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Designing and Building Active Outdoor Learning Stations: Teaching STEM Concepts at a Farm-Nature Preschool for Children with Exceptional Needs

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Designing and Building Active Outdoor Learning Stations: Teaching STEM Concepts at a Farm-Nature Preschool for Children with Exceptional Needs



An Interactive Qualifying Project submitted to the faculty of the Worcester Polytechnic Institute in partial fulfillment of the requirements for the Degree of Bachelor of Science.

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Turn Back Time Farm
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Date: June 1, 2018

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Executive Summary

Problem / Sponsor Need:

Exposure to and engagement with nature is critical for child development (Faber, Kuo, and Sullivan, 2001; Kahn and Keller, 2002; Strife and Downey, 2009). Citing research that spans over the last two decades, Strife and Downey explain that “access to nature and green space provides children with a myriad cognitive, emotional, and physical benefits, such as increased ability to concentrate, improved academic performance, reduced stress and aggression levels, and reduced risk of obesity” (p. 2). Lack of exposure to nature, referred to as nature-deficit disorder by Louv (2008), has been shown to have detrimental impacts on childhood health and development, including the doubling of the number of children diagnosed with depression in the last five years, and rising rates of Attention-Deficit Hyperactivity Disorder and childhood obesity - with a sharp increase in rates of obesity for children aged 2-5 years old over the last three years (Cheung et al, 2016).

A recent resurgence in research in this area has led to a rise in nature, farm, and environmental education schools and programs in the U.S. over the last ten years (Brown, 2017). Farm and nature-based education programs explicitly combine expertise and practices from early childhood and environmental education (Larimore, 2016; NAEF, 2010). Turn Back Time, Inc., (TBT), run by Lisa Burris, provides farm and nature-based programs for children, including those with exceptional needs, to learn and develop through play in nature. Children with exceptional needs at TBT include those with social, behavioral, and emotional challenges, including children who have experienced trauma or those with diagnoses such as Autism. While Burris has a degree and years of experience in nature-based early childhood education, she does not have a knowledge base in environmental education. Therefore, Burris asked our team to develop science, technology, engineering, and math (STEM) learning stations, games, and tools on the farm and in the woods for children. The purpose of the project is to research, develop, build, and assess nature and play-based STEM learning stations at TBT to help fill this gap, enhancing and building upon TBT’s innovative educational programs.

Background of Nature/Environmental Education:

Nature preschool programs, such as Turn Back Time (TBT), provide an unstructured play environment that helps influence crucial developmental, cognitive, and social milestones, such as risk taking, conflict management, stress reduction, motor skill development, and creative thinking (Clements, 2004; Ginsburg, 2007; Skar et al., 2016). Unstructured play is play that is child-led, voluntary, without a specific learning objective, and is not instructed or rewarded (vs. structured play, like baseball) (Gopnik, 2016). Child-led, unstructured play, such as making mud pies or pretending to find fairy homes in the woods, is important because it engages areas of the frontal lobe that regulate emotions and behavior, help with decision making, and solving problems (Barker et al, 2014; Hamilton, 2014). Nature-based play during childhood also leads to a more active adulthood with healthier lifestyles, as well as adults who are more likely to be involved in environmental stewardship (Finch, 2009).

Children with behavioral and neurodevelopmental disorders (e.g. Autism) experience particular benefits from exposure to nature, including improved muscle tone and reduction in anxiety. However, these children are often discouraged from running, jumping, climbing and other outdoor behavior perceived to be “risky” due to concerns that they will get hurt (von Benzon, 2017). In a research study focused on perceptions of children with disabilities and their engagement with green spaces, von Benzon (2017) found that staff who cared for these children did not allow the children to “interact with outdoor spaces on their own terms...to minimize

perceived dangers”. This results in a loss of opportunities for these students to develop critical skills (e.g. risk taking, confidence, independence), as well as a lack of opportunity for these children to develop beneficial and therapeutic relationships with nature (von Benzon, 2017). Turn Back Time runs integrated programs, where 30% of the population has exceptional needs (e.g. in foster care, have experienced trauma, have a documented diagnosis). The teachers, space, and curriculum are designed to enable all students to develop emotionally, mentally, physically, and cognitively.

Project Goal and Objectives:

The goal of this project is to design, build, and evaluate eight environmental/STEM-based “learning stations” for children at the developmental age of 3-6 years old. Our project objectives include:

Objective 1. Research other nature- and farm-based education programs for STEM learning stations, activities, and modules suited for pre-school students, including those with special needs.

In order to meet this objective, we reviewed nature-based preschool curriculum, STEM preschool learning modules, nature-based education websites, and academic journal articles focused on nature-based education and pre-K childhood development. Additionally, the team interviewed subject matter experts who have experience in environmental and nature-based education, education assessment, and experts in designing and implementing STEM preschool curricula.

As a result of our primary and secondary data collection, the team compiled a list of STEM topics that were appropriate for children ages three to six, such as recycling, observations and inferences, species identification, and solar energy all which are considered developmentally appropriate STEM topics for children 3-6 years old by the Massachusetts Department of Education (2016). Following interviews with qualified experts, such as the Director of Drumlin Farm’s Nature-Based Preschool and WPI’s Director of the STEM Education Center, the team determined which topics were most appropriate for the populations at TBT. These interviews led us to narrow the scope of topics to five: food webs, five senses, species identification, recycling, and energy production. These topics provided a building block for the nature stations that the team designed and constructed to meet the other objectives of the project.

Objective 2. Evaluate TBT farm site and learn about constituent needs to consider, evaluate, and develop potential modules and tools.

To accomplish this objective, the team utilized site evaluations and interviews to consider the following: the constituents of TBT and their educational needs and accommodations; the potential locations of the learning stations; how to design the modules and activities to facilitate independent, self-directed learning by children of varying developmental ages and abilities; and the initial content and presentation of activities at TBT. Interviews with the farm’s instructors were used to distinguish gaps that were present in the farm’s current programs. These programs were then assessed to determine what additions or new activities could be added to the curriculum. Finally, the team used primary data collection to sample and identify over 50 flora and fauna species on the site to potentially be used in activity designs.

Objective 3. Design, build, and pilot final learning stations, activities, and modules.

In order to satisfy this objective, the team had to design suitable stations that consisted of building materials that were economic, age-appropriate, developmentally appropriate, and safe for the participants. The team drew on the literature, STEM and nature education modules used elsewhere, expert interviews, as well as their own areas of interest and expertise (e.g. electrical engineering, wood burning artistry) to design eight learning stations focused on food webs, five senses, species identification, recycling, and energy production. The team created infographics of each design and presented the designs to our sponsor, TBT certified preschool teachers, and other experts in STEM and nature-based early education for evaluation. Each design was revised based on feedback from these evaluations, and final drafts were submitted to our sponsor for review and approval. With the station designs finalized, the team created a materials list, sought out and collected donated used materials, and obtained \$100 in donated new materials from Home Depot. We then began construction, which lasted approximately three weeks, at which point the stations were installed on the farm.

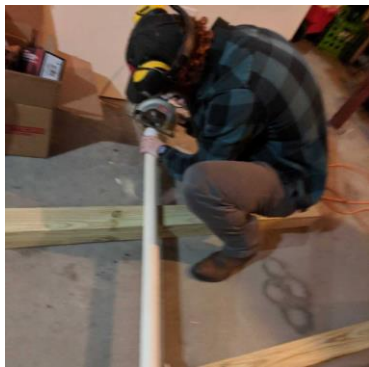


Figure 1. James O'Connor Cutting PVC for the wildlife observation station



Figure 2. Lock Bonomo sanding logs for the food web station

Objective 4. Assess piloted stations and make recommendations.

The team conducted assessments to determine if and how the modules were meeting the desired educational and developmental goals. To accomplish this, the team researched different types of educational assessments, assessment methods that could be applied to unstructured learning settings, and assessments appropriate for kids developmentally aged three to six. We were also interested in assessments that could evaluate whether the children enjoyed playing with the stations. Interviews with the sponsor also provided valuable feedback on what techniques would be most effective in determining the extent to which the educational and developmental goals were met. We developed an initial assessment strategy that was reviewed by WPI's STEM Education Center and by Dr. Traver of WPI, who is an expert in educational assessment.

After revising and finalizing our assessment strategy, we began our assessment by observing the participants use and engage with our stations and modules. Our assessment showed that most of the desired educational and developmental goals were met. Observation also provided information on learning outcomes that were met that extended past what was intended in the

original designs. The sponsor was then able to provide feedback on what the stations did well and potential recommendations for future growth and improvement. Assessments were limited in scale and scope, as they took place over a week. A longer evaluation period is needed to more fully and effectively assess the stations and modules.



Figure 3. Food Web Station



Figure 4. Chicken Scrap Station

Conclusions:

The project purpose was to develop STEM learning stations and modules to help fill a gap in TBT's nature-based education programming. Through the collaboration and mentorship of our sponsor and advisor, as well as expert input from people with knowledge and experience in early STEM and nature-based education, our team designed, built, and assessed eight educational learning stations, as well as a field guide with over 50 flora and fauna species at TBT. The members of the team learned a tremendous amount in the process, and the learning stations have assessed well and been well received by the teachers, parents, and children. Further assessment will be needed, and the modification and future development of existing and other stations can provide additional educational and developmental opportunities at TBT. Through this project, we have worked to help enhance TBT's innovative curriculum to provide opportunities for children to engage with STEM to develop and learn in new ways. Through this process, we have been fortunate to develop and learn in new ways as well.

Abstract

Research shows exposure to nature is critical for child development. Farm and nature-based education programs explicitly combine expertise and practices from early childhood and environmental education. Turn Back Time, Inc., (TBT) provides farm and nature-based programs for children, including those with exceptional needs, to learn and develop through play in nature. While TBT has years of experience in nature-based early childhood education, they lack a knowledge base in environmental education. The purpose of the project was to research, develop, build, and assess nature and play-based science, technology, engineering, and math learning stations at TBT to help fill this gap.

Acknowledgments

The team would first like to first thank our sponsor, Turn Back Time farm which is located at 250 Marshall Street, Paxton Massachusetts along with its constituents. Lisa Burris the owner of the farm, provided a tremendous amount of support throughout the building phase of the project as well as providing our team thoughtful and useful feedback for our learning stations. Ali Johnston who is a teacher at the farm provided us insightful feedback on our stations early in the design process, which we appreciated a great deal. In addition to our sponsor, we would also like to thank our advisor Dr. Elisabeth Stoddard for her endless support throughout the project. Particularly, Dr. Elisabeth Stoddard helped the team stay on schedule in addition to helping resolve any issues that arose during the project. The team would also like to thank Dr. Robert W. Traver for helping the team in building a strong foundation on what our project would be in A term of 2017. Finally, the team would like to thank all of our experts that we interviewed throughout the project, as they provided the team with critical information that helped the team shape the project as a whole in more than one way.

1.0 Introduction

Exposure to and engagement with nature is critical for child development (Faber, Kuo, and Sullivan, 2001; Kahn and Kellert, 2002; Strife and Downey, 2009). Citing research that spans over the last two decades, Strife and Downey explain that “access to nature and green space provides children with a myriad cognitive, emotional, and physical benefits, such as increased ability to concentrate, improved academic performance, reduced stress and aggression levels, and reduced risk of obesity” (p. 2). Lack of exposure to nature, referred to as nature-deficit disorder by Louv (2008), has been shown to have detrimental impacts on childhood health and development, including the doubling of the number of children diagnosed with depression in the last five years, and rising rates of Attention-Deficit Hyperactivity Disorder and childhood obesity - with a sharp increase in rates of obesity for children aged 2-5 years old over the last three years (Cheung et al, 2016).

Children with behavioral and neurodevelopmental disorders (e.g. Autism) experience particular benefits from exposure to nature, including improved muscle tone and reduction in anxiety. However, these children are often discouraged from running, jumping, climbing and other outdoor behavior perceived to be “risky” due to concerns that they will get hurt (von Benzon, 2017). In a research study focused on perceptions of children with disabilities and their engagement with green spaces, von Benzon (2017) found that staff who cared for these children did not allow the children to “interact with outdoor spaces on their own terms...to minimize perceived dangers”. This results in a loss of opportunities for these students to develop critical skills (e.g. risk taking, confidence, independence), as well as a lack of opportunity for these children to develop beneficial and therapeutic relationships with nature (von Benzon, 2017). Turn Back Time, Inc., (TBT) is a farm preschool and farm-nature education center in Paxton, Massachusetts. TBT provides outdoor play opportunities as well as farm- and nature-based education for its constituents — primarily, children and teens of developmental ages three to six. The benefits of exposure to nature are born out at TBT, which runs over a half-dozen programs, serving over 500 children, exposing them to almost 9,000 hours in nature. Programs include a yearlong preschool camp, a six-week summer camp, school age programs, family farm times, and human service agency visits. Thirty percent of the children TBT serves come from underserved populations, including children with a documented diagnosis, children living below the poverty line, and children who come from a family that is involved with the Department of Children and Families. These programs provide opportunities for children to develop critical skills (e.g. risk taking, cooperation, gross motor skills) at their own pace, while establishing deep, personal connections with the natural environment.

Nature and farm-based programs combine the core values of early childhood education and environmental education to foster a love and appreciation for the environment and to promote the importance of conservation to children (Larimore, 2016; NAEE, 2010). While TBT excels in providing high quality programming to serve children through nature and farm education and play, they lack the education and experience in environmental and STEM education. Therefore, the goal of this project is to design, build, and evaluate eight environmental/STEM-based “learning stations” for children with and without special needs. In the sections that follow, we will begin by reviewing the literature on the tenets and core principles of nature preschools and nature-based education, the benefits of nature-based education for kids with and without exceptional needs, as well as current nature/farm-based programs in Massachusetts, including

TBT. Next, we will detail the methods we used to accomplish our project goals, including semi-structured interviews, field visits, and participant observation. Finally, we will share our results and recommendations.

2.0 Literature Review

There has been a rise in nature, farm, and environmental education schools and programs over the last ten years (Brown, 2017). For example, in 2007 there were 20 nature preschools in the U.S.; today there are over 250 (Brown, 2017). Nature- and farm-based education uses the outdoor physical environment to meet curricular goals, developmentally appropriate milestones, and to foster an early love for nature (Larimore, 2016; EPA, 2018). Environmental education focuses on the appreciation of nature, environmental problems, and different ways to address these problems (Larimore, 2016; EPA, 2018). In this review of the literature we will first discuss the key tenets or principles of farm and nature-based education and the benefits of these education practices for children with and without exceptional needs. Finally, we will detail the specific program limitations and program needs of Turn Back Time Inc. (TBT), which this project aims to address.

2.1.0 Tenets & Key Principles of Nature- & Farm-Based Education

In nature- and farm-based education, the physical environment, and the animals within it, provide the educational materials and context for the educational programs. Natural Start Alliance explains that in nature and farm-based education programs “nature is the integrating thread that intentionally ties together the preschool’s philosophy, methodologies, classroom design, outdoor spaces, and public identity”. Farm and nature-based education programs explicitly combine expertise and practices from early childhood education and environmental education (Larimore, 2016; NAEE, 2010). The curriculum is often designed through the collaboration of experts in early childhood education and in environmental education, creating opportunities for early education that provides children with critical outdoor play, as well as a better understanding of and appreciation for nature. Nature-based preschools have been shown to support the development of children in the cognitive, physical, social, emotional, aesthetic, and spiritual domains. These developments have been shown to lead to a greater environmental ethic (Louv, 2008; Larimore, 2014).

2.1.1 Benefits of nature and Farm Education for Children

The benefits of nature- and farm-based education include opportunities for unstructured play, reducing symptoms of anxiety, the development of gross motor skills, developing a love of and relationship with nature, and learning to take risks. There are also particular benefits for children with exceptional needs. These benefits are discussed in detail in the sections that follow.

The Benefits of Unstructured Play

Unstructured play is play that is child-led, voluntary, without a specific learning objective, and is not instructed or rewarded (Gopnik, 2016). For example, at TBT, many children love to engage in unstructured play in many forms, such as making animal “homes” in the forest and playing in the mud kitchen (Burris, personal communication, January 23, 2018). Alternatively, structured play is instructor-led and has a specific goal or learning objective (Gopnik, 2016). Structured activities, like baseball and other sports, make up most children's outdoor play (Finch, 2009). According to a study by Finch, children engage in an average of only 30 minutes of unstructured, outdoor play every week (2009). Child-led, unstructured play is important because it changes the

connections of neurons in the frontal lobe; these changes contribute to regulating emotions, making plans, and solving problems, which results in increased self-directed executive functioning (Hamilton, 2014). In a study by Barker et al (2014), increased executive functioning resulted in children being better able to self-regulate their own behavior, and better engage in goal-directed behavior than students who were engaged in only or mostly structured, adult-led activities (Barker et al, 2014).

Reducing Symptoms of Anxiety

Nature play is an essential part of childhood development, especially for children with anxiety. Indoor classroom settings can increase symptoms of anxiety because they offer less time for child-directed activities and play, which takes away a child's outlet for stress-relief and may negatively impact social and emotional development (Ginsburg, 2007). Alternatively, outdoor play can provide an unstructured environment that helps influence crucial developmental, cognitive, and social milestones (Ginsburg, 2007). Studies show that as much as half an hour of being active outdoors a week reduces risk of depression and high blood pressure, all of which are symptoms of anxiety (Clements, 2004; Ginsburg, 2007; Skar et al., 2016). Regular habits of active play during childhood also lead to reduced stress and anxiety in both adults and children.

Improving Gross Motor Skills

Despite its importance, the numbers of U.S. children participating in unstructured, outdoor play is decreasing (Ginsburg, 2007; Skar et al., 2016). This has been linked to changes over the past 50 years in technology, family, and schooling. Increasing parental concerns for child safety due to neighborhood crime has led to parents keeping their children indoors (Clements, 2004). Additionally, an increased reliance on technology for child entertainment, as opposed to outdoor play, has resulted in children being more confined to indoor activities than their parents were (Clements, 2004; Skar et al., 2016). Researchers believe that this has led to increases in childhood obesity, low muscle tone, and reduced gross motor skills (Clements, 2004; Skar et al., 2016; Tremblay et al, 2015; Adams et al, 2017).

Being outdoors in nature helps children with gross motor skills (Patino, nd). Seemingly small everyday activities, like catching a ball or jumping, are the building blocks for fine motor development (Patino, nd). Navigating the environment is one of the easiest and safest ways children can enhance their gross motor function. Stepping over branches, twigs, and foliage is a somewhat passive part of outdoor play but may also be one of the most beneficial aspects for children challenged by gross and fine motor skill development (Patino, nd).

The Benefits of Developing a Love of and Relationship with Nature

Several behavioral studies on this subject show that playing outside fosters an early love and appreciation for the environment (Greenberg et al., 2016). Studies have also shown that children who play outdoors when they're young are more inclined to be environmentally aware as adults, including practicing conservation activities and working to reduce the environmental impacts of human activities (Moss, 2016; Wilson, 1996). Other benefits include increased environmental literacy (e.g. knowledge of species and ecosystem services), and engagement with the environment as it offers children and adults a sense of wonder, joy, and awe (Wilson, 1996). If children are not introduced to a sense of respect to the environment at an early age, they are much less likely to develop such feelings later in life (Wilson, 1996).

The Benefits of Risk Taking for Children

Risk taking, such as climbing trees or learning to ride a bike, is important for childhood development in all areas, including physical, social, emotional, intellectual, creative, and spiritual (Finch, 2012). Research shows that taking risks helps children to develop good judgment, persistence, courage, resilience, and self-confidence (Finch, 2012). During outdoor play, children can take risks by challenging themselves to jump over logs, jump from rock to rock, or climb one branch higher than they did the day before. By taking these risks, they gain judgement honed through practice, success, and failure. Finch (2012) explains, “kids are not born with the gift of informed judgment, nor with awareness of their own abilities and weaknesses. Instead, they learn their capabilities, their vulnerabilities, and their good decision-making skills through real life experiences – sometimes happy, sometimes harsh, but always instructive”. A child who regularly navigates risk will be better equipped to face ongoing and future dangers and challenges they will necessarily face in adult life (Finch, 2012).

On the other hand, many teachers and professionals in education claim that the incorporation of risk in young children’s educational programs is not worth the potential safety concerns that can arise, often because of liability concerns (Traver, informal conversation, September 23, 2017; Finch, 2012). However, there is a lack of statistical evidence showing that outdoor or nature play is more risky than indoor or sedentary play (Finch, 2012). For example, each year over 8,000 are injured, or even killed, by accidents involving flat screen TVs. Injuries associated with organized sports, falling down stairs, and car accidents, all prove riskier than environmental play each year (Finch, 2012). This is not to say that there are not dangers or true hazards associated with outdoor play, such as steep drops, deep water, or dangers children cannot see. However, these dangers can and should be mitigated in a nature preschool or other outdoor settings, while allowing children to benefit from minor risks, such as climbing trees with soft ground or mulch underneath (Finch, 2012).

Experts explain that it is better for children to be exposed to these types of lessons at a younger age rather than at an older age (Finch, 2012). When children aren’t exposed to an appropriate level of risk at a young age, they may take more hazardous chances as a teenager (Finch, 2009; Finch, 2012). This underexposure to danger stunts the potential to develop key skills, such as problem-solving and critical thinking, that can come with play in nature (Finch, 2012). Critical thinking is the building block for independent lifestyles and the start of one’s future. The ability to think and systematically problem-solve are at the heart of crucial life skills, including future careers (Wilson, 1996).

2.1.2 Benefits of Farm- and Nature-Based Education for

Children with Exceptional Needs

In this section, we focus on the particular benefits of nature-based education for children with exceptional needs, particularly children with Autism. Autism is a neurological developmental disorder that is defined by impairments in social skills, communication, and sensory integration (Emma, 2017). Children on the Autism spectrum often struggle in the traditional classroom settings because of sensory overstimulation. This is due to their heightened sensory functions and decreased self-inhibition (Greenberg et al., 2016). These children can benefit from nature-based education programs because the outdoor environment is the perfect catalyst for their minds and sensory needs. Nature is the ideal catalyst as it allows children to

recover from mental fatigue, such as stress and anxiety in a shorter time period than when in an urban or indoor setting. When children and adults are in nature, there is less blood flow to subgenual prefrontal cortex, which allows the brain to become relaxed, similar to relaxing an overworked muscle -- thereby physically reducing symptoms of stress and anxiety (Reynolds, 2015; Williams 2016). Children with Autism also have lower muscle tone, balance, and strength. Studies conducted in the United Kingdom have shown that nature-based programs can improve muscle tone, balance, and strength, while also helping children to feel calmer and more relaxed (von Benzon, 2017).

2.2.0 Nature- and Farm-Based Programs in Massachusetts

In addition to TBT, there are several organizations in Massachusetts that offer nature and farm-based preschool and other educational programs. These organizations include Massachusetts Audubon Society (MA Audubon), Drumlin Farms, and Heifer Farm. These programs specialize in child farm and environmental education, as well as broader public education around the importance of farming and protecting the environment. Drumlin Farm offers a certified nature preschool program. MA Audubon offers guided trail walks for children, and Heifer farm offers guided tours as well as seasonal programs that educate children and adults about global and sustainable farming practices. While all of these programs provide multiple benefits for all kids and adults, none offer specific programming for kids who are at risk or who have exceptional needs. Turn Back Time is unique in this way, with thirty percent of the children at TBT coming from underserved populations, including children with a documented diagnosis, children living below the poverty line, and children who come from a family that is involved with the Department of Children and Families (Turn Back Time, 2017).

2.3.0 Current Programs and Offerings at TBT

In this section, four aspects of TBT farm will be discussed in detail. These aspects consist of TBT farm's current programs, the strong points of TBT's curriculum, TBT's curriculum's gap, and our project's role at TBT.

2.3.1 Current Programs and Offerings: An Overview

TBT farm offers multiple programs, including summer, school-age, homeschool, and preschool programs. Their summer camp program, for children of ages three to fourteen, incorporates themes such as time travelers, cook what you grow, and nature detectives (Turn Back Time, 2017). Other programs offer gardening, animal care, various crafts, and woodworking (Turn Back Time, 2017). TBT also runs a farm and nature-based preschool program for kids three to six years in age (Turn Back Time, 2017).

2.3.2 TBT Program Strengths and Gaps

TBT is run by Lisa Burris who has a master's certificate in Nature-Based Early Childhood Education. Burris also has 15 years of experience as a parent of two adopted children with special needs (e.g., severe Autism and emotional trauma). Ali Johnston, the head preschool teacher, has a degree in early childhood education, child literature, and is a certified nature-based early educator in the Tinkergarten program. TBT's programs have shown to provide benefits in social-emotional competencies, gross motor skills, and learning through play (Turn Back Time 2017). Family farm time at TBT encourages the children to socialize and connect with their families in a nature setting. The children also develop gross motor skills through crafts in the mud kitchen as well as woodworking. Additionally, the children learn through play by playing in the nature playground and going on nature walks to places such as the beaver pond (Turn Back Time, 2017). TBT's nature, farm, and forest setting provides the context for early STEM learning, as exposure to nature has been shown to be one indicator in early interest in STEM (Bulunuz and Jarrett, 2010). However, Burris and Johnson lack a background education in environmental education, which is part of science, technology, engineering, and math education, or STEM. STEM learning in early childhood development is important because the brain is more receptive to learning topics such as science and math between the ages of one and four (Chesloff, 2013).

2.3.3 Project's Role in Filling in Curriculum Gap

With the identified gap of environmental STEM education, our project will aim to create modules that can effectively fulfill this gap. Our project will consist of data collection on early environmental STEM education, the design of outdoor learning stations and educational modules, the construction of the stations and modules, and then the assessment of their use. Data collection and analysis for this project includes expert interviews, content analysis of educational modules, curricula, and websites, the physical and photographic collection of flora and fauna species on the farm for identification and use in stations and modules, and the development and evaluation of our module designs, learning stations, and assessment plans. Our methods will be discussed in greater detail in the methods section that follows.

3.0 Methodology

The goal of this project is to design, build, and evaluate of eight environmental STEM-based learning stations for children with and without exceptional needs. The following objectives were designed to accomplish this goal.

These include:

1. Research other nature- and farm-based education programs for STEM learning stations, activities, and modules suited for pre-school students, including those with exceptional needs;
2. Evaluate TBT farm site and learn about constituent needs to consider, evaluate, and develop potential modules and tools;
3. Design, build, and pilot final learning stations, activities, and modules;
4. Assess piloted stations and make recommendations.

3.1 Objective 1: Research other nature- and farm-based education programs for environmental science learning stations, activities, and modules suited for preschool students, including those with exceptional needs.

In order to accomplish this objective, our team needed to learn the following:

- What concepts & topics are being taught?
- How are they being taught?
- What approaches are the most successful?
- How to evaluate the different concepts for effectiveness in meeting learning outcomes?

These questions were answered through secondary and primary data collection. To begin, secondary research was carried out. This included researching what others have done in nature-based education modules and curricula, nature-based education websites, and peer reviewed journal articles. Primary data collection that our team conducted included interviews with experts, as well as participant observation. For interviews, we separated the experts into two categories:

- 1) Those with degrees and/or expertise in environmental and nature-based education
- 2) Those with experience in designing and/or implementing preschool and kindergarten curricula, including in environmental science and studies.

Purposive Sampling

We used purposive sampling to select our interview participants in category one. Purposive sampling is non-probability sampling that, through research, targets certain characteristics of a specific population (Crossman, 2018). To select participants in category one, we researched farm and nature-based preschool and child educational programs in Massachusetts and contacted educators within these programs for interviews. We used convenience sampling to select participants in category two.

Convenience Sampling

Convenience sampling is non-probability sampling with samples selected from nearby, or convenient, populations (Saunders & Lewis, 2012). To select interview participants in category two, we interviewed staff from WPI's STEM Education Center.

3.2 Objective 2: Evaluate TBT farm site and learn about constituent needs to consider, evaluate, and develop potential modules and tools.

The team accomplished this objective by learning the following:

- Who are the constituents of TBT farm, and what are their unique educational needs?
- Where is the best location for the potential stations, based on the landscape and environmental resources, access by children with varying abilities, and where the stations could be easily incorporated into the existing daily activities and curriculum?
- How can we design learning stations and modules to provide both independent learning and more structured learning opportunities for unique sets of students at TBT?
- What content is currently being presented at the farm, and how is it presented?

Our team answered these questions through primary data collection, including field visits, semi-structured interviews, and the identification/collection of flora species on the farm. We also used secondary data collection to identify local fauna on the farm, and to confirm flora species identification. Field visits were conducted to identify potential locations for stations/activities, as well as to collect and identify flora species. For station locations, variables considered were areas where the children spent a lot of their time learning and playing and areas with access to multiple habitats (e.g. beaver pond, forest). Semi-structured interviews with our sponsor were also conducted to understand who TBT farm's constituents were, including birth age, developmental age, exceptional needs, and interests. Interviews with our sponsor also aimed to understand the current content being presented at the farm and to understand how it's presented. This was done to understand the teaching styles and learning approaches at TBT that we could build upon, and to ensure we were not duplicating content. Interviews were also conducted to identify the gaps in environmental STEM education. Through interviews with our sponsor and other farms as well as secondary data collection, we identified gaps at TBT, as well as what environmental STEM concepts are commonly taught per age groups.

3.3 Objective 3: Design, build, and pilot final learning stations, activities, and modules.

To meet this objective, our team needed to learn the following:

- What variables and boundaries need to be considered in our learning station designs, including child age, child development, safety, and cost?
- What kind of activities and topics are most interesting and exciting for the population at TBT?
- When will the children most likely be utilizing the learning station/activity, including time of day and season?
- What materials, equipment, and labor do we need to construct these learning stations?

The questions above were answered through both primary and secondary data collection.

Methods Associated with Design

Secondary data collection involved reviewing pre-developed nature lesson plans, activities, designs, and schematics of existing learning stations at other nature education centers. Using this secondary data, the team brainstormed ideas for our own stations, as well as ways we could modify existing learning stations to meet our constituent and site needs. Using purposive sampling, we conducted interviews with professionals at other nature schools, with the STEM Education center, and with Ali Johnston, the certified preschool teacher at TBT.

Designs considered the cost of setup and materials, safety features or concerns, and age- and need-based appropriateness of the activity, use of local species, and its educational content. The drafted designs were reviewed by the sponsor and relevant experts, and subsequently revised based on their feedback. These designs were reviewed by Lisa Burris and Ali Johnston, then were appropriately modified for our final build of the stations. The team began construction of the learning stations once final designs were approved.

Building and Installation Methodology

In order to create a bill of materials, the team evaluated what materials would be best when cost, durability in outdoor use, and safety were considered. The team also divided building and construction work based on team member experience and expertise. For example, Justin is majoring in electrical engineering and thus handled the solar fields station; Locke is a biology major, so he decided the relevant species for stations, and had the experience/tools for wood burning needed for two learning stations; James used his mechanical engineering knowledge to consider and evaluate station designs, including the structural integrity and materials used. The team also created deadlines for when each station component would be completed off campus as well, as when installation would take place at TBT. Deadlines were based on material availability, weather, evaluation opportunities, fundraising, and collection of donated materials.

Once the learning stations were built, the team placed them in predetermined locations at the farm for piloting, which is elaborated upon in the next section. The locations were selected based on our guidelines, as explained in Objective 2, such as the children's traffic or tendency to play in that area.

3.4 Objective 4: Assess piloted stations and make recommendations.

To accomplish this objective, we answered the following:

- What are appropriate criteria for educational assessments?
- Which of these criteria apply to our learning stations and modules and for our unique population and learning environment?
- How can we assess the children to determine if they're meeting learning goals, without having them take tests?
- How can we document success or failure in meeting learning outcomes?
- How can we modify our learning stations and modules if students aren't meeting the associated learning goals?

Methods to Development Assessment Strategy

To develop our assessment strategy, we used both secondary primary and primary data collection. Our secondary data collection largely consisted of researching educational assessment tools and strategies, as well as appropriate learning goals and objectives for children at the developmental ages of three to six. Sources included educational websites, educational reports and guide books, as well as scholarly research articles.

For primary data collection to develop assessment strategies, we conducted semi-structured interviews with experts who have knowledge and experience in the fields of educational assessment and pre-K STEM education and assessment. Convenience sampling was used to select our interview participants from WPI's STEM Education Center and from WPI faculty who have expertise in education and assessment. The team also interviewed our sponsor and her certified preschool teacher, Ali Johnston.

Assessment Strategy

Once all stations were piloted, we visited the farm on April 23, 2018 for three hours to conduct participant observation of students at TBT interacting with our modules. Prior to this, IRB approval was received to observe the children interacting with the modules, and consent forms were signed by all parents whose children were participating in the activities. We intended to conduct at least 12 hours of observation, but a delay in getting all consent forms signed resulted in having one three-hour period for participant observation. To try to minimize this limitation, we also assessed the modules through parental, teacher, and sponsor feedback, considering the following variables: student interest and engagement, developmental/physical outcomes, meeting intended learning outcomes, unintended learning outcomes, and safety.

4. Results

The goal of this project is to design, build, and evaluate eight environmental/STEM-based “learning stations” for children with and without exceptional needs. The following objectives are designed to accomplish this goal. Four objectives were used to accomplish this goal. The results of the project are discussed under each project objective.

4.1.0 Results, Objective 1: Research other nature- and farm-based education programs for STEM learning stations, activities, and modules suited for pre-school students, including those with special needs

In order to meet this objective, we analyzed literature and educational modules from the websites of farm- and nature-based organizations. Through these materials, we compiled a list of STEM topics appropriate for children ages three to six years old. These include reduce/reuse/recycle, observations and inferences, species identification, solar energy, food webs, biodiversity, habitats and ecosystems, extinction, pollution, water cycle, climates, erosion, and rock formation (Massachusetts Department of Education, 2016). We then conducted semi-structured interviews with educators at farm and nature preschool education programs and experts in pre-K and elementary STEM education. In these interviews, we asked them to evaluate which topics are appropriate for children at the developmental age of three to six years old. Through these interviews, we narrowed our focus to the following five topics, including food webs, the five senses, species identification, recycling, and energy production. The following sections will explain why each of these topics are best suited for teaching STEM to the developmental ages three to six.

4.1.1 Food Webs

Every living thing depends on a source of energy, whether it is another living thing or the sun, in order to survive. This concept of energy moving through trophic levels and food chains is a fundamental phenomenon of our world, making it important to understand. These concepts of energy movement and energy in general however, are complex for young children to understand (Mia Dubosarsky, 2/14/18). According to Renatta Pomponi, the Drumlin Farm Sanctuary Director, food webs can show the interdependent nature of food chains. This represents the fundamental energy movement in a far more elementary way. Food webs are very compatible with the place-based education style of learning that is emphasized at TBT. Pomponi stressed the importance of place-based education or learning from the local surroundings saying “place-based education needs to be relating to where you are...it gets children talking about what’s right in front of them” (Renatta Pomponi, 2/10/18). The fundamental principle of a hierarchy of organisms is a much more attainable concept for children to observe if the habitat in question is their own. This concept, shown in Figure 1, can be broken down into very basic forms, such as food webs (Food Chains and Food Webs, LeGuen). Breaking down the local food chains can take the movement of energy in the environment and put it right in front of the children in the

form of food webs.

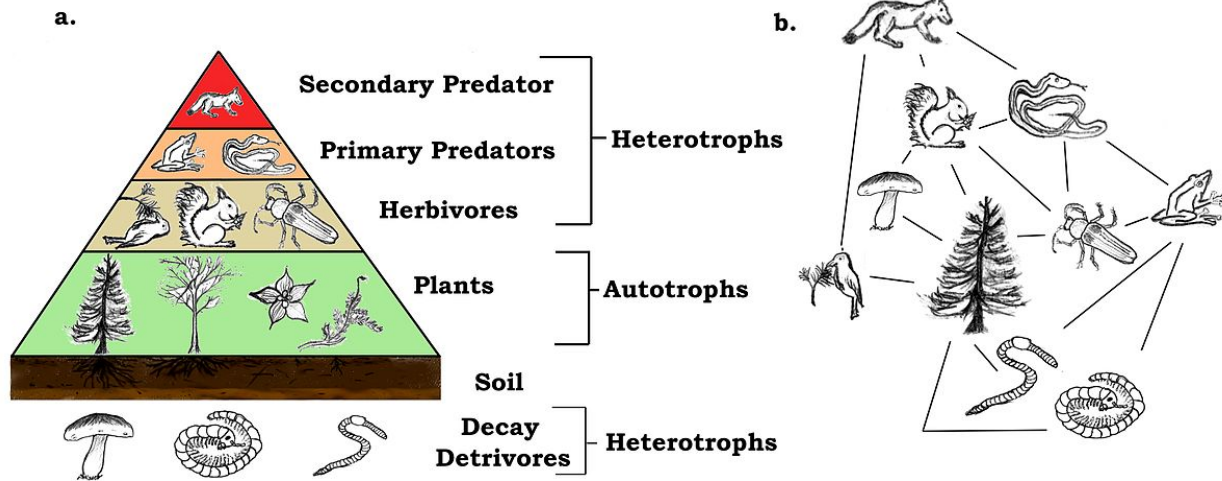


Figure 5. Trophic levels and food webs

4.1.2 Five Senses & Species Identification

The five senses are an extremely important initial subject in the realm of sensory play, or activities that stimulate the five senses. It is important to expose children to sensory education at a developmental age, since the five senses are the primary way a child interacts with the world around them (Exploring the Benefits of Sensory Play, 2016). A member of the WPI STEM Center described the five senses as a “child’s doorway into the world around them” (Mia Dubosarsky, 2018). Experts in sensory play claim that child interaction with the environment around them using their senses is crucial to brain development. Nerve connections in the brain are built on the reactions of the body through outside stimuli (Exploring the Benefits of Sensory Play, 2016). For example, a child stepping over leaves and maneuvering through trees takes coordination and focus. This kind of hyper focus on the senses helps to build body awareness and balance. Children with disabilities are often overprotected and aren’t allowed to be as explorative as other children (von Benzon, 2017). Cat Healey, a certified preschool teacher at Forest Gnomes, spoke on the importance of independent sensory play at a young age, particularly outdoors. Sensory play naturally encourages children to use the scientific process and their own imagination while they play (Cat Healey, 2018). Sensory exploration is the foundation of a learning station at the EcoTarium in Worcester, Massachusetts, a child’s science museum. This station allows children to learn facts on different animals by looking through the telescoping lenses. By focusing on exploration, creativity, and investigation, strong connections are made in the brain that improve the response to sensory information (Exploring the Benefits of Sensory Play, 2016).

4.1.3 Recycling

Recycling is a concept that can help teach and foster environmental stewardship at a young age. By introducing children to the effects that waste can have on the environment, they can become motivated to try to address the problem in their daily lives (Mills, 2015). Recycling has several different avenues that could be explored for potential lessons. One being composting. Research shows that more than 20 million tons of food are wasted every year. If that food was composted, it would have the same effect as removing 2 million cars from the planet (Lappé, F. M., &

Collins, 2015). Large scale impacts like these are the important points that early childhood teacher Vanessa Levin believes should be introduced at a young age (Levin, 2018). Discussing recycling in education provides kids with the knowledge on how certain items and materials can affect the environment around them (Levin, 2018).

4.1.4 Energy Production

Energy Production is a key concept that can help children understand the energy relationship between plants and the sun. With solar power being one key energy producing technology of the future, engagement now will create a foundation for future interest. While solar panels may seem like a complex subject, Sher Warkentin of “Thinking Sustainability” believes that “you don’t need a physics degree to do it...and your kids will have fun while they’re at it” (2018). One of the best ways to go about teaching children about a subject like energy is with a hands-on learning approach, since some concepts could be too complex to explain (Warkentin, 2018). This makes energy production a very viable option as far as educational value goes in the farm’s programs. “Kids love hands on experiences” (Warkentin, 2018). This subject also offers a great deal of growth potential. Lisa Burris wants concepts that will be capable of expansion in the future as children in these programs grow older. Energy production in solar power can be broken down into simple hands-on activities, but they can also be brought up to very complex sciences (Warkentin, 2018).

4.2.0 Results, Objective 2: Evaluate TBT farm site and learn about constituent needs to consider, evaluate, and develop potential modules and tools

In order to accomplish this objective, we collected, physically and through photographs, native flora and fauna on the farm for species identification to inform module and tool content. We learned more about the TBT constituents through semi structured interviews with Ali Johnston, a certified preschool teacher at TBT, as well as Lisa Burris, the owner of TBT and an expert on farm- and nature-based education for children with exceptional needs. The five STEM module prototypes developed under objective 1 were evaluated by Mia Dubosarsky, director of the STEM pre-K -12 Education Center at WPI. They were also evaluated Johnston and Burris of TBT in order assess the modules’ and tools’ abilities to meet specific learning objectives. The modules were then refined as necessary.

4.2.1 Findings: Evaluation of Farm Site to identify local species and potential locations for learning stations

As described in our methods, we visited the farm to identify local species at TBT; thus, providing more place-based content for our developing modules and tools. We observed, collected, and subsequently identified over 25 plants and fungi, as well as documented animal signs, in the forested areas of the property. Upon identifying most of the observed plants, fungi, and animals, we inferred which other animals are likely to be in the area. We accomplished this by researching animals (birds, reptiles, rodents, insects/bugs, etc.) found in Central Massachusetts, including their diet and prevalence in the area. This information was cross-referenced with our list of identified species to determine if there is likely an available niche (role) in the TBT ecosystem for each species.

We first identified herbivores and omnivores likely to be present, as the majority of our identified species consisted of plants and could subsequently infer additional omnivores and

carnivores that would predate on these species. Thus, we constructed the basic trophic levels present in the TBT ecosystem, based on direct and indirect evidence of species presence, from the bottom up (from plants to top carnivore). A diagram of trophic levels of local species is shown below, in Figure 2. This information was crucial in filling out the learning modules and tools associated with food webs, as our initial site evaluation didn't turn up much direct evidence of animal species at the farm.

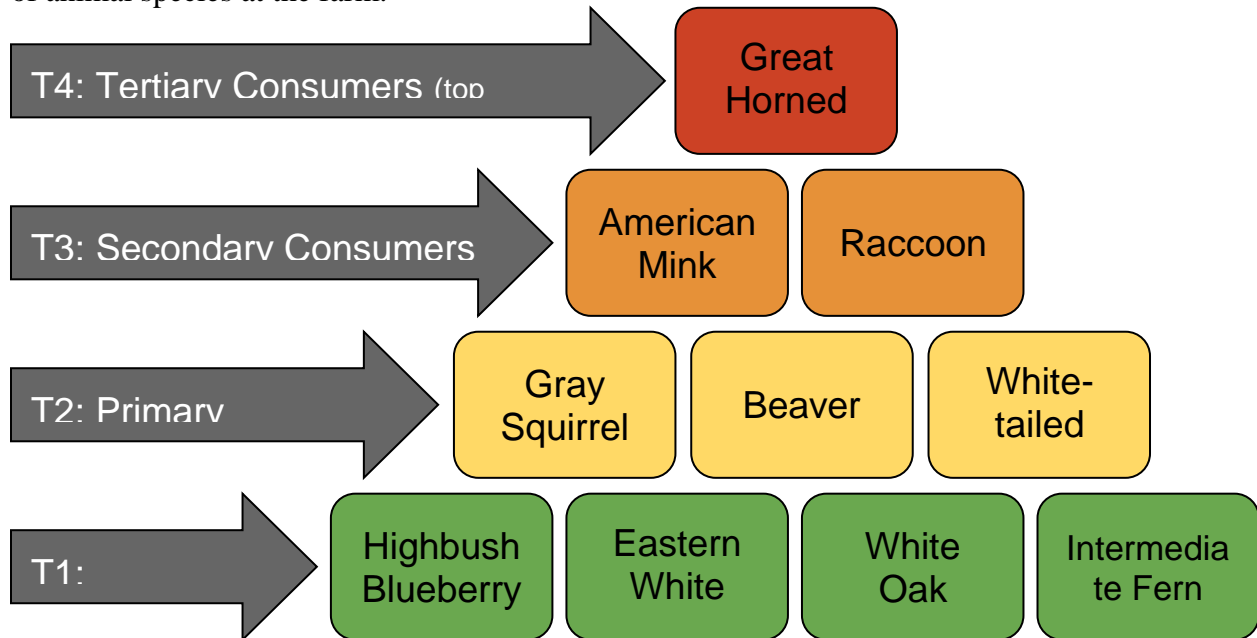


Figure 6. Diagram of trophic levels at TBT, including ten species

We identified 19 species of flora, 16 species of fauna, and four species of fungi; for a full list, see Appendix B. Most biota were identified down to the species level, although some could only be specified at the genus or family level. Examples of flora species identified include trees and shrubs, such as American chestnut (*Castanea dentata*) and black highbush blueberry (*Vaccinium fuscatum*); smaller flowering plants and herbs, such as bushy aster (*Symphotrichum dumosum*); as well as club mosses and ferns, such as intermediate wood fern (*Dryopteris intermedia*). We didn't directly observe any animals, but their presence was inferred from animal signs (prints, scat/feces), the habitats present in the farm area, and the presence of food sources for the specific animal (i.e., a niche). Some animal signs, such as a decaying log chopped down by a beaver, were obvious to identify and helpful in ensuring that prominent local species are incorporated. Of course, not all flora, fauna, and other biota could be identified.

For our stations, the specific species selected were chosen based on several factors, including presence of animal signs, relative prominence/familiarity at the farm and among the children (e.g., the beaver), and sufficient interactions with other species in the constructed TBT food web. Exclusion criteria included little-to-no interactions with other food web species as well as the presence of similar species (e.g., snowshoe hare and cottontail rabbit) with a stronger/more defined niche at TBT.

Through field visits and site evaluations, we considered possible locations for our future learning stations based on several criteria, including:

- Safety of the location (e.g. is it near a large body of water? Next to a slope?)
- Nearby species/habitat as they relate to the theme/topic of the station

- Foot traffic in the area/visibility of the station
- Proximity to the other stations

We kept note of the potential locations for station piloting later on. Before we could begin to plan our stations, we first had to understand the needs of our sponsor and her constituents at TBT; this is discussed in the next subsection.

4.2.2 Findings: Needs of TBT Constituents

The major findings associated with understanding the needs of the TBT constituents include: 1) Learning topics and goals appropriate for the population of developmentally aged three to six-year-old children at TBT; 2) The need to incorporate unstructured play, place-based learning, and engaging topics in modules and tools; 3) The need for a field guide of the major flora and fauna at the property.

1) Learning topics and goals appropriate for developmental ages three to six

To ensure the efficacy of our stations and their accompanying learning modules, we needed to make the learning goals appropriate for developmental ages three to six. Through meetings and interviews with Mia Dubosarsky, director of the STEM Education Center at WPI, we determined how to make both our learning outcomes and our suggested teaching methods appropriate and accessible for the students at TBT. Simplified learning outcomes are key to the children’s proper understanding of the topic (Mia Dubosarsky, 2018). If our learning goals are not tailored to the developmental age (i.e., too complex), one major consequence includes the children adopting misunderstood/incorrect perceptions or beliefs related to the topic, which may persist for years. This could affect the child’s understanding of future topics. Mia recommended using the Massachusetts State guidelines for STEM learning outcomes as a guide for refining our own learning outcomes (2018).

Additionally, Mia had several recommendations for the methods of teaching our learning modules. One key recommendation related to the zone of proximal development (ZPD) — the difference between what a child can and can’t do on their own, and what they can do with the assistance of an adult (McLeod, 2012). Adult assistance is key in giving children experiences that are within their ZPD, as the children learn from the adult’s example and eventually can do the task unaided (Dubosarsky, 2018). For topics that are more advanced, it is especially important to incorporate the “Teacher Portion” of each learning module. This provides the children with the background knowledge and understanding necessary to eventually do the activity, or its more challenging aspects, with little-to-no adult intervention (Dubosarsky 2018).

2) The need to incorporate unstructured play, place-based learning, and engaging topics into Modules and Tools

As discussed in our literature review, unstructured play and place-based learning are the major approaches to teaching and learning at TBT. Thus, we needed to incorporate both methods into our learning stations. In addition to this, our learning stations needed to be centered around topics or themes of interest to the children at TBT; we learned about these topics through several interviews with Lisa Burris and Ali Johnston. Some of these topics and themes of interest included:

- Earthworms
- Loose parts

- Story stones
- Puppets
- Sensory engagement
- Beavers
- Animal habitats/ “homes”

We incorporated these topics into our various stations and modules, which is described in the following section, 4.3. In relation to place-based learning and engaging topics for students, many students have a keen interest in the local flora and fauna at TBT. However, our sponsor doesn't have a field guide that meets her and her students' needs; this will be discussed in the next subsection/paragraph.

3) The need for a field guide of the major flora and fauna at the property

A final major finding was the sponsor's need for a field guide of the local species at TBT. From interviews with Burris and Johnston, we learned that the students regularly ask their teachers to identify plant, tree, and animal species (e.g. “What kind of plant is this Miss Lisa?”), but the teachers lack the background knowledge and resources to confidently answer (Burris and Johnston, Nov. 10, 2017). Burris and Johnston also described several desired criteria for an effective field guide, which are listed below:

- a. Pocket-size
- b. Accessible for both children and adults
- c. Augmentable - field guide can be easily expanded upon in the future, if desired (e.g., use binder rings so Burris can add more species pages in the future)
- d. Local, common flora and fauna species - at least 25 total species

With these criteria, we designed and planned both the physical size/composition and the content of the field guide; this will be explained in more detail in the next section.

4.3.0 Results, Objective 3: Design, build, and pilot final learning stations, activities, and modules

To accomplish objective three, we followed a carefully planned design and construction process. To begin the design process, the team first developed an initial design for each of the learning stations, based on what other schools and programs elsewhere have done and our own original ideas. Designs were sketched on paper and then made digital through Piktochart in order to be presented to Burris, Johnson, and Dubosarsky, who evaluated and modified these stations based on their ability to meet the specified learning and developmental outcomes. Next the stations were evaluated on their site suitability criteria, discussed in 4.2.1. Finally, considerations of the availability and price of different materials and tools that were made. The final designs are shown below in Figures 7-15.

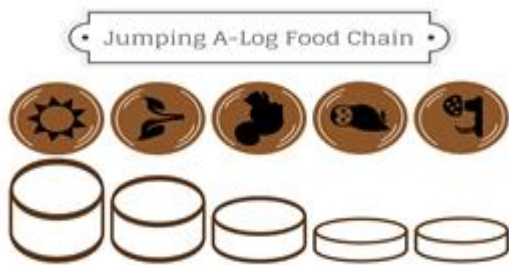


Figure 7. Final Design of Jumping A-Log Food Chain Learning Station



Figure 8. Final Design of Story of Life Learning Station

Tackle Box Sponges	Tackle Box Unifix Cubes	Tackle Box Wood Cookies
Tackle Box Corks	Tackle Box Pipe Cleaners & Pom Poms	Tackle Box Sea Shells

Figure 9. Final Design of Loose Parts Learning Station

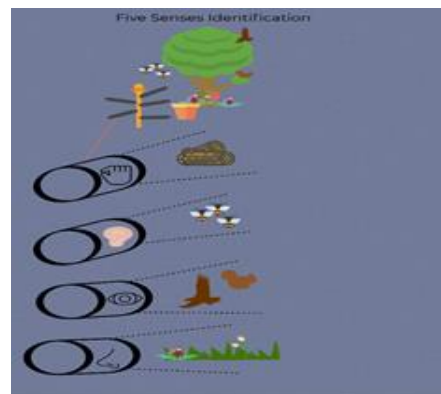


Figure 10. Final Design of Five Senses Learning Station

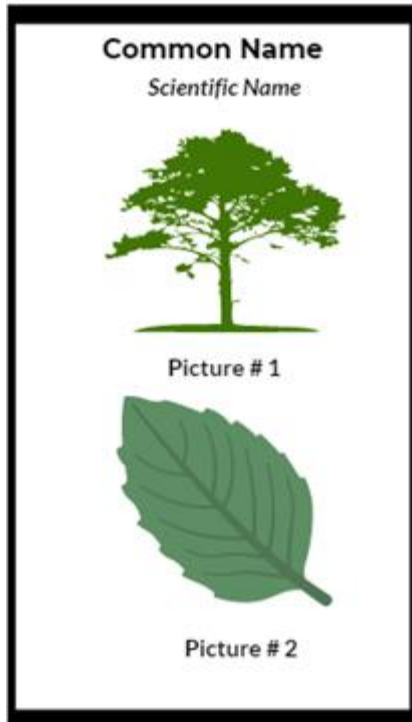


Figure 11. Final Design of Field Guide Content Sheet Template (front)



Figure 12. Final Design of Field Guide Content Sheet Template (back)

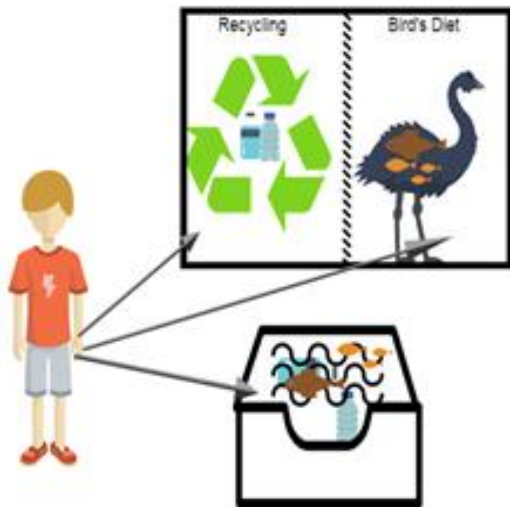


Figure 13. Final Design of Recycling Learning Station



Figure 14. Final Design of Solar Fields Learning Station



Figure 15. Final Design of Chicken Scrap Learning Station

With the design process complete, the team purchased materials and began the construction process. Each of these stations were built over a period of three weeks at the beginning of D-Term. Problems that arose during the construction will be discussed in greater detail in each of the following station subsections.

4.3.1 Food Webs

4.3.1.1 Jumping A-Log Food Chain

Description: The Jumping A-Log Food Chain consists of ten spruce logs that each have a picture of an animal or plant wood burned onto the top of them. These logs vary in height, representing the different trophic levels within a food chain. Furthermore, these logs will be oriented into a triangle shape, allowing the students to jump between the different logs in both an easy and safe manner.

Learning Goal: The students will learn that each species on the log can be grouped into trophic levels of producers or consumers. Additionally, they will learn that these species are dependent on each other and other species in the environment.

Developmental Goal: One developmental skill that the children will learn from this station is core strength and balance. The children will learn this by jumping and crawling between the logs.

Learning Process: The students will learn the trophic levels of producers and consumers first by a short teacher led-lesson and then by jumping between the logs that are different heights. To learn about the connectivity of the species students will jump between logs that are in a straight line.

Construction Process: To begin building this station, ten spruce logs were cut to the heights of 2 ft, 1.5 ft, 1 ft, 0.75 ft, and 0.5 ft. Once the logs were dried, they were sanded extensively for several hours to make the surface suitable for woodburning. Next the species to be wood burned were printed out and traced onto the log using a thin point permanent marker. After this the traced species were carefully wood burned into the log. When the wood burning was completed, each log was then coated with clear wood sealer.

Implementation Process: To implement this station on the farm, a station site was first selected to be near the playground at TBT. Once the site was made level, sand and gravel was then spread out on the site. Next the ten logs were buried into the sand and gravel, while being organized into a triangle shape.

Documentation of Build:



Figure 16. Non -Sanded Logs



Figure 17. Sanding of the Logs



Figure 18. Sanded Logs



Figure 19. Wood Burned Log



Figure 20. Wood Sealed Logs



Figure 21. Holes for the logs



Figure 22. Implemented Station

4.3.1.2 *Story of Life*

Description: The Story of Life station includes 14 wood cookies that have different wood burned animals and plants on them. These cookies will be able to be arranged in any desired manner by the student.

Learning Goal: When interacting with this station, students will be able to formulate their own ideas and stories around what species depend on each other, how, and why.

Developmental Goal: This station will allow the children to interact with the wood cookies in any way they please. This will challenge the children to improve on their sense of freedom. The term freedom in developmental early education refers to the ability to play and create with no adult guidance or intervention (Burris, April 19, 2018).

Learning Process: Students will be given access to the wood cookies. They will use their imagination to organize the wood cookies in any manner they like, including to create a story about the species. This process can allow them to think critically and use their imagination.

Construction Process: To build this station, the wood cookies were freed of any debris. Next the species to be wood burned were traced onto their respective wood cookies. Once this was done the species were then wood burned onto the cookies. Finally, the wood cookies were sealed with wood sealer.

Documentation of Build:



Figure 23. Unfinished Wood Cookies



Figure 24. Finished Wood Cookies

4.3.1.3 Loose Parts

Description: The loose parts station is comprised of six tackle boxes. Each of these tackle boxes include materials such as shells, corks, wood cookies, pom poms, pipe cleaners, sponges, and UniLink cubes. These different materials allow the students to use their own imagination to create whatever they please.

Learning Goal: The goal of this station is to teach the students how to create objects or shapes using a variety of materials.

Developmental Goal: Children will improve on their tactile sense and construction of different objects.

Learning Process: Students will be given access to the materials. They will be given the time, space, and freedom to interact, create, and build with the materials in any way possible.

Construction Process: To construct this station, the purchased loose parts were first put into their own respective tackle boxes. Next each tackle box was labeled with the loose part that was inside it. Finally, the six tackle boxes were organized neatly into three rows inside a collapsible container.

Documentation of Build:



Figure 25. Loose Parts

4.3.2 Five Senses & Species Identification

4.3.2.1 Five Senses

Description: In this station pvc pipes will act as tubes and will be attached to a 4x4 post by velcro. The connection of velcro between the tubes and the post will allow the tubes to be focused in any desired direction. This direction will focus the students attention to a specific object in nature (e.g. visible birds, bird sounds, smells). Additionally, this distinct object could either be part of the surrounding environment or a plastic representation of an animal or insect of some kind. Finally, the tubes attached to the post will have a symbol for an ear, eye, nose, or hand on them. This symbol will direct the student to either touch, smell, hear, or look at the object that they observe through the tube using one of their senses.

Learning Goal: Students will learn about their five senses and about the practice of observation. The five senses station will also allow the students to explore the surrounding environment using their five senses.

Developmental Goal: The five senses station will allow the children to improve on their visual and spatial skills. The meaning of this is that children will be able to have a 3D understanding of the space around them.

Learning Process: After a teacher-led lesson, students will learn about the five senses, observation, and their local environment different by going up this station and observing through a tube. They will then be able to explore the object that the tube is pointing towards using one or more of their senses.

Construction Process: To begin 4x4 posts were first cut to seven feet in height. These posts were then extensively sanded down to remove any sharp edges. Next 12 pvc pipes were cut to one foot in length. After they were cut, two pieces of felt were attached to each of the pvc pipes. This velcro was then covered with tape, and the pvc pipes were then spray-painted brown. Next the velcro for the posts were cut and then attached with staples. Finally, the ear, nose, eye, and hand symbols were attached to the pvc tubes.

Implementation Process: To implement this station, the team first found three suitable station sites that were all near the beaver pond. At each of these sites, a two-foot-deep hole was dug using post hole diggers. Next the 4x4 posts were placed into their respective holes. After dirt was used to fill in most of the hole, cement was mixed and placed in the hole to fill it up the rest of the way. Finally, the pvc tubes were placed on the posts at different heights and orientations.

Documentation of Build:



Figure 26. Cutting of PVC Pipes



Figure 27. Spray Painting of PVC Pipes



Figure 28. Spray Painted PVC Pipes



Figure 29. Attachment of Velcro



Figure 30. Digging of Post Holes



Figure 31. Cemented Post

4.3.2.2 Field Guide

Description: The field guide will enable TBT program participants to identify approximately 30 different species of plants and animals around the farm. For each species, there will be several photographs of the species on the front side of each page. On the back of the page there will be relevant information about the species that is on the front side of the page. At the end of the field guide is an appendix with different local food webs and a map of the location of each species.

Learning Goals: Use of a field guide and facts and connections about local species on the farm.

Developmental Goal: Translating learning on paper to learning in the field.

Learning Process: After a teacher-led lesson, students and teachings will use the guide to search for or identify local species. For example, students can pick a plant they find on the property. They will then see if they can match this plant or animal to any of the pictures in the field guide. If they find a species that is not in the guide, they can put it into a collection box to be identified and added to the guide later.

Construction Process: To begin, pictures and information of each species was filled into their respective pages of the field guide PowerPoint. Next, the pages were printed and then laminated. Once laminated the pages were cut to the correct size of 3x5 inches. Next three holes were punched into each page. To bind the field, guide the pages were bound together using small keychain rings. Once all of this was done, a digital version and a printed copy of the field guide was given to the sponsor.

Documentation of Build:



Figure 32. Field Guide Construction Supplies



Figure 33. Field Guide Pages



Figure 34. Completed Field Guide

4.3.3 Recycling

4.3.3.1 What Does the Bird Eat?

Description: This station will consist of a bin with a combination of recyclables (e.g. a plastic water bottle) and different foods that a bird would eat. The foods that a bird would eat for this station will be plastic frogs, turtles and fish. On one side of the bin, a stuffed bird will be placed, allowing the students to put all the foods that the birds eat on this side of the bin. On the other

side of the bin a recycling symbol will be located, signifying where the recyclables should be placed by the students.

Learning Goal: Students will learn about plastic water pollution, the impact on waterfowl, and environmental responsibility and care.

Developmental Goal: The children for this station will improve on the skill of sorting, as well as care and responsibility for others.

Learning Process: After a teacher-led lesson, students will separate plastic trash from the frogs, fish, and turtles into either the recycling or bird bin.

Construction Process: The first step taken for this station cutting of 2x6's, plywood and 2x4's to the correct lengths. Next the different pieces of wood were connected by screws. After this the box structure was then stained and let to dry. Once the stain was dry, the two-foot-tall backdrop was attached to the main box. Next felt was attached to the bottom of the box. Finally, velcro was cut and the laminated signs and stuffed great blue heron were attached to the box and backdrop.

Documentation of Build:



Figure 35. Stained Recycling Station

4.3.3.2 Chicken Scrap Station

Description: The chicken scrap station includes a container that holds three bins for collecting different things. There is a bin for trash, recyclables, and one for chicken scraps. Students will be able to walk up to the container and decide which bin they should put food, plastics, or trash in. Ultimately this will reduce the amount of trash created by TBT.

Learning Goal: Students will learn the difference between what materials they eat (and package and hold their food) can be recycled, composted/fed to chickens, and what is sent to a landfill as trash.

Developmental Goal: Sorting, environmental responsibility or stewardship, animal feeding and care.

Learning Process: After a teacher-led lesson, students will sort their lunch materials that need to be discarded. Students will take the chicken scraps and feed them to the chickens.

Construction Process: To begin the plywood and 2x4 boards were cut to the correct length. Next each side of the container was put together using deck screws. After each side was complete the container was put together as a whole. Next three circular holes were cut in the top of the container. Once this was done, the front doors were attached using three-inch T-Hinges and eye and hook latches. With the doors on, 4x4 boards were attached to the bottom to prevent the container's bottom from rotting. Finally, velcro was cut and the signs for trash, recycling, and chicken scraps were cut, laminated and attached to the top of the container.

Implementation Process: The constructed container with the bins inside was brought to TBT. It was then unloaded and placed next to the cabana where the students at the farm would eat their lunch.

Documentation of Build:



Figure 36. Initial Container Constructed



Figure 37. Finished Container



Figure 38. Container on the farm

4.3.4 Energy Production

4.3.4.1 Solar Fields

Description: The solar fields station will contain both a solar powered windmill and a solar powered water fountain. For the windmill, students will be able to plug in a USB cord to a solar panel battery bank and observe the windmill to rotate. The water fountain contains a nine-volt solar panel connected to an electric water pump. When the panel is connected to the pump and pointed at the sun, the students will be able to observe the water go up into the air.

Learning Goal: Both substations aim to teach the students the concept that the sun is a source of energy and can be used in various applications.

Developmental Goal: The solar fields station will let the children to be able to develop fine motor skills. This is the case due to the station presenting the children with the opportunity of plugging in cords/moving a solar panel around.

Learning Process: After a teacher-led lesson, students will interact with the solar fields stations by plugging a USB into the battery bank or pointing the solar panels towards the sun.

Construction Process: For the windmill substation, a circuit of two connected power jack adapters was soldered onto a breadboard. Next a small 2x4 block of wood was cut, in which the DC motor was attached to. Once this was done, the 2x4 and circuit board were placed inside a plastic container.

Design Changes: The windmill substation was originally planned to just be on a non-enclosed platform. However, after testing, and observing the high speed of the plastic propeller it was redesigned to be in an enclosed plastic container. This was done to ensure the safety of the students by making it not possible to get injured by the rotating propeller. Additionally, the water pump substation was redesigned after testing. This was due to the original design of just pumping water from one bucket to another not working as expected. Instead the station was redesigned to have submersible water pumps connect directly to a nine-volt solar panel.

Documentation of Build:



Figure 39. Solar Panel Water Fountain



Figure 40. Testing of Fountain

4.4.0 Results, Objective 4: Assess piloted activities, revise accordingly, and make recommendations

The purpose of assessment was to determine if the implemented nature modules were meeting the desired educational goals and what other unforeseen learning outcomes they may be meeting. Of the nature modules that were designed, the following stations were assessed: the food web station and chicken-scrap station. The team did not have the opportunity to observe the other nature modules given the program schedule and unexpected weather at TBT. Assessment was based on observation of station activity and feedback from the sponsor/participants at TBT.

4.4.1 Food Web Station: Jumping A-Log Food Chain

The assessment for the food web station was predominantly in the form of observation and feedback received from the sponsor and participants. As we observed and took notes, Burris taught a lesson about the specific species on the logs, their interactions, and their presence at the farm, all while engaging the students and prompting them to share their knowledge on the subject (Burris, May 2, 2018). Lisa proceeded to cover all major learning goals: the definition of a food web; the importance and types of interactions that occur between plants/animals and animals/animals; the definitions of herbivore, omnivore, and carnivore, as well as the representing species on the logs. In addition to the predetermined learning goals, Lisa also related each species on the log back to the farm, which assisted the students' understanding and enhanced their engagement in both the lesson and station (Burris, May 2, 2018). For example, when Lisa asked the students about the beaver log, several students related it to the beaver pond at the farm; Lisa also taught about the relationship of the beaver to trees and how they provide it with both a habitat and a food source. These are perfect examples of the place-based education emphasized at the farm; as students are able to relate what they learn to a familiar object or concept, they are better able to understand and participate in the lesson (Burris, May 2, 2018). In general, the Jumping-A-Log Food Chain station appeared to be well-received by the constituents at TBT. The sponsor and constituents, including Burris, Johnston, and the students observed all appeared to enjoy the activity as Burris was teaching and carried the lesson into other play on the farm. For example, after the children interacted with the log with an image representing an Eastern White Pine, it led them to play in the pine trees. This demonstrates unstructured, self-directed play, the children used their own imaginations, not guided by any concrete rules or adult intervention. Furthermore, Lisa explained the importance of how outdoor education is not just learning but experiencing the lessons.

The sponsor, participants, and the sponsor's associate at Antioch New England provided feedback for the logs. The feedback was overwhelmingly positive, both about the aesthetics and educational value of the logs for multiple lessons. Antioch University professor, Joy Ackerman, who writes science and nature education textbooks for children, documented the logs, module, and their potential for nature education lessons elsewhere. Given the success of this station, we determined that no revisions are necessary for the physical station or the accompanying lesson plan.

4.4.2 Conservation: Recycling/Compost/Chicken-Scrap

We arrived after lunch time, therefore, we did not directly observe children engaging with the chicken scrap station. Therefore, our assessment is based on feedback from the sponsor and TBT constituents. Lisa Burris explained that "children putting their apple core into a compost pile is

the first exposure they have to composting and conservation” (Burris, May 2, 2018). One of the many benefits of nature education is developing an appreciation for the environment, Burris mentioned the station made a significant impact on earth day by introducing concepts of conservation. By differentiating between what goes into ‘recycling’ or ‘trash’, the children can begin to see the difference in the ‘good’ and ‘bad’ for the environment (Burris, May 2, 2018). Burris also observed the important connection that the station allows children to draw, from what they’re eating at lunch to how the scraps become the chickens food (Burris, May 2, 2018). The station resulted in early exposure to sorting, a crucial scientific and practical developmental skill (Burris, May 2, 2018). Sorting is an important developmental skill as it is useful not only in mathematical situations but everyday activities as well (Harris, 2013).

4.4.3 Energy: Solar Panels

Assessment for the Solar Panels station is based solely on feedback from the sponsor. We could not obtain results from participant observation of children engaging with this activity due to several factors, such as delayed station piloting and weather. Even so, Burris predicted that the activity will be well-received by the students; this station will likely appeal to students of developmental ages 4-10 due to its higher-level learning goals and concepts (Burris, May 2, 2018). For high school-aged students, it introduces the topic of energy and solar panels in a low-pressure (less anxiety-ridden) environment, which helps the students learn and potentially apply their knowledge when a similar topic is introduced in a classroom setting (Burris, May 2, 2018). Furthermore, the solar panels fill a unique niche at TBT, as the topics of solar energy and electricity are not yet included in TBT’s curriculum. Burris predicted that the station will appeal to particular students, as not all students may be interested in the topic or station itself due to its complexity. However, it could be useful in introducing the subjects of energy, the power of the sun, renewable resources for energy, and other related concepts; this would facilitate the child’s learning in the classroom when these concepts are introduced, as they have already been exposed and engaged in the topic at TBT. For many children with disabilities, introducing a topic through physical learning helps transfer their knowledge later to the classroom (Burris, May 2, 2018).

4.4.4 Loose Parts

Loose parts are objects/materials that can be moved, combined, taken apart, and rebuilt multiple ways, and are without any specific set of directions (Mincemoyer, 2016). Thus, loose parts play stimulates a child’s creativity and imagination as well as encouraging open-ended learning/problem-solving. Loose parts commonly used in nature-based preschools include: water, sand, dirt, sticks, logs, leaves, shells, feathers, rocks, and many more. Other loose parts that may be used include: balls, tires, buckets, fabric, chalk, recycled materials, art materials, and sensory materials (Mincemoyer, 2016).

Assessment for this station is based on feedback from the sponsor., as we could not obtain results from participant observation of children engaging with this activity. Burris greatly appreciated this station because it provides tactile, sensory feedback — “touch, feel, learn” (Burris, May 2, 2018). As explained in our literature review, incorporating sensory play and learning is crucial to engaging many children with exceptional needs. Also, play is entirely unstructured and self-directed, as the loose parts have no instructions or specified purpose, providing children with low-stress play and the “freedom to quit” (Burris, May 2, 2018). This is important because toys marketed to children commonly have a pre-designated purpose (as determined by the manufacturer), however, children are imaginative and often play with toys in “unplanned” ways.

For example, children with a history of trauma may be less interested in playing with “normal” toys, such as trucks or play-kitchens; however, they may be intrigued and imaginative with seemingly random “loose parts” (Burriss, May 2, 2018). One of Burriss’s adopted children falls into this category, as she won’t touch dolls or other toys but loves to play with dog food for hours (Burriss, May 2, 2018).

Overall, Burriss outlined this station’s benefits as: inspiring imagination; promoting problem-solving skills; promoting sorting skill development; and providing low-stress, self-directed, unstructured play (Burriss, May 2, 2018). Due to the limited time and delayed station piloting, we were not able to consider revisions to the loose station or its learning module. However, we believe the station will provide the planned educational benefits, based on Burriss’s initial feedback.

5. Conclusion and Recommendations:

The goal of this project was to design, build, and evaluate eight environmental STEM-based “learning stations” for children with and without special needs. Eight modules and stations were built, piloted, and installed on the farm. Each station addresses an educational concept that is developmentally appropriate for children who participate in TBT’s programs, and together, they help to fill the environmental education gap in TBT’s programming. A WPI new article about our collaboration with Turn Back Time can be found here: <https://www.wpi.edu/news/wpi-students-bringing-water-storage-and-environmental-education-paxton-farm>

We were unable to complete a full and rigorous evaluation of each learning station due to a lack of time, which is a limitation of our project. Despite this, we were able to get back initial feedback on the learning stations and modules from the students, in some cases, and from our sponsor, certified preschool teacher Ali Johnston, the students’ parents, and nature-based educational professionals in others. For example, Dr. Ackerman, from Antioch University, said she “absolutely loved” the food web station. She documented the station through photographs and invited Burris to share this and the other learning stations and modules with current students enrolled in Antioch’s Master’s Certificate in Nature-Based Early Childhood Education program as an example of effective community collaboration. Sarah Connell, an environmental humanities teacher at the Intermediate School in Auburn Massachusetts, reviewed our learning stations and modules and asked to duplicate them in an outdoor classroom she is building in her school’s arboretum. The team provided designs, bills of materials, and support through answering questions for Ms. Connell so that she could make modules and learning stations of her own. An article about her project and WPI’s involvement can be found here:

<http://www.auburnmassdaily.com/2018/05/students-count-on-the-community-to-help-activate-auburns-forgotten-greenspace/>.

We have two recommendations that aim to address the limitations of our project and to expand the potential impact of our project and WPI’s mutually beneficial collaboration with Turn Back Time Farm.

1. We recommend that further assessment be conducted. In order to assess if and how the anticipated learning and developmental outcomes of the learning stations and modules are achieved, we recommend that each station and module are assessed by Burris and Johnston, or by another project team or entity they see fit. Assessment should involve participant observation of how the students interact with the stations and respond to the modules over time. Based on the literature, we recommend at least four separate observations over the course of a year to see how the students engage with the stations during each season and to assess how their engagement with the stations and understanding of the content develops with multiple interactions over time (North American Association for Environmental Education, 2018).

2. We recommend that further additions to modules and learning stations be made where possible. Many of the nature modules were designed to have expansion potential for future projects by the students and teachers at TBT or by other community collaborators. In interviews, Burris explained that she is about 10 years away from retirement. She would like to develop learning stations, modules, and curricula that is created by a community of invested collaborators that can serve as a foundation for programming and future curricular development when she is no longer running the programs. Burris explains, “the farm, its programs, and its collaborations need to live beyond me” (January 20, 2018). Future additions onto the modules

will increase the longevity of the modules themselves, as well as their educational value and long-term impact on the programs. For example, adding more pages of local flora and fauna into the field guide would not only keep the modules up to date, but allow for the programs it supplements at TBT to grow.

Finally, adding to the modules and learning stations is a great opportunity for community partners, such students and faculty at WPI and other universities, to learn from the partnership and expertise of the teachers, students, parents, and others at TBT. Having the ability to take what we learned in the classroom over the last three years and apply it in a context with changing variables and unexpected challenges was incredibly helpful and rewarding. Burris was a great mentor who challenged us to look at each station and module from new and multiple perspectives, and the students were great motivators, as we wanted them to be excited about learning and to meet their varying needs and interests. Other students or community partners would be fortunate to work with Burris and her students and colleagues at TBT, as they will learn as much (if not more) than the students they are trying to serve.

Appendix A: Materials

Jumping A-Log Food Chain & Story of Life:

Materials:

1. 8-10" Diameter Logs
2. Gravel
3. Sand
4. Wood Cookies

Loose Parts:

Materials:

1. Tackle Boxes
2. Pom Poms
3. Pipe Cleaners
4. Wood Cookies
5. UniLink Cubes
6. Corks
7. Sponges
8. Shells

Five Senses:

Materials:

1. 4"x4"x8' Pressure Treated Wood
2. 12 feet of 1.5" Diameter PVC Pipe
3. 25 feet of 1" wide velcro
4. Brown Spray Paint

Field Guide:

Materials:

1. 60 lb. Heavy Duty Paper
2. Lamination Sheets
3. Key Chain Rings

What Does the Bird Eat?

Materials:

1. 5 mm thick plywood
2. 11/32" thick plywood
3. 2"x6" boards
4. 2"x4" boards
5. Deck Screws
6. Stuffed Bird
7. Orange Foam

8. Lamination Sheets
9. 1" wide Velcro
10. 65 lb. heavy paper

Save Those Chicken Scraps:

Materials:

1. 3-inch zinc plated tee hinges
2. Hook and Eye Latches
3. 5 mm thick plywood
4. 11/32" thick plywood
5. 2"x4" boards
6. Deck Screws
7. Lamination Sheets
8. 1" wide Velcro
9. 65 lb. heavy paper

Solar Fields:

Materials:

1. Two Solar Powered Water Fountains
2. 2 Gallon White Buckets
3. 20Ah Solar Powered Battery Bank
4. Power Jack Cables
5. Power Jack Adapters
6. Solderable Breadboard
7. Miscellaneous Plywood and 2x4 inch boards
8. Deck Screws

Appendix B: List of Species

<u>Producers - Plants</u>	<u>Consumers - Animals</u>	<u>Detritivores, Decomposers</u>
White Oak (<i>Quercus alba</i>)	Eastern Cottontail (<i>Sylvilagus floridanus</i>)	Earthworms (<i>Annelida spp.</i>)
Northern Red Oak (<i>Quercus rubra</i>)	New England Cottontail (<i>Sylvilagus transitionalis</i>)	Turkey Tail (<i>Trametes versicolor</i>)
American Chestnut (<i>Castanea dentata</i>)	Eastern Gray Squirrel (<i>Sciurus carolinensis</i>)	Common Split Gill (<i>Schizophyllum commune</i>)
Shagbark Hickory (<i>Carya ovata</i>)	White Tailed Deer (<i>Odocoileus virginianus</i>)	Hen of the Woods (<i>Grifola frondosa</i>)
Eastern White Pine (<i>Pinus strobus L.</i>)	North American Porcupine (<i>Erethizon dorsatum</i>)	Scaly Pholiota (<i>Pholiota spp.</i>)
American Beech (<i>Fagus grandifolia</i>)	North American Beaver (<i>Castor canadensis</i>)	One Flowered Indian Pipe (<i>Monotropa uniflora</i>)
Black Cherry (<i>Prunus serotina</i>)	Eastern Chipmunk (<i>Tamias striatus</i>)	
Eastern Hemlock (<i>Tsuga canadensis</i>)	American Mink (<i>Neovison vison</i>)	
Red Maple (<i>Acer rubrum</i>)	Wild Turkey (<i>Meleagris gallopavo</i>)	
Striped Maple (<i>Acer pensylvanicum</i>)	Raccoon (<i>Procyon lotor</i>)	
Black Highbush blueberry (<i>Vaccinium fuscatum</i>)	Great Horned Owl (<i>Bubo virginianus</i>)	
Mountain laurel (<i>Kalmia latifolia</i>)	Coyote (<i>Canis latrans</i>)	
American Aster (<i>Symphyotrichum novi-belgii</i>)	Black Bear (<i>Ursus americanus</i>)	
Eastern Spicy Wintergreen (<i>Gaultheria procumbens</i>)	Deer Tick (<i>Ixodes scapularis</i>)	
Swamp Dewberry/Bristly Blackberry (<i>Rubus hispidus</i>)	Bumblebee (<i>Bombus spp.</i>)	
Bushy Aster (<i>Symphyotrichum dumosum</i>)		
Prickly Clubmoss (<i>Dendrolycopodium dendroideum</i>)		
Intermediate Wood Fern (<i>Dryopteris intermedia</i>)		

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