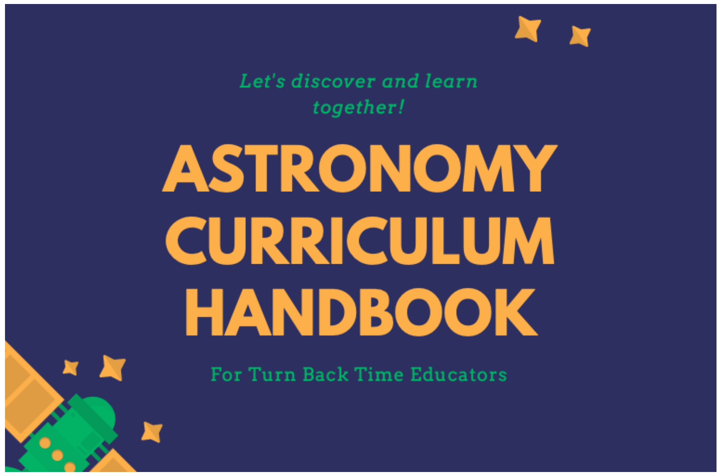

Developing an Astronomy Curriculum and the Reimagining of STEM Education

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Abstract

Turn Back Time grew from a small farm-based preschool in 2012 to a thriving, blended program that takes advantage of nature's ability to educate and heal. The farm caters to individuals of all ages, especially the underprivileged, neurodivergent, and at-risk youth. These populations often require an alternate learning environment to thrive academically. In order to create an optimal lesson plan, I gathered data from interviewees experienced in the field of education and visited educational sites that specialized in project-based, hands-on STEM learning. Drawing upon my research, I designed the most effective ways to teach STEM to create an engaging and accessible astronomy curriculum, while also keeping true to Turn Back Time's roots as a nature-centric educational initiative.

Acknowledgements

To begin, I would like to thank these individuals for their assistance, support, and guidance during the course of this project. This project would not have been possible without these essential contributors.

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2. Thank you to my sponsor Professor Elisabeth Stoddard for being involved with my project, reviewing my progress, and providing assistance when needed.
3. Thank you to the Turn Back Time farm, located in Paxton, MA, for allowing me the opportunity to pursue this project.
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Background Chapter

STEM fields, on average, are projected to grow 8% according to the U.S. Bureau of Labor Statistics while only 20% of U.S. high school graduates are prepared for college-level coursework, required for STEM majors, according to the American Affairs Journal. Subjects relating to math and science are essential to creating an educated student populace and the continuation of an innovative society in the modern era. However, there are issues the education system runs into trying to engage students in these fields. While this is the case for neurotypical students, it is even more so for those who are underprivileged, with disabilities, and/or are at-risk in other aspects. In this background chapter, I explain 'STEM', its role in education, and its importance. Next, I introduce alternate methods to teach STEM such as project and nature-based learning. Finally, I introduce Turn Back Time, its mission, and how it incorporates alternate learning methods to create an educational environment that is both accessible and engaging.

1. STEM Education

STEM is an abbreviation for 'science, technology, engineering, math'. STEM education is valuable in the current era due to the major demand for knowledge and experience in such subjects (Walker, Zhu, 2013). The term 'STEM education' represents the process of teaching and learning the fields of science, technology, engineering, and mathematics, respectively. (Kennedy, 2014). STEM appears in many levels of education, from elementary, and all the way to the collegiate level. This exemplifies its necessity within the education system. There are also adult programs and STEM activities outside of a formal educational setting as well. STEM education also integrates the components of the four main subjects. Furthermore, STEM curriculums have been revamped in recent years to use more hands-on activities to teach the subjects to its audience. In November of 2009, former President Obama initiated the 'Educate to Innovate' campaign to improve STEM education nationwide to propel American students back to the top of global math and science rankings. Aside from the private initiatives, there was also a focus on expanding participation to those who are less represented in STEM fields (women, underserved minorities). While this campaign doesn't address systematic reasons as to why the education system falls short, it shows that there is a need to revamp education in the STEM fields. There has been a surge of STEM labs, makerspaces, and other similar settings appearing throughout educational spaces to encourage student and community engagement, but over the past decade the USA has not improved in terms of STEM education.

The precedent for STEM curriculums is that they're focused on pure memorization and regurgitation, whether it be text book problems or sets of formulae. This is considered a passive learning technique. To understand what this entails for the broader student base, we can look to statistics. Research shows that, on average, the United States lags behind in STEM-related sectors such as math and science. Data from the Programme for International Student Assessment (PISA) shows that the USA ranks 38th and 24th, respectively (Desilver, 2017). Comparing that to other countries that rank higher on such rankings, we already see a clear difference. Richards of *USA Today* explains in her article that there has to be a strong upheaval in the traditional methods of teaching math and science, specifically in America, and that higher-ranking countries teach such subjects much more effectively. (Richards, 2020). According to the scholarly journal article, "Math, Science, and Technology in the Early Grades", math learning must be reconstructed in a manner that makes it more "effective and efficient—but also creative and enjoyable" (Clements, 2016). Students are very much interested in STEM, but there needs to be an educational precedent ensuring that they will be engaged and kept interested in activities (Clements, 2016). There have been initiatives to do just that, through the usage of makerspaces and other engaging settings. Due to maker culture increasing in relevance in education, it is being used more commonly as a "vehicle for cross-curricular, higher-order thinking" in classrooms. (Paganelli, et al, 2017). Makerspaces are spaces in which people of all ages can engage with STEM and STEAM-focused projects and interests in a free, creative setting. They offer an example of an enjoyable approach to STEM learning. Within settings like those in makerspaces, collaboration through hands-on activities is incentivised.

1.2 Why is STEM Education important?

STEM education and literacy is very important to academic and career success. Learning skills, integrated with STEM curriculums, is essential to the technological, intellectual, and societal progression of the modern world. Jobs, research, and academia are all important settings that need high level, STEM-educated bodies. STEM skills are also needed for those in the humanities as well. Scientific inquiry, problem-solving techniques used in engineering, and math skills are important for those of all disciplines.

2. What is Project-Based Learning?

Project-based learning is a method of educational growth that allows students to solve challenging problems, using both their technical knowledge gained from the classroom and their creativity. It encourages students to learn by doing, which means that they can apply the concepts they've been taught and put them to use. Project-based learning is a student-centered education method that focuses on solving real world problems and complex questions for an elongated period. The problem-based learning framework improves collaboration by enabling knowledge and information sharing and discussion. Due to this, it is highly recommended for educational use (Almulla, 2020). This application of this active learning style is more effective, as it leads to better outcomes.

3. Turn Back Time (TBT)

"Let nature be your teacher" is the motto of the Turn Back Time initiative. Based in Paxton, Massachusetts, Turn Back Time is a not for profit nature-based education center. Turn Back Time holds all its operations and activities on a farm of the same name. They have learning spaces both indoor and outdoor, and conduct various educational and therapeutic programs. Turn Back Time also serves underprivileged and neurodivergent youth, and other groups which don't have as many STEM learning opportunities as those more privileged than they. The activities Turn Back Time provides also are designed to be therapeutic, vehicles in healing processes, and to assist with self-esteem building.

Turn Back Time's activities can be interpreted as a combination of project-based learning and nature-based learning. They are conducted outdoors, but also put to use their indoor learning spaces for educational lectures. The purpose is to teach STEM-related subjects and encourage educational play in an environmental setting. This makes Turn Back Time a setting rich with potential for STEM engagement and learning. Nature-based learning and activities are also extremely appealing and engaging for school-aged children. In Issue 3 of the "International Research in Geographical and Environmental Education" journal, researchers explain that young students are engaged with activities that take place outside the classroom and in a "natural environment" (Ballantyne, 2002).

Turn Back Time wants to grow its efforts. Moreover, astronomy is a subject that has been neglected in the education system. It used to be a required subject back in the 18th century, but in the present era, only 4% of high school students take an astronomy class in school (Krumenaker, 2009). Teachers of astronomy in the K-12 grades are often faced with the prioritization of other science classes (chemistry, physics, biology) and the loss of funding and low student enrollment for astronomy-related courses (Krumenaker, 2009). Astronomy is a subject of scientific, societal, pedagogical, and cultural significance (Percy, 2016). Therefore, for my project I worked with Turn Back Time to develop an astronomy-based curriculum that can be offered to 8-12 year-olds on the farm.

Methods

Goal

The goal of this project was to design a curriculum and an effective learning experience centered around astronomy and space environments for third to eighth grade students at Turn Back Time. I developed five objectives in furtherance of this goal. Below, I describe my objectives in more detail.

Objective 1. Identify Learning Outcomes and Target Audience

To identify the needs of students at Turn Back Time, I first set up an interview with the sponsor to learn their expectations. The sponsor for this project was Professor Elisabeth Stoddard. Professor Stoddard is the Co-Director of the Environmental & Sustainability Studies at WPI, and Director of the Farm Stay WPI Project Center. I drafted interview questions about the sponsor's teaching, curriculum, and learning outcome expectations. A set of interview questions for Professor Stoddard are listed in Appendix A. Furthermore, as per WPI's Institutional Review Board Protocol, prior to each interview, I obtained the interviewees' informed consent. The informed consent details are listed in Appendix B. I also interviewed Katie Baker, educator and coordinator at the Turn Back Time farm and Lisa Burris, Executive Director of the Turn Back Time farm. The questions intended for Lisa Burris are included in Appendix C and those for Katie Baker are included in Appendix A. Through their insight, I gained more insight on the intricacies of Turn Back Time's educational methods, the process in which the farm developed activities, what made them successful, and the learning standards they reference.

Objective 2. Explore the Most Effective Activities and Methods for Engaging the Target Audience in STEM

Ahead of building the curriculum that would be best suited for the students at Turn Back Time, I explored teaching styles that could effectively meet Turn Back Time's learning outcomes and the needs of the target audience identified in Objective 1.

To begin, I conducted an online search for scholarly articles and online studies about the best teaching methods, activities, and manners in which students can best learn and understand STEM concepts. Through scholarly databases, Jstor and Scopus for example, provided through the Gordon Library at WPI, I searched through the studies using terms such as 'STEM learning', 'STEM education', and 'Problem-based learning' to refine my results.

I also performed a content analysis of the existing Turn Back Time mission statement and information available on their website. Content analysis is a research method used for the analysis of content derived from a slew of data. Specific portions of such data are organized in a manner in which more accurate, honed analysis can be made. It can be both qualitative and qualitative as well, which makes it a very versatile research method. As such, I studied the Turn Back Time mission statement using those specific research techniques and made it the framework of my curriculum. This also built upon the information I collected in Objective 1 so I could build a curriculum that reflects the essential elements of the Turn Back Time mission statement and the needs of the sponsor.

In order to learn from experienced educators, I interviewed two STEM education program leaders and instructors. Specifically, I interviewed Donna Lynn Taylor, an educator at the STEM Education Center. She has experience in the fields of teaching, earth science, and astronomy. At her job at the STEM Education center, she advises teachers on how to best teach

STEM subjects. Due to her experience, I asked her about the use of project and problem-based learning, and the most effective methods to engage students in STEM. The question set I used for Ms. Taylor is under Appendix D. Following Ms. Taylor, I constructed an email interview with the Director of STEAM Education at the Acton Discovery Museum, Elizabeth Leahey. With my interview with her, I focused on accessibility, as well as the development and evaluative process of new exhibits at the museum. The question set I used for Ms. Leahey is under Appendix E.

In addition to the interviews, I traveled to two STEM-focused museums that utilize hands-on methods to teach STEM, the EcoTarium in Worcester MA and the Acton Discovery Museum in Acton MA. While there, I directly observed how the exhibits operate and which teaching methods the exhibit employs to teach the subject it represents. Direct observation is one of the oldest and most common research methods used in scientific data collection. It is effective in studying modes of education and research centered around childhood development (Jersild, 1939). For the direct observation of the EcoTarium and the Acton Discovery Museum, I referenced the directives presented in “Collecting Evaluation Data: Direct Observation” by Ellen Taylor-Powell and Sara Steele (1996). This article provided me with many tools and a solid understanding of direct observation and how to best apply it as a research method. For the direct observation portion, I organized the information I gathered from the site visits in Table 1 (shown below).

Criteria	Describe if/how exhibit meets the criteria
Hands-on? How does it engage the child?	
What senses does it engage?	
Self-Directed or teacher guidance?	
Collaborative? Does it require that there be a second party? If so, how does it make students work together?	
Active or Passive?	
If outdoors, how does it use the nature element to its advantage?	

Table 1 - Table for Observations at Site Visit

I used Table 1 above to study the individual exhibits offered at both the Acton Discovery Museum and EcoTarium. For each exhibit listed, I recorded if it is hands-on, what senses it engages, whether it is self-directed or teacher-guided, if it requires collaboration, if it's an example of active or passive learning, and how it utilizes nature, if outside. I used these criteria because they emerged from my interview data as important for STEM education to the target population. By sorting my observations into the table shown above, I could effectively understand the educational aspects of the EcoTarium and the Acton Discovery Museum. This was important to the final project because I was able to then reference this data when designing the astronomy curriculum.

Objective 3. Analyze Data

I populated the following table with information from the interviews conducted Objectives 1 and 2. Once populated, I was more easily able to analyze the data I collected. I understood the key components of my research and referenced the data during the curriculum's creation. I developed two tables: one for interview data, and the other comparing the EcoTarium and the Acton Discovery Museum.

	Ms. Baker	Professor Stoddard	Ms. Taylor	Ms. Burris	Ms. Leahey
Profession/Educational Experience					
Project-Based Learning					
Accessibility					
Healing					
Emergent Curriculum					
Learning in Nature					

Table 2: Comparative Table for Interview Data

In the table above, I organized the similarities and differences between interviewee answers in order to develop my findings. On the x-axis, I grouped my interviews, and on the y-axis, I grouped the most common themes. Within the empty boxes, I placed their prominent talking points corresponding to each section. This allowed me to see how their answers compared and how each interviewee interpreted each question.

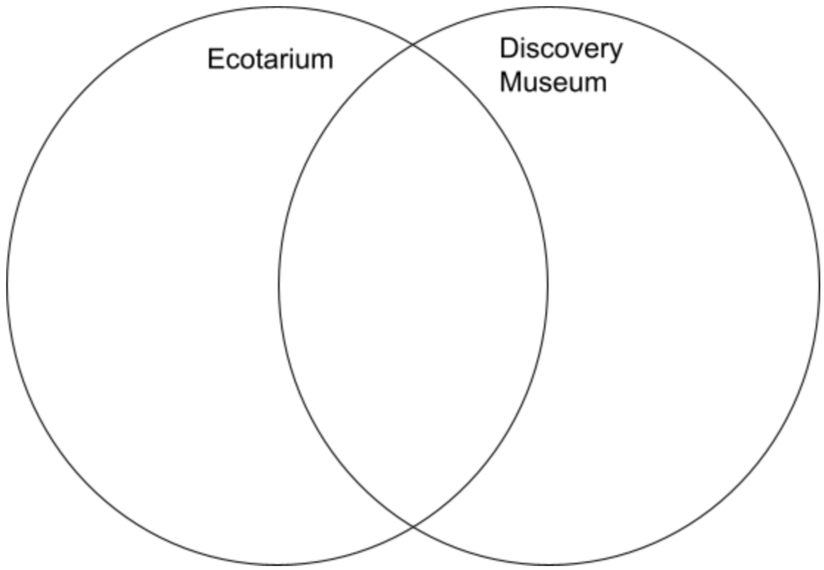

Table 3: Venn Diagram to Organize Site Data

To more simply view the observations from each of the site visits, I reconstructed the data from the EcoTarium and the Discovery Museum into a simple Venn Diagram. Similarly to Table 2, this organization helped me in understanding both the similarities and differences between the two sites. The visual organization provided by the Venn Diagram allowed for the data to flow more logically than in the table. Using this method, I could understand more of how to engage Turn Back Time's target audience and, more confidently, start writing my curriculum.

Objective 4. Develop Draft Curriculum and Seek Feedback from Sponsor

Next, I began developing the curriculum using the information I'd collected in the previous objectives. I aimed to include each aspect of the Turn Back Time farm, which the educators use in their own lessons. In the process of developing activities, I researched astronomy activities online, brainstormed activities with Ms. Taylor and Professors Dehner, and wrote out a variety of concepts. I shared those concepts and received feedback. From there, I expanded upon the concepts that were most positively received. During that process, I referenced the tables from above and my online resources. I created the draft using an online editing program called Canva and submitted it to my advisor and sponsor for revisions.

Objective 5. Finalize and Present Curriculum

The last objective is to finalize and present the astronomy curriculum to the educators and fellow IQP teams at the Turn Back Time farm. My sponsor and advisor made adjustments to the curriculum and gave me suggestions on what to edit. Using the feedback I received on the draft curriculum. This would include finalizing instructions, writing out more specific learning objectives, and refining information sheets for educators. This process would repeat several times before I could officially submit the curriculum. The final presentation consisted of an explanation of the curriculum to the sponsors, a demonstration of each of the lesson plans, and an overview of the development process. This curriculum, after having been finalized and reviewed by the sponsor, includes all the necessary revisions. The implementation of the curriculum would be conducted after the official project term ends, but I intend to keep in touch with the Turn Back Time farm to offer anything they may require.

Findings

Over the course of this project, I completed two site visits and five interviews. Using this information, I created three activities focused on astronomy and space environments. In this findings chapter, I discuss my results in two separate parts. First, I explain the educational framework, which tells of the teaching and education methods I found work best with the Turn Back Time demographic. To follow that, Ithen explain the development of the astronomy curriculum. In this chapter, I also show the data that I'd gathered through this research process. Through those visual methods, I understood hands-on learning methods, as presented at the EcoTarium and the Acton Discovery Museum, the intricacies of engaging students through project based learning, and the importance of nature in an educational setting. I also explain how I utilized the data to inform the development of the curriculum.

I. Educational Framework

Every suitable curriculum requires a framework, meaning a slew of foundational concepts and ideas that lessons will be tailored around. In this section, I explain how I understood the expected learning objectives through my interviews and site visits. As shown in my background chapter of this report, active learning strategies, such as project, problem, and play-based learning, are more effective ways to engage students with STEM subjects. As indicated earlier, students require more engaging manners to introduce them to STEM. This was confirmed by all five interviewees and was visible at both the Ecotarium and the Acton Discovery Museum.

	Ms. Baker	Professor Stoddard	Ms. Taylor	Ms. Burris	Ms. Leahey

Profession/Educational Experience	Educator at Turn Back Time	Director of Farm Stay Project Center, Professor at WPI	Assistant Director of Professional Development at the STEM Education center	Executive Director and Educator at TBT	Director of STEAM Education at the Discovery Museum in Acton, MA
Project-Based Learning	"The farm is a great source for project-based learning, identifying problems, and identifying solutions."	Tells of a project in which WPI students identified water sources to create a rainwater catching system at farm Recommends utilizing the makerspace for project-based learning.	Present phenomena and allow students to create questions based upon that. Have them figure out how to answer those questions. This would be through research, investigations, visuals, and creating models.	Ms. Burris recommends alternative teaching methods and the utilization of play-based learning, even for older students. She wants to keep away from sit-down lectures, and not have students sit for more than 30 minutes. Allow them to bring fantasy into it, this keeps them engaged	"We find that the activities that engage our visitors the most are hands-on and open-ended. By open-ended, we mean that there are multiple ways a visitor could engage in the program or exhibit."
Accessibility	At the farm, Students have the opportunity to learn at their own speed. They can develop in the way that suits them best.	The farm is about celebrating differences and changing approaches to learning	X	Turn Back Time is an inclusion program. make no assumptions about children that come to the farm.	As described in the Experience Design Document, she outlined the many ways the Acton Discovery Museum incorporates accessibility in their exhibits.
Healing	Turn Back Time is about healing and learning from nature	Outdoors reduces stress, and has many benefits for one's mental and physical health	Understanding the world around them can instill a love for learning in students. Teach them to be good	X	X

			problem solvers because Knowing how to solve problems, when faced with difficulty, leads to much less stress.		
Emergent Curriculum	Emergent Curriculum is hands off (as in, with less direct involvement by a teacher) learning, where the students' interest emerge naturally.	X	Do not teach just one way and keep activities student-centered and let them guide their own learning.	Emergent curriculum: taking the interests of the child and teaching to that.	X
Learning in nature	Turn Back Time offers a way for kids to be present in nature. It is important to foster connection to nature, but not everyone has that opportunity	Outdoors reduces stress. Learning can feel more creative, fun, enjoyable without stress/pressure	X	Everything would ideally be done outside.	X

Table 4: Completed Comparative Table for Interview Data

Finding 1: In order to increase engagement, students "should be presented with a problem or certain phenomenon" that they are working on. Donna Lynn Taylor, the Assistant Director of Professional Development at the STEM Education Center says that students "should be presented with a problem or a certain phenomenon" and explains the benefits of using problem/project based learning to teach STEM. Project based learning was consistently lauded by my other interviewees. Ms. Baker, an educator at Turn Back Time, responds positively to project-based learning. She says as follows: "The farm is a great source for project-based learning, identifying problems, and identifying solutions." Professor Stoddard, the Director of the Farm Stay Project Center, in my interview with her, described elements of the farm that incentivise project based learning. For example, she described the makerspace on the farm, its potential for hands-on learning, and how education in a nature-focused environment produces beneficial results in students. Speaking of those benefits, Professor Stoddard explained that because the outdoors allow for a stress-free environment, learning can feel more fruitful for the students. Professor Stoddard's suggestions influenced me to utilize the Geodome in the curriculum. However, it was not just in the interviews. After visiting the EcoTarium and the Acton Discovery Museum, I observed how they mainly utilize interactiveness in their exhibits to present STEM concepts to youth.

Finding 2: Numerous interviewees also noted the importance of students guiding their own learning. Ms. Taylor emphasized the importance of students guiding their own learning, in which they would create their own models and simulations based upon their own observations. To support this finding with more evidence, at both site visits, I observed how they allowed for students to learn on their own accord. At both the EcoTarium and the Acton Discovery Museum, they have exhibits at which they motivate children to experiment on their own. For example, the EcoTarium hosts an exhibit that explains very basic principles in fluid dynamics. It shows that wind and water move in currents, and challenges children to prove this concept by experimenting with simple objects such as paper plates and cups. This is only one exhibit out of many. EcoTarium also has various problem solving stations that challenge children to create their own creative solutions to solve the problems presented. These include exhibits named: "Vibration Lab", "Train Tracking", "City Hot Zones", and "Maps and Models". Each of these example exhibits showcase different concepts and problems, but require children to use a skill set not often utilized in the school setting. The Acton Discovery Museum shares a similar approach. For each of the sections in the museum, they provide an “Exploration Learning Guide”. Within that pamphlet, the educators encourage the children to engage with the activities and what to look for in the process of doing so. They provide questions, but expect the children to understand the solutions for themselves through their own exploration. They also encourage children to reflect on what they learned during their time manipulating the given apparatus and experimental process. Rather than regurgitation and testing, children are presented with problems facing the real world that require critical thinking to solve. They are not rewarded with a meaningless, vague grade for their work, but a sense of organic satisfaction. A quote from Ms. Taylor provides useful context for this concept, “giving them (students) a purpose for learning something is really powerful.” The question I had asked was: how can learning be a therapeutic experience? In addition to that quote, Ms. Taylor expands on the importance of giving students a meaningful educational experience through the implementation of student-centered learning. Being a NASA Network of Educator Astronaut Teacher with over fifteen years of teaching experience, Ms. Taylor’s aforementioned insights were essential in helping me shape the educational framework of my curriculum.

Finding 3: Play is an important aspect of the learning experience, both for younger and older learners. I had an interview with Lisa Burris, an educator and the Executive Director at Turn Back Time where she assisted me with shaping the learning outcomes and her ideals for a curriculum at Turn Back Time. About the use of alternate learning methods, Ms. Burris said to keep activities play-based even for the older students. After reflecting on this insight, I was reminded of how the Acton Discovery Museum engages both children and adults in their play-based “Bessie’s House” exhibits. Adults are encouraged to be active participants, because they play their own role in the learning process. In my observations during the site visits, both the EcoTarium and the Acton Discovery Museum utilize problem, project, and play-based learning in their exhibits. As shown in the table below, I summarize the similarities and differences between the EcoTarium and the Discovery Museum's approaches to teaching STEM subjects to children.

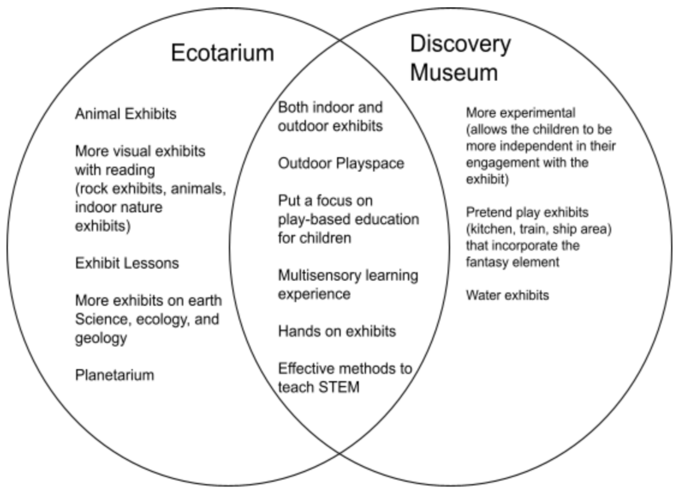

Table 5: Completed Venn Diagram for Site Visit Data

They both have indoor and outdoor exhibits, an outdoor playspace, exhibits that utilize problem-based learning, hands-on engagement, and experimental education. The EcoTarium has animal exhibits, a planetarium, and has more exhibits relating to earth science, ecology, and geology. On the other hand, the Acton Discovery Museum has sections dedicated to pretend play, and more playground areas, both inside and outside. To elaborate more on the pretend play at the Acton Discovery Museum, it has three exhibits that cater to the fantasy aspect of learning: "Bessie's House: Diner", "Bessie's House: Train Room", and "Bessie's House: Ship Room". On the Acton Discovery Museum website, they explain the importance of pretend play when it comes to learning and the development of project solving skills. "Pretend play helps children process the world in their own way, develop their large and small muscles, and practice important thinking skills" (Discovery Museum, 2020).

As I examined those areas, I was reminded of Ms. Burris' aforementioned emphasis on play and the importance of the fantasy element. Each of those exhibits require children to apply STEM skills to complete certain tasks. Whether the purpose was to use math to calculate the cost of a bill at the mini cashier, or building a model of a railroad, children practice valuable skills, both social and STEM related, through pretend-play and immersive activities. After the site visits, I further understood the direction I wanted to take my curriculum.

II. Curriculum Considerations

Finding 4: The MA STEM standards are important to follow when creating the curriculum. Developed by the Massachusetts Department of Education, the 2016 Science and Technology Engineering Framework outlines STEM standards for schools in the Commonwealth. I mention this because all of my interviewees said that MA STEM standards are useful and should be followed. For example, both Ms. Baker and Ms. Burris advised that I consult them for reference and that they follow them while creating new activities at Turn Back Time. As such, I made sure to include which MA STEM standards each activity fulfills in my Turn Back Time astronomy curriculum handout.

Finding 5: After speaking to the Turn Back Time educators, I understood the significance of the emergent curriculum. In my interview with Ms. Baker, she describes Turn Back Time's lessons as being based on an "emergent curriculum" approach. When I asked Ms. Burris a question about that very subject, she described an emergent curriculum as:"taking the interests of the child and teaching to them." She also says it incentivises scaffolding, which is the principle that older students will teach the younger students. In sum, they learn from each other, and further their understanding of the concepts together, in a different sort of collaborative experience. This is very similar to Ms. Taylor's model of teaching, in which she encourages students to explore their own questions, and build upon their own knowledge themselves. As such, in my curriculum, I developed the activities in such a way that they build on each other. For example, Students learn about the sun, its movements in the sky in the *sundial* activity, then learn about the climate and seasons in the garden activity, and, finally, students learn about constellations (which are groups of stars) in the constellation activity. As mentioned above, these activities also fit in with the MA standards.

Finding 6. As well as an effective setting for STEM learning, the Turn Back Time farm intends to work as a vehicle in the therapeutic process. Turn Back Time caters to at-risk individuals, as in, those who are neurodivergent or underprivileged. As such, my curriculum seeks to incorporate the healing aspect of the TBT farm experience with the interactive educational elements of project, problem, and play-based learning. Ms. Baker, in her answers, explains how nature is not only a vehicle for learning, but healing as well. Ms. Taylor explains that students need to learn with a "purpose", and that giving them that purpose when educating them, can have impactful effects. She also reiterates the important life skills problem based learning can support as well and that understanding the world around them can provide them both a love for learning, and a love for life. When students are adequately taught how to solve problems, she says, they can go through life with less stress and worry because they know how to handle themselves. In my curriculum, I keep in mind the nature aspect of the farm, as well as the importance of developing problem-solving skills.

Turn Back Time's motto is as follows: 'Let nature be your teacher', and as such, the Turn Back Time farm is a center for nature based education. All interviewees who work on or in tandem with the TBT farm agree that nature engagement is one of the most essential aspects of TBT lessons. “TBT offers a way for kids to be present in nature,” says Ms. Baker. Ms. Baker also goes on to explain that TBT offers children to have an experience with nature when they otherwise cannot due to their living situation. Professor Stoddard of the WPI Farm Stay Project Center explains that being outdoors reduces stress and allows for learning to be more fruitful and effective. When designing the elements of my curriculum, I kept these aspects of the Turn Back Time farm in mind. In accordance with Ms. Burris’ request that students shouldn’t sit down for longer than 30 minutes and that activities should focus on the outdoor aspect, I created lesson plans that allowed for the students to learn concepts in astronomy through nature.

The student-centered, accessible elements are an integral aspect of my curriculum. Interviewees (all experienced educators) were asked: How would you go about teaching STEM to a younger audience? As such, they are in agreement that when activities provide a multi-sensory experience and when students learn on their own, they are more likely to engage with the material. In the interviews with Ms. Baker and Professor Stoddard explain that the TBT farm is a place where difference is celebrated and learning is revamped in a way to cater to everyone, especially non-traditional learners. Ms. Baker says “they are allowed to develop and learn in a way that suits them (the student) best. Ms. Leahey of the Acton Discovery Museum, in my interview with her, outlines the necessary accessibility aspects that they take into account when designing programs and spaces. She mentions having tables with adjustable height, and chairs with varying heights around the museum. Following these examples, I committed myself to make the curriculum as accessible as I could. For example, I created an alternative for each activity if certain students have sensory troubles, specifically touch sensitivity. Furthermore, I created activities that were able to be worked on independently if a student preferred to do so. I also made my activities low-stress and relaxing without unintentionally taking away from the educational aspects.

III. Curriculum Development

In this section of the findings chapter, I introduce my curriculum and give a brief overview of each activity I developed. I created three activities for the curriculum and corresponding information sheets for each. The design for each of the activities was heavily influenced by my findings above, and I will explain how in the following explanations.

The purpose of my first activity, named "Sundial", is for students to create their own sundials using nature materials they gathered from around the farm. From there, they'd use the sundial to tell time based upon where the sun is at any given point during the day. Corresponding to the activity, the students learn why the sun moves across the sky and what the sun is. I use the nature component from Finding 7 with a hint of play-based learning, as described in Finding 3. While outside, students would be able to pretend they are the ancient astronomers of the past and study space based upon simple observations.

The second activity, "Garden" is again based in nature oriented learning to teach astronomy concepts. The purpose of the activity is for students to choose from a group of seeds, and plant them according to the season. They will be encouraged to do research on their chosen seed and choose accordingly. Students will then have their own journals to record the growth. This activity focuses on how seasons work and how they affect climate.

"Constellations" is the third activity. There, students will utilize the makerspace in the Turn Back Time geodome and create 3D printed models of constellations. Every student will be assigned one of the major constellations, and from there, they will research the constellation, where it is in the sky, model it in Tinkercad, and then print it. If the Tinkercad is not operational, then the students will use nature materials. At the end of the activity, the students will work together to place the constellations accordingly, creating a map of the sky, before explaining their research.

Recommendations

1. **Pilot Curriculum**

    My first recommendation to the Turn Back Time farm would be to pilot the curriculum. Due to time constraints, I was not able to conduct testing. As such, it would be fitting if the activities were tested with Turn Back Time youth in order to get their feedback as well. I recommend piloting the curriculum, observing how students engage with the activities, and inquiring about their opinions. As Ms. Burris mentioned before, I want to keep the activities student centered and able to be reworked, if needed, based upon student sentiment.

2. **Additional Assistance with Curriculum**

    I want to keep in touch with the Turn Back Time farm even after this project term. I am willing to create more activities for the curriculum and assist with the implementation process as needed. There were many ideas of mine that I wasn't able to include in the final deliverable due to time constraints. So, I would like the opportunity to expand upon them and hopefully elaborate on the curriculum.

Conclusion

This project was about creating a curriculum based upon the Turn Back Time learning standards and educational practices. I incorporated elements and relevant insights given to me by my interviewees and site visits. I created a curriculum with three highly detailed activities that touched upon the official Massachusetts STEM educational standards as well as the findings from my research. From there, I combined Turn Back Time's nature-based setting and astronomy concepts to create an engaging curriculum rich with potential for innovative, hands-on learning. Through this experience, young students will have the opportunity to engage with STEM concepts through astronomy and experiential, project-based education.

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Appendices

Appendix A

- Please tell me about your affiliation with the Farm Stay Project Center and Turn Back Time.
- What do you find most exciting about the farm?
- Tell me about how the farm is an effective learning environment?
- How would you go about teaching STEM subjects to a younger audience?
- Do you have a sense of any specific learning outcomes I should focus on when I develop this curriculum?
- Do you feel a project/problem-based learning approach can work on the farm?
- How have past curriculums been integrated into the farm setting and farm activities?
- Have you seen any examples of curriculums that you found particularly successful that I should look at?
- Is there anyone else you recommend that I speak with?

Appendix B

My name is Watts Herideen-Woodruff and I am a student at Worcester Polytechnic Institute (WPI) working with Professor Elisabeth Stoddard and Professor Corey Dehner on a project to develop an astronomy curriculum for students grades third to eighth at Turn Back Time (TBT). TBT serves underprivileged and neurodiverse youth and combines education and therapeutic processes. I am grateful for your participation. Please know, however your participation in this project is voluntary and you may withdraw from it at any time. There is no risk associated with your involvement. If you are comfortable, I would like to include your name and employment in my final report, but will keep your identity confidential if you prefer. Please let me know what you are most comfortable with.

Appendix C

- How would you go about teaching STEM subjects to a younger audience?
- Project based learning, collaboration, and outdoor time are all aspects I want to incorporate into my curriculum. But, what should I prioritize?
- From your observations, which activities have engaged students the most in STEM subjects?
- How do you think learning can be a therapeutic experience?
- How do you try to get students fascinated with a subject, more specifically, how should I teach astronomy to make it as exciting as I can?
- What do you think of the activities I have developed so far?
- Furthermore, do you have any suggestions for how I can incorporate astronomy subjects with nature?

Appendix D

- How do you keep your children in mind when working on the Turn Back Time initiative? And, in what ways have they shaped the mission statement and objectives?
- What is your process for developing new activities for the farm?

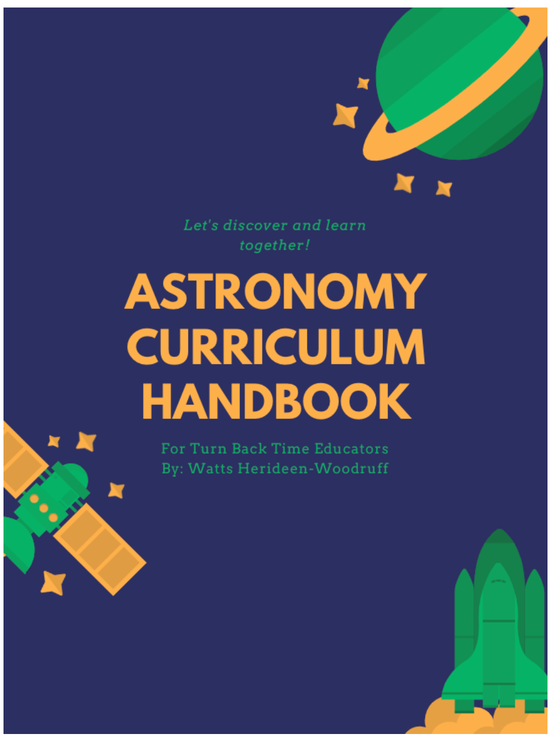
- Because I am creating a curriculum that I hope to pilot at TBT, I'd love to hear about your expectations for a curriculum. Are there any specific learning outcomes that you would like me to focus on?
- How do you balance accessibility and engagement in farm activities/curriculums?
- What have you discovered that effectively engages children in the learning process?
- What is your ideal pace for a curriculum at TBT?
- What is the ideal balance between classes and outdoor activities?
- How do you evaluate new activities and to determine how successful they are?
- Do you have any suggestions for how I can incorporate astronomy subjects with nature?
- Can you describe an 'emergent curriculum' and how this is used at TBT?

Appendix E

- Can you tell me about your process (and/or the museum's process) for developing new activities/exhibits at the museum?
- Do you identify learning outcomes in conjunction with development of new activities/exhibits? If so, can you tell me about them?
- From your observations, which activities have engaged students the most in STEM subjects?
- How do you evaluate new activities/classes to determine how successful they are?

- There is a sundial at the discovery museum. How has that been incorporated with the classes? I ask this because I plan to incorporate a sundial activity in my curriculum.
- How do you incorporate accessibility with the classes, exhibits at the museum?
- Have you seen any examples of curriculum that you found particularly successful that I should look at?
- Is there anyone else you recommend I speak with?

Appendix F



ACKNOWLEDGMENTS

Date Submitted:
May 4, 2022

Relevant Contributors:
Thank you to Professor Dehner, my advisor, and Professor Stoddard, my sponsor, for providing guidance and advise through the development process.

Table of Contents:

ACTIVITY 1: SUNDIAL

Purpose:
Students will create their own sundials using nature materials from around the farm.

Skills Developed:
- Crafting
- Nature exploration
- Creative designing
- Material knowledge

Materials:
- There are no specific material requirements because the students will choose for themselves.
  - For the educators: provide images of sundials for the students.
- If a student has touch sensitivity, provide separate materials (see page 7).
- Compass

Instructions:
For the educator, follow the link: **https://www.britannica.com/technology/sundial** for supplemental information about sundials. Show example of DIY sundials for the students to reference: **https://www.starhop.com/blog/2020/4/16/at-home-stem-activities-make-a-simple-sundial-tk54y-khjr7**

- For this activity, students can choose to work in teams or alone. If students want teams, educators are encouraged to pick them randomly.
- Begin the activity early in the morning, anywhere between 9:00AM-12:00PM to give enough time for testing.
- Allow students to roam the farm and pick out materials on their own. They can use materials from the classrooms, but encourage them to find nature materials.
- Advise them on suitable materials if necessary. Provide them with diagrams and images of sundials to reference. This is supposed to be an open-ended activity, so students can use what ever is available to create the sundial.
    - The base can be anything from a paper plate, to a large piece of bark. Though the surface should be quite wide.
    - The students can indicate the hours using anything from painted rocks to drawing on the base.
    - The gnomon (the time telling devise) can be, for example, a straw, leaf, stick, or pencil.
    - They can put the materials together using glue, string, putty, etc.
- What I listed above are suggestions, but the goal is for the students to think creatively and be resourceful with materials.

- When the students finish collecting materials, have them begin building their sundials in open areas with the sun visible and minimal shadows.
- When they're ready, pass out compasses to each group. Have them point the compass to the North, and instruct them to indicate that by marking the sundial with '12' (as shown in the example).
- If students need help, come and guide them as necessary.
- Have students, if they're comfortable, share their design process with everyone.
- During different times of the day, have them use their sundials to tell the time and notice how the sun shifts positions in the sky.

Time Approximation: 55 mins
Search for materials: 15 mins
Creation: 25 mins
Sharing: 15 mins

- Present questions to the students such as (answers are provided on page 8):
    - Why does the sun move across the sky? Why do we see it in different times during the day?
    - Why does it appear to rise and set?
    - What exactly *is* the sun?

Learning Objectives:

- Understand the position of sun in the sky and what that means.
- Observe and use evidence to describe that the Sun is in different places in the sky during the day.
- Use those observations of the Sun and show that it rises in one part of the sky and sets in another.

MA STEM Standards:

- PreK-ESS1-2(MA)
- 1-ESS1-1
- 5-ESS1-2
- 5-ESS1-1

Sundial Information:

- A sundial is one of the earliest methods humanity used to tell time.
- It reveals the time of day based upon the sun's position in the sky.
- The sundial consists of the gnomon, the gnomon shadow, and the dial. (see the Britannica link above)
- As the sun moves across the sky, the shadow will point to the corresponding hour on the dial, which tells the appropriate time.
- The use of a gnomon, itself, dates back to around 3500 BC.

ACTIVITY 1

ALTERNATIVE FOR ACCESSIBLITY

As stated before, if a student has certain touch or sound sensitivities and prefers not to use nature materials, this serves as an alternative.

Materials:

- Paper Plates (any sort of disposable plate)
- Sharpie Pen/Dark Marker
- Straw, Pencil (any sort of thin cylindrical object)
- Protractor
- Ruler
- Compass

Instructions:

- For this activity, students can choose to work in teams or alone. If students want teams, educators are encouraged to pick them randomly.
- Follow the instructions shown in the example on page 3.

ACTIVITY 1

RELEVANT INFORMATION FOR EDUCATORS

Why does the sun move across the sky?

- The sun is not technically moving in the sky, rather it is the spinning of the Earth.

Why does the sun rise in one place and set in the other?

- The sun rises in the east and sets in the west. This is because the Earth rotates counter-clockwise.

Why does the Earth spin?

- According to scientists, around 4.5 billion years ago, the Earth formed from dust particles orbiting the newly formed sun. Overtime, they clumped together to form the planets, astroids, and moons we see today. It used to spin very fast, but because of the forces of the moon, sun and other celestial objects, it slowed the Earth's spin overtime.

What is the sun?

- The sun is a star, a big, hot, glowing ball of superheated gasses. It appears larger than the others in the sky because of how close it is to Earth.

ACTIVITY 2: GARDEN

Purpose:
Students will grow a variety of plants using seasonal and climate concepts.

Skills Developed:

- Gardening/Agriculture
- Problem solving
- Research skills

Materials:

- Seeds
- Laptops (to look up information about seeds)
- Books about seeds, plants, and gardening
- Writing materials (pens/pencils)
- Pots for planting seeds
- Soil
- Journal
- Ruler or other measuring devise

Instructions:

- For this activity, students can choose to work in teams or alone. (If students want teams, educators are encouraged to pick them randomly).
- Provide the students with a large variety of seeds (This can be any sort of flower or vegetable seed).

- Have students research the seeds and decide which ones would be the best to plant depending on the weather conditions/season at the time of conducting this activity.
- Provide students with pots filled with soil for them to take home. In their journal, they should record the best places to set their respective pot, how much watering it requires, and specific needs the plant requires to grow.
- Overtime, students track their plant's growth using their journal. They should record all observations (how much it grew, if it stopped growing (and why), has it blossomed/budded etc)
- On a biweekly basis, students should share their results with each other and the teacher.
- Students should discuss what they did right, what they could improve on, what they could have done differently, etc.
- Upon completing the activity, students are encouraged to share with family/friends.

Learning Objectives:

- Understand seasonal patterns and how it affects seasonal temperature, climate patterns, and the environment.

MA STEM Standards:

- 1-ESS1-2.
- 8.MS-ESS1-1b.

ACTIVITY 2

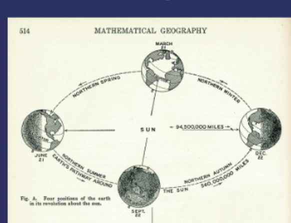
RELEVANT INFORMATION FOR EDUCATORS

Why do we have seasons?

- Seasons occur due to the tilt of the Earth. We do not rotate straight up, instead it's on an angle (23.5°). For example, in December, the sun shines less on us (in the Northern Hemisphere), and more on the Southern Hemisphere. As such, we in New England have winter while those in South America have summer.

How do seasons affect the climate?

- The temperature shift, associated with the change of seasons, affects weather patterns across the world. This is why hurricanes, tornadoes, and blizzards are more common in a certain times of the year.



For Reference:
https://www.britannica.com/science/winter-solstice

ACTIVITY 3: CONSTELLATIONS

Purpose:
Students will create their own models of a constellation using materials from the Geodome Makerspace.

Skills Developed:
- Design
- Technology Familiarity
- Research Skills

Materials:
- Laptops
- 3D Printer (and filament)

Instructions:
- Each student will be assigned a constellation (this is an individual assignment).
- Students will research their given constellation. They should understand:
  - The history of the constellation.
  - What its named after (and why).
  - Where it is in the sky and when one can see it.
- To create a physical model for their constellation, the students will utilize the Geodome Makerspace and its 3D printer. They create model in TinkerCad on a laptop and print it (Provide help if/when necessary).
- All the students should work together and put them all together to create one big model of the night sky.
- Students will explain their constellation and discuss their research.
- If Tinkercad doesn't function, students can use sticks and glue/strings and paint over where the stars appear on their constellation

Learning Objectives:
(as per the MA STEM Education Standards) Students should:
- Earth and the solar system are one of many in the Milky Way galaxy. Furthermore, students should understand there are millions upon millions of star systems and star clusters, as well as the sheer scale of our galaxy.

Time Approximation: 90 min
Initial Research: 20 min
Modeling: 30 min
Sharing: 40 min

MA STEM Standards:
- 6.MS-ESS1-5(MA)

List of Major Constellations: (For educators)
- https://stardate.org/nightsky/constellations

ACTIVITY 3

RELEVANT INFORMATION FOR EDUCATORS

What are constellations?

- Constellations are groups of visible stars in the night sky that early astronomers connected to form figures, which they then named after mythological characters. There are 88 recognized constellations. However, we cannot see all of them in the sky at once.
  - Based on their understanding of seasons and Earth's tilt from the previous activities, ask students why this is.

What is a star?

- Have them recall what they learned about the sun before answering.
  - Answer: stars are big, glowing spheres of super heated gasses, made up of mostly hydrogen and helium. Not every star looks like ours. They can come in different sizes and colors! That is dependent on how the star formed, its size, temperature, and where it is in its life cycle.

What is a galaxy?

- Galaxies are supermassive objects that contain billions of stars and massive amounts of gas, held together by gravity (the same force that makes things drop to the ground). Like stars, they can come as different shapes and sizes too!
  - Galaxies are part of big clusters in the universe, just like how, in our galaxy, stars form clusters.
  - This shows just how tiny we are in compared to the universe.

MA STEM STANDARDS

PreK-ESS1-2(MA). Observe and use evidence to describe that the Sun is in different places in the sky during the day.

1-ESS1-1. Use observations of the Sun, Moon, and stars to describe that each appears to rise in one part of the sky, appears to move across the sky, and appears to set.

1-ESS1-2. Analyze provided data to identify relationships among seasonal patterns of change, including relative sunrise and sunset time changes, seasonal temperature and rainfall or snowfall patterns, and seasonal changes to the environment.

5-ESS1-1. Use observations, first-hand and from various media, to argue that the Sun is a star that appears larger and brighter than other stars because it is closer to Earth.

5-ESS1-2. Use a model to communicate Earth's relationship to the Sun, Moon, and other stars that explain (a) why people on Earth experience day and night, (b) patterns in daily changes in length and direction of shadows over a day, and (c) changes in the apparent position of the Sun, Moon, and stars at different times during a day, over a month, and over a year.

6.MS-ESS1-5(MA). Use graphical displays to illustrate that Earth and its solar system are one of many in the Milky Way galaxy, which is one of billions of galaxies in the universe.

8.MS-ESS1-1b. Develop and use a model of the Earth-Sun system to explain the cyclical pattern of seasons, which includes Earth's tilt and differential intensity of sunlight on different areas of Earth across the year.

Source:
https://www.doe.mass.edu/frameworks/scitech/2016-04.pdf