Lettuce learn: An overview of the use of hydroponic shipping container farms in schools

by

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A REPORT

submitted in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

Department of Horticulture and Natural Resources
College of Agriculture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2026

Approved by:

Major Professor
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Abstract

The integration of Controlled Environment Agriculture, especially Hydroponic Shipping Container Farms (HSCFs), represents a useful approach to improve experiential learning opportunities for secondary students. Those systems can address common challenges in school environments, including space constraints, access to nutritious foods and their associated health outcomes, and broader concerns related to environmental sustainability. Despite those advantages, effective utilization of these facilities is often restricted by multiple factors, most notably insufficient curricular integration and support. The purpose of this report is to provide an overview of the current literature on the implementation of hydroponic systems in educational settings, with a focus on large-scale operations such as HSCFs. Furthermore, three case studies of school districts actively employing these systems are examined to evaluate implementation strategies and outcomes. Findings indicate that HSCFs can positively influence student learning, engagement, and well-being. However, successful implementation requires financial and systemic support that is underestimated at the district level. Overall, while adopting HSCFs in schools is both feasible and beneficial, their long-term success depends on clearly defined program objectives and sustained institutional commitment to meet student needs effectively.

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Chapter 1 - Introduction

The twenty-first-century educational landscape requires that students develop interdisciplinary competencies, so they are prepared to address global challenges such as climate change, food insecurity, and sustainability, while balancing the socio-emotional factors that influence student outcomes, including socioeconomic inequality, mental health, and access to nutritious foods. Several approaches have been developed over time to assist students as they learn to handle these complex problems. For example, STEM education (Science, Technology, Engineering, and Mathematics) seeks to guide students in problem-solving through hands-on, multi-disciplinary learning experiences, acknowledging that real-world problems are multi-faceted (Bybee, 2013). This approach aligns with Kolb's Experiential Learning Theory, whereby students learn through the cycle of experiencing, reflecting, thinking, and acting (Kolb, 2015).

Hydroponic Shipping Container Farms (HSCFs), a form of Controlled Environment Agriculture (CEA), have been designed to address many of these issues by offering a local, nutritious, and fresh food source that touts up to 98% less water usage than traditional outdoor farming—and with no insecticide or herbicide use (Freight Farms, n.d.). In addition, HSCFs address many constraints of traditional school gardens, such as seasonality and space limitations, while supporting student nutrition and experiential learning (Wagner et al., 2020). Despite growing interest in school-based hydroponic systems, there is limited research on the implementation of large-scale controlled environment agriculture systems such as HSCFs in schools, particularly at the district level. This report examines the implementation of HSCFs in secondary schools by synthesizing existing literature and analyzing case studies from districts currently using these systems.

Objectives

This report has two primary objectives. The first is to review existing literature on hydroponic shipping container farms in school settings. The second is to examine their implementation and educational impact in secondary school settings through qualitative case studies, with a focus on student learning and well-being, interdisciplinary and community integration, and factors affecting implementation, feasibility, and sustainability.

Literature Review

The Search It tool through K-State Libraries and Google Scholar were used to locate preliminary works that reference HSCFs in schools. General search terms included “schools AND hydroponic,” “schools AND hydroponic shipping container,” “students AND hydroponic,” and “urban AND hydroponic shipping container.” Search terms were expanded to include closely related school agriculture projects such as school gardens and their implications for student nutrition and wellness habits. The references of existing works were reviewed to find more literature related to the implementation of HSCFs in schools. The themes of content literacy and vocational skills, interdisciplinary integration, student health and nutrition, community engagement, and program feasibility and sustainability emerged from the collection of works, became the focus of the following review, and were further investigated through three case studies.

Enhancing Content Literacy

The research in this review is grounded in experiential learning theory, which posits that knowledge is developed through cycles of experience and reflection (Kolb, 2015). From this perspective, hydroponic systems such as HSCFs serve as learning environments that bridge abstract scientific concepts with hands-on application (Rahmi et al., 2025; Wagner et al., 2020; Wang et al., 2020). Schools using HSCFs further their science studies in photosynthesis, plant anatomy, genetics, nutrient math, pH, and light wavelengths. Yet, research on interdisciplinary applications shows differences in pedagogical approaches across content areas. For example, a biology teacher may require a more data-driven, analytical lens for students, whereas an agriculture teacher may prefer a more hands-on activity (Wang et al., 2020). These differences in pedagogical approaches suggest that curricular integration varies by subject and teacher, which reinforces the need for further investigation of curriculum alignment.

Addressing Student Health and Wellness

Experiential learning in childhood nutrition, such as cooking and school-based gardening initiatives have been shown to improve dietary habits and health outcomes for students and their families (Trudeau et al., 2025; Beresford et al., 2024; Song et al., 2016; Holloway et al., 2023). Collectively, these studies suggest nutrition education is more effective when paired with interactive and applied learning activities. However, some students choose not to consume produce grown in an HSCF, even when that opportunity is available (Edwards, G., 2025).

Youth gardening can have positive impacts on participants' through social and emotional well-being as well. Opportunities to take care of something such as plants in a hydroponic system has been shown to improve the self-confidence of students while giving them the structure of routine plant care and the anticipation of watching plants grow (Corveleyn, H., et al, 2020). Self-concept of one's scientific ability and the desire to do science in general increase while anxiety toward science decreases during the course of hydroponics programs (Patchen, A.

K., et al, 2017). In a 2021 study involving middle school students in Hong Kong, each group of students received green space activities, mental health activities, and healthy diet promotion. However, the group that also received hydroponic activities had elevated scores for dietary habits and resistance to substance use (Kwok et al., 2021).

Indoor hydroponic activities positively contribute to student resiliency differently than traditional outdoor gardening programs. Students in a University of Oregon study gained confidence growing in an HSCF due to the attention to detail required in this indoor setting. For example, students became more aware of concepts like pollination and fertilizing because these tasks had to be done manually and intentionally. Furthermore, the authors argue the indoor growing experience facilitates resiliency through “understanding plant basics and how to grow food, collective learning, learning and rebounding from challenges and mistakes, learning to be resourceful, and restorative/therapeutic experience” (Stapleton, S. R., & Meier, B. K., 2022).

Common Barriers

The main perceived barriers of “time, staff, funding, curriculum, and space” are well-established in the literature of school gardening projects, and are also apparent in the more limited research on the use of HSCFs in schools (Burt, K. G., et al, 2018). HSCFs are a large financial undertaking with startup costs as well as continued inputs and maintenance for the life of the facility. Even when funds are secured, various barriers can lead to underuse. Incorporating existing research-based learning models shows improved benefits for students when working through hydroponic modules, yet the lack of curriculum alignment, lack of shared planning time, and administration-imposed barriers such as mandates regarding the use of class time to prepare for high stakes testing cause many hydroponic learning activities to be pushed into the realm of extra-curricular activities, which minimizes their benefit for the general student (Rahmi et al., 2025; Wagner et al., 2020; Wang et al., 2020).

Interestingly, many program directors in after-school hydroponic programs have limited background in science and/or education yet students demonstrate improved attitude toward science activities that incorporate hydroponics. The implication is, the tasks required of basic hydroponic activities are not overly complicated, which helps teachers successfully navigate a program's curriculum. Also, in a well-paced curriculum, lessons build gradually over time, which allows for a more relaxed learning curve for teachers (Patchen, A.K., et al, 2017). To improve the horticultural knowledge of teachers in this position, a recommendation includes using required professional development time to seek out support from local institutions such as master gardeners, botanical gardens, extension services, and for-credit workshops (Burt, K. G., et al, 2018).

To better understand the students' perspectives on working in an HSCF, a 2025 study employed photovoice methodology, allowing students to document their experiences through student photography and their captions (Edwards, 2025). Regarding the interior layout, participants expressed frustration with the horizontal NFT configuration, noting that space constraints and high shelving made cleaning and maintenance physically taxing, and even impossible (to them) in some of the upper corners of the facility. Safety was also a recurring theme—students highlighted the dangers of climbing ladders to reach channels and the difficulty of lifting heavy nutrient and acid containers. Even air circulation fans posed a risk to taller students, who had to navigate the farm carefully to avoid bumping their heads or getting their hair stuck in the fans. Beyond physical utility, students suggested that the facility's "boring" exterior should be redesigned to reflect the "cool" innovative technology inside. Because these farms are originally designed for maximum efficiency and output rather than classroom instruction, there is a clear opportunity for districts to advocate for designs that better accommodate the physical and safety needs of a student population.

Research Gap

Despite the documented benefits of HSCFs in STEM education and student nutrition, there remains a significant gap in understanding how these systems are implemented across disciplines at the secondary level, especially those outside of the STEM framework, such as business and culinary arts (Wang et al., 2020). While student nutrition is addressed, investigation into other forms of student wellness is lacking. Limited research examines teacher perceptions of feasibility, cross-curricular integration, and institutional support required for sustained implementation. Furthermore, considering the socioeconomic disparities that affect nutritional and health outcomes in the United States, studies to explore cross-curricular applications of HSCFs, which students or districts benefit most, and whether HSCFs address inequality, could further benefit a much wider array of students and improve their quality of life (Fielding-Singh, 2021).

Chapter 2 - Case Studies

Hydroponic Shipping Container Farms (HSCFs), a form of Controlled Environment Agriculture (CEA), have emerged as an innovative approach to addressing challenges in food production and access by providing a local, fresh, and nutritious food source. These systems can reduce water use by up to 98% compared to traditional outdoor farming and operate without the need for insecticides or herbicides (Freight Farms, n.d.). In educational settings, HSCFs also help overcome common limitations of school gardens, such as seasonality and space constraints, while supporting student nutrition and hands-on, experiential learning (Wagner et al., 2020). Despite growing interest in school-based hydroponic systems, there is limited research on the implementation of large-scale CEA systems like HSCFs in schools, particularly at the district level. To address this gap, this study aims to explore how these systems are implemented in high school settings and to examine their role in supporting student learning, program development, and community engagement.

Background / Context (LGF & CGF)

Leafy Green Farms and Community Green Farms Initiative

Founding and Development

Leafy Green Farms and its 501(c)(3) affiliate is a new business founded in 2020 by Sacramento, California native and United States Navy Veteran Brad Fourby. At the time of the Covid pandemic, Fourby was working for an energy company, but had recently discovered an interest in aquaponics, hydroponics, and vertical farming, which he thought would be a very useful practice in his area of California. After researching many options, especially financial options, it became apparent that embarking on a new business venture would not be feasible without relocating. He had heard of Pittsburg, Kansas through the energy company he had been working for, as they have a location in Pittsburg. Finding funding for his business concept proved to be quite the challenge, as he was initially denied a start-up loan through his bank. However, during Covid shut-down, he was able to have a Zoom meeting with the Kansas Healthy Food Initiative, who decided to award him a $15,000 grant to start his business in Kansas. After showing his bank that the KHFI was willing to invest in his idea, the bank granted him the necessary resources to move to Kansas and establish his new business in 2021 (B. Fourby, personal communication, December 1, 2023).

Organizational Structure

Leafy Green Farms (LGF) operates out of a leased facility at the municipal airport in Pittsburg, Kansas, where it shares space with a former energy company and Community Green Farms, a 501(c)(3) established in 2022 to support the organization's education and outreach efforts. Under the leadership of Pittsburg native Matt O'Malley, Community Green Farms focuses on placing hydroponic shipping container farms in Kansas schools, with the goal of expanding agricultural education and improving access to fresh, nutritious food. In addition to producing leafy greens for local use, LGF acquires and repurposes refrigerated shipping containers into hydroponic farms, which are then distributed to schools through Community Green Farms. LGF also provides ongoing support, with Fourby serving as a mentor and service contractor to assist schools and teachers in implementing and utilizing the systems.

Sustainability is a central component of LGF's operations. According to communications director Leslie Montee, the organization prioritizes environmental responsibility and community impact. LGF and Community Green Farms promote sustainability by producing leafy greens year-round, using a system that conserves water and limits strains on local soil systems. At the same time, they contribute to the local economy through employment and partnerships, while supporting education and strengthening the regional food system (L. Montee, personal communication, October 20, 2023).

Technical System Overview

Each container farm is designed with identical specifications, modeled in collaboration with Freight Farms of Boston, Massachusetts (Figure 1).

Figure 1. An example shipping container farm, designed by Freight Farms, Boston, MA

The containers are 40' x 8' x 9.5', providing a total blueprint of 320 square feet. Each farm is outfitted with roughly 80% - 82% components that can be found at most hardware stores, making the building and repairs as easy as possible. The remaining parts are specialized items like climate control elements and technology to sync information with smart devices, such as temperature, humidity, light, nutrient solution pH, and basic safety information (for example, if someone left the door open by accident). Most operations such as these can be operated and adjusted off-site using smart devices, allowing the farmer to be away as necessary. The farms use

Culligan water service as a standardization measure, so the data and practices are transferable and applicable from farm to farm. Farms have the option of installing their own reverse osmosis filtering system at a later date. Seedlings are started in a soilless media, then transferred into a railing system to develop under an LED strip lighting system (Figure 2).

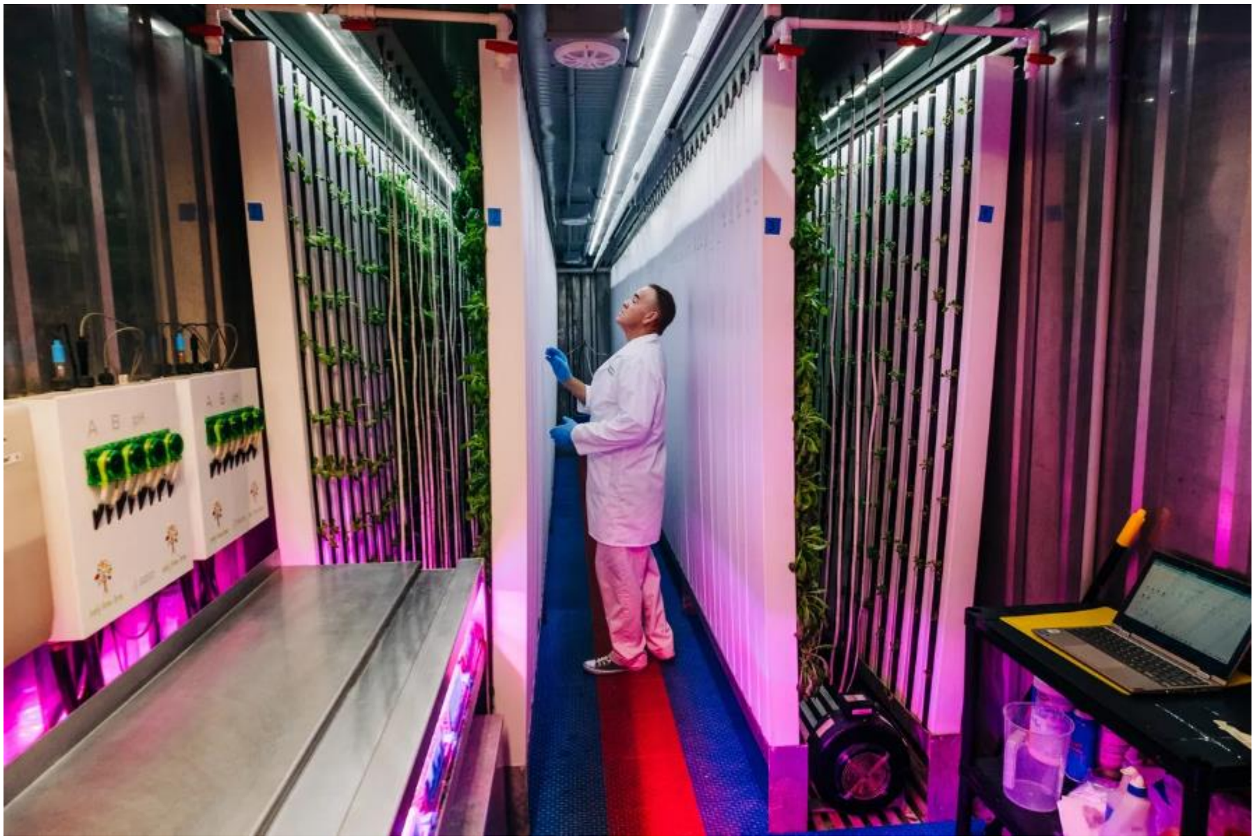

Figure 2. Vertical column and railing system

The farm is installed on site at a very gentle grade to allow water and nutrient solution to be recycled through the system once it has flowed down through the vertical columns. This prevents nutrients pooling in the bottom return channels. The vertical design of the farm is an accessibility feature that allows for significantly easier maintenance and cleaning than traditional horizonal nutrient film technique systems. This accessibility allows groups such as students with disabilities and young students to be a part of the indoor farming process when they may have been limited otherwise. There are no pesticides or herbicides required. After the farms are completely set up, they allow for two weekly harvests of roughly 400 units per harvest. The full plant is harvested, as opposed to a cut and come again method of harvesting.

Educational Initiative

Grants are a large part of the operations, especially for Community Green Farms, as they are the non-profit side of the overall system. As veterans, Fourby and Montee have found they have access to grants and other loan programs specifically designed for small businesses owned and operated by veterans. Community Green Farms also has access to a wide variety of grants, especially in Kansas, as there are several initiatives to promote healthy eating and living habits for our state's youth. For example, in September of 2023, Community Green Farms was awarded a $1,052,000 Strengthening People and Revitalizing Kansas (SPARK) Community Capacity Grant through the Kansas Department of Children and Families, on the basis that the farms promote health and awareness of health for our state's youth (Jenkins, 2023). This grant allowed Community Green Farms to establish container farms at 7 additional schools in southeast Kansas, as part of a Phase II of the overall goal of one container farm at one school in each of Kansas' 105 counties. Schools are selected based on a collaborative interview process with O'Malley and Fourby to promote a meaningful impact in the chosen community. In addition to receiving a container farm, the schools are provided with all the necessities of running the farm for a full year. Everything from set-up to seeds and nutrients to Fourby's maintenance and mentoring service contract is included. After the first year of operations, the financial responsibility of operations and the service contract falls on the respective school districts (M. O'Malley, personal communication, December 1, 2023).

Methodology

This study employed a qualitative multiple case study design. A purposive sampling strategy was used to identify participants with direct experience implementing HSCFs in educational contexts.

The sample was drawn from a Kansas-based initiative led by Leafy Green Farms (LGF) and Community Green Farms (CGF), both located in Pittsburg, Kansas. This initiative aims to place at least one HSCF in each county or consolidated school district across the state, thereby providing a unique opportunity to examine early adopters of this technology within a coordinated implementation framework. Three high schools currently participating in this initiative—Pittsburg High School, Columbus High School, and Uniontown High School—were selected as case study sites. The schools were chosen to achieve a variety of enrollment sizes and a range of program maturities in the sample.

Participants included lead teachers responsible for the operation and instructional integration of the HSCFs at each site. These individuals were recruited via direct email communication. Upon consent, in-person, semi-structured interviews were conducted with each participant, lasting approximately two hours per interview. The interview protocol included a series of guiding questions designed to elicit detailed responses regarding the five key themes of content literacy and vocational skills, student health and nutrition, interdisciplinary integration, community engagement, and program feasibility and sustainability. All interviews were transcribed through notetaking on a computer and subsequently analyzed using a thematic analysis approach. The results were then organized according the five key themes, reviewed and discussed to add to the existing narrative of what teaching with the tool of an HSCF is like for teachers as they guide their students.

Three Schools, Three Contexts

For this report, the three schools utilizing HSCFs represent a diverse range of district sizes and program maturities. The motivation and acquisition processes for the farms varied, though Leafy Green Farms (LGF) played a central role for all three.

Pittsburg High School, a school with an enrollment of 1,035 9^{th} through 12^{th} grade students, has housed its farm the longest, fully utilizing it since August of 2021. Pittsburg's initiative began organically when a staff member saw LGF on the local news, knowing the school was looking for grants to expand an existing greenhouse. The school was subsequently gifted a farm through an LGF collaboration with community benefactors. This established "Dragon Farms" at Pittsburg High School and catalyzed the broader LGF initiative for schools through Community Green Farms. The lead teacher has remained the same since the receipt of the HSCF.

Columbus High School serves 439 students in a combined 7^{th} through 12^{th} grade building and received their farm in March of 2023. Columbus adopted the program after touring LGF's facility and viewed it as an opportunity too good to turn down. "We felt this would create a wonderful opportunity for hands-on learning that can be incorporated across several different curricula and pathways within our school" (Bush, A., 2023). Columbus experienced a leadership transition after the program's first year. Initially run solely by the district's agriculture teacher, the Columbus farm was entrusted to a special education teacher because the routine tasks of managing the farm proved highly beneficial for his students' development, and he already possessed relevant gardening knowledge.

Uniontown operates on a much smaller scale, as a combined 7^{th} through 12^{th} grade school with enrollment of 178 students. This site acquired its farm in the summer of 2024 and has been implementing farm activities with students since the fall semester of that year. Uniontown's involvement began after a staff member saw a Kansas State University post regarding an LGF grant program and pursued more information. Uniontown has maintained the same lead teacher since the installation of their HSCF.

Results

Findings from the three case studies were organized into five major themes: (1) content literacy and vocational skills, (2) interdisciplinary integration, (3) student health and nutrition, (4) community engagement, and (5) program feasibility and sustainability.

Content Literacy and Vocational Skills

Across all three districts, hydroponic shipping container farms (HSCFs) supported hands-on learning and the development of academic and vocational skills. In each case, the farms were integrated into existing courses and prompted new, farm-centered offerings. Pittsburg incorporated the farm into a Botany course and later added a dedicated Hydroponics course and summer program. Columbus embedded farm activities within a co-taught Plant and Soil Science course designed to support Life Skills students. Uniontown integrated the farm into a middle school STEM elective before developing a high school Botany course. While the specific structures differed, all three programs used the HSCF as a central tool for experiential, applied learning.

Curriculum and student learning outcomes had similarities and differences among the schools. As elective courses, there is some freedom in the formation and purpose of curriculum depending on the needs of the students. Pittsburg has a developed curriculum based on the High School Engineering, Technology, and Applications of Science Standards (Figure 3), where students analyze global challenges and develop solutions using the sciences.

HS-ETS1-1 Engineering Design

Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

Performance Expectation | Grade: High School (9-12)

HS-ETS1-2 Engineering Design

Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

Performance Expectation | Grade: High School (9-12)

HS-ETS1-3 Engineering Design

Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

Performance Expectation | Grade: High School (9-12)

HS-ETS1-4 Engineering Design

Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem.

Performance Expectation | Grade: High School (9-12)

Figure 3 The High School Engineering, Technology, and Application of Science Standards from Next Generation Science Standards, nextgenerationscience.org

Students split class time equally between classroom learning and HSCF tasks so they can develop knowledge and management of crop issues such as "looking at pests, different kinds of root rot, insect pests, bacteria that we would normally see in the farm," and learning how to detect those. While Columbus has one co-taught Plant and Soil course, the primary student outcomes are designed for the Life Skills students. The focus is primarily on outcomes including fine and gross motor skills development, following multiple-step instructions, developing routines, promoting social interaction and communication between students, attention to detail and the quality of work, and becoming responsible and independent workers. Uniontown's curriculum continues to develop based on the needs and interests of the school, community, and most importantly, the students. Learning outcomes focus on "the history of horticulture, content vocabulary, understanding fertilizers and different processes that plants need to survive," but also focus on transferring the skills to the students' lives outside of school so that they may be more self-reliant and know how to plant their own gardens.

Mastery was demonstrated through student-led projects and students' ability to identify problems, communicate effectively, and implement solutions with increasing independence. At Pittsburg, students designed a simple at-home hydroponic system with a $45 budget, allowing them to apply course concepts in a personalized design. At Columbus, students assumed leadership roles in farm operations or selected cultivars to grow. At Uniontown, students explored cultivars and adjusted variables such as nutrients and lighting based on their interests and developing understanding of plant systems Pittsburg emphasized, "Hands on is the best way to learn. Having ownership over what's grown and getting to have some input on choices like seed varieties ignites motivation to learn the material and see the bigger picture, which is harder to see in a regular classroom."

The HSCFs have also become a training ground for essential vocational skills, especially "soft skills" like communication, responsibility, and time management. Care of the unit and the workspace is emphasized and demonstrated through the students' consistent completion of cleaning and maintenance tasks built into their daily routines. Daily tasks include checking the irrigation nozzles for buildup, sanitizing workspaces, and keeping the aisles free of debris. Pittsburg also focuses heavily on business, finances, and marketing, as the students learn to research market value and set product prices for the local farmer's market. Learning proper hygiene is of utmost importance, since the students are growing food for others to eat. Columbus emphasizes foundational job skills such as meeting expectations, demonstrating patience, and producing consistent, quality work. Overall, these findings suggest that HSCFs support academic learning and workforce skill development in diverse school contexts, while allowing flexibility for programs to adapt to local student needs and instructional goals

Interdisciplinary Integration

Due to the limited physical space to work within an HSCF, class size is a constraint that teachers must accept. Additionally, the highly automated systems limit the amount of manual labor required to manage the HSCF, so only 4 to 12 students maximum are required. Interestingly, each teacher commented on their respective school sizes to be ideal for hosting an HSCF program. Across all three districts, HSCFs created opportunities for interdisciplinary learning, though the depth and consistency of integration varied. All programs incorporated the farm into science-related coursework, while also extending connections into non-science areas and activities beyond the school day. However, collaboration across disciplines was often influenced by time, staffing, and program maturity.

Each district demonstrated distinct levels and forms of cross-curricular integration. Pittsburg incorporated the HSCF into multiple subject areas, including culinary arts where students processed the harvest, prepared recipes, and readied the harvest for cafeteria use, and business education, where students performed costs analysis and created a sales plan for Dragon Farms to use at the local farmers market. Columbus emphasized integrated, team-based learning across agriculture, Life Skills, and culinary programs, with students collaborating on harvesting, sorting, and preparing produce for cafeteria use. Uniontown primarily targeted cafeteria production and school-wide exposure activities such as student-led tours for younger grades.

Class size was both a limitation and a structural feature of HSCF implementation. At each site, enrollment in farm-based courses was low due to limited space within the container systems. Teachers consistently described this as a challenge and an advantage. One teacher noted that “4 to 6 kids works perfectly. This works well because we are a smaller school.” Another explained that class size is inherently limited because “they won't fit, but we do need enough [students] to complete tasks.” In contrast, a larger district emphasized larger enrollment allowed for greater student diversity, “Being bigger, you have a more diverse student population—for example, having students from migratory farming families in class with that perspective. That doesn't necessarily happen in smaller schools.”

Despite small class sizes, all three districts extended the impact of the HSCF beyond enrolled students through indirect participation, such as multidisciplinary integration, school-wide activities, and access to produce. Although small class size can easily limit the reach of the HSCF, teachers described strategies for increasing involvement through farm-adjacent activities that engage students beyond the course. However, barriers to deeper interdisciplinary integration exist, including limited time for collaboration and the additional effort required to sustain cross-curricular involvement. While not all students have the opportunity to work directly with the crops, all students have the opportunity to benefit from them in some way through collaborative school structures. These findings suggest that while HSCFs have strong potential to support interdisciplinary learning, the extent depends largely on program maturity, teacher collaboration, and structural constraints such as time and class size.

Student Health and Nutrition

At all three sites, HSCFs contributed to student health and wellness through increased access to fresh produce and broader social-emotional benefits. A small number of students directly participated in farm operations, but a much larger portion of the student population benefited from access to farm-grown produce through school meal programs.

The schools used HSCF produce to supplement cafeteria offerings, particularly salad bars. Uniontown's configuration allowed students across grade levels to access the produce. Pittsburg implemented a monthly distribution event, described as "give-away day," where roughly 200 heads of lettuce serve 100 students as they leave school. Although formal measures of student nutrition were not collected, teachers anecdotally reported an increased willingness among students to try fresh produce. One teacher described a student reaction as "this isn't too bad," illustrating a shift in openness to new foods through exposure.

Participation in the full growing process also contributed to students' understanding of food systems. As one teacher explained, "Participating helps support health and wellness because of this understanding—you have a better appreciation of agriculture and where food comes from when you do it yourself."

Beyond nutrition, HSCF sites reported positive impacts on students' hygiene and physical, social, and emotional well-being. Teachers also observed increased confidence, improved communication, and stronger peer relationships. One teacher described this dynamic, "They have to learn to get along, kind of like a 'Breakfast Club.' There are no phones in class, so the students must learn to talk to each other." Overall, these findings suggest that HSCFs support student wellness by increasing access to fresh food while fostering social development, responsibility, and engagement.

Community Integration

HSCFs supported meaningful connections between schools and their surrounding communities. In addition to contributing produce to their school cafeterias, each district developed forms of community engagement, including partnerships, donations, and public outreach.

Pittsburg established partnerships with local organizations, restaurants, and the farmers market. The program contributed to local food access through school-based distribution and broader community engagement. Leaders stated this impact occurs “to some extent—just because we're one more produce vendor at the farmers market, where there are only two other fresh veggie vendors right now.” In contrast, Columbus and Uniontown reported more localized forms of engagement, such as securing sponsorships, hosting tours during school events, and partnering with nearby businesses to supply produce. Uniontown also described a more flexible, relational approach to community distribution practices, sharing surplus produce with “whoever is around.”

HSCFs contributed to positive public perception and provided opportunities for community members to interact with school programs in meaningful ways. This suggests HSCFs can strengthen school-community relationships, with the level and form of integration shaped by local context and leadership.

Feasibility and Sustainability

HSCF programs were supported through a combination of grant funding, district resources, and community support. Start-up costs were covered through external grant funding, but long-term sustainability requires districts to continuously navigate the recurring expenses associated with operation and maintenance.

Ongoing costs were consistent for all sites and included utilities, water services, consumable inputs such as nutrients and grow plugs, Additionally, Leafy Green Farms (LGF) provided a five-year service aggrement, after which districts assume responsibility for repairs and technical issues. Teachers reported that consumables represented a particularly significant and often unexpected expense. To manage operating costs, districts adopted different financial strategies. Pittsburg was able to offset consumable costs through revenue from farmers' market sales and restaurant partnerships. As the teacher explained, "it is almost sustainable, so if you do it right you're able to pay and not having to do a bunch of grant writing." In contrast, Uniontown and Columbus relied more heavily on district funding, Career and Technical Education (CTE) allocations through the Kansas Department of Education, and community sponsorships.

Water usage emerged as a major operational expense. Pittsburg and Columbus invested in reverse osmosis (RO) filtration systems to reduce costs associated with bottled water delivery. Pittsburg reported this change significantly reduced expenses, eliminating the need for bi-weekly Culligan deliveries at approximately "$250 per delivery." Uniontown continued to purchase approximately "30 of the 5-gallon jugs bi-monthly" from Culligan. Despite these financial demands, teachers reported administrators reliably view the programs as worthwhile investments due to student engagement, skill development, and positive community visibility generated by the farms.

Beyond financial considerations, similar implementation challenges affected program sustainability. Teachers described a learning curve associated with operating a complex, technology-driven system, along with periods of underuse due to instructional demands and student engagement. Pittsburg and Columbus noted challenges of limited communication with LGF. This made it difficult to troubleshoot maintenance issues and understand system updates, including software changes through Freight Farms technology. In Columbus, a teacher transition reduced HSCF use as the program's role within the district was redefined.

Student motivation was another shared challenge. Uniontown noted that students sometimes "aren't as efficient or put in effort" because they are "just getting paid in grades." Pittsburg reported instances of low engagement resulting in "barely growing enough to sell at the farmer's market."

Teachers emphasized that long-term sustainability depends heavily on having a dedicated lead instructor responsible for daily operations, system oversight, and ongoing maintenance. Pittsburg and Columbus stressed the importance of selecting "the right person for the job"—someone who is "ready to take on that responsibility." Program maturity also influenced perceived workload. Newer programs required significantly more time for curriculum development, learning how to use the farm's systems and onboard technologies, and establishing routines. More established programs reported increased efficiency over time. Although initial setup was described as labor-intensive, teachers indicated responsibilities became more manageable once systems and schedules were established, including automated nutrient delivery and environmental controls. As Pittsburg explained, "once you have the timing and plant schedule figured out, there really isn't extra required time." Columbus echoed this sentiment, stating the farm is "not a large inconvenience," especially given proximity to the school and the ability to check systems as needed, including on weekends and extended breaks. Uniontown reported the highest workload but values the HSCF, stating it is "gladly accepted because it's such a neat thing."

Overall, these findings suggest that while HSCFs are feasible within secondary school settings, long-term sustainability depends on stable funding strategies, strong instructional leadership, and the ability to adapt to ongoing operational and logistical challenges

Discussion

Content Literacy and Vocational Skills

This study found HSCFs function as highly adaptable experiential learning environments that support content literacy and vocational skill development across diverse instructional contexts. The most consistent pattern at the targeted sites was the way students engaged in learning through problem-solving, decision-making, and assuming responsibility for living things.

Rather than operating as a fixed curricular tool, the HSCF is a flexible instructional platform that could be shaped toward various educational goals. At these three sites, students engaged in agricultural production tasks such as nutrient management, crop monitoring, and system maintenance. Simultaneously they developed broader skills including communication, independence, and workplace readiness. Instructional emphasis varied along a continuum from STEM-focused applications to life skills development. The underlying structure of "learn by doing" was consistent, reflecting Kolb's experiential learning cycle, which emphasizes experience and reflection (Kolb, 2015).

This pattern aligns with prior research indicating hydroponic systems enhance applied scientific understanding and engagement with abstract concepts such as plant biology and systems thinking (Rahmi et al., 2025; Wagner et al., 2020; Wang et al., 2020). However, this study demonstrates the primary value of HSCFs may extend to the development of vocational and soft skills, including responsibility, time management, communication, and independent problem-solving.

HSCFs are multi-purpose experiential learning environments, consistently producing academic and workforce-related outcomes. This versatility is an important factor for school districts considering adopting an HSCF. Since the farm's goals and activities can be tailored to serve STEM students, special education programs, culinary arts partnerships, and general science offerings, the long-term investment of the farm can be justified. Ultimately, the HSCF is a blank canvas that can be shaped entirely by the goals and curricular intentions of district administrators and the educators who manage it.

Interdisciplinary Integration and Curriculum Alignment

The baseline goal for any HSCF should simply be serving the educational and developmental needs of the students at hand This perspective is especially important when navigating cross-curricular integration. While collaborating with other departments sounds appealing, it is crucial to recognize not all faculty will have the desire or capacity to incorporate farm activities into their instruction. A key pattern among all three sites was the presence of interdisciplinary integration was largely dependent on teachers. The HSCFs functioned as spaces where integration could occur, but was often initiated by individual teachers as time and interest allowed rather than intentionally designed and implemented. This finding aligns with the work of Rahmi et al. (2025) and Wang et al. (2020), highlighting that curriculum misalignment and lack of shared planning time can significantly limit the depth of integration, even when physical infrastructure supports it. This is further supported by Tonnetti and Lentillon-Kaestner (2023), who note that true interdisciplinary practices are rare in secondary schools, frequently defaulting to multidisciplinary sequences due to a lack of professional development on interdisciplinary teaching and the strong discipline-specific identities that many teachers have spent years learning to protect and advocate for.

Across contexts, integration was strongest in science-related courses and extended outward into other disciplines in more limited ways. Established programs demonstrated broader and more intentional multidisciplinary connections, particularly where agricultural production intersected with culinary applications, business concepts, or life skills instruction. Other programs showed localized integration, typically centered on cafeteria use or introductory activities. This aligns with Wang et al. (2020), who emphasize that interdisciplinary implementation is shaped by disciplinary pedagogies.

Most notably, the findings suggest interdisciplinary integration is not tied to how long a program has been in place, but instead depends on whether collaboration is intentionally designed into the program from the beginning. Interdisciplinary learning in HSCFs is not inherently guaranteed by the technology itself. It emerges when structural conditions—particularly time for collaboration and administrative support—are present. Without these conditions, integration remains surface-level or happenstance. For schools, this means successful interdisciplinary implementation is less about expanding participation and more about building the structural capacity to support sustained collaboration from the beginning. As Tonnetti and Lentillon-Kaestner (2023) emphasize, educators are dependent on administrative choices. Without established resources, the preparation time required for interdisciplinary work becomes a significant barrier. Teachers are already navigating a heavy slew of expectations—adding the mastery of a highly specialized technology to existing tasks can be overwhelming. However, if a district or a willing group of educators actively chooses to pursue interdisciplinary learning, success hinges on systemic support. Administrators must provide dedicated time and resources for teachers to communicate, develop trust in their colleagues, co-plan, and familiarize themselves with the HSCF environment. Fostering collaboration in this manner ensures that all involved educators feel competent and successful, which is a more sustainable approach for long-term integration (Tonnetti and Lentillon-Kaestner, 2023). Cross-curricular and multidisciplinary integration are excellent bonuses if they can occur, but the primary expectation should remain practical and student-focused.

Student Health and Nutrition

HSCFs contributed to student wellness through exposure, participation, and familiarity rather than formal health instruction. The most consistent outcomes were increased student engagement with fresh produce through school meal programs, and positive shifts in willingness to try new foods. This aligns with existing research indicating experiential nutrition education improves dietary behaviors and food acceptance when students are actively involved in food production (Trudeau et al., 2025; Beresford et al., 2024; Song et al., 2016). The findings also suggest exposure without formal curriculum change may be sufficient to influence student attitudes toward food systems. While this may be optimistic, the opposite was also apparent. Student motivation and disinterest may always be present and interfere with initiatives designed to improve student wellbeing (Edwards, G., 2025).

Beyond nutrition, a second pattern emerged in socio-emotional development. Teachers noticed increased confidence, communication, and responsibility when working in shared environments. This supports prior findings that plant-based experiential learning improves self-concept, reduces anxiety toward science, and increases student engagement (Corveleyn et al., 2020; Patchen et al., 2017). This occurs across diverse student populations suggesting the benefits are not limited to STEM-oriented learners, but are accessible to all.

The physical limitations of the HSCF environment required close interaction among students, which appeared to foster peer relationships and social development. This aligns with the work of Stapleton and Meier (2022), who posit controlled environment agriculture systems promote resilience through shared problem-solving and adaptive learning experiences.

Overall, these findings suggest wellness outcomes in HSCFs are a result of participation in structured but socially interactive environments. For educators, this indicates HSCFs may function as indirect wellness interventions, even when that is not their main purpose.

Feasibility and Sustainability

The acquisition of an HSCF can generate immediate excitement within a school district, but the findings across the three participating schools highlight the necessity of establishing realistic goals and timelines to sustain the program. A program's development is dictated less by how long the district has owned the farm, and far more by the initial vision and intentionality of the lead educator. While financial resources are necessary, the most critical factor influencing program continuity was the presence of a dedicated lead teacher responsible for both student instruction and managing the multifaceted systems within the HSCFs. Pittsburg High School had a teacher with a clear vision from the start. Because the educator actively sought out the HSCF with the specific intent of building a STEM-focused, production- and business-oriented program, she was able to hit the ground running. The cross-curricular ties and community networking this program would need to make that vision a reality existed well before the farm even arrived on campus. Columbus and Uniontown were presented with HSCFs as great opportunities for students, and the farms were placed under the management of very competent and wellintentioned educators who did not necessarily have prior hydroponic experience or a clear vision for their use. For programs initiated in this manner, the learning curve is naturally much steeper. The initial timeline must allow these teachers a significant grace period to learn the complex automated systems, experiment with nutrient math, and discover where the farm best fits within their specific content area. Teachers consistently emphasized that sustainability required individuals willing to assume significant responsibility for daily operations, troubleshooting, and long-term planning. This aligns with Stapleton and Meier (2022), who emphasize that experiential learning environments require consistent facilitation to maintain instructional effectiveness over time.

While funding, time, staffing, and space remain well-documented barriers in school-based agricultural education (Burt et al., 2018), this study found the significant technology demands are unique to HSCFs. Teachers experienced a distinct learning curve in operating hydroponic systems, particularly in nutrient balancing, software navigation, and system troubleshooting. These challenges were compounded by limited external technical support and inconsistent communication with vendors

All programs followed a similar progression from high initial effort during setup and learning phases to increased efficiency after routines and systems were established. However, disruptions in staffing or role transitions created noticeable declines in HSCF use, highlighting the vulnerability of systems that rely heavily on one lead teacher. This suggests that sustainability is not simply a function of financial or material resources, but of continuity, training, and knowledge retention. For districts, this means long-term success depends on the understanding that HSCF leadership is a highly specialized role requiring sustained support.

Inconsistent student motivation was an operational barrier that affected productivity and system efficiency. This reinforced that even highly automated systems remain dependent on human engagement for successful operation. This finding supports the literature showing engagement is a pedagogical issue and an operational constraint in production-based learning environments (Burt, et al., 2018).

Despite the many barriers and constraints, a consistent pattern also emerged—over time, routines reduced perceived difficulty, and teachers reported increased confidence as the many systems became more familiar and predictable. This suggests that barriers can diminish with experience, provided adequate time and institutional support are available. For districts, this indicates that sustained success depends not only on initial training but on sustained financial, technical and instructional supports that extend beyond the startup phase. While grant opportunities make the acquisition of an HSCF possible, the participating districts reveal that long-term program sustainability requires commitment—financially and through personnel. Administrators must recognize an HSCF is not a one-time purchase, but an ongoing investment. Navigating the recurring financial realities and protecting the educators who manage the facilities are the two most important factors in sustaining an HSCF program.

Limitations

This study is limited by its qualitative case study design and the small number of participating school districts, which restricts the generalizability of the findings to broader K–12 contexts. Although these sites provide meaningful variation in program design, implementation, and teacher experience, they do not represent all possible models of hydroponic shipping container farm (HSCF) integration. In relation to student learning and well-being, the findings reflect teacher-reported experiences and site-level observations rather than direct measures of student achievement or longitudinal outcomes. Interdisciplinary and community integration were impacted by variation in program maturity and available collaboration time which were inconsistent among the sampled sites. Finally, differences in teacher experience, institutional support, and program age likely shaped implementation outcomes as much as the technology itself, and the absence of longitudinal data limits conclusions about long-term program stability and impact.

Conclusion

As hydroponic shipping container farms (HSCFs) continue to emerge as novel educational tools, this report sought to provide a foundational overview of their practical application within secondary schools. This report has two primary objectives: to review existing literature on HSCFs in school settings and to examine their implementation and educational impact through qualitative case studies, with a focus on student learning, nutrition, and well-being, interdisciplinary and community integration, and factors influencing implementation, feasibility, and sustainability. Because research on this technology in K–12 settings remains limited, the experiences of Pittsburg, Columbus, and Uniontown High Schools provide valuable insight into how these systems function in different instructional contexts.

The findings demonstrate HSCFs are highly versatile experiential learning environments. Students developed communication skills, responsibility and independence while engaging in hands-on, production-based learning that supported STEM content knowledge, agricultural applications, and vocational skills. Although the same technology was used at each site, outcomes varied based on program design, teacher intent, and local context. This reinforces the belief that the impact of HSCFs is influenced more by instructional purpose than by the technology itself.

The study found consistent outcomes even with variation in implementation. HSCFs supported student engagement and well-being through hands-on learning and increased interaction with food systems. Interdisciplinary and community integration occurred in all programs but varied in depth, largely depending on intentional design, collaboration time, and staff capacity. Feasibility and sustainability challenges were consistent across sites and driven by financial demands such as consumables and maintenance. Structural and human factors also played a role, particularly the reliance on a dedicated lead teacher to manage instruction and system operations.

Overall, the findings suggest HSCF success is not defined by program age or a universal model of implementation, but by intentional design, realistic expectations, and sustained instructional support. Districts must therefore define success in relation to their own students and goals while recognizing the ongoing operational demands these systems require. Without adequate support, even well-equipped facilities risk underuse over time.

This study contributes to the limited body of research on HSCFs in K–12 education by highlighting how program outcomes are shaped by teacher capacity, program design, and institutional support. Future research should continue to examine long-term sustainability, interdisciplinary integration as a function of intentional design, and measurable impacts on student learning and well-being.

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Appendix A - Shipping Container Farm Case Study Questions

1. School Context

- What is your school's enrollment?
- How many years has your district housed a shipping container farm?
- Have you been the lead teacher for the farm since the beginning?
- What motivated you and/or your school to apply for a farm? How were you selected, and what did the application process entail?

2. Content Literacy and Vocational Skills

- Which class(es) are offered as a result of the farm, and/or which pre-existing class(es) adopted use of the farm?
- What standards or learning objectives does the farm facilitate for your students?
- How do students demonstrate learning (lab reports, production planning, student projects, maintenance and repairs, etc.)?
- What opportunities are there for student-led projects?
- Describe a typical lesson or activity in the farm including opportunities for problem-solving. How do these lessons/activities differ from the traditional classroom learning?
- What job or technical skills do students learn through farm activities?
- Are students involved in planning, maintenance, marketing, or sales? How so?
- Do students interact with industry professionals, or have access to internships or certifications?
- Have students pursued career pathways because of the program?
- What other thoughts do you have regarding content literacy through farm activities?

3. Student Health and Wellness

- What non-academic student outcomes have you noticed?
- Which students have access to the farm experience?
- Are any groups of students under- or over-represented?
- What happens to the food grown in the shipping container?
- Have students' food preferences or willingness to try vegetables changed?
- Are families affected in any way in terms of health and wellness?
- Have you observed changes in student behavior, attendance, or engagement due to farm participation?
- How does the shipping container farm support your students' health and wellness? For example: behaviors, attendance, participation, socialization, etc.? Please explain.
- Have you assessed any of the student learning and health outcomes through assignments or surveys?

4. Interdisciplinary Integration

- How have non-science classes/extracurricular groups successfully incorporated the farm?
- Do you do anything in particular to promote farm activities to or include other content areas in the school?
- What challenges have you faced with cross-curricular farm projects?
- What professional development or support was necessary to achieve collaboration?
- Do you have a specific example of a project where multiple content areas collaborated? What did that look like?

5. Community Integration

- What partnerships exist outside the school due to the farm, and how did they begin?
- Is produce sold, donated, or shared locally?

- Do families or community members participate directly in any farm activities?
- Does the school host tours, outreach, or student-led instruction?
- How has the farm affected relationships between the school and community?
- Has the farm affected food access in the community?
- What other thoughts do you have regarding the farm's impact on your community?

6. Feasibility and Sustainability

- Is funding for the farm revenue-, grant-, or district-supported? Or a combination? What does this look like? Is the current funding model long-term?
- What are the major operating costs?
- What unexpected costs or logistics surprised you?
- Do administrators approach the farm as an expense or as an investment? How can you tell?
- How are the costs of sustaining this program justified?
- Would your school install the farm again knowing the true costs?
- What has been the biggest challenge to sustaining the program?
- What ongoing maintenance and staffing are required?
- How is the shipping container farm managed during weekends/holidays/school breaks?
- How has the farm impacted teacher workload?
- Has staff turnover ever threatened the program?
- Has the farm ever been underused? How so / why?
- Has anything caused the farm to nearly fail? If so, how was that prevented?

7. Reflection Items

- What were the original goals of the farm? Have those goals changed over time?

- What impact does your school's size have in terms of what you are able to accomplish through your farm?
- In what ways has the farm impacted overall school culture or identity?
- What advice would you give a school considering implementing this style of hydroponic farm?