



Establishing an indoor agriculture system at a rural Montana PreK-12 school creates hands-on experiences for college seniors studying horticulture

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RESEARCH NOTE

Establishing an indoor agriculture system at a rural Montana PreK-12 school creates hands-on experiences for college seniors studying horticulture

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Abstract

In 2022, seniors studying horticulture at Montana State University (MSU; Bozeman, MT) had the opportunity to participate in a unique community-based learning project in collaboration with the newly built PreK-12 public school in the rural town of Winifred, MT, to establish the greenhouse infrastructure to be used in curriculum at the school. The new greenhouse facility presented an opportunity for Winifred students to not only gain experience growing vegetables, but also to provide a source of fresh vegetables for school lunches and for community members. This course presented two unique opportunities for the MSU horticulture students: (1) to experience problem-solving horticultural challenges through designing and troubleshooting the setup of the cropping systems for the greenhouse and (2) to participate in a course with a real-world impact on improving food security in rural areas of Montana. Over the course of the semester, the MSU students successfully established the infrastructure for the Winifred School greenhouse, which has continued to be integrated into the curriculum as well as providing fresh produce for students and community members. By the end of the course, MSU students demonstrated program learning outcomes including demonstrating the content knowledge and skills necessary to function successfully in a horticultural career and being able to identify and analyze plant growth problems and develop solutions or strategies to solve those problems.

1 | INTRODUCTION

Community-based learning (CBL) can be broadly defined as a type of pedagogy that engages communities in the learning process (Mooney & Edwards, 2001). These courses center learning around developing relationships in partnership with a community or organization outside of the university.

Courses that incorporate CBL can provide students with real-world problem-solving opportunities and course outcomes that can mutually benefit both students and communities (Shostak et al., 2019). CBL courses focus on students working directly with a local organization to solve community-focused challenges and can have many benefits to student learning, including increased understanding of course material and practical hands-on skills, as well as improved self-esteem and self-confidence (Eyler et al., 2001; Novak et al., 2007). Additionally, CBL courses offer students a chance to be

Abbreviations: CBL, community-based learning; MSU, Montana State University; PGC, MSU Plant Growth Center.

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civically engaged in their communities by working through challenges these communities are facing in real time (Eyler et al., 2001; Parker-Gwin & Mabry, 1998). When students work on real-world problems, they are typically motivated to work harder, grapple with the complexity of the problems, are more accepting of uncertainty, understand issues more deeply, and develop the ability to use material they have learned in new ways (Eyler et al., 2001). Generally, there are three main goals in CBL courses: (1) real-world challenges in which to apply learning; (2) opportunities for reflection and personal growth; and (3) a positive impact on community partners (Shostak et al., 2019). Ideally, students develop equitable and mutually beneficial relationships with community partners to accomplish the overall goals of the project and create outcomes with significance to both students and communities.

Capstone courses are taken by students near the end of their program of study and aim to integrate the concepts they have learned throughout their coursework with practice, in preparation of graduating and entering the workforce. Incorporating a CBL pedagogical approach in a capstone course can provide students opportunities to apply what they have learned throughout their degree program in a real-world context while simultaneously providing valuable outcomes to the community partner (Shostak et al., 2019).

All seniors in the Environmental Horticulture major at Montana State University (MSU) are required to participate in a capstone research experience. These courses are intended to be a culmination of the student's academic experience and challenge students to design, plan, and execute a hands-on experiment or research project in their field. Learning experiences emphasize the qualities of "Effective Communicator" and "Thinker and Problem Solver" and are intended to prepare students for their future careers. Capstone projects in this curriculum often involve CBL, where students work directly with a local community or business to solve real-world horticultural challenges. Our paper outlines a unique capstone CBL research experience for students in the Environmental Horticulture program at MSU working with the PreK-12 school in rural Winifred, MT (Figure 1). The learning objectives for this course were as follows: (1) Be able to identify and analyze horticultural challenges and develop solutions or strategies to solve those problems; (2) Be able to design and execute a horticultural experiment and analyze data; and (3) Be able to effectively present horticultural research through oral and written communications.

In the summer of 2022, construction was completed on a new PreK-12 school in the town of Winifred, MT (47.5578° N, 109.3749° W), close to the geographical center of the state of Montana. There are 172 residents of Winifred (U.S. Census Bureau, 2020), which forms a community that supports the surrounding ranches and cereal grain farms (Figure 1). Funded by a businessman who grew up in Winifred, this

Core Ideas

- Community-based learning can benefit both university students and the communities in which they are working.
- Students participating in the horticulture capstone course gained experience problem solving horticultural challenges through designing and troubleshooting the set-up of the cropping systems for the greenhouse at the school.
- This course led to a real-world impact on improving food security in rural areas of Montana.

school has a focus on industrial arts and agriculture and includes a state-of-the-art greenhouse and vertical garden facility. The new school attracts students from all over Fergus County, resulting in 150 students enrolled for the 2022/2023 school year. MSU was contacted by the school in the summer of 2022 asking whether MSU could provide expertise to establish the greenhouse facilities at the new school. Seeing an opportunity for horticulture majors to both gain real-world experience and develop the greenhouse as a resource for the Winifred School, course instructors developed this opportunity into the capstone course.

Vegetables can be difficult to find near Winifred, MT. While many families garden to provide vegetables for part of the year, the closest full-service grocery store is about 40 miles away, significantly limiting access to fresh fruits and vegetables year round. The new greenhouse facility at the school presented an opportunity for elementary through high school students to not only learn about and gain experience growing vegetables but also to provide a source of fresh vegetables for school lunches and for community members. Despite the new greenhouse infrastructure, the school lacked the expertise to set up and establish the two different indoor



FIGURE 1 Town of Winifred, MT, USA (47.5578° N, 109.3749° W) in 2015. Source: Rwslyivka (2016).

cropping systems within this new greenhouse facility. This presented two unique opportunities for the MSU Environmental Horticulture seniors through a CBL pedagogical approach: (1) to experience solving horticultural challenges through designing and troubleshooting the setup of the two cropping systems for the greenhouse and (2) to participate in CBL and outreach with a real-world impact on improving food security in rural areas of Montana.

2 | METHODS AND IMPLEMENTATION

This capstone is taught as a 3-credit semester-long course for seniors in the Environmental Horticulture major at MSU. In 2022, students were instructed by Dr. David Baumbauer, the Plant Growth Center Manager at MSU, and Brandon Tillett, a PhD candidate in Plant Sciences at MSU. Both instructors have significant experience in controlled-environment horticulture. Also critical to this experience were the cooperation and enthusiasm of the science teacher at the Winifred School, Julie Ewen. This combination of instructor time, commitment, and expertise made teaching this CBL course possible. The class also received funding from a donor for student and instructor travel to cover the 200 miles each way to Winifred, which was crucial to the success of the course.

Learning activities for the class were developed to focus on experiences in a community-based environment and to assess the learning outcomes for the course. A major goal was to have students interact with the client in a real-world setting where problems that arise have consequences and require immediate solutions. Students were expected to identify limitations and concerns with the environmental conditions of the greenhouses they were establishing. No specific problems were established before the project began, requiring students to recognize where their attention was needed to establish a proper functioning indoor agriculture system. Problems regarding light intensity and quality, temperature, air flow, and water quality had to be identified specifically by the students and then addressed appropriately. Identifying and solving such problems promoted a “materials at hand” method of problem solving as the resources surrounding Winifred, MT, are rather limited. Other learning activities included developing grade appropriate curriculum ideas for the greenhouse facilities by K-12 students at the Winifred School and presenting the results of this project to the community and the university.

Students made three separate trips to Winifred throughout the semester. In addition, the students constructed similar indoor growing systems at the MSU Plant Growth Center (PGC) on the MSU campus to be able to understand how the two systems worked and to be able to troubleshoot challenges as they arose. Before the first trip to Winifred, the MSU team had very little information about the facility at

the new school. The information provided by the architects identified (1) a ~300-ft² greenhouse with natural light supplemented by high-pressure sodium lamps, housing a Bato Dutch Bucket system (Crop King) consisting of 24 buckets that would grow tomatoes and peppers; (2) a second room of similar size to the greenhouse intended for indoor production with no natural light and only supplemental light that would house up to eight RADIX indoor vertical hydroponic production modules (Sananbio) that would grow lettuce; and (3) a room connecting these two spaces that serves as a headhouse facility including a potting bench, fertilizer storage, and sink (Figures 2–4). A primary challenge for the students was to learn about and troubleshoot the setup of these two different indoor growing systems within this context.

The Bato Dutch Bucket system was to be assembled in the greenhouse space at the Winifred School. The buckets were fitted with baskets that encompassed 90% of the bucket volume, leaving a small nutrient bath collection space at the bottom of each bucket. A recirculating nutrient solution irrigation system was constructed to supply the tomatoes with water and fertilizer. Each bucket was filled with small, fired clay spheres, approximately 1 cm in diameter, that support the root systems of the tomatoes. The Dutch Bucket system at the MSU PGC is shown in Figure 3 with 2-week-old tomato plants. All supplemental lighting at the PGC was with LED, due to its high efficiency (Singh et al., 2015).

The RADIX indoor vertical hydroponic production module consists of multiple levels of stacked flood tables (Figure 4) in conjunction with LED lighting bars suspended above each layer. Nutrient solution is pumped from a reservoir to the top of the tower where it cascades down each layer, filling each flood table and eventually returning to the reservoir below the tower. Small dams are utilized in each flood table layer to control the depth of the nutrient solution that sits in the table before cascading down to the next layer. Plants, propagated in rockwool rooting cubes, are inserted into holes in each flood table lid so that the vegetative growth sits above the table, directly under the light bars, while the root system grows into the nutrient solution contained in each layer.

To gain experience with the equipment prior to the first Winifred trip, students assembled a single RADIX vertical hydroponic production module and a Bato Dutch Bucket system with six buckets at the MSU PGC. The greenhouse tomato cultivar, Geronimo (Johnny’s Selected Seeds), was planted in the Dutch Bucket system, and six different cultivars of lettuce, bred for greenhouse cultivation, were planted in the RADIX vertical module. These cultivars included Breen romaine, Green Forest romaine, Green oakleaf, Green sweet crisp, Lollo atonement, and Red butter (Johnny’s Selected Seeds). Utilizing the General Hydroponics Flora Grow fertilizer series, the students learned first-hand about the nutrient requirements and pH adjustments necessary to maintain a hydroponic reservoir that promotes healthy plant growth.



FIGURE 2 Floor plan for Winifred School indoor agriculture facility: Greenhouse on the left side with the Bato Dutch Bucket system, headhouse in the center, and indoor production room with the RADIX vertical hydroponic production modules on the right.



FIGURE 3 Dutch Bucket system at the Montana State University Plant Growth Center. The pink hue is due to LED plant lighting.

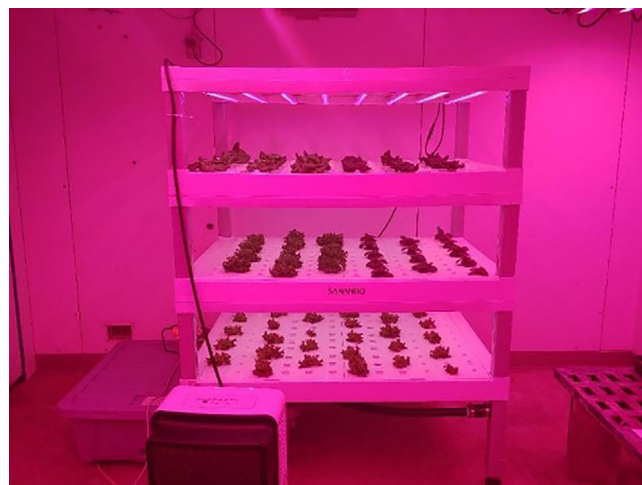


FIGURE 4 RADIX indoor vertical hydroponic production module at the Montana State University Plant Growth Center. The pink hue is due to LED plant lighting.

Additionally, students gained experience conducting a variety trial by collecting data on yield and performance for the different lettuce cultivars in both locations.

3 | RESULTS AND DISCUSSION

After building the basic systems at MSU, students took their first trip to Winifred on September 29, 2022. During the first trip, the team assessed the facility, itemized all equipment available on site, determined what additional equipment was necessary to complete the setup, and began to set up the two growing systems in Winifred. Four challenges presented themselves during this first trip. The first challenge the students found was that while the materials for the Bato

Dutch Bucket system were in the greenhouse, they were not yet assembled. The students attempted to assemble the system with the materials provided; however, the students identified a major issue with the design of the system at the school. The Dutch Bucket system was designed to pump nutrients from a reservoir into each of the buckets and then drain into a common drain trough that carried the excess nutrient bath into a floor drain. This was a significant inefficiency and would require mixing up a nutrient reservoir daily for the system, wasting a large amount of both nutrient solution and time resources of staff. Utilizing a small amount of excess plumbing material that was included with the Dutch Bucket system, the students were able to redesign the system to return the excess water into the reservoir tank. This allowed for continuous recycling of the nutrients and only required a

reservoir exchange every 2 weeks. Perlite was included with the Bato Dutch Bucket system as a growing media, but the perlite on location was pulverized into a powder, which the students determined would just clog the drain lines in the system. The students suggested that clay pellets, like those used at MSU, would be required to get this system fully operational. Given these challenges, the students took notes on what materials were needed and left the system unplanted until the second trip.

The second challenge was that the eight RADIX modules were present in the indoor agriculture room but had been assembled incorrectly. The students first reassembled one of the towers. However, the pumps included with the Winifred system were much more powerful than what was required and caused the trays to overflow. The students went to the local farm and ranch supply store to look for parts to solve this problem. Utilizing a series of splitter and ball valves that were available locally, the students crafted a series of flow reducing points in the system that facilitated the proper flow rate through the tower despite the overpowered pump. The single tower was successfully set up and was planted with the six selected lettuce cultivars. The remaining seven towers were left unassembled.

The third challenge identified on the first trip to the school was that the supplemental lighting system for the greenhouse was working; however, the timers that ran the light system did not turn the lights on and off at the correct times. The students needed to figure out how to troubleshoot this challenge and fix the timing system for the greenhouse. And finally, the fourth major challenge was the results of the test of the water available for the hydroponic systems. The test indicated alkalinity levels above 500 ppm CaCO_3 equivalent and a pH close to 9. The students correctly identified that this water quality was far too alkaline to effectively grow tomatoes and lettuces and that a reverse osmosis system was needed to mitigate this issue. This issue was addressed on the second trip to the school, about a month later. These four challenges required critical thinking and problem solving by the students, and successfully solving them was critical to the implementation of the systems.

The trips to Winifred were spaced out by a month. This gave the students time to research and acquire all the materials needed to fix the problems from the initial visit. Before the second trip, the students were able to observe the plant growth at the MSU PGC setup and to troubleshoot nutrient mixture requirements, airflow, and humidity problems. The successful harvest of lettuces from the MSU vertical module demonstrated how quickly these tower systems can produce mature lettuce plants, ready to eat, and prompted students to think about how all eight towers at the Winifred School could be cycled in an effective cropping regime to maximize production for students and the Winifred community. Students calculated what production would look like at full capacity.

The second trip to the Winifred School was the most work intensive of the trips. The goals of the second trip were to install a reverse osmosis system to reduce the alkalinity of the water, set up the Dutch Bucket system in the greenhouse, and properly assemble more of the RADIX vertical towers. As expected, the plants left in the vertical tower from the first visit were all dead, due to the high alkalinity of the nutrient water. The students worked to install the reverse osmosis system to get the towers operational. Despite the planning ahead of time, the students had to troubleshoot several small issues with the system, which required creative solutions using supplies found at the local ranch supply store. During this trip, the Bato Dutch Bucket system was completely installed, tested, and planted with tomato and pepper plants. A second RADIX vertical module was assembled, and both functional modules were planted with lettuce plants. All the systems were filled with water from the reverse osmosis system, and Flora Grow series nutrients were added. While the MSU students were working, multiple groups of younger students from the school came through to observe the progress. They were quite excited about the plants, which was motivating for the MSU students.

The third trip to Winifred was focused on assessing how well the systems performed after a month of use and assembling the final RADIX vertical towers. Science instructor Julie Ewen had been changing the reservoir water weekly and mixing up new nutrients each time. Results were better than expected as both vertical garden towers were filled with lettuces ready for harvest (Figure 5a,b). Additionally, the tomato and pepper plants were well established and were ready to be supported by a trellis (Figure 6). Grade school students assisted the MSU students with the harvest of the lettuce plants. Some of the lettuce plants were retained by the MSU students for the purpose of collecting performance data on the project, but most were immediately integrated into the school lunch program in Winifred. Everyone agreed that the lettuce was delicious! All the operational towers were refilled with seedlings, and every aspect of the systems was inspected and found to be functioning effectively.

4 | CONCLUSIONS

Overall, this course provided several valuable learning opportunities. The MSU students successfully set up and established the indoor growing systems in collaboration with the Winifred School science program. In the process, they learned how to problem solve in real time and develop a project with real-world impact. By the end of the semester, the Winifred School was using the indoor growing facility in their science curriculum, with many plans to increase its use in the coming years in biology and agriculture-related curriculum including experimentation, introduction to growing plants and plant biology, and economics of agriculture. In addition to



FIGURE 5 (a) Lettuce root system at harvest time at Winifred School. (b) RADIX vertical gardens at Winifred School, ready to harvest.



FIGURE 6 Dutch Bucket system at Winifred School. Peppers in the foreground and tomatoes ready to trellis in the background.

being a teaching resource, the greenhouse and growth chambers are now producing vegetables that go directly into the school lunch program and are also being sold at the local grocery store. Results from this course indicate that if the facility were operating at maximum capacity, it would be able to produce around 200 heads of lettuce per week, as well as a regular supply of tomatoes and peppers. This would have a significant impact on fresh produce availability in Winifred and have the added benefit of raising money for school programming through produce sales.

There are challenges to being able to run the facility at full capacity. Despite having the indoor growing facility as a physical resource, labor shortages are a real challenge. The teachers who work at the school are already stretched to their capacity. The indoor growing facility, running at full capacity, would require about 20 h of labor per week to run and maintain. While students can perform some of this labor as part of educational opportunities, more staff time is needed to run the facility at full operation. This is the primary challenge indicated by the teachers and staff at the Winifred School.

Despite the staffing limitations at the Winifred School, the established indoor gardening spaces continue to operate a year and a half after the completion of this project. Both the greenhouse and vertical tower room have run continuously since the completion of the MSU project. Julie Ewen was able to recruit a Future Farmers of America (FFA) volunteer to assist with the day-to-day operations of the facilities as part of a work study program. Students of all ages in the K-12 school assist in keeping the facility operational. Older students assist with facility maintenance, cleaning, and troubleshooting the established systems, and they have added a small aquaponic system to the greenhouse for comparison of hydroponic and aquaponic growth environments for various horticultural crops. Younger students assist with planting, pollinating, and harvesting the rotation of crops that have been raised in the facility. In addition to the crops established by the MSU team, the K-12 students have grown cucumbers, snap peas, and strawberries, all of which are made available as healthy snacks for students and faculty at the school. Lettuce is still being grown regularly in the vertical tower system and is incorporated both into school lunches and sold at the local grocery in Winifred. The K-12 students are also now writing age-appropriate lab reports on the growth experiments being run in the facility, benefiting not only their own scientific writing skills, but future students who can build new experiments in the facility upon the previous student's results. It is hard to imagine a better result from the efforts of the MSU students to establish this growing facility, and all parties involved are excited for the continued learning opportunities the facility will provide.

MSU students fully demonstrated the Environmental Horticulture program learning outcomes. These include demonstrating the content knowledge and skills necessary to function successfully in a horticulture field and being able to identify and analyze plant growth problems and develop solutions or strategies to solve those problems. CBL and problem-based learning opportunities are shown to increase student engagement, leadership skills, and critical thinking when appropriately designed (Abbey et al., 2017). This was

fully demonstrated in this course. The MSU students were motivated to solve problems and set up the facility at the Winifred School, in part because they saw firsthand the impact they were having on the learning opportunities for the Winifred students and the increase in local produce availability from their efforts. These types of community-engaged learning opportunities prepare students for jobs and careers postcollege (Parrella et al., 2023; Waliczek & Zajicek, 2010). By working on a project that directly improved the lives of community members through greater accessibility of fresh produce in rural Montana, the students were engaged and motivated to work hard. They saw the direct impact that their project had on the lives of the students, teachers, and community in Winifred. The challenges presented in establishing this facility are analogous to challenges faced in the workplace, and more broadly to solving the very real and complex challenges that agriculture faces due to factors such as climate change (Francis et al., 2011). CBL opportunities such as the one described here develop critical problem-solving skills and systems thinking. Not only are college students well served by these kinds of experiences, but tangible improvements of all kinds can also be felt in local communities with these types of projects. If the goal of a university education is to prepare students for careers and civic life, then there is no better way than involving students in community-based projects.

AUTHOR CONTRIBUTIONS

Brandon Tillett: Conceptualization; formal analysis; investigation; methodology; project administration; writing—original draft. **David Baumbauer:** Conceptualization; funding acquisition; investigation; methodology; project administration; supervision; writing—review and editing. **Julie Ewen:** Methodology; project administration; validation; writing—review and editing. **Claire H. Luby:** Supervision; writing—original draft; writing—review and editing.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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