February 2024

Vertical Agriculture in the Classroom:

# A GLOBAL ASSESSMENT OF VERTICAL AGRICULTURE EDUCATION TRAINING MATERIALS AND CURRICULA

Shelbea Julseth-White
Dr. Alesandros Glaros

University of the Fraser Valley
Food and Agriculture Institute

## ACKNOWLEDGEMENTS

The Food and Agriculture Institute at the University of the Fraser Valley is situated on the sacred lands of the Stó:lō peoples.
The Stó:lō have an intrinsic relationship with S'ólh Tém:éxw (Our Sacred Land), and we express our gratitude and respect for the honour of living and working in this territory.

We acknowledge the generous funding provided by the Royal Bank of Canada that supported this project.

# TABLE OF CONTENTS

# INTRODUCTION

Vertical agriculture is an innovative method of food production that utilizes stacked shelves to grow various vegetable and fruit crops. Hydroponic, aquaponic, or aeroponic techniques are most often used in vertical systems, saving land and water resources and generating higher yields than conventional agriculture (Avgoustaki et al., 2020). The industry is rapidly growing in British Columbia and beyond, yet there remain key questions and considerations for its on-the-ground implementation. For example, it is unclear where these facilities should go, what their measurable food security impacts could be, and what skills are required to match industry needs.

For vertical agriculture to flourish, it is crucial to have well-developed education and training materials or curricula to equip individuals with the necessary knowledge and skills to participate in the emerging industry (RBC Thought Leadership, 2019; B.C. Food Security Task Force, 2022). This research paper catalogues and explores the current, publicly available, English-language vertical agriculture education and training materials and curricula. The research analysis spans the following four key educational topics: vertical agriculture and sustainable food systems, fundamentals of vertical farming practices and techniques, key challenges and future directions, and planning and policy considerations. The findings of this research will be factored into future educational workshops and materials developed through the Food and Agriculture Institute at the University of the Fraser Valley. By aligning with the four themes of the workshops, the research efforts aim to contribute to finding and assessing the gaps in vertical agriculture educational materials.

## BACKGROUND

As we face new and more environmental challenges, the need for sustainable food production is becoming more vital. Vertical agriculture (VA) enables the growth of vegetables and some fruits without soil, reducing land use significantly. The controlled environment of VA allows for year-round crop production, optimal growing conditions, and higher yields of food production (Glaros et al., 2022). Further, the hydroponic or aeroponic systems greatly reduce water usage and alleviate strain on freshwater supplies, which poses a significant challenge in traditional farming. The systems have the capability to capture and recycle water; for instance, in hydroponics, the nutrient water solutions are recirculated, minimizing water and nutrient waste.

A key advantage to VA is the ability to maximize land use efficiency. VA leaves room for creative development and innovation in small, underutilized, and even urban spaces as individuals find ways to utilize vertical spaces to grow multiple crop layers (Glaros et al., 2022). This vertical stacking saves valuable land resources while allowing various crops to grow simultaneously. An added benefit to VA is reusing and reinventing spaces and materials that would no longer be used. Vertical growing systems may challenge public understanding of what constitutes conventional agricultural production.

However, vertical agriculture's widespread acceptance and implementation face challenges such as public skepticism, concerns about artificiality and cost, and potential land shortages for other purposes (Broad et al., 2022). Additionally, there is a lack of public knowledge, training, and skills development programs in this field. The types of skills and training individuals need to enter this sector are radically different from conventional agriculture systems (RBC Thought Leadership, 2019). As the VA industry matures, it is important to design programs and materials proactively that support greater public knowledge of this emerging technology and train qualified personnel for further scaling. To address this, this project reviews existing educational materials and presents recommendations for comprehensive training materials for students and members of the public interested in entering the vertical farming industry.

## METHODS OF RESEARCH

The research involved collecting English language educational materials for vertical agriculture, participating in farm tours, and in-person interviews with industry leaders from a vertical farm in British Columbia. The analysis procedures involved both quantitative and qualitative approaches, including summarizing and counting the types of educational and training documents, as well as conducting a thematic analysis of the content across the four key educational topics. Findings from this analysis procedure illuminate potential gaps in training materials for vertical agriculture. Despite the thoroughness of the research methods employed, there are limitations, including the focus solely on English language materials. This may result in the exclusion of valuable information available in other languages as well as unrepresentative samples of materials related to each of the four educational topics.

### Description of Vertical Agriculture Education Documents

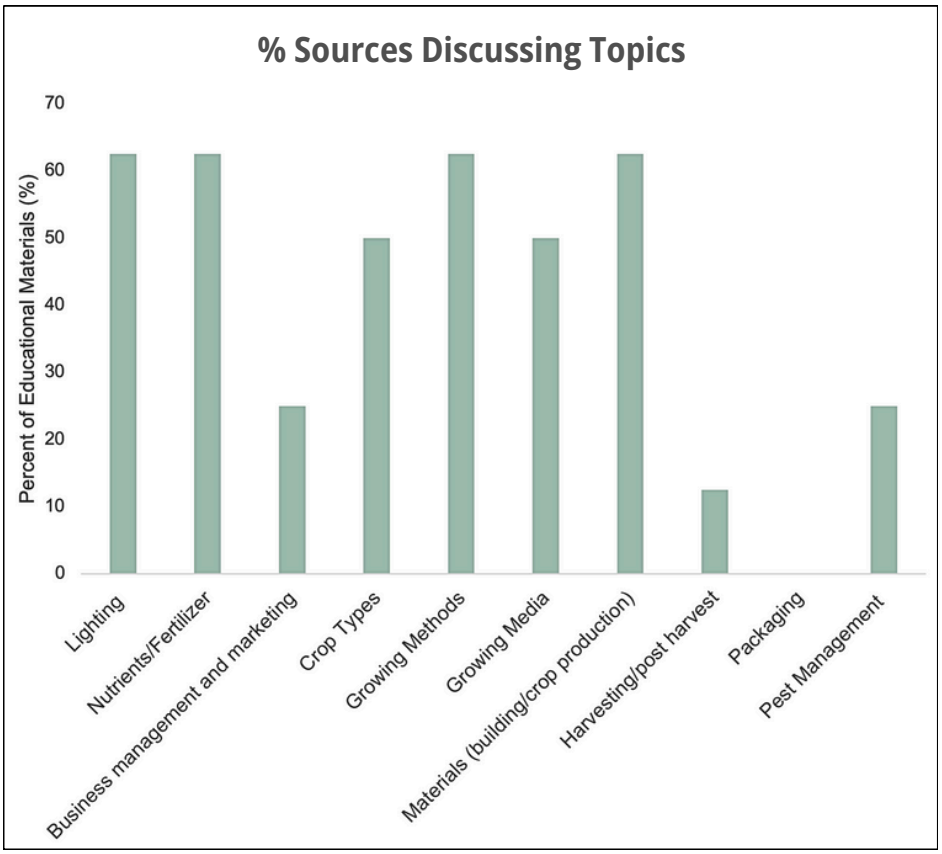


*Figure 1. Percentage of Sources Discussing Key Topics and Techniques in Vertical Agriculture*

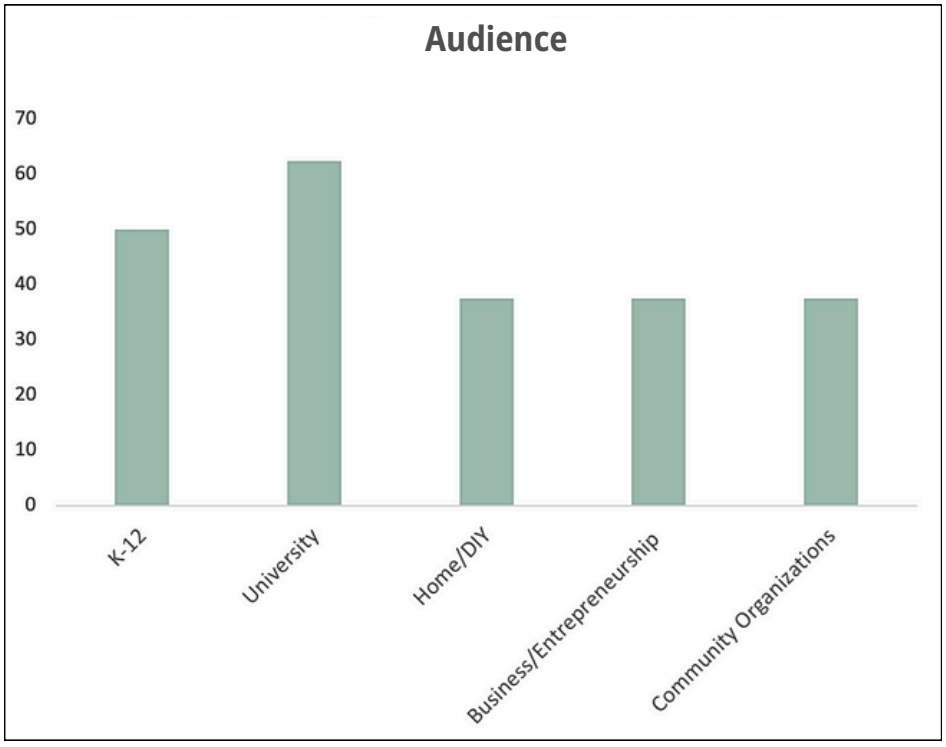


*Figure 2. Intended Audiences of Sources*

## Qualitative Summary of Documents, by Each Educational Topic

### *Theme A: Vertical Agriculture and Sustainable Food Systems*

This topic considers the role of ag-tech and vertical agriculture in contributing to food system's sustainability. Concepts related to 'vertical agriculture and sustainable food systems' could include but were not limited to 'bigger picture' items such as: resource efficiency, waste reduction, and water conservation, as well as discussing the food security implications of vertical farming in urban areas.

### *Theme B: The fundamentals of vertical farming practices and techniques*

This topic considers the technical specifications of vertical agriculture systems, highlighting key operational considerations and approaches. Concepts related to 'the fundamentals of vertical farming practices and techniques' could include but were not limited to the following: lighting systems, pest management, lighting systems, and growing methods.

### *Theme C: Key challenges and future directions for vertical farming*

Vertical farming faces several challenges and considerations for the industry to develop in ways that sufficiently contribute to food security. This topic considers those challenges, addressing topics such as the following: energy use, labour, and the use of emerging technologies (e.g., genomics) in vertical agriculture.

### *Theme D: Planning and Policy Considerations Around Vertical Agriculture*

This topic considers planning considerations for including vertical agriculture in urban environments, considering land use opportunities and barriers to its implementation. Potential topics could include the following: land use scenarios and building permitting considerations. No relevant results were found in searching for resources or references to planning and policy considerations, and thus are not presented below.

## Theme A Results

Several companies offer training materials that engage with vertical agriculture and sustainable food systems' related topics. For example, in addition to selling grow systems, the company ZipGrow (Ontario, Canada), offers educational resources such as course curricula, blogs, guides, manuals, farmer stories, case studies, newsletters, and a YouTube channel (Ellapasco, 2022). They have an Upstart University training center, where customers can access training and support services upon purchasing equipment. However, they do not aid in maintaining or growing the products. The company's educational materials include some engagement with broader sustainability related concepts such as the adverse environmental impacts of growing media and the financial requirements of starting up growing systems (Ellapasco, 2022). Similarly, the company Freight Farms provides training programs and materials for individuals interested in learning more about their grow systems. They promote operations for use on school campuses as well as a variety of community food contexts, engaging with broader sustainability concepts related to food access (Freight Farms, 2022). They offer training programs to teach both theoretical and practical skills for operating the container farm that can be integrated into curriculum, cafeteria, and campus sustainability initiatives, as they state in the following: "Providing grow space close to institutions to feed people. Educating and feeding in one." (Freight Farms, 2022).

The eGFI (Engineering Go for It) is a teacher's education program that provides course materials and instruction for engineering students, specifically in vertical farming. It aims to introduce students to the fundamental technologies of vertical agriculture and explore design characteristics through an engineering lens (eGFI – Engineer a Vertical Farm, n.d.). The program uses a case study approach, looking at a fictional town facing food security issues and requiring students to present the case for vertical agriculture to urban planners and legislators (eGFI –Engineer a Vertical Farm, n.d.). With free and accessible resources on its website, eGFI emphasizes the importance of social sustainability and how vertical farming can address population pressures and food security challenges.

The Association for Vertical Farming (AVF), a non-profit organization based in New York City, has partnered with Columbia University to research urban and vertical farming practices and existing certification systems (Association for Vertical Farming, n.d.). Their mission is to foster the growth and development of the vertical farming movement through education and collaboration. They have developed a sustainability certification system for urban and vertical farms, oriented around sustainable environmental practices and community engagement. The certification framework "encourages farms to choose a site that either disrupts an existing agricultural system in a more efficient and sustainable way or addresses future food scarcity issues" (Association for Vertical Farming, n.d., p. 30). Community engagement, educational programs, and outreach initiatives are important and key to the certification process. The sustainability certification system is the only example we found of efforts to standardize the collection and use of data within the vertical agriculture industry (Association for Vertical Farming, n.d.).

The article "Students' Experiential Learning and Use of Student Farms in Sustainable Agriculture Education" discusses the role of student farms in sustainable agriculture education (Stapleton & Meier, 2021). It suggests that students are instrumental in creating these farms on college campuses. Noting that student farms provide hands-on learning opportunities in horticulture, agriculture, and marketing on a small scale, the article recommends that educators focus on understanding why students choose to work and study on student farms and what they value regarding education approaches (ibid).

The research from "Science education for and as resiliency through Indoor Agriculture" describes the potential benefits of including indoor agriculture in science education to support learning for resiliency. They define resiliency as "learning through and rebounding from challenges/mistakes, learning resourcefulness, and experiencing restorative benefits of working with plants" (Stapleton & Meier, 2021). The article examined the use of shipping container agriculture in a cocurricular pilot program and highlighted how science education can foster mental well-being and enable participants to engage in engineering design, problem-solving, and learning about chemistry and biology. Some of the pilot program's activities include selling produce to the campus community, donating to a local food bank, and comparing indoor and outdoor growing in a campus garden plot (Stapleton & Meier, 2021).

### Theme B Results

Education and training materials focused primarily on topics related to the 'fundamentals in vertical farming production techniques', including engineering

considerations, horticultural concepts, and life cycle analysis thinking, among others. Most sources discussed hydroponics production processes, as opposed to aeroponics or aquaponics techniques, and reviewed production methods for leafy green crops (Figures 3 and 4).

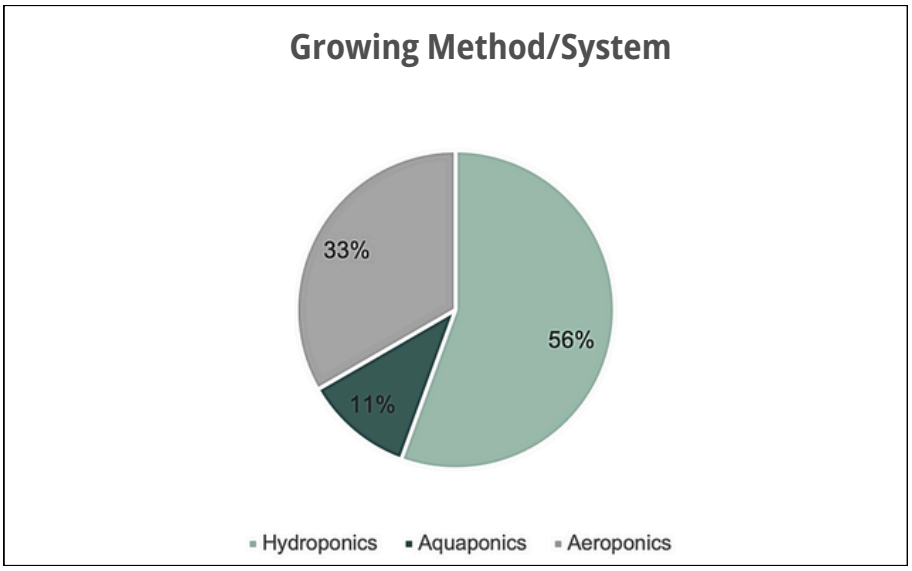


*Figure 3. Hydroponics is the more utilized growing system in vertical agriculture compared to aeroponics and aquaponics.*

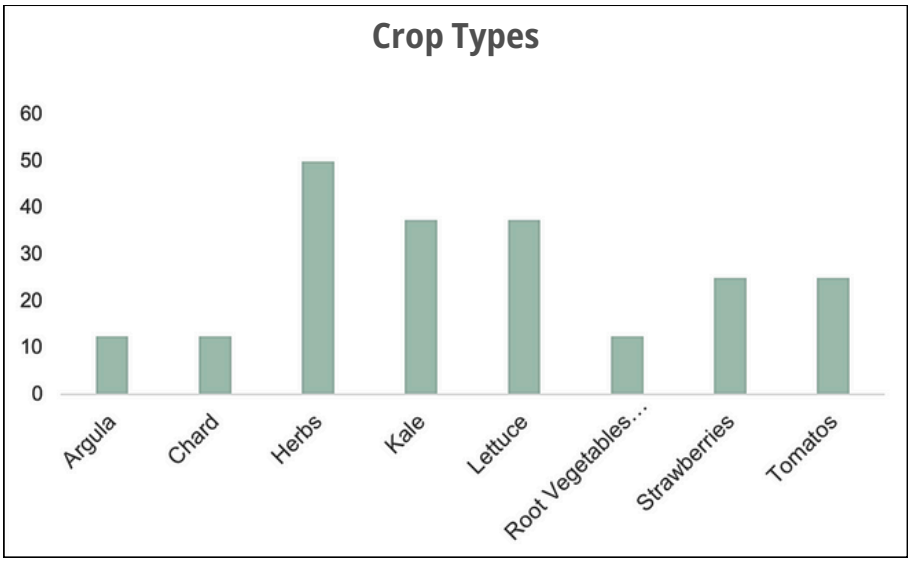


*Figure 4. The popular crop types currently grown in vertical agriculture.*

The Japan Plant Factory Association (JPFA) offers courses on plant factories with artificial lighting (PFAL) to introduce the topic and provide specialized training (JPFA Online Training No. 22-1). Based in Japan and offered online through lecture videos and files, the courses aim to provide a foundation in theory and practical experience for developing and disseminating technically and economically sustainable PFALs. The classes cover various aspects such as light environment and plant growth, hydroponic cultivation processes, nutrient solutions, plant nutrition and water uptake, business administration of PFALS, hydroponic crop production, and specialized programs in business and novel applications like phenomics (JPFA Online Training No. 22-1).

HAS Green Academy in the Netherlands offers a course called "Growing without Daylight" (HAS Green Academy, n.d.). The course focuses on practical applications of indoor farming using climate chambers lit by LED lights. The course covers several topics such as photosynthesis, water quality and preparation of fertilizer solutions, different crops and their yield potential, soil, and substrate management, as well as temperature, humidity, CO2 control, respiration, and transpiration (HAS Green Academy, n.d.).

The Association for Vertical Farming also disseminates original research-gathered information on vertical farming techniques and practices (e.g., Association for Vertical Farming, n.d.). In their sustainability certification for indoor farms they include a strong focus on strategies to boost energy efficiency in controlled environment systems, such as thorugh natural ventilation and shading systems. Further, they discuss LED lighting, including their energy requirements, longevity, and wavelength considerations to match plant needs. This resource highlights reusable growing mediums to minimize waste, as well as the potential for anaerobic digestors fed by organic waste for sustainable energy production (Association for Vertical Farming, n.d.).

## Theme C Results

The interview with staff and management at a vertical farm allowed for an in-depth exploration of some of the key challenges facing the vertical agriculture industry. Several key considerations for vertical agriculture training materials emerged through this interview. For example, one of the major challenges their farm was facing is the wear and tear on the mechanics of their system. Limited support or subsidies are available, as the industry is still in its infancy, and to-date there have been no loan benefits specific to vertical agriculture in the farms provincial location. Additionally, the growing policies and standards have not been adjusted to

accommodate the unique requirements of vertical farming. For example, marketing/packaging requirements fail to match the unique production specifications of vertical growing that may include additional root weight. Providing individuals who may be interested in vertical agriculture with in-depth, practical experience is important for future training materials, as is recognizing the policy hurdles and the lack of support available to new farmers.

Data and certified data records are another key area of growth for the vertical agriculture industry, according to some educational and training materials. As one example, AVF is focused on developing a stand-alone certification system for urban and vertical farms to encourage sustainable practices and standardize data collection (Association for Vertical Farming, n.d.). Once sufficient data is collected, the system will use benchmarking and performance-based criteria to assign and validate certification. This outline aims to provide guidance, establish a database, create an inclusive system, and promote a shared learning platform for certified members (Association for Vertical Farming, n.d.). However, data standards in the industry are not widely used, and certification systems remain in development.

Another challenge concerns the energy use of vertical agriculture and the need for technological improvements to make it more sustainable. The eFGI highlights the importance of careful analysis of existing prototypes and advancements in energy systems for the future success of vertical farms (eGFI –Engineer a Vertical Farm, n.d.). Their educational materials center around a mock-presentation to the city council regarding a vertical farm's construction, placement, and design considerations, underscoring the importance of democratic municipal governance structures for integrating novel agricultural technologies into the built environment. It provides a resource for educators to introduce vertical agriculture education in the classroom, specifically tailored to younger students. EFGI aims to develop children's interest in engineering and focuses on the design and planning aspects of vertical agriculture (eGFI –Engineer a Vertical Farm, n.d.).

## DISCUSSION/CONCLUSION

Overall, this research found that vertical agriculture education and training materials are mostly focused on the technical aspects of vertical growth, such as engineering and horticulture, while lacking in areas like business management, community planning, and pre-or post-production processes. This indicates a need for future educational materials to include these broader skills related to the industry. One significant finding from the research is the popularity of hydroponics as the preferred vertical farming system. While this is extensively covered in educational materials, there is an opportunity to explore further training in aquaponics and/or aeroponics. By expanding the knowledge base on alternative systems, individuals involved in vertical agriculture can diversify their practices and potentially improve efficiency and sustainability, given aquaponics' high efficiency as compared to hydroponic production (Yang & Kim, 2020). Sustainable practices, such as reducing waste and reusing materials, are essential in the long run for cost savings and environmental stewardship. However, the existing educational materials often fall short of emphasizing these practices. The designing and planning phase can prepare individuals to prioritize waste reduction and material reuse right from the start.

Figure 2 highlights that the current educational materials are mainly targeted toward secondary and post-secondary students, with limited cross-sharing and collaboration with on-the-ground organizations. This lack of collaboration may hinder the development of practical, hands-on training opportunities for students, which is demonstrated as an effective method of vertical agriculture teaching and skills development. To fully grasp the impact of vertical agriculture on the farming industry, it is important to move beyond contributing solely to the existing supply chain. Exploring agricultural economic models and alternatives, such as circular economic approaches, can provide fresh perspectives and possibilities for industry. Moreover, looking at vertical agriculture as a socio-economic resource and integrating it into communities can contribute to broader sustainable initiatives.

Some key vertical agriculture companies in the educational space, such as ZipGrow and Freight Farms, are actively working towards advancing the field of vertical agriculture through education, collaboration, and the development of innovative technologies. However, challenges exist in the industry, particularly in tracking and standardizing important metrics. The lack of open quantitative data and inconsistent data formats make establishing life cycle comparative baselines and implementing standardized practices required for certification difficult to achieve (Monteira et al., 2023). This issue is particularly evident in the search for planning and policy considerations related to vertical agriculture. The scarcity of available information or

sources highlights the need for more studies and discussions to address the foundations of vertical agriculture planning. Policies and planning play a crucial role in the success and sustainability of vertical agriculture initiatives. The inadequate number of resources in this area may hinder the development of effective strategies and guidelines for policymakers and entrepreneurs.

In conclusion, the current state of educational materials on vertical agriculture has strengths in the technical aspects of engineering and horticulture, but gaps exist in areas such as business management, community planning, and pre-or post-production processes. There is also an opportunity to expand education on alternative vertical farming systems like aquaponics and aeroponics. Sustainable practices, collaboration, and integration into communities are essential aspects that should be included in the educational curricula. Finally, addressing the lack of quantitative data and inconsistent responses and focusing on planning and policy considerations are vital for the industry to progress and thrive. By addressing these strengths and gaps, future educational materials can better equip individuals involved in vertical agriculture and contribute to the industry's overall success.

## REFERENCES


Association for Vertical Farming. (n.d.). *Sustainability Certification for Indoor Urban and Vertical Farms*. https://agfundernews.com/wp-content/uploads/2016/05/Sustainability-Certification-for-Indoor-Urban-and-Vertical-Farms-1.pdf

Avgoustaki, D. D., & Xydis, G. (2020). Indoor Vertical Farming in the Urban Nexus Context: Business Growth and Resource Savings. *Sustainability, 12*(5), 1965. https://doi.org/10.3390/su12051965

B.C. Food Security Task Force. (2021). The Future of B.C.'s Food System. https://engage.gov.bc.ca/app/uploads/sites/121/2020/01/FSTF-Report-2020-The-Future-of-Food.pdf

Bhattarai, K., & Adhikari, A. P. (2023). Promoting urban farming for creating sustainable cities in Nepal. *Urban Science, 7*(2), 54. https://doi.org/10.3390/urbansci7020054

Broad, G. M., Marschall, W., & Ezzeddine, M. (2022). Perceptions of high-tech controlled environment agriculture among local food consumers: using interviews to explore sense-making and connections to good food. *Agriculture and Human Values, 39*(1), 417–433. https://doi.org/10.1007/s10460-021-10261-7

eGFI – for teachers » Engineer a vertical farm. (n.d.). http://teachers.egfi-k12.org/engineer-a-vertical-farm/

Ellapasco. (2022, December 22). *Controlled Environment Cultivation program.* ZipGrow Inc. https://zipgrow.com/controlled-environment-cultivation-program/

Freight Farms. (2022, March 8). *How high school teachers use a vertical farm to put lessons into practice* [Video]. YouTube. https://www.youtube.com/watch?v=X1ixpDlzpY8

Glaros, A., Marquis, S., Major, C., Quarshie, P. T., Ashton, L., Green, A. G., Kc, K. B., Newman, L., Newell, R., Yada, R. Y., & Fraser, E. D. G. (2022). Horizon scanning and review of the impact of five food and food production models for the global food system in 2050. *Trends in Food Science and Technology, 119*, 550–564. https://doi.org/10.1016/j.tifs.2021.11.013

Goodman, W., & Minner, J. (2019). Will the urban agricultural revolution be vertical and soilless? A case study of controlled environment agriculture in New York City. *Land Use Policy, 83*, 160–173. https://doi.org/10.1016/j.landusepol.2018.12.038

Greenery S Campus Farm. (n.d.). *Hydroponics for Students with Freight Farms*. Freight Farms. https://www.freightfarms.com/education

HAS Green Academy. (n.d.). *Growing without daylight.* https://www.has.nl/en/business-courses/growing-without-daylight/

Introductory & Specialized Courses (JPFA Online Training No. 22-1). (2022).

Japan Plant Factory Association. (2022). JPFA Online Training No. 22-1. https://npoplantfactory.org/wp-content/uploads/2022/06/Information-on-Online-JPFA-Training-Courses-July-15-Aug.3-2022.pdf

Lloyd, C. (2023). "Not just go into a field to turn the soil over, they've got to understand the science behind it." using pedagogic content knowledge to uncover teaching practice in agriculture. *Research in Post-Compulsory Education, 28*(2), 295–312. https://doi.org/10.1080/13596748.2023.2206711

Monteiro, J., Barata, J., Veloso, M., Veloso, L., & Nunes, J. (2023). A scalable digital twin for vertical farming. *Journal of Ambient Intelligence and Humanized Computing, 14*(10), 13981–13996. https://doi.org/10.1007/s12652-022-04106-2

Parr, D., & Trexler, C. J. (2011). Students' experiential learning and use of student farms in sustainable agriculture education. *Journal of Natural Resources and Life Sciences Education, 40*(1), 172–180.https://doi.org/10.4195/jnrlse.2009.0047u

RBC Thought Leadership - How the coming skills revolution can transform agriculture (Farmer 4.0). (2019). https://thoughtleadership.rbc.com/wp-content/uploads/Farmer4_aug2019.pdf

Research & Resources | nofia. (n.d.). Nofia. https://www.nofia-agri.com/research

Stapleton, S. R., & Meier, B. (2021). Science education for and as resiliency through indoor agriculture. *Journal of Research in Science Teaching, 59*(2), 169–194. https://doi.org/10.1002/tea.21724

Yang, T., & Kim, H.-J. (2020). Comparisons of nitrogen and phosphorus mass balance for tomato-, basil-, and lettuce-based aquaponic and hydroponic systems. *Journal of Cleaner Production, 274*, 122619. https://doi.org/10.1016/j.jclepro.2020.122619