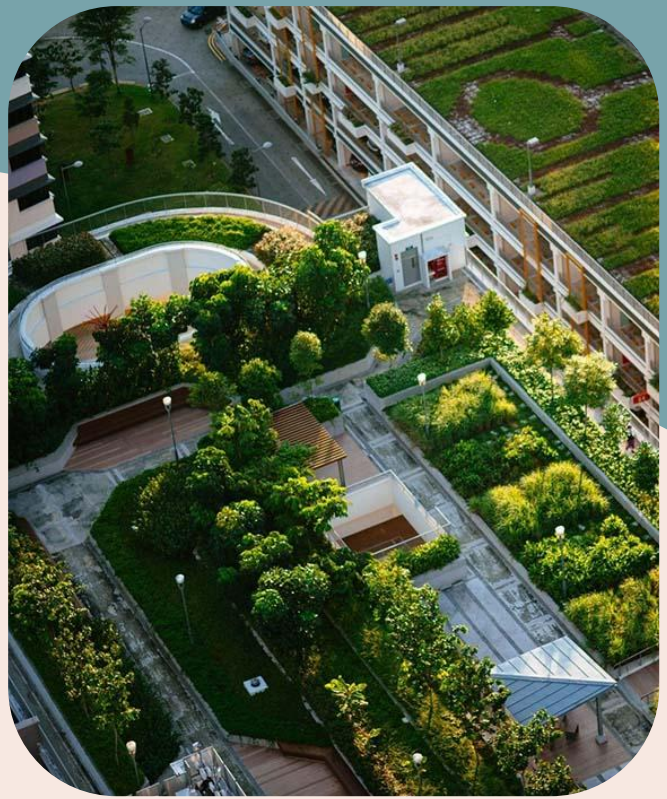


Figure 2: This is a rooftop garden in Chicago

Our overall goal is to **build a rain garden** for Turn Back Time Inc. in order to **address stormwater runoff** problems and **develop new relevant lessons** for their students.

02

Background

All about rain gardens

Figure 3: A picture of Ethan and Ligia standing in the garden outline for size reference.

Rain Garden Benefits

Bak and Barjenbruch (2022) describe rain gardens as green spaces, or a type of green infrastructure, dedicated to **increasing soil retention of water** by using specially selected plant species. These gardens not only promote water retention but can also help to **purify any bacteria or metals that may be found in rainwater** before they make their way into the ground (Li et al., 2018). The image on the right is an example of pollutants that runoff carries into waterways. According to Grehl et al (2007), environmental sustainability involves taking steps to protect our Earth, but it is just as much about leading others to do the same. That is why visibility is such an important factor in rain garden placement; the more people who see it, the more they see its benefits, and the more likely they are to **take steps towards environmental conservation themselves.**

Figure 4: An image of typical runoff pollutants.

Rain Garden Benefits Cont'd

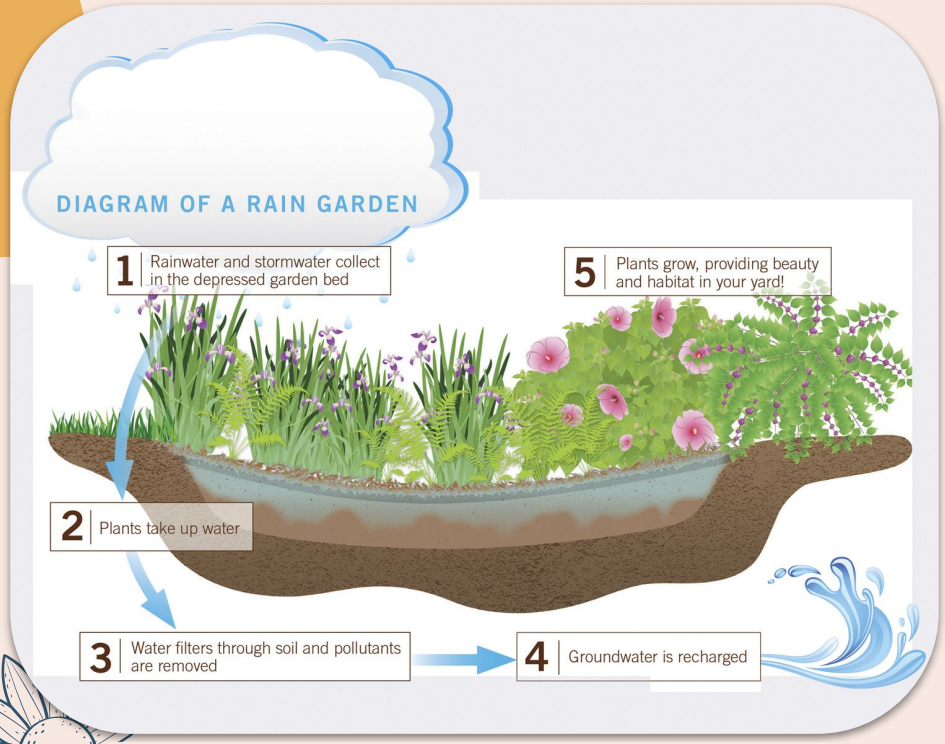


Figure 5: A picture showing the simplified cycle of a rain garden.

The main function of a rain garden is to **control excess water and flooding**, which is what makes them good at environmental stabilization. They are able to **retain excess water in their soil**, as well as allow rainwater to filter through the ground, preventing puddles (Bak and Barjenbruch, 2022). These aspects of a rain garden are also what allow it to **maintain the natural hydrology of the environment** it's in quite efficiently (McGauley et al., 2023). This means that rain gardens keep the local environment stable by preventing flooding, as well as drought, by creating **conditions that allow local flora and fauna to thrive**. Rain gardens come in many varieties and can be built to **withstand many different rainfall conditions**. It has been shown that their capacity for flood mitigation holds against even heavy rainfall events (Zhang, 2020).

Rain Garden Benefits Cont'd

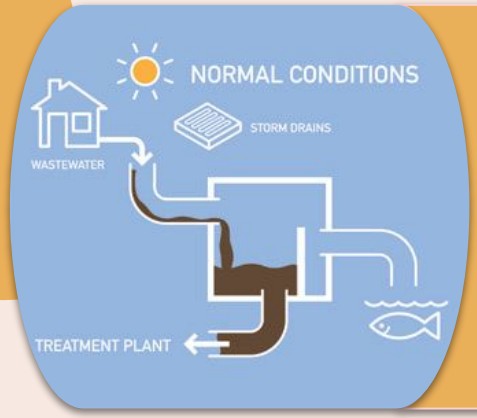
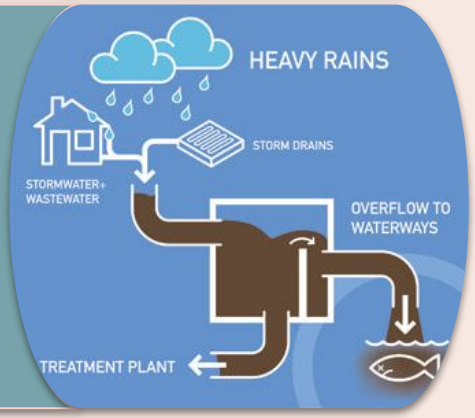


Figure 6: Normally, wastewater would easily make it to the treatment plant.

Figure 7: In extreme conditions, polluted runoff along with wastewater overflow into waterways, harming that ecosystem.



While controlling water flow is their main function, rain gardens are also highly **effective at reducing pollution rates of many chemicals** commonly found in soil by over 75%, as well as bacteria populations (Chen, 2023). Stormwater **picks up and brings many chemicals with it when it runs**, gathering spilled car oils from parking lots, litter, and a variety of harmful metals. Rain gardens are efficient at reducing the levels of metal found in stormwater, particularly zinc, lead, and copper, because many **plants actually thrive off these metals and soak them up from the soil** with ease (Bak and Barjenbruch, 2022). Runoff water has also been known to become a **breeding ground for bacteria** when it remains stagnant for prolonged periods of time, specifically for fecal coliform and E. coli (Bak and Barjenbruch, 2022). With a rain garden reducing the amount of liquids heading to treatment plants, overflow can be prevented. It can also help with the microorganisms in its soil, which work alongside natural sunlight to kill bacteria from pets or wild animals that make their way into the garden (Stiffler, 2013).

Elements of a Rain Garden

Green infrastructure is when nature is used as an infrastructural system to provide services such as **protection against flooding, excessive heat, and improving air and water** quality (Silverstein & Green, 2020). There are many elements of a rain garden that must be considered in order for it to function efficiently such as: placement, soil type, expected runoff amounts, size, and plant life. The **placement of this type of garden is crucial** if natural water filtering is to occur.

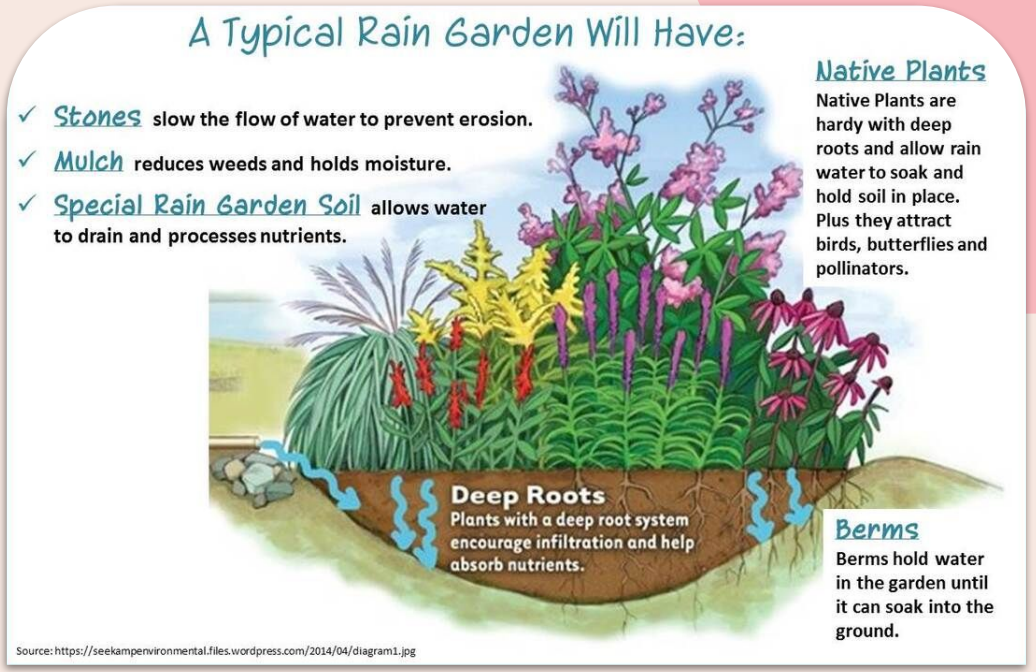


Figure 8: A picture showing the components of a rain garden.

Elements of a Rain Garden

Placement

- Depressed area
- Purposeful puddle

Runoff

- Snowmelt
- Rain water

Plants

- Forb-rich perennials
- Biodiversity

Size

- Impervious area
- Depth
- Shape

Soil

- Sandy
- Ribbon test

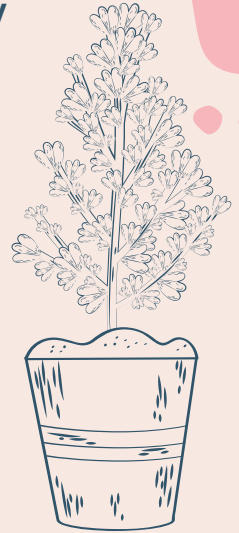


Figure 9: Ligia conducting the ribbon test on a soil sample from between the yurts.

Figure 10: Examples of different soil types during the ribbon test.

Ribbon Test

A specific soil mixture and layers are used for optimal water drainage. A simple test should be conducted called a ribbon test which will help **determine if a location is viable for a rain garden**. To conduct a ribbon test, collect a few tablespoons from about 4-6 inches below the soil surface and add drops of water to it until it feels like a moist putty. Knead it while the water is added and roll it into a ball, then gently squeeze it to determine what kind of soil it is (National Groundwater Association, 2022).

Soil sticks together = clay heavy

Soil doesn't stick together = sand heavy

Soil sticks together loosely = clay and sandy soil

Rain Garden Sizing

Next, the size of a rain garden needs to be determined. The size **depends on the volume of water that it has to hold**, and this is calculated based on estimated water runoff and the impervious area to be treated such as the roof. Generally, the garden should be about **ten percent of this calculated area** (Bell, 2023). For example, an impervious area of 360 ft^2 would require a rain garden of 36 ft^2. As for depth, if sandy soil is used, a depth of three to six inches is recommended as they tend to have a **percolation rate greater than one inch** per hour of drainage. Once the area and depth are calculated, the shape must be taken into consideration. It generally does not matter as long as it has enough surface area, however, it should be at least five feet wide to “accommodate gentle side slopes that will host plants and **minimize soil erosion**.” (Bell, 2023).

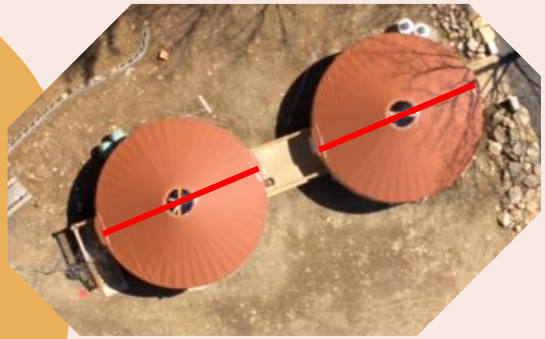


Figure 11: Image of the impervious area we will work with. Red lines represent the diameter of the yurts (27′)

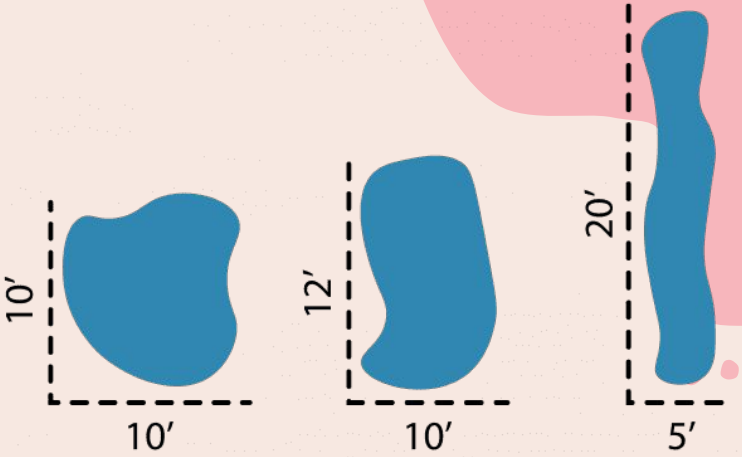


Figure 12: Rain gardens can be arranged in different shapes while still treating roughly the same amount of stormwater runoff.

Precipitation

In addition to considering the type of soil for a rain garden, it is important to account for the rainfall and snowmelt in the area. Understanding the amount of **rainfall, melt, and weather conditions** that a rain garden is likely to endure will help us understand how it should be built. In the last 24 years, Worcester county, which includes Paxton, has seen 56.07 inches of rainfall on average every year, as seen below (NOWData, 2024). Rainfall is not the only type of weather rain gardens are capable of handling. “Rain gardens have even **proved to be effective in regions with heavy snowfall**,” (Muthanna, 2007). The average of snowfall in the same area is about 46 inches per year (NOWData, 2024). If built properly, our rain garden should be prepared to function well in every season during the year.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2022	3.12	5.33	3.46	3.91	2.42	3.16	3.54	2.91	6.14	4.44	3.84	6.07	48.34
2023	6.13	1.65	4.33	4.79	2.54	4.73	12.30	5.88	8.78	3.81	1.47	7.39	63.80
2024	8.18	1.35	8.57	M	M	M	M	M	M	M	M	M	M
Mean	5.81	2.78	5.45	4.35	2.48	3.95	7.92	4.39	7.46	4.13	2.66	6.73	56.07
Max	8.18 2024	5.33 2022	8.57 2024	4.79 2023	2.54 2023	4.73 2023	12.30 2023	5.88 2023	8.78 2023	4.44 2022	3.84 2022	7.39 2023	63.80 2023
Min	3.12 2022	1.35 2024	3.46 2022	3.91 2022	2.42 2022	3.16 2022	3.54 2022	2.91 2022	6.14 2022	3.81 2023	1.47 2023	6.07 2022	48.34 2022

Figure 13: Image of precipitation in the Worcester area from the last three years.

Plants

Figure 14: Mown grasses are sparse with no diversity.

Figure 15: Forb-rich perennials, higher diversity in roots and benefits.

Once an area is located for the rain garden the next consideration should be plants. Forb-rich perennials, which can be thought of as almost any leafy plant with flowers (see Figure 1), **promote both water retention and detention** as their roots will break up the soil and soak in some of the water for the plant itself (Yuan et al, 2017). The use of such plants will **create an area of high absorption land** that can drain itself in the presence of too much water. Other plant types that we should consider are those with large above-ground growths, which is to say plants that have big leaves. Both the forb-rich perennials and the big-leafed plants contribute positively to a process known as evapotranspiration, or **the process through which water returns to the atmosphere**. This speeds up the rate at which portions of water absorbed by the garden are taken up by plants then returned to the atmosphere which will help us ensure that the rain garden doesn't need to be drained every time there is a rainstorm. Using native plants **promotes biodiversity by providing more living areas** and necessary flora that the local fauna relies on. It can help animals such as birds and deers, insects including butterflies and dragonflies, and amphibians such as small frogs. This helps create **more stability in fauna populations** and it also provides great learning opportunities for teachers and students alike at Turn Back Time Inc.

Health and Safety

Maintaining a **safe and healthy** environment at the farm is one of the biggest reasons for undertaking this project, and while rain gardens provide many benefits, there are also some **possible setbacks** to be aware of. While rain gardens can help **mitigate water pollution** and **stormwater runoff**, they also come with a few risks. If built improperly, rain gardens can act as **ponds of stagnant water**, creating the perfect environment for **mosquitos and bacteria to breed and grow**, which can lead to the spread of illnesses such as **West Nile virus or Eastern Equine Encephalitis**. To avoid this, the rain garden must be carefully designed and sized as mentioned above.

Figure 16: A close up of a mosquito. These insects carry diseases and spread them easily by sucking blood from many different people.

Maintaining a Rain Garden

- Plants:
  - Weed
  - Remove dead branches
  - Remove dead vegetation
  - Pruning

- Soil:
  - Remove buildup
  - Cover bare soil w/ mulch
  - Don’t:
    - Fertilize
    - Use pesticides
    - Compost

Maintaining a Rain Garden Cont'd

In order for a rain garden to function to the best of its ability, it is important to **maintain the cleanliness** and order of a garden to ensure its functionality. Keeping the garden clean of invasive plant life and keeping larger plants properly pruned will ensure that the garden runs smoothly. Bak and Barjenbruch (2022), explained that any **dead branches, dead vegetation, weeds, and invasive species that end up in the rain garden must be removed** to keep the plant life healthy and maintain the surface permeability. It is important to **remove built-up sediment and cover up bare soil with mulch or reseed in order to combat erosion.**

It should also be kept in mind that a rain garden should **never be fertilized, have pesticides applied to it, or be composted,** as these will add unnecessary and unwanted nutrients to it such as **phosphorus or nitrogen** that can change the soil's ability to absorb water and **harm critters that live in the garden.**

Rain Gardens as an Educational Tool

In addition to stabilizing local environments, rain gardens can also provide a **valuable source of education** for children. Play-based learning in nature, whether it is structured or completely up to the children, has been shown to have many benefits (Becker, 2017). It **encourages communication and critical thinking**, it stimulates the **imagination,** it results in **better behavior,** and it leads to more c**reative and engaged students** (Becker, 2017, Dennis, 2014). Some of the other benefits of a nature-based education surprisingly revolve around the adults. During morning drop-off researchers found there to be **less separation anxiety between a child and parent** due to there being a plethora of activities for a child to busy themselves with the moment they step outside. It also allows for a time of connection between parents and children during afternoon pickup (Dennis, 2014).

Figure 17: A picture taken during the school day at TBT Inc. showing a teacher easily engaging her students.

Rain Gardens as an Educational Tool

A rain garden can also have useful **applications in education and help improve learning**. A study observed multiple centers that utilized gardens as teaching tools, and nearly every one of them was able to achieve their goals of teaching valuable life skills to children (Dennis, 2014). These skills include **teamwork, empathy, critical thinking, and creativity** to name a few. Rain gardens can be used to teach children about nature, and research has shown that an education with a more **outdoors and hands-on approach** is very beneficial to child development. Not only do rain gardens help teach children about life skills, but they can also be used to **teach more complex subjects**, such as the water cycle, in an easier-to-understand way.

Figure 18: A picture taken during the school day at TBT Inc. showing children playing together to redirect water flow.

Rain Gardens as an Educational Tool

Rain gardens filter water and help control its flow. As such, this type of garden can be utilized to teach about the water cycle and how soil works as a natural filtration system (Ogelman, 2012). The water cycle is an **important concept regularly taught at schools through books and lectures**, however, it can be observed within the rain garden too. Rain falls and waters plants, it gets used by living creatures and the **excess runs off to bodies of water or gets filtered by the soil**. The water that remains on the surface evaporates and accumulates into clouds until it rains down again. Similarly, it could also be used to teach about the soil cycle.

Rain gardens have been proven to be an effective tool for controlling environmental instabilities, and double as a valid source of curriculum for younger children. A lot of consideration must be put into the construction of a rain garden, from the soil it's planted on, to its management, the plants it will use, the rainfall it will see, and any concerns about cleanliness. If all of these elements are thoroughly researched and construction of the garden is conducted properly, the resulting product will be an **effective tool for controlling and maintaining environmental stability** as well as serving as a **valuable learning opportunity for children.**

Figure 19: A picture showing a child interacting with the pond who later talked about their observations and questions.

Rain Gardens as an Educational Tool Cont'd

Better behaved
Less separation anxiety
Critical thinking
Communicative

Child Behavior

Teamwork
Empathy
Critical thinking

Life Skills

Water cycle
Plant behavior
Environmentally conscious

Nature Education

Summary

Our project seeks to address an issue on the Turn Back Time Farm in Paxton MA. Turn Back Time is a nature-based learning center that focuses on teaching children about nature from a young age with a hands-on approach. Currently, the farm is experiencing water runoff problems near one of its classrooms, which is causing **issues for teachers and students to navigate the farm.** In response, our team will be building a rain garden that will hopefully alleviate this issue while **providing an educational tool for the children.**

Figure 20: An overhead image of the farm. It shows the two yurts and the area in between that floods.

Figure 21: Image of the yurt.

03 Methodology

Goal:

The goal of this project was to create a rain garden for the Turn Back Time Inc. farm that would reduce rainwater runoff on and around the gravel path to the kindergarten yurt and act as a new source of nature-based education for the children who attend school there.

Objective 1:

Understand the needs and wants for a new rain garden for flood mitigation and curricular use.

Objective 2:

Assess the physical features of the farm landscape where runoff water is causing problems

Objective 3:

Design and receive feedback on proposed rain garden plans

Objective 4:

Design and receive feedback on the proposed rain garden curriculum

Figure 22: Ligia showing the soil sample used for the ribbon test for soil composition.

Objective 1: Understanding Curriculum and Garden Wants and Needs

Interviews:

We used the **semi-structured interview method** to understand what the school wants and needs surrounding the storm water runoff problem and their **educational goals for the rain garden**. Semi-structured interviews were the best course of action for collecting the needed data because according to the Beebe reading on pg 50, interviewees will feel more relaxed and open to having something closer to a casual conversation than they would in a formal interview. When interviewers let the conversation flow instead of strictly sticking to their prepared questions, interviewees might be more **comfortable** with **sharing their ideas**.

Figure 23: Example of a semi-structured interview

Interviewing Staff Members

Interviews were conducted with some of the stakeholders, such as the teaching staff. We wanted to learn more about what the **teachers might need or expect** from an addition to their lesson plans. This provided us with more information about what the school **already teaches,** so we were more informed when figuring out what lessons we wanted to implement later on.

Figure 24: A photo showing an interview

Interviews Cont'd

Determining basic requirements helped guide the following objectives and our assessment of the school's ability to maintain a rain garden. Similarly with the educational component, knowing which staff members would be available to utilize the new lessons helped determine the scope and depth of information and materials we used. We also learned about **what sets Turn Back Time apart** from traditional US schools.

An important step in our curriculum development was understanding how exactly the teachers at the farm **create their curriculum** and how we could mimic that as we worked on our own rain garden lesson plans. We knew they used a type of teaching known as **emergent curriculum**, as shown in the image, so we looked into what that is, what it entails, and **how it is applied here on the farm**.

Figure 25: With emergent curriculum, children are allowed to explore on their own under teacher supervision. Their exploration leads to new questions, new learning, and development of different skills.

Interviews Cont'd

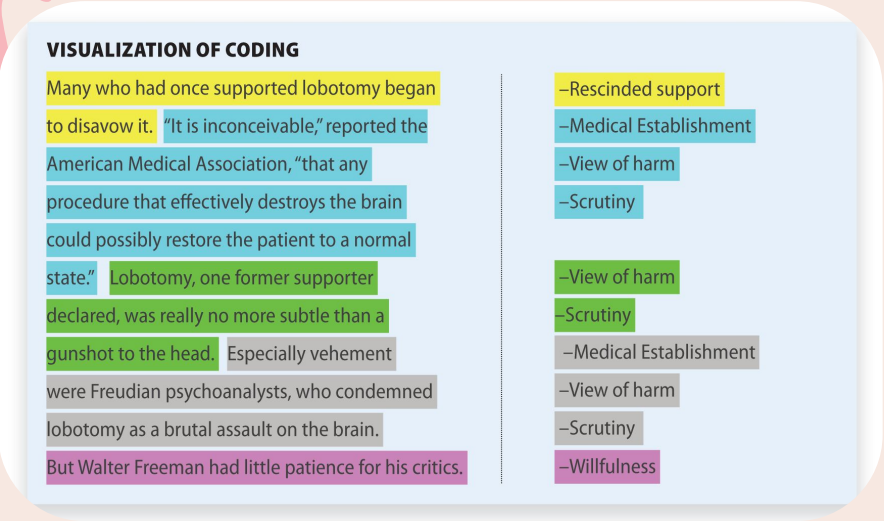


Figure 26: A visualization of qualitative coding

We learned **what kind of lessons** we should develop for the rain garden throughout our time on the farm by **interviewing our sponsors** and other knowledgeable sources such as a wetland scientist and the youth education coordinator at the New England Botanical Gardens. We analyzed our interviews by looking for **similarities and consistent details** that were brought up in responses, also known as **qualitative coding**.

We asked the Assistant Director, Katie Baker, which **teachers lead classes with the younger kids** that would interact with the garden so we could determine who to interview first. After our first interview, we interviewed three more teachers that had the **most experience teaching using emergent curriculum**. For selecting external organizations, we started by asking our **sponsors about possible connections** to other organizations they had, and used **snowball sampling** to learn about other organizations that we can contact as we went.

Objective 2: Assess The Physical Features Of The Farm Landscape Where Runoff Water Is Causing Issues

Site Assessment: Once we arrived at the farm, we **surveyed the land** and talked with members of the staff there to **determine where the ideal rain garden location** was. To accomplish this we performed a site assessment.

Site assessment can be considered **a form of mapping**, which can help with **analyzing the spatial distribution of societal or environmental "problems"** (Schensul & LeCompte, pg 117). This helped us figure out where the rainwater runoff was the **most severe** so we could begin to think about where we wanted to place the rain garden. We had been told by our sponsors that one of the **main problem areas** for snow melt and water runoff puddling was **on the path leading to the kindergarten yurt**. While putting the rain garden in the path would solve the puddling problem, it could still make it difficult for both the teachers and the children to reach the classroom so that would not be considered an ideal location.

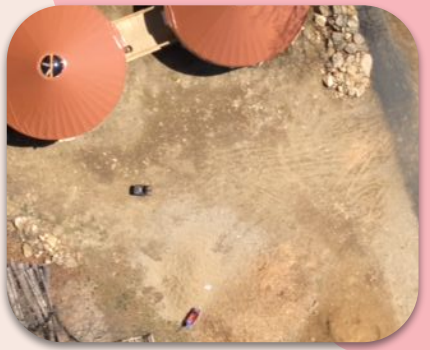
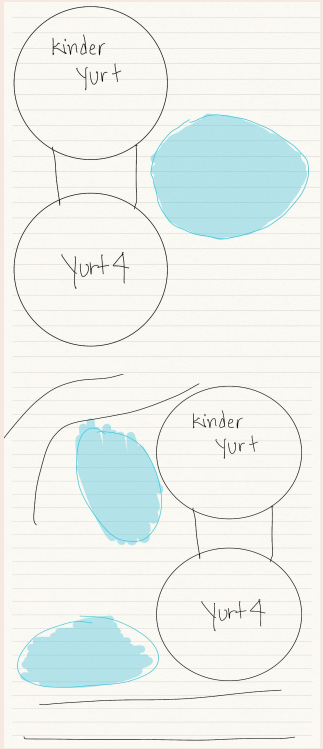


Figure 27: An overhead shot of the yurts



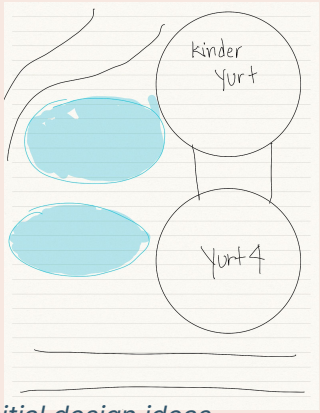


Figure 28 a-c: Different initial design ideas based on our preliminary site assessment.

Site Assessment Cont'd

In our site assessment we included information about the **soil type** of the area and the **dimensions** of the area we had to work with. In order to determine these two things there were a series of tests we conducted.

Assessing the soil type of the area was a simple task that we completed by performing a **soil ribbon test as was explained in the background chapter.** Knowing the type of soil we would be working with was important because if the soil had **too much clay**, the rain garden would not be successful because a high clay content decreases the soil porosity and prevents good drainage of water.

Figures 29 & 30: Our measurements of the problem area (based on photos from Katie)

Site Assessment Cont'd

In the pictures on the right, the light colored mound is a screened **loam**, which is composed of a higher concentration of sand than the clay heavy soil of the farm (bottom photo). The extra sand is what helps the loam to dry quicker than normal soil.

The darker mound is the dug up soil from the garden site, and is still visibly moist after being exposed to the sun for an extended period of time, showing a **higher clay content**.

This is, in part, why it was so important to know the dimensions of our rain garden. By knowing what space our garden would occupy we could test the soil to make sure we were choosing the **best possible location**.

Figures 31 & 32: First image is of loam the day it arrived at the farm. The second image is of dirt dug from the garden site.

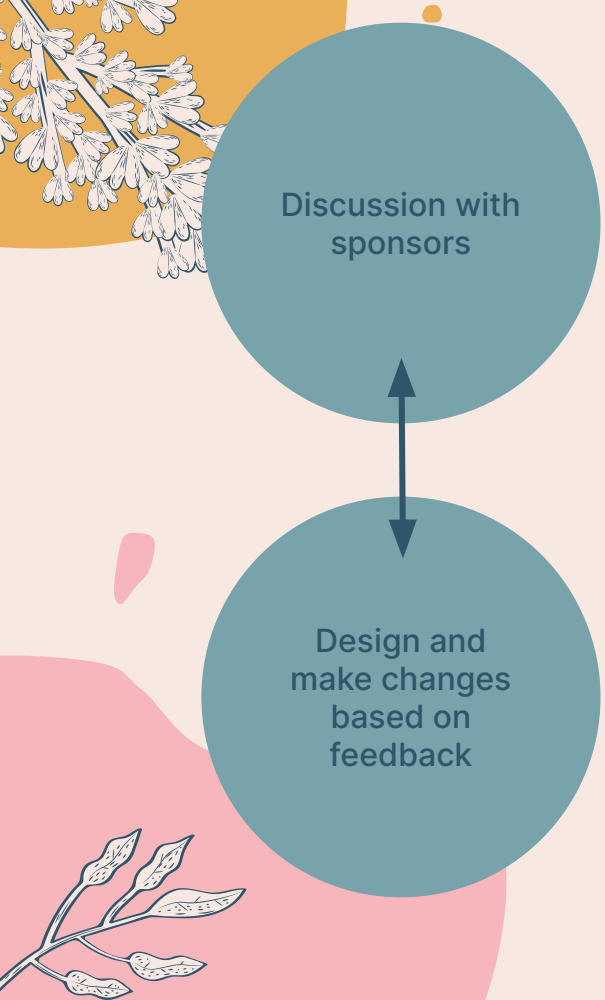
Objective 3: Design And Receive Feedback On The Rain Garden Plan

Figure 33: Image of a semi-structured interview.

Interviewing Local Landscapers

Figure 34: An image of a landscaper with a big red X over top

We wanted to **learn the methods and processes** that landscapers employ when designing a rain garden so we planned on conducting **semi-structured interviews with local landscapers** familiar with the kind of environment we were working with. We thought interviewing landscapers either over the phone or in person would help us gather the information we needed to determine the **best location** for the rain garden, more specific information on **how to build** them, determine if the **designs we drew up were realistic**, and how to **calculate runoff amounts**. This was because we figured local landscapers would have **practical experience** working in the areas that, up until this point, we had only researched. However, **every landscaper we called** for an interview or meeting had **no idea what a rain garden was**, much to our surprise, so we were **unable to gather any useful information** from them. Instead we were able to get into **contact with an environmental consultant** who gave us valuable information about size and shape and **plants that were good and bad** for the garden. We also conducted more **online research** to expand our knowledge on this topic.



Once we had gathered sufficient information from our interviews, we began the **design iteration process.** We presented our rain garden designs to our sponsors on a weekly basis and **received feedback** on whether they thought anything was missing or might cause issues, and, on our very first rain garden plans, their **opinions on the shape**. These periodic meetings helped us ensure the rain garden **met all of their expectations** while still being fully functional.

We received this feedback in a routine casual presentation setting. Most meetings were attended by our advisor, Professor Stoddard, and Katie Baker. However Lisa Burris, the owner of Turn Back Time, made the occasional appearance at these weekly meetings to give her thoughts. By receiving feedback from multiple different people, we heard **multiple different viewpoints** that helped us assess how we should **reorient our design** to **accommodate** the concerns and requests that were brought to us.

Objective 4: Design And Receive Feedback On Rain Garden Lesson Plans

Analyze Interviews

Design Educational Content

Focus Group

Implement

Observe Implementation

Figure 35: One of three bingo card designs Ethan came up with

Objective 4: Focus Groups Cont'd

We asked teachers at Turn Back Time how they **devise their lesson plans** and what the more effective lesson plans and activities are. Refer to appendix B for the list of questions. Once we collected this data, we used it and our other research into child learning and lesson plan development to **draft our rain garden lesson plans**.

After we created some preliminary lesson plans, we showed our ideas to our sponsors **to gather feedback** during one of our weekly presentations. First we presented our ideas for possible lesson plans and then discussed with them about **what seemed feasible, useful, and what didn't**. This never took more than 30 minutes, and after hearing their feedback, we **adjusted the content** and returned to our sponsors the next week to gather more feedback on our newest plans. We **repeated this process** until the lessons satisfied all parties.

Figure 36: An graphic demonstrating a focus group

Insert focus group/interview photos later

Results, Recommendations, and Deliverables

Objective 1: Understand the curriculum and garden function wants and needs of the school in relation to the rain garden

Figure 37: A still frame from a video shared with us by Katie Baker showing flooding between the two yurts

Finding 1: Turn Back Time wants a rain garden to stop puddling on the path between the yurts

Our first and most fundamental finding was that Turn Back Time needed a rain garden to be installed in order to **stop puddles** from forming between the two yurts on their property, which was happening as the result of stormwater and snowmelt runoff. We came to this determination after an interview with Katie Baker and Lisa Burris, the education director and owner of the farm respectively, in February 2024. They told us about the flooding problem that was **limiting their student's ability to travel** back and forth between the kindergarten yurt, especially those with mobility issues, due to the large sections of mud that made themselves at home there in the wetter months.

Finding 2: They want the garden to be stimulating to the kids year round

Our second finding is one that drives a large part of this project, and it is that Katie and Lisa want the garden to be **stimulating to the students** year round. This is something that they have made very clear to us throughout multiple sponsor meetings and presentations. They wanted the garden to have this appeal so they could use it to introduce **new curriculum** to their students, but also because they have found that children are **more engaged** with their surroundings when **all 5 of their senses** are stimulated.

Objective 2: Assess the physical features of the farm landscape where water runoff is causing problems.

Finding 1: The soil quality in the dig site is not viable for use in the rain garden.

The topsoil in the digsite contains a **large amount of clay**, which would hinder the functionality of the rain garden because clay absorbs water at a **significantly slower rate** than sandier soil, according to the National Ground Water Association, 2022. The soil that we removed from the digsite clumped together and stayed moist after we excavated it. This soil is unusable because if it is **clumped and moist**, it means it is absorbing rain water and retaining it within the soil instead of releasing it into the ground around it. This is a sign of **poor drainage** and high clay content.

Figure 38: Clay rich soil excavated from the garden site

10”/Hr
Sand

Clark, C. A. (n.d.)

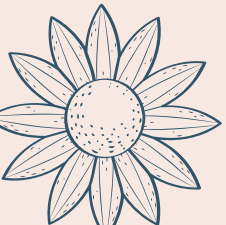
.05”/Hr
Clay

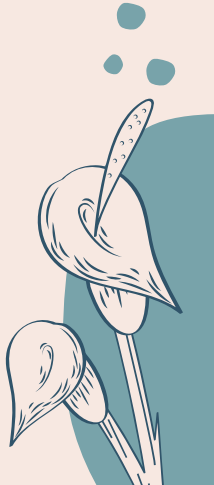
Objective 2 Cont'd:

Finding 2: The area with the most puddling is set lower than the rest of the surrounding ground.

One of our sponsors, Katie Baker, sent us a video that shows the walkway between the yurts flooded with snowmelt during early January. It helped us develop a preliminary understanding of where the problem area was before we got to the farm. It **highlighted the puddled areas** which indicated lower ground. This informed our preliminary decisions on where we might want to put the rain garden and what shape we might like it to be. The video provided evidence of the ground being set lower in certain areas because due to gravity, water naturally wants to get to the lowest point possible. This tells us where the lowest points of the walkway are.

Through informal observations of the area, we noticed a few important factors. There were a lot of tire marks surrounding the area, suggesting that the **ground is soft and prone to erosion**. Then we noticed that there were clear streaks of soil erosion by water runoff, which corroborated our initial thoughts on what the tiremarks meant. These **eroded areas collected water** when it rained at the farm as our observations suggested. The region between the yurts was especially bad when it rained, containing a lot of mud that was **difficult even for adults to walk through** (some of our shoes were almost yanked off our feet). As water flows from higher to lower ground, our observations proved that the region where the garden will be installed, where most of the puddling happens, is lower than the surrounding area.





Objective 2 Cont'd:

Finding 3: Electrical and septic won't be in the way of our dig site.

We conducted an interview with Katie Baker and Lisa Burris in February 2024 to understand what they hoped to achieve by installing a rain garden. During this meeting they said that there should be **no electrical or septic lines** in the area that we were planning on digging. Then to clarify, we had a sponsor meeting with Katie Baker in which we asked about electrical lines. She told us they ran under the bridge between the yurts but nowhere else we might run into. We intend to create a frog cave underneath the bridge, but we won't be placing anything so tall that it will **interfere with the wires** running along the underside. The septic field is over in what they call the valley, which is a solid 50 to 100 feet away from where we're digging right next to the yurts.

Figure 39: Electrical lines under the yurts

Objective 3: Design and receive feedback on rain garden plan

Finding 1: Adding a layer of gravel at the bottom of the rain garden will increase drainage.

One source we found provided a design for a rain garden that contained a drainage bed coated in gravel (Zhang et al, 2020). Gravel **increases drainage** by increasing the permeability of the soil. Because there are larger gaps between the individual pieces of gravel than there are between soil, this allows the rain water to **filter down into the soil beneath the gravel quicker** (NOAA, 2022). This garden design was affirmed in an interview we conducted with an environmental consultant who specialises in wetlands delineations and permitting, who also suggested placing a layer of gravel at the bottom of the garden in order to increase drainage (Matt Marro 3/26).

Figure 40: The excavation site filled with gravel

Finding 2: Using landscaping fabric on top of the gravel will maintain the layers in the correct locations

Kevin Baker, a mechanic who provides construction work and equipment to the farm in his free time, helped us **dig out the rain garden** and taught Ethan how to use a backhoe. After the hole was dug and filled with gravel, Kevin told us we might want to put down a **layer of landscaping fabric** before we put in the loam. He told us this would **prevent the gravel from rising to the surface** and mixing in with the loam, which would **alter the composition** of the garden and **affect drainage negatively.**

Objective 3 Cont'd:

Finding 3: The best shape for a rain garden is usually a rounded triangle or a trapezoid

We determined that a trapezoid would be the **best shape for our garden** after an interview that we conducted with environmental consultant Matt Marro. He said the trapezoid shape worked well in the area we chose and would **effectively trap water runoff** from the yurts.

Finding 4: The rain garden should be composed of a variety of plants that prefer different seasons and soil conditions

The garden needs plants that like wetter soil at the center of it where most of the water will puddle, while the outer edges should have more drought resistant plants (Grehl, et al, 2007). While not functionally critical, our sponsors want a garden that is **visually appealing all year**, so we also need plants that are interesting through the seasons. This is important to them because they want the garden to also **increase the beauty** of the farm as well as **address the puddle issue** and **provide educational opportunities.**

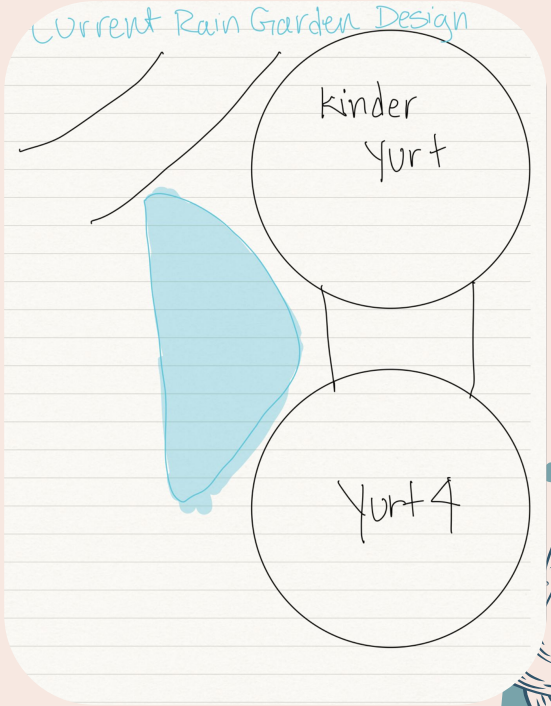


Figure 41: Trapezoidal design of rain garden

Objective 3 Cont'd:

Finding 5: The space under the bridge will be turned into a frog cave to utilize that space and the shade

We wanted to use the space under the bridge for the garden since it **also gets a lot of water**, but it is always in the shade which is not ideal. After an informal conversation with our sponsors, we decided that if time allows, we will create a frog cave to **attract more wildlife**, use the water that accumulates there effectively, and prevent stagnant water problems with the frogs. We also plan to plant milkweed and maybe others such as cardinal flowers, which frogs are attracted to. (LaVaute, 2024)

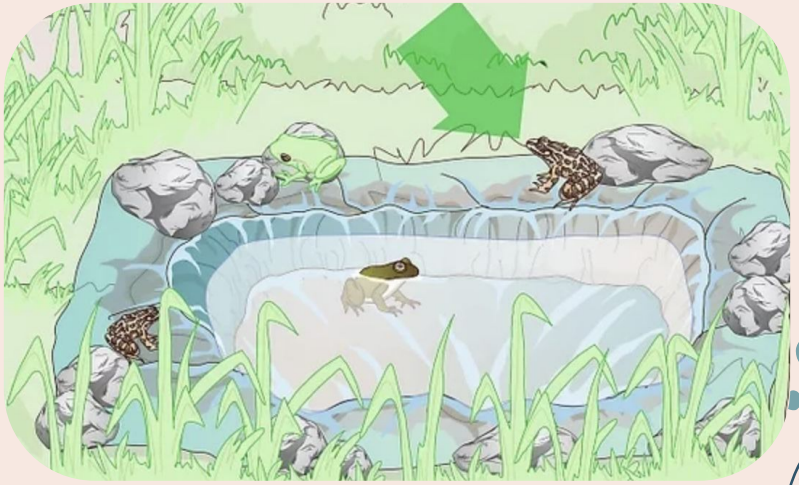


Figure 42: This was inspiration for the frog cave.

Objective 4: Design and receive feedback on the rain garden lesson plans

Finding 1: The rain garden should incorporate sensory stimulation as a primary educational component.

Lisa Burris and the teaching staff were very intent on finding a way to have plants in the garden that **stimulate all 5 senses** as part of the rain garden curriculum, such as having plants that are fuzzy, plants that are different colors and plants that are edible. Lisa wanted the garden to be more than a way to address the puddles and mud, but to also be a source of engaging activities and curriculum for the kids.

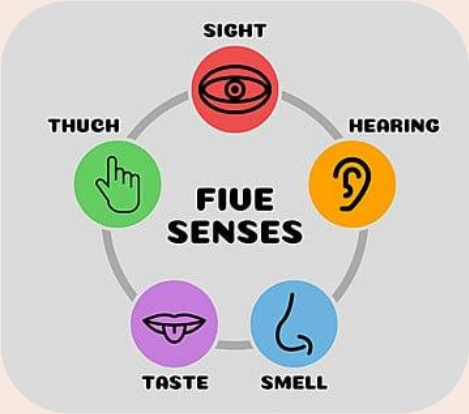


Figure 43: A graphic of the 5 senses

Finding 2: The rain garden should incorporate wildlife interaction as a primary educational component.

While interviewing three members of the Turn Back Time teaching staff, all expressed interest in having the garden **attract wildlife**, as well as the idea of having an area designed to attract frogs to the location. Due to the fact that they regularly **use wildlife interaction in their lesson plans**, it was important that the garden reflected that.

Figure 44: A photo of a salamander in an acorn cap from the TBT website.

Objective 4 Cont'd:

Finding 3: There should be plaques for each type of plant with their common and scientific name

During our interviews with the teachers, Rachael suggested utilizing the plaques as an activity to get the kids reading and writing. Then, in an interview with Amy, Katrina, and Veda they agreed that the proposed activity by Rachael was something they wanted. Because Turn Back Time uses **emergent curriculum**, having the plaques with the common names of the plants as well as the scientific names will hopefully **pique the curiosity** of the kids and that **could become a lesson**. It was important to the teachers that the kids are able to **interact with our garden in a meaningful way** which is exactly what we're hoping these plaques will achieve - a chance for the kids to interact in **deeper and more meaningful ways** with the garden. Furthermore, it's a great way to passively inform parents and visitors about **what plants are in the rain garden.**

Figure 45: Plaque created for the garden. Photo taken by Ligia.

Figure 46: Plaque being laser cut. Photo taken by Trixie.

Objective 4 Cont'd:

Finding 4: The space under the bridge between the yurts is not being used.

As we were making plans for the rain garden, we noticed that the spot under the bridge could be incorporated into the garden design. After talking about it more, we decided that it would be a perfect spot for a frog cave instead! It's shady and humid, and there were extra materials in the farm that we could use to make a little pond and frog hotel out of pipes. During conversations with sponsors and teachers, we found out that the kids love finding frogs. With this in mind, we created a simple infographic showing the frog life cycle that was placed near the frog cave. We transformed another unused space into a fun learning environment.

Figure 47: Image of the initial construction of the frog cave.

Recommendations for Maintenance:

- Re-mulch the garden once a year for the first two years:
  - This ensures that there's enough mulch for the loam will retain moisture while the plants settle in.
- Weed the garden regularly:
  - This maintains a clean look and prevents invasive species.
- Keep dead branches and leaves out of the garden:
  - This maintains a clean look.
- Keep plant plaques and signage in place
  - We did not have time to lacquer them, so that May be something to be done later for upkeep

Figure 48:

Garden Deliverables:

1. Garden Construction process
    a. Marking off area
    b. Conducting soil test
    c. Starting excavation
    d. Laying down gravel
    e. Laying down landscaping fabric
    f. Filling in loam
    g. Installing plants
    h. Placing perimeter and stepping stones.

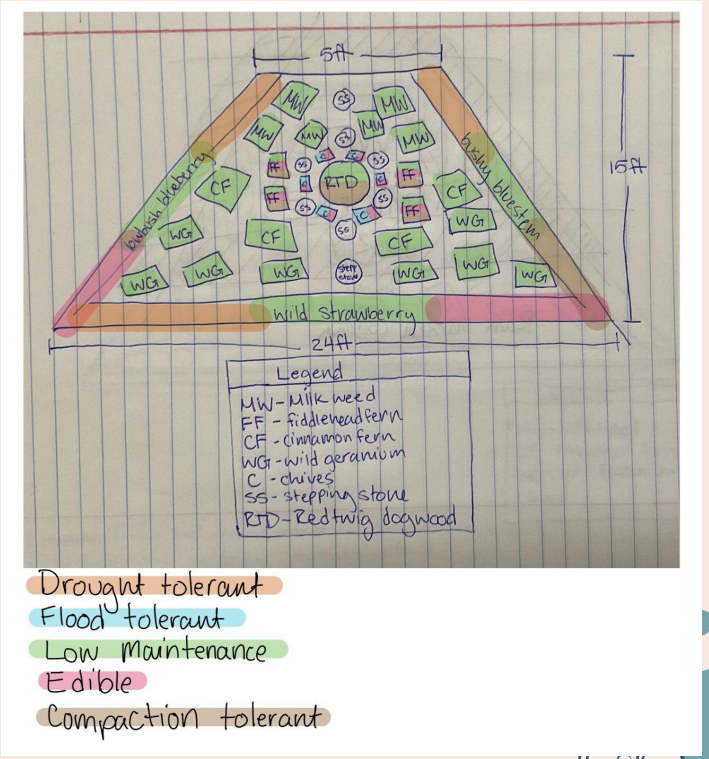


Figure 49: Final design of the rain garden

Construction Timeline Process A

Figure 50: Chosen garden site before any test or digging.

Construction Timeline Process B

Figure 51: This was taken when we dug two holes in order to test the drainage rate of the site. This determined that we needed to get loam to replace the clay heavy dirt that we dug up later.

Construction Timeline Process C

Figure 52: Ethan using the backhoe to clear dirt from the excavation site

Construction Timeline Process D

Figure 53: Image of the excavated garden with 1 ½“ gravel layer.

Construction Timeline Process E

Figure 54: Several rolls of landscaping fabric that were laid down on top of the gravel.

Construction Timeline Process F

Figure 55: Finalized 6” layer of loam.

Construction Timeline Process G

Figure 56: Red twig dogwood, the first plant put into the garden

Construction Timeline Process H

Figure 57: Chives around the red twig dogwood in the center, little bluestems on the right side, highbush blueberries on the left side, and milkweed seeds in the back. Remaining plants hadn't been received yet.

Construction Timeline Process I

Figure 58: Ethan digging holes for the pipes to go in to create the frog hotel under the bridge.

Construction Timeline Process J

Figure 59: A photo of the completed rain garden with the frog cave in the background.

Deliverables - Education:

- A laminated rain garden cross section:
  - Trixie drew the cross section and laminated. It will be attached to the lattice of the kinder yurt near the garden.
  - This can lead to questions about how the garden works and discussion about natural cycles.
- Bullet point list of curriculum ideas for the teachers to use.
  - This will go on the QR code in the fairy door.
  - It'll contain ideas for what teachers could talk to kids about.
  - Will have more in depth explanation of the rain garden and frog cave.
- Bingo cards.
  - It will be a scavenger hunt activity for the kids. To get bingo they'll have to find different things in the garden.
- Plant name plaques.
  - Each species of plant in the garden has a dedicated plaque with its common and scientific name.
- Frog cave.
  - A habitat that will be suited to house and attract frogs
  - Will feature plants that frogs enjoy

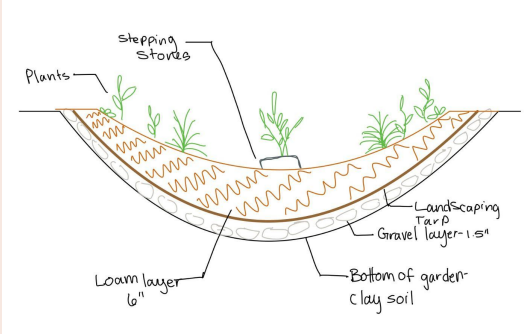


Figure 60: Cross section of the rain garden

Figure 61: Example of a bingo card for the garden

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2. https://sustainability-lexicon.com/urban-greening-urban-planning-concept-for-planting-in-cities/
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55. Taken by Trixie
56. Taken by Ethan
57. Taken by Ethan
58. Taken by Ligia
59. Taken by Trixie
60. Taken by Trixie
61. Taken by Ethan

Authorship

Section	Author/Lead	Editor
Abstract	Collaborative effort	
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Green Infrastructure	Trixie	Ethan
Background		
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Ribbon Test	Ligia	Ethan
Rain Garden Sizing	Ligia	Trixie
Precipitation	Trixie	Ligia
Plants	Trixie	Ethan
Health and Safety	Ethan	Trixie
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Interviewing Staff Members	Ethan, Trixie, Ligia	Trixie, Ligia, Ethan
Objective 2	Ligia, Ethan	Ligia, Ethan
Objective 3	Ligia	Trixie
Interviewing Local Landscapers	Trixie, Ligia, Ethan	Ligia, Ethan, Trixie
Objective 4	Trixie, Ethan	Ligia
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Objective 3	Ligia, Ethan	Ethan, Trixie, Ligia
Objective 4	Ethan, Ligia	Trixie, Ligia, Ethan
Recommendations for Maintenance	Ligia	

Garden Deliverables	Ethan	Ligia
Construction Timeline	Ethan	Ligia
Deliverables Education	Ethan	Trixie
Bibliography	Collaborative Effort	
Authorship	Ligia, Trixie	Ethan
Appendix A	Trixie	Ligia, Ethan
Appendix B	Trixie	Ligia, Ethan
Appendix C	Ethan	Trixie, Ligia
Appendix D	Ethan	Ligia, Trixie
Appendix E	Ligia	Trixie, Ethan
Appendix F	Ligia	Trixie, Ethan

Appendix A: Teacher Consent Form

- Introduction: Hello! Our names are Ethan, Ligia, and Trixie and we're WPI students conducting research at Turn Back Time about nature-based education as part of our junior year capstone project. We were hoping we could ask you some questions about what it's like teaching here on the farm.
- Research Purpose: We are building a rain garden to utilize as an educational tool for children. It will focus on using a nature-based learning curriculum.
- Publication: This project will be published and made public on the WPI library website.
- Desired Information: We're interviewing teachers because we'd like to gather information about how your students learn best so that we can tailor our curriculum surrounding rain gardens to best meet their needs. When our design process begins, we would also like to hear feedback from you.
- Survey Length: About 30 minutes.
- Anonymity: All participant responses and participant information will be kept anonymous.
- Voluntary Participation: All participants will have flexibility in regards to which questions they choose to answer. Participants will not have to answer a question they do not wish to respond to and may stop the interview at any time.
- Questions?: Before we begin, are there any questions you'd like to ask or any concerns you may have?

For more information about this research or about the rights of research participants, or in case of research-related injury, contact: gr-raingarden-D24@wpi.edu or eastoddard@wpi.edu

Appendix B: Questions for Teachers

- What has been your experience with nature-based teaching?
- Why nature-based teaching?
- Have you taught at traditional schools before?
    - If yes, is there a noticeable difference between your current students and the students you taught at the traditional school(s), whether that be mental, emotional, or anything else?
- Can you give us an example of a nature-based learning curriculum that you currently utilize?
- What is the range of topics that you cover in a nature-based learning curriculum?
- Are there any recurring lesson plans you teach that the children seem to prefer?
- Are there any recurring lesson plans you teach that the children seem to dislike?
- Are there any recurring lesson plans you teach that you are particularly fond of?
- Are there any recurring lesson plans you teach that you dislike?
- Is there anything specific that you want to see in the rain garden for lesson plans?
- Would a rain garden curriculum fit well into your current lesson plans?
- Do you have any curriculum on topics similar to rain gardens?
    - If yes, what are they?
    - What do you think the similarities are?
    - Do you think a rain garden curriculum would be too similar to your existing curriculum?

Appendix C: Landscaper Consent Form

- Introduction: Hello! Our names are Ethan, Ligia, and Trixie and we're WPI students conducting research at the Turn Back Time farm in Paxton, MA about nature-based education as part of our junior year capstone project. We were hoping we could ask you some questions about landscaping and more specifically rain gardens (if you have knowledge on the topic).
- Research Purpose: We are building a rain garden to utilize as an educational tool for children. It will focus on using a nature-based learning curriculum.
- Publication: This project will be made public on the Worcester Polytechnic Institute library website.
- Desired Information: This interview is meant to help us better understand the many considerations needed to build and maintain a rain garden as well as selecting an optimal location so we can build the best possible rain garden for TBT Inc.
- Interview Length: We expect this interview will take up to 30 minutes at the most.
- Anonymity: All participant responses and participant information will be kept anonymous.
- Voluntary Participation: All participants will have flexibility in regards to which questions they choose to answer. Participants will not have to answer a question they do not wish to respond to and may stop the interview at any time.
- Questions?: Do you have any questions or concerns you would like to voice before we start the interview?

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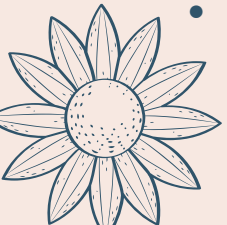
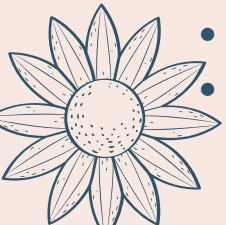
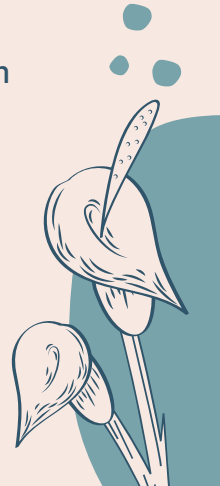


Appendix D: Landscaper Interview Guide

- What experience do you have with rain gardens?
    - (If not, do you have any experience with any types of garden?)
- What are the most difficult aspects of building them in your opinion?
- During the planning stages, how do you determine the best spot to place a rain garden?
- Do you have advice on how we can best determine runoff and snowmelt amounts that the rain garden will have to hold?
- (After showing pictures of the area) Our current plan is to have this depth and size (put the actual numbers here), that we calculated based on the impervious surface area of the yurts. Does it seem reasonable to you?
- We want to use plants native to the area and we know the rain garden needs more forb-rich perennials to work best, so what do you think of the selection we currently have?
- With regards to maintenance, do you have any tips or pointers?
- Do you have any suggestions on how to best fit the rain garden in the proposed area?





Appendix E: Non-TBT Educators Consent Form

- Introduction: Hello! Our names are Ethan, Ligia, and Trixie and we're WPI students conducting research at the Turn Back Time farm in Paxton, MA about nature-based education as part of our junior year capstone project. We were hoping we could ask you some questions about what your experience has been as a nature-based educator.
- Research Purpose: We are building a rain garden to utilize as an educational tool for children. It will focus on using a nature-based learning curriculum.
- Publication: This project will be made public on the Worcester Polytechnic Institute library website.
- Desired Information: This interview is meant to help us better understand teaching methods with nature-based education so we can build the best possible curriculum along with a rain garden for TBT Inc.
- Interview Length: We expect this interview will take up to 30 minutes at the most.
- Anonymity: All participant responses and participant information will be kept anonymous.
- Voluntary Participation: All participants will have flexibility in regards to which questions they choose to answer. Participants will not have to answer a question they do not wish to respond to and may stop the interview at any time.
- Questions?: Do you have any questions or concerns you would like to voice before we start the interview?

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Appendix F: Non-TBT Educators Questions

- Do you have Experience with traditional teaching, and if so, how do you believe nature-based learning helps children learn differently or better than traditional learning?
- What kinds of Nature experiences have you found best work for educating children?
- Do you have any advice for designing nature based lesson plans to go along with a rain garden?
- What kind of obstacles, if any, do you face when trying to find a way to apply curriculums when they differ so vastly to those found in regular schools?