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Roots And S.T.E.M.: A Greenhouse Science Curriculum

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ROOTS AND S.T.E.M.

A GREENHOUSE SCIENCE CURRICULUM

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To my interns at Urban Roots. You inspire me every day.

"Teach the student to see the land, to understand what he sees, and enjoy what he understands."

— Aldo Leopold, *The Role of Wildlife in a Liberal Education*

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Thank you to Chris, who continues to support me and my crazy ideas every day. Thank you to all the brilliant teachers I have worked with, at Highland Park Senior High, St. Paul Central, Washington Technology Magnet, and Twin Cities Academy who mentored me, taught me how to teach, and to ask the hard questions.

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CHAPTER ONE

Introduction

Overview

I am studying greenhouse and garden curricula and academic content. I will be examining curricula from many types of gardening and agriculture programs, curriculum writing models, and the established benefits of garden education in order to create a greenhouse curriculum that fits the needs of our after school program at Urban Roots. There are two profound gaps I have identified in current available curriculum. One is in accessible, highly engaging material in the high school biology curriculum, and the other is a need for hands-on greenhouse agriculture/horticulture curriculum for high school aged students. Therefore, this capstone project presents a greenhouse-based curriculum for an after-school program for high school students. The curriculum includes highly engaging lessons focused on teaching the scientific method and best practices to care for plants. In the following paragraphs, I will tell the story and set the scene about how I arrived to discover these gaps, and the intention for writing this curriculum. The question that guides this project is: *how do I design a winter greenhouse curriculum for our high-school aged after-school internship program at Urban Roots that will be highly engaging, increase scientific understanding, and make our interns better farmers*?

A Changing Biology Curriculum

In 2004 I graduated from college with a biology major. In 2014 I taught AP Biology. In the ten years that passed, so much changed in biology that I had to learn most of the curriculum for the first time before teaching my students. I have such fond memories as a 15-year-old biology student learning zoology and classification, ecology and plant biology, slowly making sense and finding order of the seemingly chaotic world around me. Most of these topics were absent from the curriculum by the time I began teaching. While working at an environmental education center in Ely, MN I learned the names of the plants and the trees all around, and all of a sudden the forest felt familiar. Later I travelled to New Zealand to ride my bicycle around the country. I looked into the forests and did not recognize anything and felt so unsettled that I immediately bought a giant plant identification guide that I deemed so important, I carried it on my bike for four months in order to feel more comfortable in a foreign world. Understanding the natural world can provide both great power and great comfort to humans. I noticed when I became a biology teacher in 2012 that these wonders of classification and zoology were completely absent from the high school biology curriculum. Ecology was reduced to three weeks and animal and plant biology were almost absent, while cell and microbiology consumes 19 out of 33 Life Science academic standards at the high school level (MN Department of Education, 2009). A study done on biology curricula across the United States in 2005 verified the claim that we are in fact teaching much less macrobiology and much more microbiology (Chessman, Swails, Chessman, French, & Thomas, 2007; see Chapter Two for more details on this study). My worry is that the magic that I felt in my high school biology class is gone from today's curriculum, that the beauty of the world becoming colored and familiar as one learns the names and behavior of plants and animals is missing from the biochemistry and microbiology curriculum. While we are doing a good job of training future geneticists, an explosive field of study, we may be reaching fewer students. Furthermore, we might never inspire those future geneticists because they'll never cultivate a love for biology in the first place. The average age of the Minnesota farmer right now is 55 (University of Minnesota, 2018). We need to do better work to hook future biologists, not to mention future farmers. I think one way we can do this is to teach our youth how to grow food and plants when they are young. Agricultural education is highly engaging (see discussion in Chapter Two) and has many research-supported benefits to the mind, body, and community (Larson 2014).

After three and a half years of teaching the biological sciences in St. Paul Public Schools, I left the classroom to return to the outdoors, to teach youth how to farm in urban areas. To me, our work is science in action. It is tangible, accessible, and relevant. Still, in an informal poll, more than half of our youth rated themselves as below average in their abilities in science. I notice through casual conversation with our interns, as well as during our "Green Your Mind" science sessions in the summer, that many of them struggle in their science classes in school and with some of the basic concepts of science. Therefore, I also want to write this curriculum to help our youth do better in their science classes. I believe that, through their work at Urban Roots, they already have a better science understanding than most youth their age and with this curriculum I hope to help them realize that. I hope to engage them in content I already know they are interested in and incorporate science, particularly the scientific method, so that when they go back to their science classes in school they feel they are already experts in their own niche.

Programming Need at Urban Roots

Urban Roots is a non-profit on the East Side of St. Paul whose mission is to provide access to healthy food and nature to all people. Urban Roots currently employs 60 youth interns with some sort of barrier to employment each summer and 20 interns each school year. Thirty of those youth work at least part time in our Market Garden Program, a fully-operational urban farm that produces 13,000 pounds of produce each year. Currently, however, our programming is still restricted by the growing season Minnesota offers. During the summer, we are able to provide youth with 8-24 hours of work per week; however, once the school year begins we are restricted to two three-hour shifts per week (with the exception of the Saturday farmers market in the fall). Historically we have taken a break in our programming during the winter for the lack of outdoor work available.

For years we have simply not offered winter programming. Through youth feedback, we learned that this left them searching for other jobs to pay their bills in the meantime. In response, we began to offer winter programming that was certainly enriching but more of a class than a job. I wanted to create a meaningful curriculum that would not only make our youth better employees year-round, but also help improve our production in some way. Metropolitan State University and our director at Urban Roots potentially offer a solution to this problem of winter programming. For four years they have been working together to raise funds to renovate a shuttered greenhouse that is between Metropolitan State and Urban Roots property into a research center/greenhouse/classroom/community gathering space called the GROW-IT center. Construction for the GROW-IT center, **G**ateway for **R**esearch, **O**utreach, **W**orkforce development, **I**nnovation, and **T**eaching, will break ground this April of 2019. The center is scheduled to be ready for use by fall of 2019. A letter of intent was written in March of 2018 for funders and all stakeholders outlining the GROW-IT center project describing the history, goals, impact, and partners of the GROW-IT Center. This letter can be read in Appendix A.

Urban Roots' use of this greenhouse through the curriculum I am developing will address, to some degree, almost all of the eight proposed goals of the GROW-IT Center, particularly: 1. Increase educational opportunities, 2. Propagate plants, 3. Expand workforce development opportunities, and 6. Enhance local E-12 STEM education. One of the main objectives of my curriculum will be discovering, through experimentation, the best methods for germinating seeds in order to have efficient production come spring time. We will also be looking at a variety of other factors affecting plant growth in order to make our youth better able to understand the growing methods we use, and thus make them better farmers. I am excited to be a part of such a broad-reaching and impactful project and hope that this curriculum is only the beginning of the ways we will be engaged with the GROW-IT Center.

The Agriculture Curriculum Gap

I have also discovered through this research that there are curricula available for elementary age youth in garden programs and for vocational horticulture for post-high school students, but not much in between. The curricula that are available are designed for the classroom and not the greenhouse. University-level horticulture programs likely would have pieces of their curriculum that could be used for these purposes, but there is no access to that curriculum for the general public. I discuss many examples of the above types of curriculum in Chapter Two. Therefore, this capstone project presents a greenhouse-based curriculum for an after-school program for high school students. The curriculum includes highly engaging lessons focused on teaching the scientific method and best practices to care for plants.

Conclusion

It seems that in this country, the biology curriculum is changing. The major areas of study we are losing are the highly engaging topics of zoology, plant biology, and ecology. I believe that in order to recruit both future scientists and farmers, we need to offer more of these accessible areas of study to our young students. Agricultural education seems like a great place to start. Even within agricultural education, the Urban Roots setting seems to be unique in that the training we offer is hands-on and engaging (similar to some elementary school garden curricula) but also high level, like vocational horticultural training. Because of the amazing, soon-to-be-built GROW-IT Center project, we will soon be able to offer this type of programming year-round. I hope that through designing a winter greenhouse curriculum for Urban Roots we will be able further engage our youth in science and agriculture,making them both better scientists and farmers.

In Chapter Two, I review the literature on the gap in today's science education, the highly engaging nature and benefits of agriculture education, the academic content I will include in the curriculum, the existing garden curriculum, and the curriculum design process. In Chapter Three, I go on to explain my methods, an outline of the curriculum and the setting where this curriculum will be rolled out. Chapter Four provides a reflection of this whole process.

CHAPTER TWO

A Review of the Literature

Introduction

This chapter examines existing research and curricula. In the subsection, "A Gap in Science Education," the need for qualified employees in the areas of STEM and agriculture is discussed. Despite this need, science education seems to be less and less engaging. Many studies have been published regarding the "Highly Engaging Nature of Urban Agriculture Education." This subsection discusses the researched social, emotional, physical, and academic benefits of gardening and agriculture, claiming that this could potentially fill this need for highly engaging science education. The following subsection, "Greenhouse Curriculum Content," refers to experts in the field to begin to determine which topics would fulfill this goal of creating highly-engaging, informative curriculum. "The Available (or lack thereof) Curriculum," examines available agriculture curriculum and assesses its viability for the purposes of this project. Finally, in "Curriculum Design," the practical and theoretical influences for this particular curriculum are explained. This chapter should give the reader a thorough understanding of the gap in current science education and available agriculture curricula, as well as theory and resources that will inform the making of a curriculum that will be highly-engaging, increase scientific understanding, and make Urban Roots interns better farmers.

The guiding question for this project is: *How do I design a winter greenhouse curriculum for our high-school aged after-school internship program at Urban Roots that will be highly engaging, increase scientific understanding, and make our interns better farmers?*

A Gap in Science Education

The importance of STEM (Science, Technology, Engineering, Mathematics) education is well documented. The U.S. is falling behind international competitors in science and technology innovation (Kennedy, 2018). The job market is demanding more and more employees with STEM experience while STEM scores in the U.S. are dropping (Havice, 2015; Kennedy, 2018). STEM-related jobs in the U.S. have grown three times faster than in other professions (Schiavelli, 2011) but there are not enough workers to fill these jobs. Furthermore, people of color are severely underrepresented in STEM careers (Williams, 2013), likely due to factors such as: school district funding disparities, stereotype threat, and premature departure from high school (Musesus, Palmer, Davis, & Maramba, 2011).

Although written by a greenhouse manufacturer, and thus having the potential for bias, the article, “Rewarding Horticulture Careers Take Root in Greenhouse Training,” outlines careers that are available to students who learn the foundations of agriculture and horticulture early in education greenhouses or school-yard gardens. Gothic Arch Greenhouses lists career possibilities including production and sales, public garden management, marketing, research, teaching, industry support, inspection, landscape construction and management, landscape design, communication, and pest management (2017).

Despite this high need for people in the fields of STEM, the national biology curriculum is changing to include less engaging, less accessible material, thus inspiring fewer youth to go into the field of science. In fact, in a survey of college biology departments reviewing courses required for a biology degree first in 1990 (n=204) and then in 2005 (n=403), they found that there has been a 31% decrease in departments requiring physiology and a 49% decrease in those requiring zoology, while in contrast there a has been a 333% increase in biology departments requiring biochemistry (K. Chessman et al., 2007). Yet the National Research Council (2002) thinks that undergraduate education has not been transformed enough to meet the needs of the bursting field of research biology even though personal observation has shown that in young children, plants and animals are an accessible, engaging hook into the field of biology. While biochemistry is indeed fascinating to some, as educators, we made need to reexamine whether it is reaching as many students as we would like.

The active and learning by doing nature of STEM education makes it feel particularly engaging and relevant to students. Through it they can expect to learn real-world connections and skills. Not only is it good for students, but it is also good for communities as these types of jobs are said to be the wave of the future (Havice, 2015).

The STEM employee gap is not the only science-related job deficit in this country. According to the University of Minnesota (2017), the average age of the Minnesota farmer is 55. Something is needed to hook and engage diverse youth to fill these high demands in American STEM and agriculture fields. The following paragraph gives evidence as to why agriculture education addresses these gaps and provides an engaging entry point into the fields of science and agriculture.

Highly Engaging Nature of Urban Agriculture Education

Using a garden as a classroom and tool for learning has well-documented benefits. Perhaps gardening education has the capacity to fill the hole in our current curriculum, finally hooking in future biologists and farmers again. Larson, in his book *Teaching in Nature's Classroom* (2014), compiles the studies behind this idea. The following sub-sections summarize Larson's compilation:

"Let the Garden Be the Teacher." Larson discusses the magic of discovery in learning when stepping back and letting what is happening in the garden guide the lesson plan. This is the "teachable moment" (Havighurst 1953) happening each day as the garden reveals its own curriculum.

"Make it Hands-On." Here Larson describes hands-on learning as similar to experiential learning and discusses how the process leads to deeper and longer-lasting understanding. Additionally, as Chawla and Davis (as cited in Larson, 2014) describe, it creates an emotional bond, and increased likelihood that children will eventually be stewards of their environment.

"Let Kids be the Gardeners; Build Self-Efficacy." By letting youth take the lead, they can benefit from making mistakes and being active, rather than passive, learners (James & Bixler, 2008; Rahm, 2002). Larson describes how when kids are given the space to take the lead, they gain confidence and self-esteem. Teachers still need to provide scaffolding, however, so that youth can experience success in their learning.

"Build a Diverse Learning Community; Make Connections to Home and Community; Cultivate a Sense of Place." Larson (2014) explains how working in horticulture creates a space that brings people together. Gardening is very nostalgic for many people. Research by Boullion and Gomez; Finn and Checkoway; Hazzard; Moreno; Beall and Zidenberg-Cherr; and Rogaoff, Matusov, and White (all as cited in Larson, 2014) all support the idea that people of all ages, socio-economic statuses and cultures can connect in growing food together. This connection is beneficial and creates a learning space for all parties involved. Gardening connects people with their community and can create a sense of pride in place. Growing food creates a valuable product that benefits the community.

"Cultivate a Sense of Wonder; Engage the Senses." The sense of wonder Larson is talking about is genuine curiosity and inquiry-driven education. As research by Cosco and Morre and Louv (as cited in Larson, 2014) shows, the appeal to the senses that the garden provides helps hook this curiosity and deliver a "multimedia" experience that solidifies memory. The temporal lobe of the brain is the area responsible for both smell and memory. Scientists think that this may be why certain smells bring back such strong memories.

"Immerse Yourself in Nature; Engage with Worms, Bees, Chickens and Other Animals." There are also few places where a person finds themselves hugging tomato vines to grab that ripe tomato that is hard to reach, hands up to the wrists in soil to get to the bottom of that quack grass root, or eye to eye with a bumblebee to study the little pockets of pollen it's collecting from your squash flowers. Gardening provides an intimacy with nature that is hard to match. This intimacy has been shown to lower stress and provide relief for people with ADHD (Wells & Evans, 2003; Taylor et al. 2001); the same can be true working with animals.

"Engage Kids in Meaningful Fitness & Work *and* Play in the Garden." Authentic fitness and activity happens in gardening (Larson, 2014). There are no forced push-ups or repeat sprints in gardening; physical activity happens organically. Doing real work and physical activity in the garden is part of what makes growing things so fun for kids. They're not just "playing house"; they are doing the real thing.

"Cultivate a Connection to Food." Larson has experience with children who otherwise completely avoid vegetables, eating tomatoes fresh off the vine, or kale straight off the plant. He talks about the excitement and pride of youth eating veggie wraps from food they have grown themselves. These observations of increased affinity to healthy food after work in urban agriculture is supported in studies by Gatto, Ventura, Cook, Gyllenhammer, and Davis; McAleese and Rankin; and Ratcliffe, Merrigan, Rogers, and Goldberg (as cited in Larson, 2014).

“Utilize an Integrated Curriculum.” The garden is a brilliant backdrop for not only science curriculum, but also math, the arts, social studies, and even language. Agriculture has a connection to all these disciplines. Integrated, project-based curriculum has been shown to have positive and substantial learning gains (Krajcik, McNeil, and Reiser, 2008).

Larson is not the only one who writes about the extensive benefits of gardening. A study done by Tufts University on youth participating in 4-H, an elective after-school program grounded in agriculture, showed that 4-H youth excel beyond their peers. The study showed the following (J. Lerner, R. Lerner, J. V., 2013):

- 4-Hers in grades 7-12 are nearly four times more likely to make community contributions
- 4-Hers in Grades 8-12 are about 2 times more likely to be civically active
- 4-Hers in Grades 10-12 are nearly 2 times more likely to participate in science programs during out-of-school time
- 4-H girls are 2 times more likely (Grade 10) and nearly 3 times more likely (Grade 12) to take part in science programs compared to girls in other out-of-school activities
- Grade 7 4-Hers are nearly 2 times more likely to make healthier choices

The benefits for youth in agriculture education are well-documented and may very well be the missing part of the biological curriculum and what is needed to inspire future food growers. At Urban Roots, the site for which this curriculum is designed, strong urban agriculture programming takes place during the summer. The organization is now looking at extending the "learning season" and all its benefits through the winter because of a soon-to-be renovated greenhouse. The following paragraphs will examine the specific benefits of working in a greenhouse.

The University of Minnesota's Regional Sustainable Development Partnerships (RSDP) teaches the concept of Deep Winter Greenhouses (a type of greenhouse that uses passive solar heating and underground rock bed, soil, and drain tiles to store heat; this is not the type of greenhouse that will be built at Urban Roots, but the idea still applies) to farmers as a means of increasing value to the whole farm, extending the growing season in a cold climate and creating an educational opportunity where the community can come together (Braatz, 2017).

Urban Roots hopes to use urban agriculture programming, enhanced by a rich greenhouse curriculum to engage youth in order to help them become better farmers, biologists, and human beings.

Greenhouse Curriculum Content

As this researcher has never managed a greenhouse, other experts in the field must be called upon to find out what good topics of study in a greenhouse might be. First, Mark Asplen, Associate Professor of Biology and an entomologist at Metro State, says that the greenhouse is the perfect place for conducting biological study since it is large enough to simulate real-world conditions, unlike a test-tube, but has the ability to control environmental variables like temperature, water, and humidity (personal communication, October 2018).

Ussery (2007) provides a very useful basic greenhouse management guide. He gives advice in his article about greenhouse structure, caring for the soil, and winter growing strategies. The winter growing strategies outlined below are most useful in this application.

In greenhouses growers need to be careful to not over-fertilize leafy plants because this can lead them to build up unhealthy levels of nitrates (Ussery, 2007). This happens because when plants convert nitrogen to useful amino acids *when they are growing*. The key here is that last phrase, *when they are growing.* In winter months, when the sun is shining less than 10 hours per day, plants go into a dormant state in which they either stop growing completely or grow very slowly. However, the soil is generally warm enough in a greenhouse that the roots are still functioning, sucking up the nutrients, including nitrogen, from the soil, thus, building up unhealthy, even toxic levels of nitrates in the leafy greens. What farmers can do to avoid such a situation is simply use actual compost as fertilizer instead of liquid nitrates. Compost releases its nitrogen slowly, and even more so in cold weather, while if using a liquid fertilizer all the nitrogen is available to the plant immediately. This should be closely watched if growing vegetables hydroponically (Collie 2013).

Ussery (2007) says not to worry if plants droop after a cold night. He explains that plants adapt to survive freezing temperatures by moving their water out of their cells into intracellular space so that the freezing won't burst the cell walls. This causes the cells to go flaccid and the plant to droop. In part because of this survival strategy it is best to water plants in the morning, when the plant has plenty of time to dry before potential freezing and to water deeply occasionally rather than a little each day.

Another major component to growing success in greenhouses is air movement (Ussery, 2007). Since there is no natural air movement, the oxygen immediately around plants can actually build up and prevent plants from getting the CO_2 that they need.

The main strategy to winter growing has to do with timing plantings in order to solve the problem of decreased daylight. This problem is talked about in many greenhouse growing guides (Coleman, 2009; Ford, 2017; Ussery, 2007). As discussed above, when daylight dips below 10 hours a day, plants go dormant or decrease growth dramatically. So, in the first half of winter, the benefit of a "Deep Winter Greenhouse," which is a passively heated greenhouse that attempts to limit its consumption of fossil fuels and maximize the vegetable output, is not really to extend the *growing season,* it's to extend the *harvest season.* In Minnesota there are fewer than ten hours of daylight between around November third and February sixth. Therefore, in this growing zone crops should be planted in August or September in order to reach almost maturity before this photoperiod date. Then the plants can stay fresh and ready to harvest while growing very slowly. New crops can then be seeded when these mature plants are taken out that will do little but sprout to then be ready for vigorous and accelerating growth come

February 6th. During this dark period, days from seed to harvest has been shown to increase two to three times, depending on how often the plant experiences below freezing temperatures (Coleman, 2009). The final design of the GROW-IT center indicates that it will be heated year-round, which will increase production; however, it will still be subject to these principles of photoperiodism. At this point, the main purpose for the greenhouse during the months of December, January, and February will be education, not production, but these principles are important for every grower and biologist to understand. Eventually Urban Roots may move to some winter production in the GROW-IT Center, so research by the youth about how to grow winter crops may be an important entrepreneurial endeavor.

These same sources share comprehensive lists of vegetable crops that grow well in winter greenhouses. The following is a table was created from information in Ford (2017) that inform the curriculum:

Table 1. *Crops That Grow Well in Deep Winter Greenhouses in Minnesota*

Diminishment Season (Oct.-Dec)	**Solstice Season (Dec- early Feb.)**	**Expansion Season (Early Feb.-April)**
• Arugula • Astro Arugula • Carlton Komatsuna • Summerfest Komatsuna • Bulls Blood beets • Golden beets • Wrinkled Crinkled Cress • Red Veined Sorrel • Hon Vit • Tatsoi • Mizuna • Mustards ○ Green Wave ○ Scarlet Frills ○ Ruby Streaks ○ Garnet Giant	• Arugula • Astro Arugula • Carlton Komatsuna • Summerfest Komatsuna • Bulls Blood beets • Golden beets • Wrinkled Crinkled Cress • Tokyo Bekana • Red Russian Kale • Tatsoi • Mizuna • Mustards ○ Green Wave ○ Scarlet Frills ○ Ruby Streaks ○ Garnet Giant	• Arugula • Astro Arugula • Carlton Komatsuna • Summerfest Komatsuna • Bulls Blood beets • Golden beets • Wrinkled Crinkled Cress • Tokyo Bekana • Spinach • Hon Vit • Tatsoi • Mizuna • Mustards ○ Green Wave ○ Scarlet Frills ○ Ruby Streaks

○ Red Giant ○ Carlton ● Claytonia ● Minutina ● Red Russian Kale ● Johnny's All-star Lettuce Mix ● Mai Qing Pac Choi ● Joi Choi ● Purple Pac Choi ● Hakurei Turnips ● Broccolii: DeCicco ● Broccoli Raab ● Champion Collards ● Bright Lights Chard ● Kale ○ Winterbore ○ Starbor ○ Toscano ● Red Oak Leaf Lettuce ● Green Butter Lettuce ● Fenberg Romaine ● Breen Red Romaine	● Johnny's All-star Lettuce Mix ● Johnny's Wildfire Lettuce Mix ● Broccoli Raab ● Mai Qing Pac Choi ● Joi Pac Choi ● Purple Pac Choi ● Chinese Cabbage	● Claytonia ● Minutina ● Johnny's All-star Lettuce Mix ● Johnny's Wildfire Lettuce Mix ● Hakurei Turnips ● Alpine Daikon Radish ● Sessantina Grossa Raab ● Minuet Chinese Cabbage ● Any leaf lettuces ● Small head Romaine

Purdue University (2018) publishes a website called, “Greenhouse Management Guidesheets”. It provides links to peer-reviewed articles published by universities around the country with titles like, “Spring Greenhouse Bedding Plants: Insect Mite and Disease Management,” “Disinfecting the Greenhouse,” and “Greenhouse Production.” There is a wealth of information here that could be helpful for troubleshooting as experiments are rolled out in the greenhouse.

Perhaps the piece of literature that most informs this research is called, “Guide to School Greenhouses” (Beliveau,1995). The instructions are clear and straightforward and the ideas are plenty. Lesson ideas include: keeping a growing journal, measuring the effect of shade on temperature, forcing branches of blossoming trees, and starting seedlings for a plant sale. See Appendix D for the comprehensive list.

Beliveau (1995) even gives advice on how to start from cuttings; begonia, coleaus, geranium, impatiens, ivy, philodendron, tomato, or wandering jew are some of the best species to use. She explains how to remove all but the top few pairs of leaves from the cutting, place in soil, optionally apply a rooting hormone, put a put plastic bag around the plant, since high humidity is important for rooting, leave for at least a week, and then tug gently on the plant. When there is resistance, they have roots ready for transplanting.

All of these pieces from expert greenhouse growers will come together to inform the content of a highly-engaging curriculum that will make Urban Roots interns better practitioners in the field of agriculture.

The Available Curriculum

In searching for examples of curriculum this researcher has been coming up short. There are a variety of resources available but each seem to specialize in one piece of the objective for this study, but there is nothing with all of the components together. In particular, this is intended to be an after-school, hands-on, greenhouse curriculum that is designed for high-school aged students with some vested interest in agriculture. It should have elements of fun, science, and agriculture. None of the curricula encountered contains all of these elements. The following paragraphs contain a review of available curriculum.

Perhaps the most relevant is the *Guide to School Greenhouses: Growing Ideas* by Beliveau (1995), as it is a guide to writing curriculum in an educational greenhouse.

However, it is just a guide, not a comprehensive curriculum and written more specifically for an elementary age audience. Some concepts can transfer to high school aged youth, but not all. It is also only available in microfiche, an outdated medium.

Minnesota Nursery and Landscape Association (dates published between 2016-2018) provides a comprehensive and accessible high school horticulture curriculum with units in careers; botany and plant growth; design and installation; garden center basics; landscape and turf management; and plant materials. Each unit is divided into 1-10 lessons, each containing a PowerPoint slideshow, lesson plan, and sometimes a script available to download. Each lesson is planned to take anywhere between two and fifteen hours and is connected to MN state standards. There are pieces of this curriculum that I think would be useful for our programming, but it is too extensive for just one winter season, and not lab-based or designed to take place in a greenhouse.

In the Wisconsin School Gardens Network online library (2018) there is a search program that allows the user to search lessons and materials based on topic. Here there are links to many sources. "Wisconsin Ag in the Classroom" (www.wisagclassroom.org) is one example. Most of the curriculum available here is geared toward big commodity agriculture careers or elementary age students. "Toward a Sustainable Agriculture" (www.cias.wisc.edu) has a curriculum with relevant material regarding sustainable systems. The lessons, however, are very specific and not greenhouse related. The "School Garden Wizard" (www.schoolgardenwizard.org) has fun ideas to do with elementary age kids in a school garden. Links on this page teach how to do everything from nature journaling (lancaster.unl.edu/nature-journaling-youth-activity), to square foot gardening (www.mysquarefootgarden.net), to garden songs and games (https://us7.campaign-archive.com/?u=de183d3fbb459b209137418c7&id=7e12f9de5f Wisconsin School Garden Initiative). The majority of these resources have highly engaging content, but is designed for an elementary school audience.

The Georgia Agricultural Education website (http://georgiaffa.org/curriculum/topic.aspx?ID=7&TID=89) has some greenhouse curriculum content. They have an entire page of PowerPoint slideshows dedicated to greenhouse operation and management. Slideshow topics include, "Greenhouse Transplants," "How to Trim a Bonsai Tree," and, "Fertilizer Injector Installation." As evidenced by the last title, the intended audience seems to be more conventional, larger-scale growers or horticulturists who are going to work managing a greenhouse. Some of these themes will work for our youth, but the niche we are looking for is a blend of accessible/fun activities, science, and practical growing skills. It seems that there are curricula available for each of these different genres but none blended together, focused on the greenhouse, or age and program appropriate.

Lafayette University of Southwestern Louisiana published *Greenhouse Management Curriculum Guide for Vocational Agriculture/Agribusiness Curriculum Development* (1987). This curriculum includes the following units: Producing Annual Bedding Plants; Foliage Plants; General Greenhouse Management; Poinsettia Production; Vegetable Bedding Plant Production: Tomatoes, Peppers, and Eggplants; Production of Potted Chrysanthemums; Flowering Pot Plants; and Foliage-Type Hanging Baskets. The curriculum is designed for 11th and 12th graders who are intending to go into the profession. This curriculum is age-appropriate and has some units that would be relevant, but doesn't quite have blend that would reach the particular audience at Urban Roots.

The person who perhaps modeled urban agriculture education best is urban farm icon, Will Allen of Growing Power in Milwaukee, Wisconsin. "Growing Power", with a mission of supporting people from diverse backgrounds in an urban area to gain access to healthy food and learn about healthy lifestyles through understanding food systems (www.growingpower.org), is the program most similar to the one at Urban Roots. At one time Growing Power composted more than 40 million pounds waste annually, had over 200 varieties of crops on 300 acres of land, and worked hard to provide equal access to high-quality food to diverse communities. Sadly, in 2017 the doors of the Growing Power greenhouses were locked and program abandoned due to multiple lawsuits for $500,000 of unpaid bills. Allen used to do inspirational workshops around the country, however, he never published any of is curriculum. This is a new reason to write this curriculum, as perhaps it will be the resource that other urban farm educators are looking for.

It seems that there is much agriculture curricula written, however, none that is specifically designed for high-school aged youth, in a greenhouse after-school program, that focuses both on science and highly-engaging content.

Curriculum Design Theory

This curriculum will be designed with influences from *Understanding by Design* (Wiggins & McTighe, 2006), *Integrating Differentiated Instruction and Understanding by Design* (Tomlinson & McTighe, 2006), and *Teaching Secondary School Science-Strategies for Developing Scientific Literacy* (Bybee, Powell, & Trowbridge, 2008).

The basic principle of *Understanding by Design* is to first identify the objectives, then to decide how growth in those objectives will be evaluated, and then finally create lessons that will teach those objectives and prepare students to be successful in the chosen evaluation method (Wiggins & McTighe, 2006). The overarching philosophy of their work is backward design; looking first at the goals of the unit and then designing a unit to meet those goals. The authors note that when we truly understand a concept, we are able to:

1. *Explain*- share facts, data, examples etc. about a topic
2. *Interpret*- make the topic relatable to a particular audience, provide meaning
3. *Apply*- use the knowledge gained in another situation
4. *Have perspective*- take in multiple points of view
5. *Empathize*- understand what how others might feel negatively or positively about a topic based on their direct experience
6. *Have self-knowledge*- be aware of bias

It is suggested that all these types of understanding be considered when designing a unit and particularly evaluation.

Researchers say that simply delivering good curriculum is, however, not enough; that additionally educators must consider the individuals that make up the classroom. Educators are told to connect content and kids by incorporating "Understanding by Design" and "Differentiated Instruction" (Tomlinson & McTighe, 2006). Tomlinson and McTighe provide many tables with tips on how to be a more responsive teacher by selecting instructional strategies that respond to diverse student need and encourage deep thinking. They describe the WHERETO model for a teacher to reflect on a curriculum and be sure it is responsive. The WHERETO model is summarized as follows:

Table 2. *WHERETO model.*

W-What/Why	What are students learning, why are they learning it, and what will be evidence to show their learning.
H-Hook	How will the teacher hook and engage their learners and connect content to student interest?
E-Equip	How will the teacher equip students to succeed and meet objectives?
R-Rethink/Revision/Refine	How will the teacher help students to rethink, revise, and refine old ways of thinking on their journey to new understandings?
E-Evaluation	How will the teacher promote students' self-evaluation and reflection?
T-Taylor	How will the teacher tailor learning activities and teaching to address the different readiness levels, learning profiles, and interests of students?
O- Organized	How will the learning experiences be organized to maximize engaging and effective learning? What sequence will work best for the students and content?

Bybee, Powell and Trowbridge (2008) round out these three influences with a specifically scientific perspective. Using inquiry and constructivism as a primary method of teaching science is a main theme in this work. The authors claim that teaching science for understanding is of the utmost importance. The text is rich with researched-based instructional strategies and teacher self-reflection activities. Through the influence of these three works, this curriculum will be grounded in researched-based educational theory and curriculum design.

As has been established through the investigation of research and available curricula, there is a gap in engaging, accessible science education and greenhouse curriculum for high-school aged youth. Through the examination of what experts in the field of greenhouse horticulture and education have to say, this researcher will develop a highly-engaging, scientific, and agricultural curriculum for this particular population. This research will be driven by the question, "*How do I design a winter greenhouse curriculum for our high-school aged after-school internship program at Urban Roots that will be highly engaging, increase scientific understanding, and make our interns better farmers?"*

Conclusion

In this chapter the current gap in engaging science curriculum was explored. This led to a discussion about the well documented, highly engaging nature of agricultural education. Then the current curriculum available in agriculture education was researched and reported upon. It was seen that there are a variety of curricula available but none fit the particular needs of the Urban Roots youth and GROW-IT center. Finally, curriculum design theory was explored in order to be sure that the new greenhouse curriculum is designed with education best practices.

The next chapter will describe the framework for this particular curriculum. The reader will see, in greater detail: a general outline, curriculum design, MN state standards, objectives, the setting, participants, instructional strategies, formative and summative assessments, and materials.

CHAPTER THREE

Project Description

Research Question

How do I design a winter greenhouse curriculum for our high-school aged after-school internship program at Urban Roots that will be highly engaging, increase scientific understanding, and make our interns better farmers?

Introduction

This chapter contains a framework for the curriculum itself. In the following subsections, first an outline explains the desired results, then expected evidence for achieving those results is discussed, and finally the learning plan to make that happen is proposed. The sources for the curriculum design are shared in the second subsection. The third subsection relates Minnesota state science standards to lessons in this curriculum. In the objectives subsection, the big ideas, enduring understandings, essential questions, and related standards are broken down for each lesson. The long term and short term objectives for the entire unit are also included here. The setting is an important piece of this curriculum. In this section the neighborhood, program, and greenhouse where this curriculum will take place are described. The participants are the other key inspiration for this curriculum. These youth are described in the sixth subsection. Instructional strategies for how the lessons will be carried out are described in subsection seven. In subsection eight, formative and summative assessments are described with an example. Finally, materials for each unit are listed in subsection nine. This chapter is intended to provide an overview of what is found in the curriculum and how the curriculum was written to be approached.

Setting

The setting of this particular curriculum is one piece that makes it unique. This curriculum is designed for a high-school aged after school program that has access to a greenhouse. Our particular program, Urban Roots, is a non-profit founded in 1968 with a mission of empowering youth leadership and development through the lenses of urban farming, conservation, and healthy cooking. Urban Roots resides in the Dayton's Bluff neighborhood on the East Side of St. Paul, where 44% of households have an income of less than $35,000, 35% of neighbors are White, 15% Black or African American, 32% Asian, and 12% Hispanic, more than half of households are rentals, and median household income has dropped since 1999 from $49,649 to $38,827 (Minnesota Compass, 2018).

In the summer, Urban Roots employs 60 youth across our three programs, and around 20 continue with us throughout the school year. Our "Cook Fresh" program takes place in the kitchen of our building. The Conservation program does most of their restoration work in local parks and natural areas, while also installing rain and pollinator gardens in smaller green spaces throughout our part of the city. The Market Garden program has six garden sites all within a mile of each other, together totalling a space of one acre. In that space we have grown over 13,000 pounds of produce in both 2017 and 2018.

This curriculum is intended for the Market Garden Program in order to provide meaningful, high-quality work and programming year-round. For several years, Urban Roots has been partnering with Metropolitan State University to gain funds in order renovate the shuttered greenhouse that resides on university property immediately adjacent to the Urban Roots offices. The $1.7M project has been named the **GROW-IT** Center, **G**ateway for **R**esearch, **O**utreach, **W**orkforce Development, **I**nnovation, and **T**eaching. Appendix A contains a document written by the GROW-IT design team describing the project.

Participants

This curriculum could be used for any after-school program for youth ages 14-18. It will likely be most successful in programs that youth have some background or interest in science or agriculture.

In my particular case, youth in the Urban Roots after school winter session are the focus of my curriculum. These youth are Urban Roots employees via Right Track, a city-funded program that employs high-school aged youth (ages 14-18) based on the qualification of having one or more barriers to employment. Barriers could include but are not limited to: low income, time in foster care, being an English Language Learner, having parents with addiction, etc. The youth in this program have spent at least one summer working at Urban Roots in the Market Garden Program. In this progressive program, the youth have spent their summer performing all aspects of urban farming, including planting, tending to plants, harvesting, processing vegetables, and processing and delivering orders. Youth spend more hours each week and gain more and more opportunities each year they return to the program. The first year they are called "Seed Crew," work eight hours per week, and focus on learning the basics of farming. The second year participants are called "Grow Crew," work 15 hours per week, and begin to learn to teach younger youth. In their third year, youth are called "Harvest Crew," and receive 18 hours per week to hone their leadership and mentoring skills. Harvest Crew also have an offsite career field experience. Finally, the highest achievable position at Urban Roots is the "Harve*star,"* this position is chosen based on work ethic, leadership and dedication.

Each week in the summer, the youth have a one hour course called "Green Your Mind," where they engage in activities to learn about topics like plant identification, weed identification, plant nutrients, soil texture, soil toxins, food systems, garden insects, and more. Beyond this one hour per week, the science behind farming is currently just taught through teachable moments.

Curriculum Outline

This is a 16 week winter greenhouse curriculum with one three-hour session per week, designed for high-school aged students in an after school urban agriculture program.

Table 3*: Curriculum outline. This table outlines the desired results, evidence required by the students, and learning plan of the curriculum.*

Desired Results
Long-term: Give youth more background, knowledge and experience in the fields of both agriculture and biology so that they do better in school science classes, demonstrate more confidence and competence as farmers, and become more invested in our spring, summer, and fall programming. **Short-term:** 1. Youth will be able to design and conduct their own experiments testing a variety of factors on plant germination and growth. 2. Youth show increased confidence, understanding, and affinity to/in the following topics, as evidenced by a pre- and post- survey rating their comfort and interest in the topics of a. The scientific method, b. Factors affecting plant growth, c. Farming, and d. Working in greenhouses.
Evidence
1.Growing vegetable plants using methods they learn throughout the unit 2. An improved rating of their own confidence and understanding of the scientific method and factors affecting plant growth. 3. Designing experiments using the scientific method throughout the unit.
Learning Plan
The lessons below include all the main topics in the curriculum, but most take two weeks to run. Generally, weeks later in the unit will be filled with data collection and analysis, while earlier weeks will be learning background, setting up experiments and then caring for plants and tending to experiments. 1. **Introduction to Greenhouses** 2. **Nutrient deficiencies-** Tomato hydroponics- nutrient deficiency experiment 3. **Propagating plants-** i. Basics ii. Propagating plants from the grocery store challenge 4. **Photoperiodism-** Tricking house plants to bloom or grow 5. **Seed Germination-** i. **Effects of seed age** ii. **Variety** iii. **Light** iv. **Water/humidity** v. **Soil medium** 6. **Winter veggie growing**- Grow-a-salad competition 7. **Crop Expert Project**- Summative Project 8. **Greenhouse Plan**- using math and knowledge from seed germination experiment to make a plan for spring starts

Table 4. *Pacing Guide. Titles and pacing of all lessons.*

Week	Topic
1	Intro to Greenhouse
2	Plant Nutrients (Tomato Hydroponics)
3	Salad Contest
4	Crop Expert Project
5	Propagating Plants
6	Plant Nutrients
7	Propagating plants challenge
8	Bulb Forcing
9	Seed Germination
10	Seed Germination/Photosynthesis
11	Seed Starting Plan (math)
12	Seed Starting Plan (math)
13	Bulb forcing/ Salad Contest
14	Propagating plants
15	Seed Germination
16	Crop Expert Project

Curriculum Design

My most essential influence for curriculum development is Understanding by Design (Wiggins, Grand & McTighe, 2006). Both the structure and philosophy from this resource are guiding my work. The main idea of Understanding by Design (UbD) is first identifying the desired results of the curriculum, then choosing evaluation methods that would accurately give evidence that those results are met, and then finally deciding on a learning plan that will help students meet all those goals. The table above illustrates such a model. The overarching philosophy is Backward Design: looking first at the desired result, and then deciding on a process that will take students there. All of the tables included in this chapter are from Understanding by Design. The steps in designing a lesson according to Wiggins & McTighe (2006) are as follows:

Stage 1- Identify Desired Results

A. Established Goals:

B. What essential questions will be considered?

C. What understandings are desired?

D. What knowledge and skills will students acquire?

Stage 2- Determine Acceptable Evidence

A. Performance Task Summary

B. What other evidence needs to be collected in light of Stage 1 Desired Results?

C. Student Self-Assessment and Reflection:

D. Rubrics

Stage 3- Plan Learning Experiences

Standards

This is not a standards-based curriculum; in fact, on the contrary, part of the objective of its design to generate content that is not included by the Minnesota Science Standards. However, there are still many standards that are related to this curriculum. Appendix B lists standards addressed by this curriculum.

Understanding by Design helps break down the goals and standards of each lesson by organizing it like so (Wiggins and McTighe, 2006, p. 283):

Table 5. *Big Ideas Table. This table outlines the big ideas, enduring understandings, essential questions, and standards uncovered in each topic.*

Big Ideas	**Enduring Understandings**	**Essential Questions**	**Standards**
Greenhouses	1. Greenhouses work because of the "greenhouse effect." 2. There are several different designs of greenhouses, each with different benefits. 3. There are certain procedures we must follow and tools we must use to keep ourselves and our plants safe and healthy in a greenhouse.	1. Why do greenhouses work? 2. Are all greenhouses the same? 3. How do we manage a greenhouse? 4. What are we doing in this unit?	9.1.3.1.3 9.1.3.4.2 9.4.4.1.1
Plant Nutrients	1. Plants need certain nutrients in order to survive. 2. Hydroponics is a method we can use to test this claim. 3. The scientific method is an organized way of doing experiments.	1. What happens to plants if they don't have one of their major nutrients (N, P, K, Ca)? 2. How do you grow plants using hydroponics? 3. How can we test a claim using the scientific method?	9.1.1.2.1 9.1.3.4.4 9.4.1.1.1
Ideal Growing Conditions (Crop Expert Project)	1. Different crops require different growing conditions. 2. How to design an experiment to test for one variable.	1. Which growing conditions do my crop like best? 2. How do I design an experiment to test one variable.	9.1.1.2.1 9.1.3.4.2 9.1.3.4.4 9.4.1.1.1
Winter Greenhouse Veggies (Salad Contest)	1. Certain veggies grow better in the winter in the greenhouse than others.	2. What veggies can I grow in 2.5 months in the winter in a greenhouse to make a salad? 3. If we ever do a winter CSA, what could we grow for it?	9.1.1.2.1 9.1.3.4.2 9.1.3.4.4 9.4.1.1.1
Bulb Forcing	1. Bulbs are a food storage organ for plants. 2. Bulbs can be forced to grow out of season with the proper techniques..	1. Why do plants have bulbs? 2. How can we get bulbs to grow flowers for valentines day?	9.4.1.1.1 9.4.2.2.1

Plant Propagation	1. Just like animals, plants have organs that work together to maintain homeostasis. 2. Many of these organs can be used to propagate new plants via mitosis.	1. Do plants have organs? Can you name them? 2. Is a seed the only part of a plant that can be used to grow new plants?	9.1.1.2.1 9.1.3.4.4 9.4.1.1.1 9.4.3.2.2
Seed Germination (Part 1)	1. Germination is the process of seeds growing into plants. 2. Seed variety and age can affect germination rate. 3. Soil medium can affect germination rate.	1. How do seeds work? 2. Will different varieties of the same species germinate at different rates? Will our seeds from last year grow as well as our new seeds? 3. What is the best soil medium to use for germination?	9.1.1.2.1 9.1.3.4.4 9.4.1.1.1 9.4.3.2.2
Seed Germination (Part 2-Photosynthesis)	1. Reactants for photosynthesis are CO_2, H_2O and light. Products are O_2 and sugar. 2. Amount of light/day can affect germination rate. 3. Watering technique and amount can affect germination rate. 4. Because plants are green, the absorb blue and red light best.	1. What do plants need for photosynthesis? 2. What is the best amount of light for germination? 3. What is the best way to water our seeds? 4. How much light do our seeds need? 5. If photosynthesis is happening in plants, will there be more oxygen nearer to the plants?	9.1.1.2.1 9.1.3.4.4 9.4.1.1.1 9.4.1.1.2 9.4.1.2.5 9.4.2.2.1 9.4.2.2.2
Spring Seed Start Plan	1. Math is needed in order to figure out how many plants are needed for a farm. 2. More calculations are needed to figure out what resources are needed to grow the desired number of plants. 3. A timeline must be carefully devised in order for plants to be ready for start dates. 4. The conclusions we drew in the seed starting experiment will inform this plan.	1. How do we figure out how many of each plant we need? 2. How do we figure out what we need to grow those plants? 3. How do we figure out when to plant what? 4. How do we apply what we learned to do the best possible job of seed starting?	9.1.3.4.2 9.1.3.4.3

Instructional Strategies

Each of the lessons will be lab- and inquiry-based. There will be an instructional portion at the beginning, generally with slides in order to teach background and methods to a topic, and then we will move out to the greenhouse and do lab and inquiry style projects. Some, especially at the beginning, will be more guided, and others will be more youth-centered. Students will record notes, experiment structures, findings, and reflections in their growing journals. Students will be provided with templates for experiment design to ensure they are using the scientific method each time they design an experiment.

Formative/Summative Assessments

Formative assessments in this curriculum will be informative, yet informal. Students will have growing journals, where they will write a reflection at the end of each day. This, along with their data collection will be their formative assessments.

Their summative assessment will be the survey given before and after the unit, in which they rate their own confidence and competence in the areas of: the Scientific Method, the practice of farming, the science behind farming, and greenhouse growing. The survey is in Likert Scale and open-ended question format. See **Appendix C** for the summative assessment.

Conclusion

Chapter three has outlined, in detail, the content to come in chapter four. We now see a curriculum outline, objectives that will be met, MN state standards that will be covered, a curriculum design template, who will participate in this curriculum, where it will take place, instructional strategies, and examples of assessments.. The next chapter is a reflection on the process of writing this curriculum.

CHAPTER FOUR

Reflection

Introduction

My project begun with this question: *How do I design a winter greenhouse curriculum for our high-school aged after-school internship program at Urban Roots that will be highly engaging, increase scientific understanding, and make our interns better farmers*? Now that the curriculum is complete I will take this chapter to reflect upon the process, product, and propose the next steps.

In this final chapter I review what I learned throughout this process, the parts of the literature review that were deemed most important in creating this product, possible implications of this research, limitations of this particular project, ideas for future projects, a discussion of how I will use the curriculum and research, and, finally, how this project is a benefit to the profession of teaching, science and agriculture.

What I Learned

Throughout this process I have learned how to write a formal research paper. The extended literature review was the piece that was the newest to me. It was rewarding to discover that many notions I had (that farming is good for you, for example, or that the biology curriculum has changed over the years) were in fact backed by sound research. I will be a more credible practitioner going forward now that I have researched this. It feels good to have done this type of writing and research in my academic career in order to have a better understanding of the research process and review how to gain access to credible information in a world whose access to information has changed dramatically since the completion of my undergrad degree in 2004. I feel that I will now be able to better guide my students through their information gathering endeavors. It has been a long time since I have written a formal reference section in APA format. This was also a helpful exercise in order to become a better teacher of students who will likely need to do the same thing. I was surprised at how much of the capstone was doing background work and writing the formal paper and how little was available for creating the project itself, although it is clear to me that the project is more sound because of all the research backing it.

Specifically regarding my project, I have learned volumes about working in a greenhouse. In my background the only work I have done in a greenhouse is starting seeds for transplants. All the projects in my curriculum I created through research or by applying my own knowledge as a farmer and a scientist. I enjoyed exploring the science topics behind the projects in the curriculum. I learn something new every time I prepare to teach.

I was surprised at how much of what I have learned over the years from colleagues, professional development, or my education classes came into play while writing the curriculum. I really do not think I could have written something like this early in my teaching career. The flow of the lessons, the method of setting up a growing journal, the pacing and judgement of appropriate content for my intended audience, are all products of working with brilliant colleagues or for years in the classroom.

A Review of the Literature Review

The most helpful part of the literature review for writing this curriculum was reviewing other related curricula. It was interesting to see what others are doing (or not doing) in garden education. The most helpful publishing was *Guide to School Greenhouses: Growing Ideas* by Beliveau (1995). The format was excellent for my purposes, as it was just a list of ideas, not a formal curriculum, so it gave me some material to explore and expand upon. Reading greenhouse growing guides (Coleman, 2009; Ford, 2017; Ussery, 2007;) informed me as a farmer and also future greenhouse educator. I was surprised to find how much garden- or agriculture-related curriculum is out there but how little of it pertains to high school aged students working in a greenhouse.

In reviewing science education and careers, I was surprised to find that someone had actually done a study on the changing biology curriculum (Chessman et al., 2007) and showed that while the amount of macrobiology taught in U.S. biology classrooms has decreased, departments requiring microbiology have gone up 333%. I was not surprised to find more evidence that women and people of color are underrepresented in STEM and agriculture fields (Musesus et al., 2011; Williams, 2013).

Understanding by Design (Wiggins & McTighe, 2006) was my essential technical and philosophical guide in writing curriculum. The goals and purpose of the curriculum would not have been so focused and deliberate without it. The book gave me a template for which to create my lessons and objectives.

As a manager at a non-profit, reading about the studies done that support the highly engaging and healthful nature of garden education in *Teaching in Nature's Classroom* (Larson 2014) has and will prove to be powerful in communicating the importance of my work, both to funders and our community.

Possible Implications

It is well documented that women and people of color are underrepresented in STEM and agriculture(Musesus et al., 2011; Williams, 2013). Perhaps more state and federal funding for programs like Urban Roots would increase numbers of youth served in non-profit organizations that focus on STEM and agriculture. It takes more than one lesson to get youth to care about the food they eat and green spaces in their city; it most often takes having a relationship with that food and those green spaces. Then, once a person cares about healthy food and access to nature they can become the policy makers to make positive change. The work we are doing at Urban Roots is science, but science while taking the time to establish a relationship with food, place, and the environment.

This type of programming will hopefully inspire some of our underrepresented youth to go into science fields.

I think this study might also urge us to a look at our biology science standards and evaluate whether they are best serving the needs of the scientific community because while they are providing students with a good background in the ground-breaking field of molecular biology, they are leaving out, or brushing over, other highly engaging fields of study that might hook a population of students that is currently uninspired by STEM.

Limitations

I think there must be some good greenhouse curricula out there, it just seems like it in inaccessible to the common person. There are universities, like the University of Minnesota, that have strong agriculture programs but their curricula are not available to the general public. I both wish that I could have seen some of that curricula and hope that writing this will provide something that is accessible to fill that gap.

I would have liked to have more time to work on the curriculum itself. I had more ideas for lessons that I was unable to complete given the time I had, but am still generally pleased at the scope of the project. Given the nature of the timeline for this project, the publishing is due before I will be able to try the curriculum for myself. I used many teaching techniques that have been successful in my classroom in the past, but these particular lessons have not been tried. I would like to be able to roll them out, make edits, and then do a final publishing, but that is not possible. Perhaps I can figure out a way to add notes or provide a link to an amended version of the lessons once I try them next winter.

Future Projects

With 16 lessons, I have only begun to scratch the surface of great activities and experiments possible in the greenhouse. I would love to create twice as many lesson plans. I would also love to make an amended version once I try out the curriculum in its entirety. It would also be interesting to create some adapted versions that would be more suitable for classroom teachers. The follow-up project with that would be to create a way to evaluate student engagement or likelihood to enter a STEM or agriculture career while doing a classic curriculum or a greenhouse-themed curriculum. It would also be interesting to study what currently inspires students to go into a STEM or agricultural field.

I would also like to create a version of the curriculum that could be used in community education classes. This would perhaps be something that could stand alone, a series of one-time classes.

Based on my research, I would recommend that all teachers find a way to get their students outside, even if it is not for an entire unit, it seems that the benefits of working in nature and in the dirt are bountiful.

The Product

I designed this product to be used in an after school gardening program for three hour sessions once a week for sixteen weeks. The GROW-IT center (which I spoke of in earlier chapters) is scheduled to be ready to use by the end of summer 2019. This means that I will use this curriculum for our after school youth shifts next winter from approximately the end of November until March.

That said, I also believe this curriculum to be very adaptable. Educators can pick and choose the lessons they use if they have less time. They could also do twice-a-week lessons for eight weeks, perhaps with a few other things sprinkled in to allow for some things to grow. I also believe that some of the lessons could be adapted to one-time classes for field trips or community education. Others could be expanded to last longer. I even think it is possible to use approximately one lesson a week for five 50-minute class periods, adding a warm-up and reflection each day, or going into a little more scientific depth about each topic in order to fully meet the Minnesota state standards. I hope the curriculum provides a depth of material that could be used in a variety of ways.

A Benefit to the Profession

I hope that this project is a benefit to teachers, educators, scientists, and people who work in agriculture. My goal is that this curriculum will be useful to both biology teachers and agricultural educators. It is material that could be used in an after school program or in the classroom. It is designed to be highly engaging to youth to spark their interest in the field of biology and agriculture. If that is successful, then this curriculum would also be a benefit to science and agricultural professions, as it may engage a more diverse group of youth to become involved. This is a small step to chip away at that goal, but hopefully if we, as educators, continue to search for ways to provide hands-on, relevant experiences for youth we can begin to engage more youth in the fields of STEM and agriculture.

Conclusion

In this chapter I reflected on the process, product, and proposed the next steps. I discussed the benefits of experiencing the research process and that I learned a great deal about working in a greenhouse. I highlighted pieces of literature that were particularly important in different parts of the process. I discussed possible policy changes and other implications as a result of the study. Both time and lack of access to university curricula felt like limitations of this project. In the future, I would love to create more lessons as well as adapted lessons for different educational venues. The product I created is intended to be used in the Urban Roots after school program but is hopefully adaptable enough that it could be used in the classroom, for field trips, or community education classes as well. I hope that this curriculum will be a valuable resource for educators to inspire their students to become engaged in science or agriculture.

I set out to write this curriculum because I was hoping to make an engaging winter plan for our youth at Urban Roots. Through it, I was able to uncover excellent resources about the benefits of garden education, articles about the underrepresentation of people of color in STEM and the shift to microbiology across the U.S.in biology curricula, and fascinating information about how to grow and care for plants in a greenhouse. I emerge much more informed than I started. I hope that the curriculum I created will be a benefit to the community where I work and strengthen our partnership with Metropolitan State University, as it will be another thing we can offer our community in the GROW-IT center. My biggest wish is that the curriculum will be inspiring to our youth, help them gain confidence in their science skills, and become better and more engaged urban farmers.

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Appendix A. *Letter of intent for GROW-IT Center.*

Metropolitan
State University

Institute for Community
Engagement and Scholarship

Community-University **GROW-IT** Center
March 2018

Overview
The GROW-IT Center will be a community-university urban agricultural Gateway for Research, Outreach, Workforce Development, Innovation and Teaching. Partners envision a year-round learning hub for scientists, students of all ages and community practitioners to exchange knowledge and grow healthy communities. Our purpose is to generate and disseminate best practices in sustainable urban agriculture, healthy food production and access, and ecological preservation, and to inspire and prepare the next generation to address these issues. Primary partners are Metropolitan State University, Urban Roots (East Side St. Paul's largest youth employer), Friends of Swede Hollow (a grassroots environmental, community-building group) and First Lutheran Church (an urban mission-oriented ELCA congregation); many other organizations and academic departments have indicated interest once the facility is constructed.

The Site
The GROW-IT Center is located at 445 Maria Ave on Metropolitan State University's St. Paul campus in the Dayton's Bluff neighborhood. Despite high concentrations of poverty and its federal designation as a food desert, this community is also home to a dynamic range of community groups, leaders and scholars who are committed to the well-being of the East Side through entrepreneurship, agricultural production, food justice and environmental advocacy, neighborhood stewardship, education and service. Since fall 2014, more than 80 community representatives, university departments and leaders, State and elected officials have developed a vision, plan and resources to transform a former Minnesota Dept. of Agriculture research facility (shuttered in 2008) into a shared community-university asset. To date, over 90% of the estimated $1.126M renovation cost has been secured from public, private and university sources.

GROW-IT Center Goals
The Center will act as a catalyst to address eight strategic goals:

1. Increase educational opportunities – *for youth, community members and university students.*
2. Propagate plants – *growing and contributing edible for community-based market gardens, local food pantries and backyard producers alongside and native plants for local ecological restoration.*
3. Expand workforce development opportunities – *in areas such as entrepreneurial food production, greenhouse management, community-based gardening, environmental restoration and aquaponics.*
4. Create and expand associate-to-baccalaureate degree career pathways – *with college partners;*
5. Conduct applied research –*to meet the needs of traditionally underserved partners and local food producers, while contributing to the national discourse on related issues.*
6. Enhance local E-12 STEM education – *in partnership with area youth organizations and local schools.*
7. Strengthen community outreach – *through demonstrations, workshops and continuing education.*
8. Showcase our partnerships –*best practices and reciprocity in community-university work.*

Annual Impact
At minimum, the Center will enhance learning for 4000+ K-12 school youth to college students through youth internships, academic coursework, community education and workforce training. Access to healthy food will improve through increased local production, shared knowledge of community resources, and greater collective action among local food and environmental stewards. More than 1000 lbs./year of fresh surplus produce will be donated to area food shelves. Diverse networks of growers, activists, scientists and policy makers will benefit from applied research and the dissemination of best practices. GROW-IT Center partnerships will strengthen the capacities of local communities and the university.

Metropolitan
State University

Institute for Community
Engagement and Scholarship

Thank you!

The GROW-IT Center is made possible through the contributions of many dedicated individuals from the community and Metropolitan State University, the incredible efforts of the Planning Team and the Design Team, and unwavering support from university and Minnesota State leaders, local funders and several public officials, most especially St. Paul Ward 7 Councilmember Jane Prince, MN Representative Sheldon Johnson, MN Representative Rod Hamilton, MN Senator Foung Hawj and MN Department of Agriculture Commissioner Dave Frederickson.

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Metropolitan State University
Minnesota Department of Agriculture
Minnesota State

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* Also served as a member of the GROW-IT Center Planning Team (October 2014-January 2018)
** Planning Team Co-Chair
*** Design Team Co-Chair

Questions? Ideas? Interested in a meeting, individually or with your group?
GROW-IT@metrostate.edu or Jodi Bantley, 651-793-1294.

Appendix B. *Standards Chart*

Code	**Benchmark**	**Relationship to this curriculum**
9.1.1.2.1	Formulate a testable hypothesis, design and conduct an experiment to test the hypothesis, analyze the data, consider alternative explanations, and draw conclusions supported by evidence from the investigation.	All experiments will follow the scientific method in their design, implementation, and analysis.
9.1.3.1.3	Describe how positive and/or negative feedback occur in systems. For example: The greenhouse effect	The Intro to Greenhouses lesson teaches this phenomenon.
9.1.3.4.2	Determine and use appropriate safety procedures, tools, computers and measurement instruments in science and engineering contexts. For example: Consideration of chemical and biological hazards in the lab.	In designing experiments and working in a greenhouse we constantly need to keep safety of both people and plants in mind, we also need to determine our instruments for each experiment.
9.1.3.4.4	Relate the reliability of data to consistency of results, identify sources of error, and suggest ways to improve the data collection and analysis. For example: Use statistical analysis or error analysis to make judgments about the validity of results	After each experiment we will look at each set of data and have a discussion about the results, looking for sources of error etc.
9.4.1.1.1	Explain how cell processes are influenced by internal and external factors, such as pH and temperature, and how cells and organisms respond to changes in their environment to maintain homeostasis.	All of the experiments we are conducting have the same basic structure; exposing living plants to a variety of external factors to see to which they respond best.
9.4.1.2.5	Compare and contrast passive transport (including osmosis and facilitated transport) with active transport such as endocytosis and exocytosis.	Plant cells become hydrated through osmosis and passive transport. We look at how different watering techniques affect germination.
9.4.2.2.2	Explain how matter and energy is transformed and transferred among organisms in an ecosystem, and how energy is dissipated as heat into the environment.	We are studying light and how it affects plant growth.
9.4.2.2.1	Use words and equations to differentiate between the processes of photosynthesis and respiration in terms of energy flow, beginning reactants and end products.	It is important to understand the photosynthesis equation in order to understand why plants need water, sunlight, and carbon dioxide. We will be testing water and sunlight as variables, and measuring CO_2 concentration near the plant leaves vs. away from the plants.
9.4.3.2.2	Use the processes of mitosis and meiosis to explain the advantages and disadvantages of asexual and sexual reproduction.	Propagating plants from roots, stems, leaves etc. is mitosis and from seed is a result of meiosis.
9.4.4.1.1	Describe the social, economic, and ecological risks and benefits of biotechnology in agriculture and medicine. For example: Selective breeding, genetic engineering, and antibiotic development and use.	We will be growing everything organically. We will talk about the risks and benefits of organic vs. conventional farming.

Appendix C. *Summative Assessment*

Likert Scale Assessment

Name__________________________Date_______

Farming & Science- A survey

On a scale of 1-5, 1 being that you know nothing, and 5 being that you are an expert for your age, and 3 being that you know about the average amount compared to other people your age, how much do you feel like you know about the following topics:

1. The Scientific Method
   a. I understand how to design an experiment using the scientific method
      1 2 3 4 5
   b. I understand how to look and data and draw conclusions
      1 2 3 4 5
   c. I think the scientific method is really interesting.
      1 2 3 4 5
   d. Explain in one paragraph what you understand about the scientific method using words like hypothesis, variable, control, data, and conclusion..

2. The practice of farming
   a. I understand what a person must do to keep plants healthy and growing.
      1 2 3 4 5
   b. I understand what needs to happen in the garden during each season to have a productive farm. (for example, which crops grow when, what you need to be doing in the winter, when it is time to plant etc.).
      1 2 3 4 5
   c. I enjoy farming.
      1 2 3 4 5
   d. Explain in one paragraph how to keep plants healthy.

3. Greenhouses
    a. I understand what greenhouses help us do.
        1 2 3 4 5
    b. I understand what types of plants can be grown in a greenhouse and how to keep them healthy.
        1 2 3 4 5
    c. I enjoy working in greenhouses
        1 2 3 4 5
    d. Explain in one paragraph what you understand about greenhouses and working in them.

4. The science behind farming
    a. I understand what plants need in order to grow. (ie. soil nutrients, sunlight, water, etc.)
        1 2 3 4 5
    b. I understand what plants need in order to *start* growing (to germinate or be propagated).
        1 2 3 4 5
    c. I understand the parts of a plant and how they each help a plant grow.
        1 2 3 4 5
    d. I enjoy learning the science behind farming.
        1 2 3 4 5
    e. Explain in a paragraph what you understand about what plants need to grow and be germinated or propaged.
    f. Draw a picture of a plant labeling its parts and describing how those parts help the plant.

Appendix D. *Greenhouse Lesson Ideas.*

Greenhouse Lesson Ideas

Compiled from Beliveau (1995)

1. **Shadows & Light**
    - Activity: Use popsicle sticks to do shade mapping
    - Lesson: Consider how the size of the shadows is related to the angle of sunlight
2. **The Environment**
    - Activity: experiment with the factors below to see how they affect plant growth
    - Lesson: Light, Temperature, CO_2, Humidity are all environmental factors affecting plant growth
3. **Measuring Light Intensity**
    - Activity: Mapping the sun
    - Lesson: Photoperiodism and sunlight requirements of plants
4. **CO_2**
    - Activity: Measure CO_2 levels in various places around greenhouse in the presence and absence of fans
    - Lesson: If air is stagnant, CO_2 builds up surrounding leaves
5. **The Effect of Shade on Temperature**
    - Activity: Measure temp behind a piece of glass then a piece of cardboard
    - Lesson: Shade, Temp. and their effects of plant growth
6. **Microclimate search**
    - Activity: Measure and record temp throughout greenhouse
    - Lesson: Microclimates
7. **Pests**
    - Activity: Use magnifying glasses to inspect for pests, then control in the following ways:
        - Aphids-squashing, hard water spray, soadspary
        - Spider mites- hard water sprays, predators
        - Whiteflies- soap spray, yellow sticky traps, predators
    - Lesson: How to manage pests in a greenhouse

8. Growing Media

- Activity: Grow containers of different media to compare mixes prepared or made ourselves ⅓ peat moss, ⅓ perlite, ⅓ vermiculite
- Lesson: Discovering which media is best to use for plant starts

9. Keep a Growing Journal

10. Greenhouse treasure hunt

11. Hydroponic experiments

12. Seasonally Specific Activities

- Fall
  - Bulbs for forcing
  - Lichen and moss terrarium
  - Houseplant cuttings
  - Seedlings of cool season crops to put in greenhouse beds
  - Warm season crops sowed in summer
  - Plants retrieved from garden
- Winter
  - Cool season crops
  - Forced branches of pussy willows, apple blossoms etc.
  - Tender perennials
- Spring
  - Seedlings
  - Herbs for sale
  - Houseplant cuttings as above
- Summer
  - Warm season crops
  - Perennials from seed or cuttings
  - Tropical crops

13. Thematic Projects:

- Desert Garden
- Bulb garden
- Simulated rainforest
- Salad or pizza garden
- Economic crops garden (soy beans, wheat)
- Southern crops garden (peanuts, cotton)
- Herb garden
- Butterfly garden
- Sensory garden
- Dye plant garden
- Native American garden