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Integrating biodiverse edible school practices: enriching undergraduate liberal education for elevated learning outcomes

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This study investigated the implementation of biodiverse edible school concepts in undergraduate liberal education courses across universities. It aims to evaluate the impact of integrating these concepts on students' learning outcomes related to biodiversity, agriculture, and sustainability. Teaching practices incorporating biodiverse edible school elements were developed and applied in six classes at National Taiwan University and one class at Universiti Malaya, covering various disciplines including agriculture, language, and green chemistry. Data were collected using classroom observations, assignments, and questionnaire surveys. The results showed that the interventions generally enhanced students' understanding of biodiversity and agriculture, increased their willingness to consume local and seasonal foods, and supported the achievement of course learning objectives. Outdoor educational activities were especially effective in improving students' knowledge of edible plants on campus. The findings contribute to experiential learning in agricultural and environmental education, offering practical examples for implementation in diverse educational contexts. Moreover, this study revealed that these practices aligned well with several Sustainable Development Goals, particularly Goal 2 (zero hunger), Goals 12 (responsible consumption and production), Goal 15 (life on land), and Goal 3 (good health and wellbeing). This study demonstrates that biodiverse edible school concepts can be successfully adapted for higher education, providing new ways to integrate these topics into university curricula.

KEYWORDS

biodiverse edible schools, biodiversity, environmental education, food and agricultural education, higher education, liberal arts, sustainability, urban agriculture

1 Introduction

The sustainability field has received considerable attention for its importance across social, economic, and environmental dimensions (Purvis et al., 2019). The 17 Sustainable Development Goals (SDGs) are included in the 2030 Agenda for Sustainable Development, adopted by the United Nations (Sachs et al., 2019; Mensah, 2019). Among these goals, quality education is seen as a crucial transformation step for achieving the SDGs, and there has been a notable increase in higher education sustainability programs aimed at meeting these goals (Sachs et al., 2019; Brundiers et al., 2021). Various innovations, collaborations, and investments have been initiated to meet the inclusive, equitable, quality, and lifelong education targets (Owens, 2017; Ferguson and Roofe, 2020). Agriculture, which supports food security, provides ecosystem services, and serves educational purposes, is essential for achieving many of the SDGs (DeClerck et al., 2016; Viana et al., 2022). Focusing on urban and peri-urban agriculture has become a popular topic in SDG studies worldwide (Viana et al., 2022).

Urban and peri-urban agriculture involves the production of food, other outputs, and related processes occurring on land and in various spaces within cities and surrounding regions, aiming to address local population needs and achieve multiple goals and functions (FAO et al., 2022). It has the potential to mitigate urbanization challenges and offers advantages such as improved wellbeing, social cohesion, and food security (Kingsley et al., 2021; Wadumestrige Dona et al., 2021; Ayoni et al., 2022). Various forms of garden city and community supported agriculture help facilitate the integration of sustainability and agriculture into educational frameworks (Brown and Miller, 2008; LaCharite, 2016). Examples of garden cities, urban farms, and different edible landscapes have been implemented in metropolitan areas such as Taipei city (Hsiao, 2021; Mabon et al., 2023; Zhou et al., 2023; Zheng and Chou, 2023b). These movements are in good agreement with the recently announced Food and Agricultural Education Act in Taiwan and offer important opportunities for ecological and nutritional education (FAO et al., 2022; Mabon et al., 2023; Huang et al., 2023).

Education that incorporates agriculture can provide interdisciplinary experiences for younger generations, particularly those from urban areas (Orr, 1994). Schools serve not only as centers for environmental education but also as valuable reservoirs of urban biodiversity (Rickinson, 2001; Liu et al., 2021). Recently, the concept of "Biodiverse Edible Schools," demonstrated in a secondary school in Berlin, connects healthy food, school gardens, and local biodiversity. This approach has the potential to strengthen students' connections with nature, deepen their understanding of food production, and promote healthier diets (Fischer et al., 2019).

1.1 Biodiverse edible schools and the potential in higher education

The idea of biodiverse edible schools has been influenced by previous research on the benefits of school gardens for children and young students. Blair (2009) underscored the positive impact of school gardening on academic performance, nutrition knowledge, and environmental attitudes. Ohly et al. (2016) conducted a systematic review that linked school gardening programs to improved health and wellbeing. Similarly, school gardening not only enhances students' academic, health, and environmental outcomes but also increases their willingness to try new vegetables and their ability to identify them (Ozer, 2007; Ratcliffe et al., 2011).

The biodiverse edible schools described in Fischer et al. (2019) represent a special approach to integrate food production, environmental education, and biodiversity conservation within educational settings. A biodiverse edible school encompasses four key components: (1) a school kitchen supplied with food from local producers; (2) a garden on the school grounds for producing food; (3) a neighboring wild site that serves as a habitat for edible wild plants; and (4) collaborative activities in planning, managing, and using these spaces. The school kitchen emphasizes the use of local produce to prepare nutritious meals, encouraging students to understand where their food comes from and to adopt healthier eating habits. The school garden serves as a practical learning environment where students grow a variety of vegetables, fruits, and herbs. The nearby wild site provides opportunities for students to explore urban natural habitats, learn about edible wild plants and expand their understanding of local ecosystems. Collaborative activities involve various stakeholders, including school staff, students, local government representatives, environmental organizations, and researchers, who work together to develop biodiverse edible school programs. These activities include workshops, garden maintenance, foraging, and lessons that integrate topics such as biology, nutrition, and environmental science.

While biodiverse edible schools have demonstrated to be well-suited for secondary education, their potential for adaptation to university settings remains unexplored. Can these concepts be effectively implemented in university education? Its applicability in higher education could be supported by integrating agriculture into sustainability education (LaCharite, 2016) and incorporating experiential learning in food studies at universities (Lehrer, 2024). Our discussions among university educators through the platform of Presidents' Forum of Southeast Asia and Taiwan Universities have further explored this idea. The framework of biodiverse edible schools is chosen for implementation in university courses because of its unique approach, which expands beyond traditional school gardens by incorporating wild urban spaces and edible plants. Building on these concepts, we have attempted to integrate the principles of biodiverse edible schools into four liberal education courses in Taiwan and Malaysia. These works include brainstorming biodiverse edible school options suitable for campuses and conducting outdoor vegetation survey activities to engage students with local biodiversity and sustainability practices.

1.2 The liberal education courses and sustainability education in this study

At National Taiwan University (NTU), the integration of SDGs into liberal education courses follows the Ministry of Education's policies and the "Learn SDGs for Taiwan Schools" handbook (Liu and Kan, 2024). This reflects an increasing awareness of the importance of the SDGs and the actions needed to achieve them (Ho et al., 2022). To contribute to these goals, the first author previously implemented experiential learning activities in an agricultural course, encouraging students to explore campus biodiversity (Shen et al., 2023). To explore the relevance of some existing teaching practices with biodiverse edible school elements, new activities and assignments were developed and expanded to three other courses in this study: Introduction to Agriculture in Taiwan (IAT), Organic Agriculture (OA), and Taiwanese Conversations in the Rural Life (TCRL), with the aim of examining the current state of biodiverse edible cases from university students' perspectives in Taiwan. These efforts aim to explore university students' perspectives on biodiverse edible practices and assess their linkages to the SDGs.

From the perspective of the Universiti Malaya (UM), the use of biodiverse edible school practices in liberal education curricula was previously lacking. In the past, the campus's role in food production and consumption, and its connection with local biodiversity, were often overlooked. However, the UM campus community has experts to cater opportunities for students to better understand both urban nature and healthy food, allowing them to meet the 17 SDGs at the same time. Effective from the end of October 2023, the UM Sustainability and Development Centre started integrating the 17 SDG elements through selected final-year projects among undergraduates. The program focuses on six sustainability clusters: waste, energy and climate change, water, transportation, good health, and wellbeing and setting and infrastructure. In this study, the Introduction to Green Chemistry (IGC) course at UM is designed for students from diverse faculties. The aim of implementing the biodiverse edible school in the course is to provide students with a hands-on, practical approach to understanding sustainable agricultural practices and their connection to waste management, renewable resources, and alternative energy.

1.3 Objectives

In this study, we seek to extend biodiverse edible school concepts to higher education. The specific objectives are as follows:

(1) To investigate food and agricultural educational models and examples based on biodiverse edible school concepts in university general education curricula.
(2) To evaluate the impact of biodiverse edible school teaching practices on achieving course learning objectives.
(3) To assess students' perceptions of food, agriculture, and sustainability in the educational process.

2 Materials and methods

2.1 Overview of educational schemes

The educational schemes in this study were conducted at NTU, Taipei, Taiwan, and UM, Kuala Lumpur, Malaysia. The activities involving the concepts of biodiverse edible schools (Fischer et al., 2019) were integrated into liberal education courses designed for undergraduate university students from various backgrounds using a variety of languages. This study included three courses in Taiwan and one course in Malaysia: Introduction to Agriculture in Taiwan (IAT), Organic Agriculture (OA), and Taiwanese Conversations in the Rural Life (TCRL) at NTU and Introduction to Green Chemistry (IGC) at UM. Each course was scheduled for a 2-hour session per week, granting students two credits. During the 2023-Fall semester, the IAT, OA, and 2 classes of TCRL (TCRL-23-01 and TCRL-23-02) were conducted. Additionally, two more TCRL classes, which use the same pedagogical approaches, were included in the subsequent 2024-Spring semester for the investigation (TCRL-24-01 and TCRL-24-02). The IGC course was conducted during semester I of the 2023–2024 academic year. Three languages are used in these courses: IAT and IGC are in an English-medium instruction environment (Dearden, 2014; Richards and Pun, 2023), OA instruction is conducted in Chinese (Mandarin; Wang, 1973; Kane, 2006), and for TCRL, the primary language of communication is Taiwanese (Taiwanese Southern Min; Taiwan Southern Min; Iun et al., 2005; Hsieh, 2014; Chappell, 2019; Lau and Tsai, 2020). Each course syllabus is provided in Supplementary Table 1.

2.2 Participants

The participants in this study included instructors, teaching assistants, and students. The instructor of the courses in Taiwan is the first author, whereas the instructor of the course in Malaysia is the second author. One teaching assistant is assigned to each class, with the exception of IGC. The student participants of the IAT, OA, TCRL-23-01, TCRL-23-02, TCRL-24-01, TCRL-24-02, and IGC courses consisted of 36, 36, 37, 38, 44, 41, and 32 university students, respectively, from 18, 17, 20, 21, 21, 21, and 6 departments. The students' backgrounds for each class are detailed in Table 1. There was a greater proportion of freshmen in the IAT, OA, TCRL-23-01, TCRL-24-01, TCRL-24-02, and IGC classes, whereas sophomores dominated the TCRL-23-02 classes. Additionally, a few graduate students were enrolled in the OA, TCRL-23-01, TCRL-24-01, and TCRL-24-02 classes. The student body of the IAT was diverse, with students from Taiwan, America, France, Indonesia, Israel, Japan, Korea, Malaysia, and the Philippines, whereas almost all the students in OA, TCRL-23-01, TCRL-23-02, TCRL-24-01, and TCRL-24-02 were Taiwanese. The students in the IGC course were all Malaysian except for one international student from China. The classification of the students' major fields followed the International Standard Classification of Education (UNESCO, 2012). All the classes included students from various disciplines, such as "social sciences, business and law," "science," and "engineering, manufacturing and construction." The IAT and OA classes had the highest number of students majoring in "agriculture"; TCRL-23-01, TCRL-23-02, and TCRL-24-02 had the highest number of students majoring in "social sciences, business and law"; TCRL-24-01 had the highest number of students majoring in "engineering, manufacturing and construction"; and IGC had the highest number of students majoring in "science" (Table 1).

2.3 Implementation of biodiverse edible school teaching practices

Agricultural-related topics and concepts of biodiverse edible schools (Fischer et al., 2019) were incorporated into the teaching materials and student activities of our university courses. Depending on the course learning objectives and students' backgrounds (Tables 1, 2), some classes focused on brainstorming potential farm and food options suitable for campus, whereas others adapted similar outdoor vegetation survey activities from

TABLE 1 The background of participants in the liberal education courses.

Course name		Frequency	Percentage (%)
Introduction to Agriculture in Taiwan (IAT)			
Gender	Female	22	61.1
	Male	14	38.9
Grade	1	22	64.1
	2	10	27.8
	3	3	8.3
	4	1	2.8
Fields	Social sciences, business, and law	8	22.2
	Science	3	8.3
	Engineering, manufacturing, and construction	6	16.7
	Agriculture	11	30.6
	Health and welfare	8	22.2
Organic agriculture (OA)			
Gender	Female	17	47.2
	Male	19	52.8
Grade	1	12	33.3
	2	7	19.4
	3	7	19.4
	4	9	25.0
	Graduate student	1	2.8
Fields	Humanities and arts	1	2.8
	Social sciences, business, and law	7	19.4
	Science	6	16.7
	Engineering, manufacturing, and construction	2	5.6
	Agriculture	17	47.2
	Health and welfare	3	8.3
Taiwanese conversations in the rural life 2023-01 (TCRL-23-01)			
Gender	Female	17	45.9
	Male	20	54.1
Grade	1	12	32.4
	2	11	29.7
	3	1	2.7
	4	11	29.7
	Graduate student	2	5.4
Fields	Humanities and arts	5	13.5

(Continued)

TABLE 1 (Continued)

Course name		Frequency	Percentage (%)
	Social sciences, business, and law	13	35.1
	Science	5	13.5
	Engineering, manufacturing, and construction	9	24.3
	Agriculture	1	2.7
	Health and welfare	4	10.8
Taiwanese conversations in the rural life 2023-02 (TCRL-23-02)			
Gender	Female	17	44.7
	Male	21	55.3
Grade	1	6	15.8
	2	21	55.3
	3	3	7.9
	4	8	21.1
Fields	Humanities and arts	4	10.5
	Social sciences, business, and law	17	44.7
	Science	1	2.6
	Engineering, manufacturing, and construction	10	26.3
	Agriculture	3	7.9
	Health and welfare	3	7.9
Taiwanese conversations in the rural life 2024-01 (TCRL-24-01)			
Gender	Female	23	52.3
	Male	21	47.7
Grade	1	17	38.6
	2	14	31.8
	3	4	9.1
	4	8	18.2
	Graduate student	1	2.3
Fields	Humanities and arts	6	13.6
	Social sciences, business, and law	11	25.0
	Engineering, manufacturing, and construction	20	45.5
	Agriculture	3	6.8
	Health and welfare	4	9.1
Taiwanese conversations in the rural life 2024-02 (TCRL-24-02)			
Gender	Female	20	48.8

(Continued)

TABLE 1 (Continued)

Course name		Frequency	Percentage (%)
	Male	21	51.2
Grade	1	15	36.6
	2	10	24.4
	3	5	12.2
	4	10	24.4
	Graduate student	1	2.4
Fields	Humanities and arts	5	12.2
	Social sciences, business, and law	18	43.9
	Science	1	2.4
	Engineering, manufacturing, and construction	11	26.8
	Agriculture	4	9.8
	Health and welfare	2	4.9
Introduction to green chemistry (IGC)			
Gender	Female	20	62.5
	Male	12	37.5
Grade	1	30	93.8
	2	2	6.3
Fields	Humanities and arts	6	18.8
	Social sciences, business, and law	2	6.3
	Science	16	50.0
	Engineering, manufacturing, and construction	7	21.9
	Services	1	3.1

TABLE 2 Learning objectives of the courses in this study.

Course	Learning objectives
Introduction to Agriculture in Taiwan (IAT)	Students will be able to acquire basic knowledge and a variety of aspects about agriculture in Taiwan through lectures, discussion, and participation.
Organic Agriculture (OA)	1. Students will be able to identify the principles of organic agriculture, management techniques, the impact and biological application within agricultural systems, policy regulations, product assurance systems, and other professional knowledge. They will also possess the ability to search for information related to organic agriculture and extend its application. 2. Upon completing the course, students will be able to distinguish the similarities and differences between organic agriculture and non-organic crop production systems.
Taiwanese Conversations in the Rural Life (TCRL)	Students will get the ability of using various Taiwanese digital resources; be able to introduce themselves in Taiwanese, try to use Taiwanese in daily life or express opinions, and be able to appreciate diverse cultures.
Introduction to Green Chemistry (IGC)	1. Students should be able to explain the principles and concept of green chemistry. 2. Students should be able to report the applications of green chemistry in Malaysia and globally such as waste, catalysis, environmentally benign solutions, renewable resources, alternative energy sources, synthesis and nanoscience, and supercritical carbon dioxide as green solvent. 3. Students should be able to elaborate the challenges of applying green chemistry concepts.

Fischer et al. (2019) to expand their knowledge of the edible plant diversity on university campuses.

Over the 16-week duration of each semester (Supplementary Table 1), assignments were issued to students in the IAT, OA, and IGC courses, whereas the IGC and TCRL classes featured specific outdoor educational activities on the campus. In the IAT course, the case study in Fischer et al. (2019) was briefly introduced in weeks 3 and 4, preceding midterm assignments where students worked on written and oral reports, either individually or in groups. Upon completion of tasks in week 10, an associated field trip at Taipei Botanical Garden was carried out in week 11 to strengthen learning. For OA, students formed groups and were tasked with delivering a final oral report expanding on Fischer et al. (2019) in the context of organic agriculture. Details of the assignment and group formation were provided for week 5. Following lectures and discussions on organic farming technologies, final oral reports were presented in weeks 15 and 16.

For the IGC course, the assignment and formation of student groups were explained at weeks 8 and 9. Students were informed about the principles of green chemistry and their linkage to agriculture. The concept was narrowed down to the campus environment where they study and further discuss it in the context of Malaysia. For the formation of student groups, they were asked to choose group members from different departments to gain exposure to diverse backgrounds. Furthermore, to adjust the learning objective of the IGC course, each group was given a specific topic determined by the course instructor. To apply the concept of agriculture and the principles of green chemistry in this IGC course, the students were first asked to perform an extracurricular activity in week 8. They were asked to find information on fruits, vegetables and edible trees that are found on the UM campus. They assembled according to their respective groups and spread out in different areas. This activity coincided with the implementation of the school's teaching practice of edible biodiversity. The time allocated for the activity was ∼1 h and was performed in the evening. The temperature in the campus area was ∼35°C, with clear weather. Students were asked to identify the items that could be eaten and know the name of the items. They were also asked to record the results of these outdoor activities and make a casual presentation in the classroom in the ninth week. Presentation/seminar activities and delivery of final assignments for the IGC course, according to the respective groups, were held at the 13th and 14th weeks. The report had to comply with the learning objectives of the course (Table 2).

In the four TCRL classes, a blend of classroom and outdoor activities on the campus, namely, the "Agri-food campus tour in Taiwanese," was implemented in the fifth week. The class began with an introduction to the legislative context of the Food and Agricultural Education Act in the nation, as well as the contents of edible landscaping (Zheng and Chou, 2023b) and biodiverse edible schools (Fischer et al., 2019). The eight groups of students in each class subsequently participated in collaborative activities focused on the exploration of edible plants and local biodiversity on campus for 40 min. They documented their observations through taking photographs or footage and later communicated their findings in the classroom using Taiwanese, in accordance with the course's language focus (Table 2). The activities related to the topic in the TCRL classes were completed within 2 h. According to weather records from the Taipei Astronomy and Weather Station, the outdoor average temperatures during the TCRL-23-01, TCRL-23-02, TCRL-24-01, and TCRL-24-02 classes were 25.1, 24.7, 15.0, and 15.4°C, respectively. It also rained during the TCRL-24-01 outdoor activities, with a recorded precipitation of 1 mm.

To summarize the biodiverse edible school teaching practices at NTU, the course observation data of IAT, OA, and TCRL during relevant weeks were collected using COPUS, the Classroom Observation Protocol for Undergraduate STEM (Smith et al., 2013). The observation process involved reviewing videos recorded by the automatic lecture recording system installed in the classroom, under the platform of the NTU Course online (NTU COOL; Shih et al., 2021; Shen et al., 2023) by the instructor and teaching assistants. The instructor's behaviors of presenting (lecturing, real-time writing, demonstration), guiding (follow-up/feedback on an activity, posing a question, posing a clicker question, listening to and answering student questions, moving and guiding, one-on-one discussion), administration, and others were recorded, whereas the students' behaviors of receiving, working (individual thinking, discussing clicker questions, working in groups, other group activities, making a prediction, taking tests), talking in class (answering questions, asking questions, engaging in whole-class discussions, presenting to the entire class), and others were recorded (Smith et al., 2013; Reisner et al., 2020). Behaviors were visualized at 2-minute intervals using COPUSprofiles.org and categorized based on the anatomy of the teaching method used in science, technology, engineering, and mathematics (STEM) courses (Stains et al., 2018).

2.4 Data collection and analysis

Practical examples were extracted from the works of the IAT, OA, and IGC courses. The biodiverse edible school cases worldwide, on a regional scale, and within the campus were explored collaboratively by the participants. The authors examined the written assignments and all the recorded materials, summarizing the findings after the teaching practices.

Students' perceptions were surveyed before and after the intervention of biodiverse edible school teaching practices. The intervals between the two questionnaires for the IAT, OA, and IGC were 8, 11, and 4 weeks, respectively, whereas the interval for all the TCRL courses was 1 week. Baseline attitudes in each class included students' perceptions of the ecosystem, biodiversity, weeds, and attention to agricultural topics. Students' understanding of the number of edible plants on campus was assessed using a five-point scale and elaboration of a list of edible plants both before and after our intervention, reflecting the special plant survey activities described in Fischer et al. (2019). After the implementation of biodiverse edible school teaching practices, the students were surveyed regarding the intended goals of the activities and courses. The questions measured their comprehension of biodiversity and agriculture, willingness to consume seasonal agricultural products, and achievement of course learning objectives (Table 2). The responses were rated on a seven-point Likert scale: 1 = strongly disagree, 2 = disagree, 3 = slightly disagree, 4 = neutral, 5 = slightly agree, 6 = agree, and 7 = strongly agree. The data were analyzed using R (https://www.r-project.org). Analysis of variance (ANOVA) was employed to determine significance levels, and Tukey's honestly significant difference (Tukey HSD) test was used for *post hoc* comparisons. Additionally, students' attitudes toward the linkage of agricultural activities in each class to SDGs (Sachs, 2012; Sachs et al., 2019) were surveyed.

3 Results

3.1 Preintervention attitudes of students

The baseline attitudes of students before the introduction of biodiverse edible school teaching practices are outlined in Table 3. Students in different classes exhibited similar attitudes toward questions regarding ecosystems on school campuses and weeds in crop-producing fields (Q1 and Q2, not significant). Students in the IAT class scored higher on the question about their attention to agricultural news than those in the TCRL-24-02 class did (Q3, $P < 0.05$). Furthermore, the IAT students rated themselves higher in terms of their knowledge of the number of edible plant species on campus, whereas the TCRL-23-01 students scored significantly lower (Q4, $P < 0.001$). Additionally, OA students reported a greater number of edible plant species on the school campus, whereas the TCRL-23-01 class listed fewer edible plant species (Q5, $P < 0.01$).

3.2 Teaching and learning processes

The recorded teaching and learning processes in the IAT, OA, and the four TCRL classes during the selected weeks using biodiverse edible school practices at NTU are summarized in Figure 1. The instructor and students' behaviors noted in the figure correspond to those in Smith et al. (2013) and Reisner et al. (2020). During weeks 9 and 10 of the IAT course, the model of the processes was a combination of lectures on agricultural topics and students' midterm oral reports about biodiverse edible schools (Figures 1A, B), corresponding to the "interactive lectures" of clusters 4 and 3 in Stains et al. (2018). In the OA course, there was a workshop

TABLE 3 Questions and responses related to students' baseline attitudes in each class before interventions.

Do you agree with the statement of ...	IAT	OA	TCRL-23-01	TCRL-23-02	TCRL-24-01	TCRL-24-02	IGC	Pr (>F) in ANOVA
Q1: There are many different ecosystems in school campuses and the ecosystems are important parts of biodiversity.	6.55 (1.15)	6.26 (0.92)	6.06 (1.28)	5.94 (1.67)	6.12 (1.48)	5.95 (1.36)	6.03 (1.19)	0.497
Q2: In crop-producing fields, weeds should be removed.	5.42 (1.62)	4.97 (1.30)	5.23 (1.31)	5.00 (1.47)	5.12 (1.42)	5.31 (1.30)	5.27 (1.36)	0.804
Q3: I usually pay attention to news and topics related to agriculture.	5.00 (1.35)	4.63 (1.34)	4.09 (1.38)	4.22 (1.64)	4.29 (1.50)	3.83 (1.54)	4.30 (1.44)	0.027
Q4: How many species of edible plants do you know on your school campus?	2.64 (1.48)	1.74 (1.20)	1.26 (0.66)	1.44 (0.94)	2.33 (1.59)	1.83 (1.38)	1.63 (1.13)	<0.001
Q5: Write down some edible plants you know that can be found on your school campus.	2.00 (1.50)	2.18 (2.79)	0.91 (1.04)	1.03 (0.88)	1.17 (1.38)	1.29 (1.58)	1.27 (0.94)	0.003

IAT, Introduction to Agriculture in Taiwan; OA, Organic Agriculture; TCRL23-01, Taiwanese Conversations in the Rural Life 2023 class 1; TCRL23-02, Taiwanese Conversations in the Rural Life 2023 class 2; TCRL24-01, Taiwanese Conversations in the Rural Life 2024 class 1; TCRL24-02, Taiwanese Conversations in the Rural Life 2024 class 2; IGC, Introduction to Green Chemistry. A 7-points Likert scale is used for Q1–Q3 (Scale = 1–7); a 5-points scale is used for Q4 (Scale 1: 0–5; Scale 2: 6–10; Scale 3: 11–15; Scale 4: 16–20; Scale 5: >21); the numbers in Q5 are the counts for numbers of names of edible plants written by individual students. The values are shown as means; followed by standard deviations in parentheses.

on organic farm design adapted from activities in the Organic Youth Forum of IFOAM Asia (Willer and Lernoud, 2019) in week 12 (Figure 1C) and a final oral report session in week 15 (Figure 1D). The workshop class and the students' report class were classified into cluster 7, the "student-centered" style, and cluster 1, the "didactic" style, respectively (Stains et al., 2018). The four TCRL classes conducted the activity of "Agri-food campus tour in Taiwanese" in week 5, with students separated into eight groups with similar teaching and learning processes (Figures 1E–H). They all belong to the style of interactive cluster 3 in Stains et al. (2018). The average outdoor activity times of the TCRL-23-01, TCRL-23-02, TCRL-24-01, and TCRL-24-02 classes were 34.1, 33.6, 29.8, and 35.5 min, respectively. Most of the groups documented edible plants and local biodiversity on the experimental farm and along campus roadsides, whereas one group at TCRL-24-02 explored milk-producing cattle housing at the Department of Animal Science & Technology, NTU.

In the IGC course of UM, group formation resulted in 11 groups. Each group consisted of three students of which at least one student was from a different department. Each group could be all male/female students or a mix of male and female students and was given a topic related to the 12 principles of chemistry. There were three topics in total, namely, zero waste, alternative energy sources and renewable resources. The outdoor activities of IGC were as follows: Before the concepts of a biodiverse edible school were absorbed or integrated into student learning, the students were asked to perform activities outside the classroom. Students choose their own workplace locations on campus to explore fruits, vegetables, and edible plants. There were five locations for students to choose from, namely, Tasek Varsiti (varsity lake), Rimba Ilmu Botanic Garden, Ladang Mini ISB (ISB Mini Farm), around the Faculty of Science, and UM residential colleges. The students recorded the results of their observations and reported them orally in week 9. The purpose of this activity was to enable students to identify types of local edible food and relate it to local biodiversity. Students performed an analysis according to the learning objective of the course from the 10th week to the 12th week. Presentation and writing assignments were done at the 13th and 14th weeks.

3.3 Exploring practical examples of biodiverse edible school concepts in undergraduate liberal education

Using Fischer et al. (2019) as a "primer" reference, students in the IAT course applied biodiverse edible school concepts with inventive approaches on the university campus, whereas those in the OA course extended the ideas by integrating organic agriculture into their surroundings. They explored practical examples both internationally and within local regions, and subsequently proposed ideas through brainstorming.

Many IAT students found inspiration in both global and regional cases. Learning from the Edible Schoolyard Program

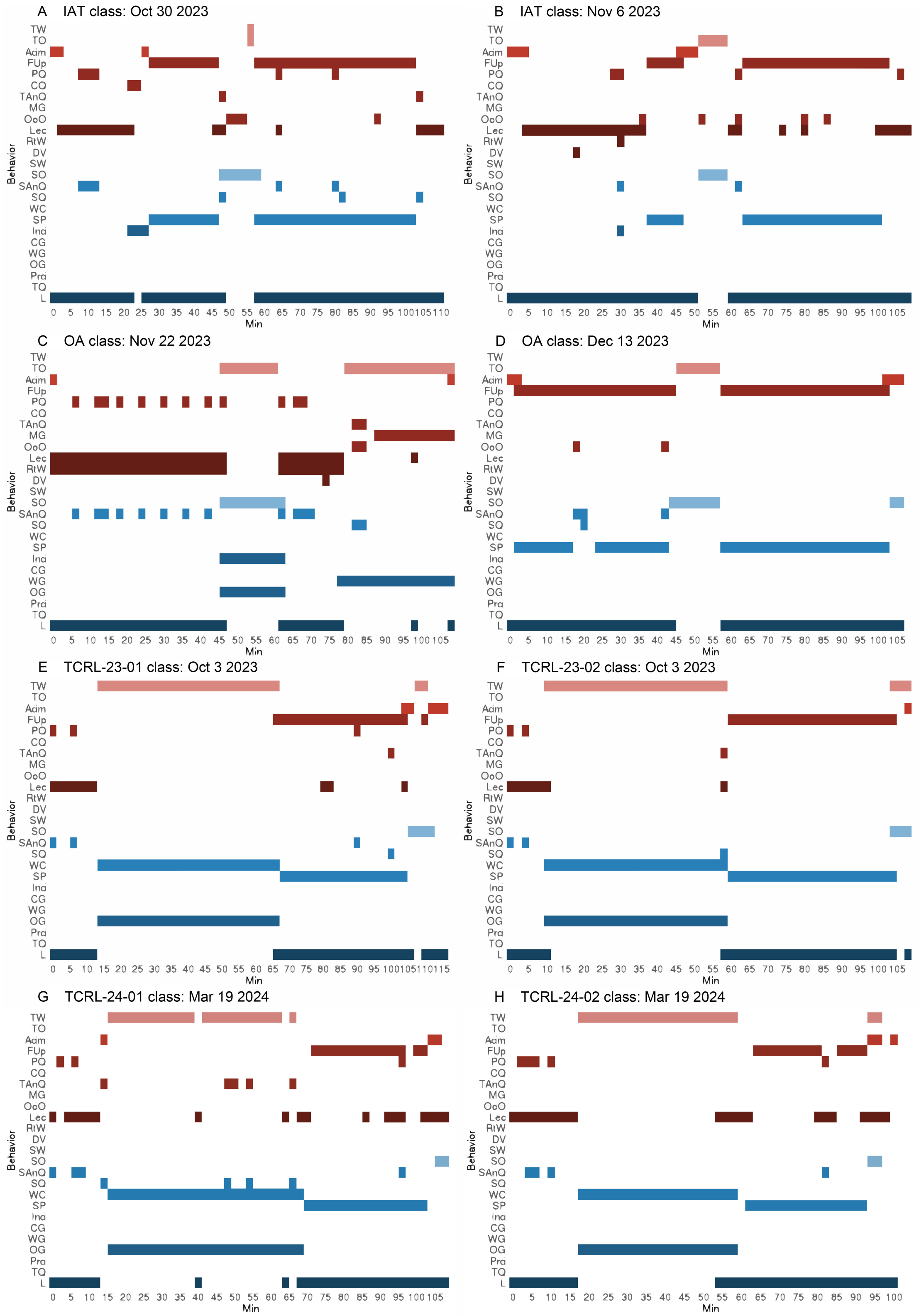

FIGURE 1
Observation of teaching and learning processes during selected weeks at National Taiwan University using COPUS, the Classroom Observation Protocol for Undergraduate STEM according to Smith et al. (2013). **(A, B)** Introduction to Agriculture in Taiwan class, **(C, D)** Organic Agriculture class, **(E–H)** Taiwanese Conversations in the Rural Life class. Red bars represent the behaviors of the teacher and blue bars indicate students' behaviors.

in American middle schools (Laird, 2013), they explored the value of hands-on learning, cultivating healthy eating habits, engaging in environmental stewardship, and promoting nature education. Expanding from the open-door pantry community model (The Open Door, 2024), the students envisioned their imaginary "Campus Garden to Table" initiative, which may serve as a vibrant platform for students, faculty, and staff to participate in sustainable practices. In light of experiences such as the biointensive vegetable gardens in school in Cavite Province, the Philippines (Monville-Oro et al., 2020), the links to nutrition education and the diversification and conservation of indigenous vegetables were emphasized. Similarly, examples from Japanese school lunch programs (Ishida, 2018; Waida and Kawamura, 2022) suggest that these approaches may contribute to food education, enhance the understanding of local food culture, and help preserve traditional culinary cultures. Taking a closer look at regional culture, traditional Korean dishes such as bibimbap, comprising rice, various vegetables, and sauces (Chung et al., 2015; Mun et al., 2023), could be integrated into cultural events during university festivals to promote interest in vegetables on university campuses.

Both the IAT and OA participants focused on practical cases of biodiverse edible schools and food and agricultural education in Taiwan. Local communities, such as the San-He community in Taoyuan city, were cited as exemplary examples of promoting edible landscapes, which extend the food production system to tourism and environmental education systems in a hilly, Hakka-culture based suburban area (Zheng and Chou, 2023a). Various forms of community-supported agriculture (Brown and Miller, 2008; LaCharite, 2016), crucial for supporting organic agriculture in Taiwan (Pisarn et al., 2020; Lee, 2023), were elaborated upon to be included in the perspective movement toward university campus-supported agriculture (Wu, 2018; Pisarn et al., 2020). In addition, several cases across Taiwan featuring food and agricultural education activities from elementary school to senior high school, including Daan elementary school, Leye elementary school, Longdu elementary school, and Chien Kuo high school, are highlighted in the reports. Their alignment with the ideas of biodiverse edible schools in Fischer et al. (2019) is summarized in Table 4. All four schools demonstrated components of collaborative activities with multiple stakeholders and school gardens for producing local food (Table 4).

In the NTU, recent efforts to implement biodiverse edible schools in accordance with the conceptual framework have been outlined through the collective work of the IAT and OA participants. Table 5 provides current and previous examples of collaborative activities, school kitchens, school gardens, and wild sites. With respect to collaborative activities, there is significant involvement from teachers and university students at the Experimental Farm of the College of Bioresources and Agriculture. Courses such as "Hand-on Experience of Modern Agriculture" designed for students at the College of Bioresources and Agriculture and "Hand-on Experience of Field Life" for students from other majors have been taught for more than 20 years. (https://nol.ntu.edu.tw/nol/coursesearch/search_result.php). Additionally, certain "student service education" courses, such as those in the Department of Agricultural Economics, require students to engage in rural service during summer vacation. Furthermore, student clubs such as "NTU Roots & Shoots" promote consideration of the wellbeing of all life on earth in their activities. Another group, "Ptumaw," focuses on using indigenous plants to enhance the understanding of ethnic cultures, and their members also manage the edible garden beside the Student Activity Center on campus. Some groups also participate in guerrilla gardening (Reynolds, 2008; Adams et al., 2015; Hardman et al., 2018) and various other undertakings. The College of Bioresources and Agriculture of the university manages the Agricultural Exhibition Hall and farmlands, offering activities such as Spring plowing and rice transplanting, farm-to-table experiences during the Azalea festival (National Taiwan University, 2008), and guided tours of the farm environment in the environmentally certified facility (Lee et al., 2020), effectively broadening outreach to a larger community. Additionally, the college collaborated with the Yunlin County Government to organize the Farmers' Market on campus in 2023, promoting local produce through University Social Responsibility projects (Vasilescu et al., 2010; Yang, 2023). With respect to school kitchens, the college manages the Agricultural Products Sales Center, where school-produced items such as milk, bread, steamed buns, eggs, tea, and beverages are sold. Previously, a farm-operated drink shop offered Aiyu jelly beverages sourced from local jelly figs (Srisai et al., 2023), but it is presently closed. There seems to be a lack of cafeterias and regular production of boxed lunches using exclusively local ingredients on the campus. The details of the school gardens and wild sites in the surroundings are presented in Table 5, which expands on the students' exploration.

The brainstorming results using the concepts of biodiverse edible schools in the IAT and OA courses in the NTU are also presented in Table 5. With respect to collaborative activities, departments can develop service-oriented educational programs and food and culture courses emphasizing local food and biodiversity, particularly for incoming freshmen. Encouraging cross-generation green urban learning, university students can engage in required, elective or voluntary teaching and learning exchanges with children from the affiliated preschools of the NTU. Moreover, "event-week booths" are frequently organized near lecture buildings and squares. "Healthy food weeks" and similar events can be held by members from departments, student clubs, associations, and other groups to advocate for biodiverse edible schools. Additionally, community-based partnerships employing a community-supported agricultural model can be established on campus, involving local farmers to supply seasonal produce for various campus events. By utilizing university resources, such as a college's experimental farm, a campus can serve as an outdoor classroom not only for university students but also potentially for neighboring schools and the public. To improve the ability of school kitchen to prepare local and fresh food, cooperation between regional small-scale farmers and campus cafeterias can be initiated. The student cafeteria serving a vegetarian meal is considered a good starting point to prioritize. Promotional strategies, such as seasonal menu guides, posters, and discounts, could be employed to nurture culinary culture. These efforts could be integrated with liberal education courses, cooking classes, and activities organized by student clubs focused on culinary arts, dessert making, and cake crafting. Considering the discontinuation of the college-managed shop selling Aiyu jelly beverages, a campus café offering popular

TABLE 4 Cases in Taiwan summarized in reports from Introduction to Agriculture in Taiwan (IAT) and Organic Agriculture (OA) courses and their alignment with the concept of biodiverse edible schools.

Category	Daan elementary school	Leye elementary school	Longdu elementary school	Chien Kuo High School
Collaborative activities	Environmental education activities and ecological facilities supported by teachers, communities, and educational foundations	Outdoor education activities supported by teachers, workers, volunteers, Parents' Association, communities, university specialists, and educational foundations	Special teaching and learning events supported by teachers, associations, non-government organizations, communities, University Social Responsibility Program group	Sustainable dining table activities including food delivery for disadvantaged groups supported by home economics teachers, retired colleagues, volunteers, non-government organizations
School kitchens	-	Casual cooking courses	Program-based Satoyama Kitchen, clubs, and activities	Cooking in the courses
School gardens	Vegetables in greenhouses, rooftop gardens, and aquaponics	Rice paddy and vegetable garden in the playground	Rotation of rice and vegetables	Small allotments in the school
Wild sites	Wetlands and ponds	-	Neighboring mountain hiking trail and ecological park	Taipei botanical garden
Locality	Bade District, Taoyuan City	East District, Taichung City	Meinong District, Kaohsiung City	Zhongzheng District, Taipei City
References	Tseng et al., 2022 and this study	This study	Lin, 2017; Wu, 2022, and this study	This study

Collaborative activities, school kitchen, school garden, and wild sites are four components of biodiverse edible schools in Fischer et al. (2019). "-": not specified. The information of the schools about the relevant issues is from the students' engagement of the reports, regional news, and the listed references.

TABLE 5 Cases in National Taiwan University and brainstorming ideas summarized in reports from Introduction to Agriculture in Taiwan (IAT) and Organic Agriculture (OA) courses and their alignment with the concept of biodiverse edible schools.

Category	Current and previous cases	Brainstorming from the IAT reports	Brainstorming from the OA reports
Collaborative activities	Hand-on courses for university students; Rural services at summer vacation; NTU Roots and Shoots student club; Ptumaw; Agricultural Exhibition Hall; Farm workshops for the public; University social responsibility projects	Required courses for freshmen; Cross-generation learning; Healthy food weeks; Novel student clubs; Collaborative programs involve students and staff members; Seasonal farmer's markets	Additional food and culture courses for university students; Community-based collaboration; Community-supported agriculture in the university; Outdoor food and agricultural education classroom for nearby schools and the publics
School kitchens	Agricultural Products Sales Center; Aiyu jelly drink shop	Cooperate with cafeterias in the campus; Collaborate with small-scale farmers to serve locally-grown vegetables; Seasonal menu guides/posters; Blend school kitchen/cafeteria functions with culinary majors and cooking classes; Campus café	Prioritize collaboration with student cafeteria serving vegetarian meal; Use of discounts and promotions; Liberal education courses; Culinary courses; Bridging garden to table through student clubs in culinary arts, desserts, and cake crafting
School gardens	Experimental farm of College of Bioresources and Agriculture; The edible garden beside the Student Activity Center; Rooftop gardens; Guerrilla gardening	Integrating surroundings of dormitory, library, fitness park and more, into edible school gardens; Dispersed small-scale gardens; Permaculture designs	Establishing more rooftop gardens; Convert unused land into organic vegetable gardens in the campus
Wild sites	Undeveloped lands in the campus; Guanyin Hill Hiking Area near Treasure Hill; Fuzhoushan Park	Insect hotel	Interpretation of edible plants and biodiversity of the sites

Collaborative activities, school kitchen, school garden, and wild sites are four components of biodiverse edible schools in Fischer et al. (2019).

food items could be an alternative option. With respect to school gardens and wild sites, the spaces near dormitories, libraries, fitness parks, and rooftops could potentially be transformed into edible school gardens, even if they are experimental, temporal, or small scale. Both permaculture designs (Ferguson and Lovell, 2014) and organic farming management principles (Van Bruggen et al., 2016) can be applied in these cases. To increase the wilderness and biodiversity of these sites, the addition of insect hotels is a feasible option (Harris et al., 2021). Additionally, engaging in environmental interpretation activities can draw attention to the habitats and niches that support biodiversity (Zuppinger-Dingley et al., 2014) in surrounding areas.

In this IGC course, students are introduced to the principles and concepts of green chemistry where they must be able to apply the concept of green chemistry in Malaysia. The course topics provided students with the foundational knowledge needed to engage in the Edible School Program's activities, such as identifying edible plants on campus and brainstorming potential sustainable farm or food options. Concepts such as waste management, renewable resources, and alternative energy were particularly relevant, as they helped students understand how organic waste could be repurposed for composting, how renewable energy could support sustainable food production, and how green chemistry principles could reduce the environmental impact of farming. Identifying edible plants on campus offered a practical application of these concepts, allowing students to see how local resources could be utilized in a sustainable way. The brainstorming session for campus food options encouraged students to creatively apply their learning to real-world challenges, considering how green chemistry could contribute to more sustainable, waste-reducing, and energy-efficient farming practices. These activities were specifically chosen to link theoretical knowledge with hands-on experience, helping students connect classroom learning with local solutions for food security and environmental sustainability. Over the semester, they studied and described the challenges of applying green chemistry concepts concerning zero waste, renewable resources, and alternative energy sources. Their research theme is closely related to agriculture and biodiverse edible school concepts (Fischer et al., 2019). Students have successfully observed the presence of edible plants on campus. They felt positive because from this course they had gone through the process of learning about the types of plants that can be eaten with colleagues from different departments. They were asked to make an oral presentation of the results of the observation at the selected location. The plants found on campus include rambutan, blackberry, papaya, young ferns, turmeric, pandan leaves, curry tree, banana, lime, coconut, ginger, jackfruit, chili, blubbery, pineapple, guava, star fruit, sugarcane, sapodilla, mango, cempedak, nangka, rambai istana, blue pea flowers, ara beringin, jambu air, screwpine, wood sorrel, palm tree, durian, pala, and belimbing buluh. The students were able to classify plants as tropical medicinal plants, local edible plants, or local edible fruits. In addition, they were able to identify the local names of these plants.

As a result of the experience from this extracurricular activity on the UM campus, they have successfully made written reports and face-to-face seminar presentations on assignments involving 12 chemical principles, with their respective topics focusing on zero waste, alternative energy sources and renewable resources related to Malaysia agriculture. Here, out of the 11 student groups formed, the zero-waste theme includes four student groups, the alternative energy sources theme comprises as many as three groups, and the renewable resources theme comprises the remaining four student groups. For the waste category, they reported that smart farming should be implemented in Malaysia agriculture. The use of smart farming applications can help farmers predict yields, minimize costs and waste resources. For example, drones and soil sensors are able to detect tree health and soil moisture during cultivation. A notable example of this smart farming is the collaboration between UM and private companies to support the growth and cultivation of black thorn durians in Malaysia (Banoo, 2023). In addition, the use of biofertilizers in agriculture, such as compost, may advance zero-waste practices, uphold the principles of green chemistry, and promote sustainability. One of the zero-waste student groups reported that composting is a key component of sustainable local food initiatives, as it improves soil health, reduces environmental impacts, promotes efficient resource use, and fosters community engagement. Integrating composting practices into local agriculture contributes to the overall resilience and sustainability of food systems. In addition, sustainability through innovation in agricultural activities in Malaysia has been reported by another group in their final assignment. In this case, the edible cassava starch is processed to produce biodegradable and compostable packaging materials (Jumaidin et al., 2024). The brainstorming of the group members, also reported the prevention of waste from coconut leaves. Here, the leaves of the plant are used in traditional crafts, such as brooms, mats, baskets, and food wrappers. In addition, the trunks of coconut trees can be used as construction materials to build furniture and bridges.

With respect to the renewable resources in agriculture in Malaysia, one of the student groups emphasized solar benefits in sustaining farming practices. The introduction of solar-powered irrigation systems and efficient drying technologies has led to a commitment to addressing water scarcity and promoting energy-saving awareness (Safri et al., 2020). To address renewable resources, another group of students debated on biomass. One of the green revolutions toward sustainable farming practices is the utilization of biomass as a renewable energy source. Biomass is an organic material derived from edible plants such as maize, sugarcane, and paddies. It can be used as an alternative to fossil fuels. Biomass can be converted into bioenergy through various processes such as combustion, gasification, and fermentation. This bioenergy can replace non-renewable resources to meet on-farm energy needs by generating heat, electricity, and biofuels.

When alternative energy sources are used, energy-efficient greenhouses are recommended for agriculture in Malaysia. Energy-efficient greenhouses play a pivotal role in revolutionizing modern agriculture by combining the principles of green chemistry with advanced technology. In Malaysia, the use of energy-efficient greenhouses has gained traction as the agricultural sector strives to increase productivity and sustainability. One notable example is the adoption of controlled environment agriculture technologies, including high-tech greenhouses, in the Cameron Highlands (Idzni and Chia, 2021). This region, known for its cool climate, has implemented energy-efficient greenhouses equipped with advanced climate control systems, automated irrigation, and energy-saving lighting. These greenhouses enable year-round cultivation of crops such as strawberries, tomatoes, and flowers, optimizing growing conditions and minimizing the environmental impact. Excerpts of student reports with their respective group topics are collected in Table 6.

3.4 Students' perceptions of teaching practices

The participants' perceptions of various questions related to the diverse edible school teaching practices are summarized in this section. These questions covered their understanding of the number of edible plants on campus, attitudes toward biodiversity and agriculture, willingness to consume seasonal agricultural

TABLE 6 Excerpt report from Introduction to Green Chemistry student assignments that parallels the theme of agriculture with their biodiverse edible school and green chemistry concepts in Malaysia.

Area	Current cases in Malaysia	Brainstorming from group of students	Challenges of applying Green Chemistry concepts
Waste	In Malaysia alone, ~13.95 million tons of solid waste were generated in 2015. This includes waste from households, industries, commercial establishments, institutions, and construction activities.	Zero waste initiatives involve the development and execution of sustainable local food strategies that integrate principles aimed at minimizing waste, optimizing resource utilization, and fostering a circular economy. Cassava starch can be used to produce biodegradable and compostable packaging materials. Banana waste can be converted into biodegradable plastic. Oil palm cultivation can contribute to lower greenhouse gas emissions compared to other oil crops due to its high yield per hectare. Local farmers also can compost to create their nutrient-rich organic fertilizer for agriculture from coconut waste such as husks, leaves, and shells. The husk and shell of coconuts can be repurposed for various uses as the husk fibers can be processed into coir, a versatile material used for making brushes, mats, and soil amendments. Coconut shell charcoal is used in the production of activated carbon, which has applications in water filtration and air purification.	Highlight precision agriculture, biopesticides, biofertilizers and waste reduction; Utilizing technology like drones. Drones have the capability to precisely distribute fertilizers or pesticides only where needed, optimizing the use of these resources on the farm. Additionally, drones offer the benefit of early detection of issues such as plant diseases, soil analysis, and weed detection. The use of biodegradable resources like banana peels that is simple, lightweight, and recyclable packaging materials, greatly aids in reducing plastic pollution and constructing a more sustainable future. Transform plants into something new like recycling to minimize waste in our world. Avoid burning unwanted plants
Alternative Energy sources	Malaysia aims to utilize a substantial portion of palm oil biomass as an alternative energy to coal. In October 2018, new biogas plants under waste-to-energy project have successfully implement green practices in the industry. The collaboration between the Federal Land Development Authority (Felda) and Concord Green Energy Sdn Bhd (CGE) involves the establishment of biogas plants at 14 of Felda's palm oil mills. The initial phase of the project focuses on four "green field" palm oil mills, two located in Pahang and two in Johor. These biogas projects by CGE aim to generate electricity from palm oil mill effluent, utilizing Felda's existing biogas systems	Discussions on transformative potential of harnessing renewable energy to cultivate a greener and more resilient future for Malaysian agricultural landscapes; These biogas projects by CGE aim to generate electricity from palm oil mill effluent, utilizing Felda's existing biogas systems. Instead of merely managing waste, millers participating in the project can convert biogas into electricity, benefiting from the Feed-in-Tariff (FiT) incentive. This initiative not only provides additional income for the millers but also contributes to increased revenues, global recognition, and higher productivity for the companies involved. With an estimated potential to generate 5,000 MW of electricity at 40% operational efficiency, this biomass has the capacity to replace Malaysia's annual dependence on coal.	Mitigate greenhouse gas emissions; combining alternative energy sources such as solar, wind and biomass energy with sustainable farming practices which may have a profoundly positive impact; The successful implementation of this alternative energy source is crucial for achieving sustainable and environmentally friendly power generation in the country. The Sustainable Agriculture Education Association (SAEA) is a group of educators, researchers, students, and farmers who are interested in alternative energy integration and green chemistry practices in sustainable agriculture. In Malaysia, the SAEA has collaborated with local schools, community groups, and farmers to implement educational outreach programs on alternative energy integration and green chemistry practices in agriculture.
Renewable resources	Malaysia focuses more on biodiesel production, which comes from vegetable oils or animal fats. In Malaysia, the oil palm plant produces about 5 tons of palm oil per hectare, significantly more than rapeseed (1 ton) and soybean (375 kg) on the same land area. Using renewable energy sources like solar, wind, biomass, and hydropower is a key component of sustainable energy in agriculture; Coconuts are Malaysia's 4th and the world's 12th most important industrial commodity. Johor, a state famous known for its largest coconut plantations. Soil erosion is a common issue faced by farmers, where soil quality declines can lead to accumulation of toxic chemicals and environmental issues.	The most common sources for biodiesel production in Malaysia are palm oil and coconut oil. Biodiesel is biodegradable, non-toxic and environmentally friendly compared to petroleum. Palm oil, being the main feedstock for biodiesel, suits the economic structure of the country as it is constantly produced. It can be harvested throughout the year and is slightly affected by the season or weather. Photovoltaic technology incorporated into the drying systems to generate a fan, which is then converted into battery power to produce hot air. This innovative system serves as a valuable tool for promoting energy-saving awareness, aiming to reduce the impact of pollution on the wellbeing of future generations. Coco peat has favorable physical properties for plants, including the ability to inhibit a variety of fungal diseases.	Biofuel laws (for example, the National Biofuel Policy or the Malaysian Biofuel Industry Act) have been passed at the governmental level and have raised biofuel production in their aim to reduce the country's reliance on fossil fuel; Informing Malaysian farmers about the advantages and application techniques of biopesticides may increase its usage; The case of Malaysia exemplifies the success and potential of integrating solar energy into various agricultural facets, from irrigation systems to drying processes; Due to the non-favorable situations, coco peat, derived from coconut husks, serves as a versatile and sustainable solution in various applications.
Biodiverse edible school	Universiti Malaya campus; Tasek Varsiti (varsity lake), Rimba Ilmu Botanic Garden, Ladang Mini ISB (ISB Mini Farm), around the Faculty of Science and UM residential colleges	Discussions on edible plants and biodiversity of the sites; Make compost fertilizer from goat manure of the ISB farm and organic waste. Cooperation of prepared compost to improve the growth of the plants in the farm, such as rambutan, durian trees and crops for livestock (chicken, sheep, goat and others). Adoption of solar farming in alternative energy resources. Proposed anaerobic digestion of organic matter in anaerobic environments. Anaerobic digesters could be implemented where wastes can be converted into renewable energy	How to determine the composting method must be further debate. Collection of green materials is mandatory. Location for composting. Patience in harvesting the compost; incorporating solar farming educational modules into school curriculums to foster environmental consciousness. Educational outreach Programs to reduce greenhouse gas emissions and increase renewable energy generation. Promote biomass sources into high-energy biogas. Additional research on these by-products

(Continued)

TABLE 6 (Continued)

Area	Current cases in Malaysia	Brainstorming from group of students	Challenges of applying Green Chemistry concepts
		biogas and the final solid residue is converted into nutrient rich fertilizers. Implementation of Biopesticides in agriculture. The use of coco peat for farming and gardening. Specifically designed solar drying systems for drying agricultural products and herbs. Various materials, such as kenaf, seafood (including seaweed), medical herbs, and sliced tamarind, can be dried in these areas within a short period of 2–3 days.	may reveal greater utility of these waste and aid in effective sustainable agriculture. Sustainable energy in agriculture. Greenhouse drying system.

products, achievement of course learning objectives, and linkage to the SDGs.

To assess participants' understanding of edible plants on campus, we compared their responses regarding the number of edible plants they could identify before and after the activities. For the question "How many species of edible plants do you know on your school campus?", we observed varying results across different classes. In the IAT class, there was a decrease in average responses after the activities ($P < 0.05$), suggesting that participants may have felt less confident in their knowledge post-activity. In contrast, the OA class showed no significant change, indicating stability in participants' perceptions. Notably, participants in the IGC class reported a significant increase in their knowledge ($P < 0.01$), along with substantial increases in the TCRL-23-01 ($P < 0.001$), TCRL-23-02 ($P < 0.001$), TCRL-24-01 ($P < 0.01$), and TCRL-24-02 ($P < 0.001$) classes (Figure 2), suggesting that the activities were effective in enhancing their understanding among these groups. For the open-ended question "Write down some edible plants you know that can be found on your school campus," we found no significant differences in responses before and after the interventions in the IAT and OA classes. However, participants in the IGC class showed a significant increase in their ability to identify edible plants ($P < 0.01$), as did those in all the TCRL classes ($P < 0.001$; Figure 3), indicating that specific teaching practices in these classes may have successfully engaged the students and expanded their knowledge.

When asked whether "This course enhances my understanding about biodiversity," the participants generally agreed that the activities enhanced their knowledge of biodiversity, with the highest score of 6.4 in the TCRL-24-02 class and the lowest score of 5.9 in the OA class (Figure 4A). Similarly, for the question "This course enhances my understanding about agriculture," the participants indicated an overall positive response, with the highest score of 6.5 in the OA class and the lowest score of 6.1 in the IGC class (Figure 4B), reflecting a consensus among participants that the course content effectively contributed to their understanding of both biodiversity and agricultural concepts. With respect to the question "After the agricultural-themed activity in this course, I'm more willing than before to prioritize consuming locally and seasonally produced agricultural products," the participants expressed increased willingness, with the highest score of 6.2 in the IAT class and the lowest score of 5.8 in the IGC class (Figure 4C), suggesting that engagement with local food systems may have positively influenced participants' attitudes toward sustainable consumption. Furthermore, when asked if "The agricultural-themed activity in this course contributes to achieving my learning objectives," the participants agreed that it contributed to achieving the learning objectives, with the highest score of 6.5 in the IAT class and the lowest score of 5.7 in the IGC class (Figure 4D), indicating that the students recognized the relevance of these activities to the educational goals.

Finally, the participants considered that the biodiverse edible school teaching practices in the study corresponded to the SDGs, with the highest agreement for Goal 2 (zero hunger). This was followed by Goals 12 (responsible consumption and production), 15 (life on land), and 3 (good health and wellbeing) (Table 7), highlighting not only an enhanced understanding of biodiversity and agriculture but also an awareness of how these practices contribute to broader global goals.

4 Discussion

This study aimed to improve learning outcomes for undergraduate students in liberal education courses at universities through the inclusion of biodiverse edible school concepts. They were introduced in six classes in Taiwan and one in Malaysia, providing practical examples related to biodiverse edible schools in East Asia and Southeast Asia. These pedagogical approaches effectively enhanced students' understanding of biodiversity and agriculture, increased their willingness to consume local foods, and helped them achieve course objectives across various fields, including agriculture, language, and green chemistry (Figure 4; Table 2). In addition to the application cases for children (Fischer et al., 2019), our teaching and learning experiences serve as pioneering examples for integrating biodiverse edible school concepts into university education. These findings demonstrate that biodiverse edible school concepts can be effectively incorporated into higher education curricula.

4.1 Implementing biodiverse edible school concepts increases learning outcomes for university students in Taiwan and Malaysia

Biodiverse edible schools have shown significant potential in transforming student learning experiences across various academic settings in Taiwan and Malaysia. This approach has been successfully applied to a range of courses, including a specialized

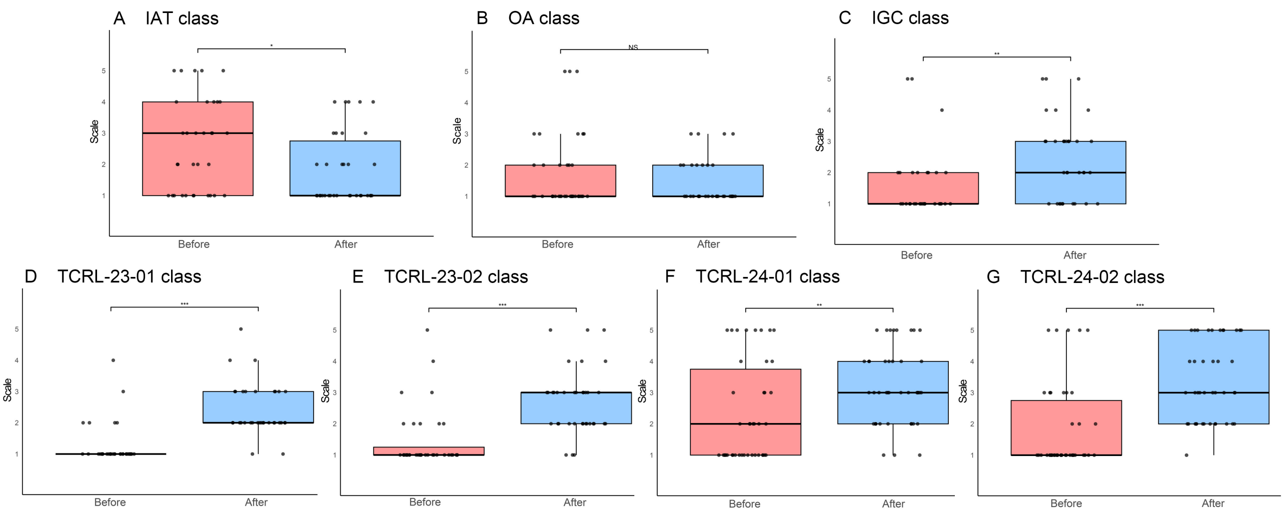

FIGURE 2
Students' perceptions regarding their knowledge of edible plant numbers on the school campus before and after intervention, presented using boxplots. **(A)** Introduction to Agriculture in Taiwan class, **(B)** Organic Agriculture class, **(C)** Introduction to Green Chemistry class, **(D–G)**, Taiwanese Conversations in the Rural Life class. Scale 1:0–5; Scale 2: 6–10; Scale 3: 11–15; Scale 4: 16–20; Scale 5: >21. Statistical significance is indicated above the horizontal bracket: "NS" denotes not significant, while asterisks represent levels of significance (*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$).

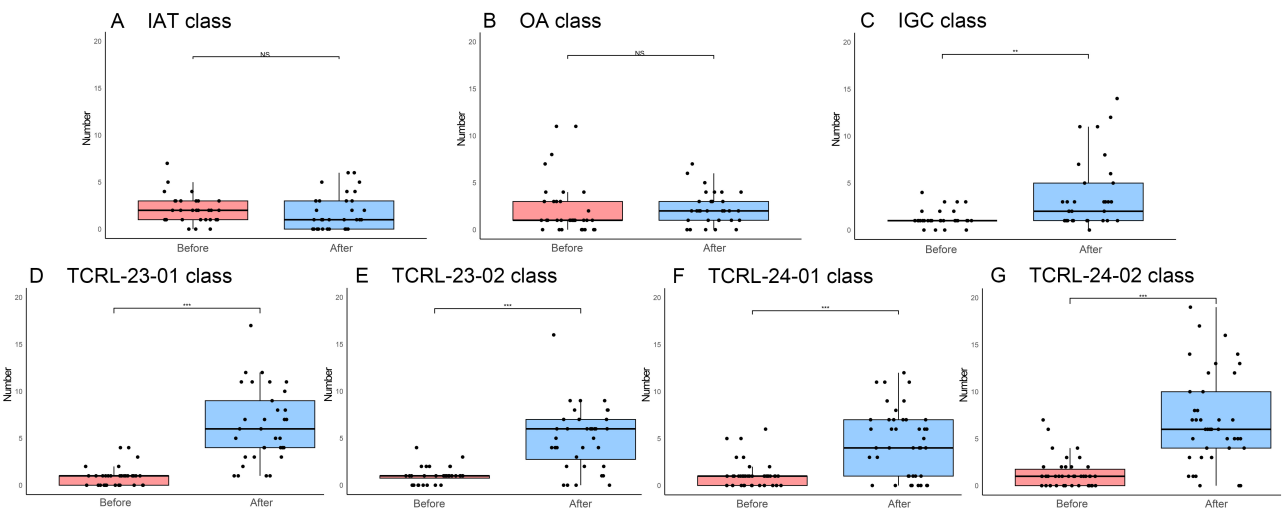

FIGURE 3
Edible plant numbers on the school campus enumerated by students before and after intervention, presented using boxplots. **(A)** Introduction to Agriculture in Taiwan class, **(B)** Organic Agriculture class, **(C)** Introduction to Green Chemistry class, **(D–G)**, Taiwanese Conversations in the Rural Life class. Statistical significance is indicated above the horizontal bracket: "NS" denotes not significant, while asterisks represent levels of significance (**$P < 0.01$, ***$P < 0.001$).

agricultural-focused class (e.g., organic agriculture), low-pressure agricultural-focused classes (e.g., introduction to agriculture and conversations in rural life), and a non-agricultural-focused class (e.g., green chemistry). Furthermore, it is adaptable to multiple instructional languages (English, Chinese, and Taiwanese) and can be integrated into both indoor and outdoor educational activities.

At National Taiwan University, the implementation of biodiverse edible school concepts involved interactive lectures on relevant topics, student-centered edible plant search activities, and didactic report assignments incorporating brainstorming sessions, covering all three broad instructional styles in STEM teaching in Stains et al. (2018). Similarly, the teaching practices employed at UM were considered to encompass all these teaching styles. Following Fischer et al. (2019), the teaching and learning process related to biodiverse edible schools can be structured around three core themes: (1) Biodiversity, which includes recognizing cultivated edible plants, wild edible plants, and non-edible plants. The concept can be expanded to cover all campus wildlife observed by university students. (2) Food: This theme emphasizes the experiences of locally grown, organic, nutritious, seasonal, and fresh food. It can be effectively integrated into food and agricultural education within university courses. (3) Students or participants: While Fischer et al.

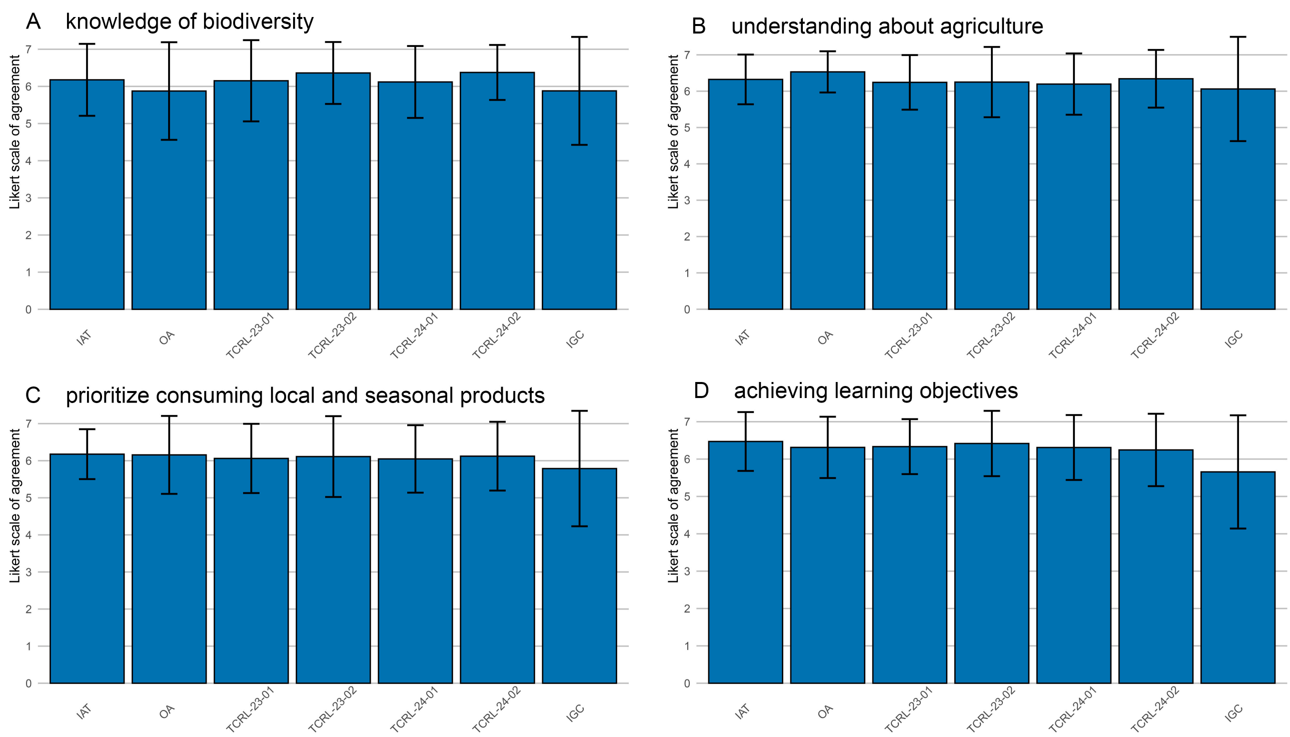

FIGURE 4
Students' perceptions regarding the impact of biodiverse edible school teaching practices in different classes. **(A)** Response to the enhancement of understanding about biodiversity, **(B)** Response to the enhancement of understanding of agriculture, **(C)** Response to the willingness to prioritize consuming locally and seasonally produced agricultural products, **(D)** Response to the contribution of activities to achieve the learning objectives. Error bars indicate the standard deviations.

(2019) focused on younger children, biodiverse edible schools in a university setting can provide education on environmental and food awareness, health and wellbeing while achieving specific learning objectives for each class.

Our findings from practical examples and the students' brainstorming ideas suggest a range of strategies for incorporating biodiverse edible schools into university environments (Tables 4–6). These strategies range from developing university courses and community partnerships to creating edible gardens and improving campus food services. While the feasibility of some approaches still needs to be assessed, the experiences learned from Taiwan and Malaysia may offer important directions for implementing biodiverse edible schools in higher education.

Interestingly, students' understanding of the number of edible plants on campus varied before and after our interventions. This variation may be attributed to the different tasks assigned: reporting assignments for the IAT and OA courses, reporting assignments combined with outdoor activities for the IGC course, and outdoor educational activities for the TCRL classes. The IAT and OA students did not elaborate more edible plant species on campus after more information was gathered (Figures 2A, B, 3A, B). In contrast, IGC students demonstrated increased knowledge (Figures 2C, 3C). Furthermore, students' perceptions of their knowledge of edible plant numbers on campus significantly improved after they participated in the language-learning "Agri-food campus tour" outdoor activity across the four TCRL classes (Figures 2D–G, 3D–G). These findings suggest that direct outdoor observations and interactive teaching methods can effectively enhance learning outcomes related to biodiversity, food, and agriculture.

While our study provides valuable information for the application of teaching practices, it has limitations in that it relies on self-reported learning measures. Future research could complement these measures with more objective assessment methods to provide a comprehensive evaluation of the effectiveness of educational interventions.

4.2 Connecting outdoor experiential learning activities with biodiverse edible school teaching practices for greater effectiveness

The biodiverse edible school teaching practices in the TCRL classes integrated outdoor exploration and classroom discussions on the university campus. This is in line with the food studies course described in Lehrer (2024), which employs experiential learning (Kolb, 1984) in food and agricultural education. Such practices facilitate self-reflection, critical thinking, and help achieve learning goals (Lehrer, 2024). The study results also agree with previous work on developing experiential learning activities using student farms in sustainable agriculture education (Parr and Trexler, 2011), as well as our previous experiences in a

TABLE 7 Students' feedback on the relevance of the biodiverse edible school teaching practices in each class to the SDG goals.

SDG goals	IAT ($n = 34$)	OA ($n = 32$)	TCRL-23-01 ($n = 33$)	TCRL-23-02 ($n = 36$)	TCRL-24-01 ($n = 42$)	TCRL-24-02 ($n = 41$)	IGC ($n = 33$)	Total ($n = 251$)
1	5	6	3	4	7	12	7	44 (17.5%)
2	20	29	23	29	26	29	20	176 (70.1%)
3	25	15	13	16	14	22	13	118 (47.0%)
4	14	7	8	8	6	13	7	63 (25.1%)
5	5	1	5	7	5	8	7	38 (15.1%)
6	9	7	8	8	7	8	7	54 (21.5%)
7	8	4	7	11	7	11	16	64 (25.5%)
8	5	9	9	13	6	9	9	60 (23.9%)
9	9	1	2	4	3	5	9	33 (13.1%)
10	5	1	7	3	7	8	5	36 (14.3%)
11	8	3	8	7	2	9	18	55 (21.9%)
12	16	25	23	22	25	25	18	154 (61.4%)
13	12	3	9	5	4	8	16	57 (22.7%)
14	7	4	8	9	4	11	8	51 (20.3%)
15	21	23	17	22	23	19	20	145 (57.8%)
16	2	12	4	4	4	11	6	43 (17.1%)
17	5	3	4	4	5	7	6	34 (13.5%)

IAT, Introduction to Agriculture in Taiwan; OA, Organic Agriculture; TCRL23-01, Taiwanese Conversations in the Rural Life 2023 class 1; TCRL23-02, Taiwanese Conversations in the Rural Life 2023 class 2; TCRL24-01, Taiwanese Conversations in the Rural Life 2024 class 1; TCRL24-02, Taiwanese Conversations in the Rural Life 2024 class 2; IGC, Introduction to Green Chemistry.

vegetable disease course, completing the experiential learning cycle encompassing concrete experience, abstract conceptualization, reflective observation, and active experimentation (Kolb and Kolb, 2009). The use of experiential learning may enhance teaching and learning effectiveness in liberal education (Shen et al., 2023). Notably, outdoor weather can significantly influence student learning. In this study, the TCRL-24-01 class, which was affected by both low temperature and rain, had a relatively shorter average outdoor activity time (<30 min) and a slightly lower increase in learning outcomes (Figure 2F). In contrast, the TCRL-24-02 class, which experienced only low temperature, had an ordinary duration of activity and did not appear to be significantly affected (Figures 2G, 3G). The finding that rain is a critical adverse weather condition for outdoor educational activities is consistent with Wagner et al. (2019) regarding outdoor exercise behaviors. In combination with the learning experience in the environment and discussions in the classroom, which are focused on the objectives of language learning, the concepts of biodiverse edible schools (Fischer et al., 2019) can be extended as specific tasks to enhance students' learning, such as the agri-food campus tour in our study. Despite the potential shortage of language learning materials about agriculture on a regional scale (Usmansyah et al., 2019), this can be a new pedagogical model of task-based language teaching (Van den Branden et al., 2009; Van den Branden, 2016) both inside and outside the classroom, which is engaging and successful in achieving course objectives.

4.3 Integrating biodiverse edible schools with green chemistry for sustainable education in Malaysia

Many projects can be suggested within the concept of biodiverse edible schools and, in turn, enrich student learning outcomes. For example, to ensure the health and sustainability of terrestrial ecosystems, such as tropical medicinal plants, edible plants, and edible fruits around the campus, consistent monitoring of soil quality is crucial. The soil organic carbon level has become increasingly important in ensuring sustainable agricultural production. Other important indicators of soil quality include physical factors (water holding capacity, soil tilth, temperature, soil respiration, and porosity), biological factors (enzymes, microbial community, and total biomass) and chemical factors (pH, nutrient cycling rates, salinity, micronutrients, heavy metals, and available N/P/K; Bünemann et al., 2018; Sharma et al., 2023). Soil monitoring involves interdisciplinary activities, supporting the educational purposes of biodiverse edible schools and achieving many SDGs. A healthy and nutritious soil helps maintain water and air quality, improving animal and plant productivity and alleviating greenhouse gases. Soil is more complex than air and water because it comprises solid, liquid, and gaseous phases. Improving soil quality is important for protecting the environment ecologically and promoting sustainable agricultural development. These approaches have the potential to enrich the learning outcomes for the IGC course by enhancing the understanding of food production, healthier diets, and the concept of biodiverse edible schools.

For students in green chemistry, the practice of composting organic waste closely aligns with the core principles of sustainable chemistry, particularly in terms of waste reduction, resource recycling, and minimizing environmental impact. By converting organic matter such as goat manure into biofertilizers, this process exemplifies biodegradation and biocatalysis, where microbial activity breaks down complex compounds into plant-available nutrients. Students can explore the underlying chemical reactions involved in nutrient cycling and the transformation of carbon, nitrogen, and phosphorus in the soil, emphasizing how these processes are governed by chemical equilibria and soil pH. Furthermore, the use of compost reduces the reliance on energy-intensive synthetic fertilizers, addressing resource efficiency and promoting the use of renewable resources a key tenet of green chemistry. This approach not only enhances soil health but also demonstrates how green chemistry can drive agricultural sustainability while mitigating harmful environmental effects, a concept that is increasingly crucial as scientific understanding and agricultural practices evolve.

For sustainable campus development to be on the right track, education incorporating agriculture is the right choice. For example, live waste compost or co-compost is a great example of a biofertilizer and a source of macronutrients and micronutrients. The addition of organic matter helps improve the soil structure, improves the soil's water holding capacity, reduces erosion, and alleviates fertilizer leaching. Moreover, feeding microbes helps increase soil biological diversity, which accelerates the breakdown of organic nutrients, and thus can be readily absorbed by plants (Rosman and Jamaludin, 2022). Currently, Ladang Mini ISB at UM is actively formulating compost fertilizer from goat manure and organic waste to increase soil fertility and promote the growth of durian and rambutan trees. Challenges in various areas, including renewable resources, arise through innovations and collaborations among students in biodiverse edible school practices. For example, the production of biomaterials from edible plants has led to the use of methylcellulose, a biodegradable material, in students' final year projects for sustainable energy storage applications (Shamsuri et al., 2024). Undeniably, the involvement of urban agriculture education in biodiverse edible school practices can create another step forward for UM policymakers to ensure the realization of the SDGs by the year 2030.

4.4 Universities' involvement in biodiverse edible school concepts

The original approach of biodiverse edible schools connects biodiversity, healthy food, and children together for environmental education in and near schools (Fischer et al., 2019). These concepts can be adapted to university settings by linking biodiversity, healthy food, and students within higher education programs. Considering the four components outlined by Fischer et al. (2019), collaborative activities, school kitchens, school gardens, and wild sites, our results summarize and adapt these elements to the university context in Taiwan (Table 5). Unlike secondary schools, where principals, teachers, and parents play key roles, university instructors can guide students directly using project-based learning strategies (Kokotsaki et al., 2016) and similar approaches to achieve biodiverse edible school objectives. Although fixed school kitchens are uncommon on university campuses, stakeholders can collaborate with students and student clubs to promote access to healthy, local foods. With respect to school gardens and wild sites, diverse ecological niches in and around university campuses may offer opportunities for exploration and management by students and community stakeholders.

Biodiverse edible schools can feasibly be integrated into agriculture-based learning, food education, and agroecology content in higher education programs (Wezel et al., 2009; Kimura, 2011; Francis et al., 2003; LaCharite, 2016; Wang et al., 2023), as demonstrated in this study. Previous reports have raised the question of the need to modify learning activities and higher education curricula to address the ecology of food systems (Lieblein et al., 2007; Wezel et al., 2009). This study establishes pedagogical models incorporating biodiverse edible school practices for university students. In addition to combining biodiversity, agriculture, and liberal arts (LaCharite, 2016; Wezel et al., 2009; Francis et al., 2003), the teaching and learning practices in this study incorporate practical examples such as campus gardens, community-supported agriculture, farm-to-table initiatives, and transdisciplinary cases in liberal education. The involvement of biodiverse edible schools in higher education virtually enhances students' understanding of biodiversity, agriculture, and potentially responsible actions.

Although initially designed for younger students, biodiverse edible schools have been adapted for university settings to provide students with practical, real-world applications such as green chemistry and sustainability principles. By involving students in activities such as identifying campus edible plants and brainstorming campus-based food production solutions, the program promotes critical thinking about sustainable agriculture, waste reduction, and renewable energy. This finding supports the recommendation of Orr (1994) to include agriculture as a part of a complete liberal arts education for college students.

We further recommend extending these concepts to a broader range, including studies in urban agriculture, edible cities, and sustainability transformation (Sartison and Artmann, 2020; Sardeshpande et al., 2021; Ayoni et al., 2022). In our study cases, the campus and surrounding areas of NTU have already been hotspots for urban farming (Zhou et al., 2023), potentially serving as satellites for urban gardens in Taipei city, benefiting both local and non-local participants (Hsiao, 2021; Mabon et al., 2023; Zhou et al., 2023). It is suggested that university campuses in urban areas can further act as reservoirs of biodiversity (Liu et al., 2021) and offer people unique restorative effects that promote mental health, wellbeing, and quality of life (Van den Bogerd et al., 2018; Gulwadi et al., 2019; Ha and Kim, 2021). Although the educational and various benefits of different types of urban agriculture have been categorized (Wadumestrige Dona et al., 2021), further studies are needed to understand how biodiverse edible school infrastructures and programs can benefit students, local communities, and urban sustainability.

4.5 Advancing sustainable development through biodiverse edible school concepts

Biodiverse edible schools should contribute significantly to reaching several SDGs. From our perspective, biodiverse edible schools not only contribute to fostering SDG 2 of ending hunger, as seen in edible urbanism (Russo and Cirella, 2019), but also promote responsible consumption and production (Goal 12), biodiversity on land (Goal 15), and good health and wellbeing (Goal 3) for students, communities, and urban environments. The mention of the SDGs in this report underscores the university's commitment to integrating global sustainability efforts into its educational initiatives. By aligning with the SDGs, UM demonstrates its dedication to addressing environmental, social, and economic challenges both locally and globally. For example, this work promotes zero hunger (SDG 2) through promoting local food production. It contributes to good health and wellbeing (SDG 3) by providing access to fresh, healthy food, and sustainable cities and communities (SDG 11) by incorporating urban agriculture into campus life. Additionally, these initiatives contribute to responsible consumption and production (SDG 12), climate action (SDG 13), and quality education (SDG 4) by fostering sustainable agricultural practices, reducing waste, and providing students with hands-on learning opportunities. The integration of the SDGs into final-year projects at the UM Sustainability and Development Centre further emphasized the university's role in preparing students to address global sustainability challenges through interdisciplinary expertise and innovative solutions.

This study has important implications for higher education policy, particularly in incorporating biodiverse edible school concepts in different regions such as Taiwan and Malaysia. When higher education institutions establish their sustainability visions according to the SDGs or regional laws such as the Food and Agricultural Education Act, biodiverse edible schools can serve as a guiding roadmap for implementation. This approach supports institutions in developing essential resources and designing effective pedagogies for Education for Sustainable Development (Wade, 2008) following the framework in Kioupi and Voulvoulis (2019). Our findings offer policymakers with practical models that combines food, gardens, and biodiversity in educational schemes across university campuses. In particular, incorporating outdoor experiential learning activities into curriculum design should boost students' active participation and pro-environmental attitudes (Sehar et al., 2025). To maximize impact, it is recommended to design teaching practices to meet both course-specific learning goals, from agriculture to chemistry topics in this study, while also addressing the broader SDGs, using biodiverse edible school concepts acting as a bridge. In addition, establishing strong partnerships with educators, school staff, student organizations, local communities, and governmental bodies is key to successful execution. From the university's perspective, the sector worked as sustainability offices can allocate funding for campus green spaces as living laboratories and offer grants for student-led campus sustainability projects, analogous to efforts in biodiversity preservation and sustainable development in higher education in Yerokhin et al. (2024) and Franco et al. (2019).

In conclusion, this study presents compelling educational examples of how biodiverse edible school concepts can be effectively integrated into university curricula. Educators (teachers and instructors) and university students, whether through student clubs, in-class tasks, or self-directed activities, can make critical use of their school environments without relying heavily on external resources. These implementations have the potential to enhance students' learning outcomes across a wide variety of courses. The inclusion of teaching strategies that explore biodiverse edible school elements—such as edible plants, local biodiversity, and school gardens, as well as neighboring wild sites—not only increases students' understanding of biodiversity, food systems, and sustainability but also promotes closer connections between students and their environment. This study demonstrates that biodiverse edible schools can be successfully adapted to higher education, providing new ways to integrate these topics into university curricula and contributing to significant advancements in sustainability education.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author/s.

Ethics statement

Ethical approval was not required for the studies involving humans because the participation in the study was voluntary, and informed consent was provided prior to the commencement of the assignment. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

YS: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. MS: Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Writing – review & editing. GC: Methodology, Writing – review & editing. HW: Methodology, Writing – review & editing. CH: Methodology, Writing – review & editing. NJ: Writing – review & editing. MK: Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2025.1472179/full#supplementary-material

References

Adams, D., Hardman, M., and Larkham, P. (2015). Exploring guerrilla gardening: gauging public views on the grassroots activity. *Local Environ.* 20, 1231–1246. doi: 10.1080/13549839.2014.980227

Ayoni, V. N., Ramli, N. N., Shamsudin, M. N., and Hadi, A. H. I. A. (2022). Urban agriculture and policy: mitigating urban negative externalities. *Urban For. Urban Green.* 75:127710. doi: 10.1016/j.ufug.2022.127710

Banoo, S. (2023). *Agritech: Farming Durians the Smart Way*. Available at: https://theedgemalaysia.com/node/654602 (accessed February 13, 2023).

Blair, D. (2009). The child in the garden: an evaluative review of the benefits of school gardening. *J. Environ. Educ.* 40, 15–38. doi: 10.3200/JOEE.40.2.15-38

Brown, C., and Miller, S. (2008). The impacts of local markets: a review of research on farmers markets and community supported agriculture (CSA). *Am. J. Agric. Econ.* 90, 1296–1302. doi: 10.1111/j.1467-8276.2008.01220.x

Brundiers, K., Barth, M., Cebrián, G., Cohen, M., Diaz, L., Doucette-Remington, S., et al. (2021). Key competencies in sustainability in higher education—toward an agreed-upon reference framework. *Sustain. Sci.* 16, 13–29. doi: 10.1007/s11625-020-00838-2

Bünemann, E. K., Bongiorno, G., Bai, Z., Creamer, R. E., De Deyn, G., De Goede, R., et al. (2018). Soil quality–a critical review. *Soil Biol. Biochem.* 120, 105–125. doi: 10.1016/j.soilbio.2018.01.030

Chappell, H. (2019). "Southern Min," in *The Mainland Southeast Asia Linguistic Area*, eds. A. Vittrant and J. Watkins (Berlin; Boston, MA: De Gruyter Mouton), 176–233.

Chung, K. R., Yang, H. J., Jang, D. J., and Kwon, D. Y. (2015). Historical and biological aspects of bibimbap, a Korean ethnic food. *J. Ethn. Foods* 2, 74–83. doi: 10.1016/j.jef.2015.05.002

Dearden, J. (2014). *English as a Medium of Instruction-A Growing Global Phenomenon*. London: British Council.

DeClerck, F. A., Jones, S. K., Attwood, S., Bossio, D., Girvetz, E., Chaplin-Kramer, B., et al. (2016). Agricultural ecosystems and their services: the vanguard of sustainability? *Curr. Opin. Environ. Sustain.* 23, 92–99. doi: 10.1016/j.cosust,.2016.11.016

FAO, Rikolto, and RUAF (2022). *Urban and Peri-Urban Agriculture Sourcebook – From Production to Food Systems*. Rome: FAO and Rikolto.

Ferguson, R. S., and Lovell, S. T. (2014). Permaculture for agroecology: design, movement, practice, and worldview. A review. *Agron. Sustain. Dev.* 34, 251–274. doi: 10.1007/s13593-013-0181-6

Ferguson, T., and Roofe, C. G. (2020). SDG 4 in higher education: challenges and opportunities. *Int. J. Sustain. High. Educ.* 21, 959–975. 10. doi: 10.1108/IJSHE-12-2019-0353

Fischer, L. K., Brinkmeyer, D., Karle, S. J., Cremer, K., Huttner, E., Seebauer, M., et al. (2019). Biodiverse edible schools: linking healthy food, school gardens and local urban biodiversity. *Urban For. Urban Green.* 40, 35–43. doi: 10.1016/j.ufug.2018.02.015

Francis, C., Lieblein, G., Gliessman, S., Breland, T. A., Creamer, N., Harwood, R., et al. (2003). Agroecology: the ecology of food systems. *J. Sustain. Agric.* 22, 99–118. doi: 10.1300/J064v22n03_10

Franco, I., Saito, O., Vaughter, P., Whereat, J., Kanie, N., and Takemoto, K. (2019). Higher education for sustainable development: actioning the global goals in policy, curriculum and practice. *Sustain. Sci.* 14, 1621–1642. doi: 10.1007/s11625-018-0628-4

Gulwadi, G. B., Mishchenko, E. D., Hallowell, G., Alves, S., and Kennedy, M. (2019). The restorative potential of a university campus: objective greenness and student perceptions in Turkey and the United States. *Landsc. Urban Plan.* 187, 36–46. doi: 10.1016/j.landurbplan.2019.03.003

Ha, J., and Kim, H. J. (2021). The restorative effects of campus landscape biodiversity: assessing visual and auditory perceptions among university students. *Urban For. Urban Green.* 64:127259. doi: 10.1016/j.ufug.2021.127259

Hardman, M., Chipungu, L., Magidimisha, H., Larkham, P. J., Scott, A. J., and Armitage, R. P. (2018). Guerrilla gardening and green activism: rethinking the informal urban growing movement. *Landsc. Urban Plan.* 170, 6–14. doi: 10.1016/j.landurbplan.2017.08.015

Harris, B. A., Poole, E. M., Braman, S. K., and Pennisi, S. V. (2021). Consumer-ready insect hotels: an assessment of arthropod visitation and nesting success. *J. Entomol. Sci.* 56, 141–155. doi: 10.18474/0749-8004-56.2.141

Ho, S. S. H., Lin, H. C., Hsieh, C. C., and Chen, R. J. C. (2022). Importance and performance of SDGs perception among college students in Taiwan. *Asia Pac. Educ. Rev.* 23, 683–693. doi: 10.1007/s12564-022-09787-0

Hsiao, H. (2021). Characteristics of urban gardens and their accessibility to locals and non-locals in Taipei City, Taiwan. *Landsc. Ecol. Eng.* 17, 41–53. doi: 10.1007/s11355-020-00430-x

Hsieh, M. L. (2014). "Taiwanese Hokkien/Southern Min," in *The Handbook of Chinese Linguistics*, eds. C. T. J. Huang, Y.-H. A. Li, and A. Simpson (Hoboken, NJ: John Wiley and Sons), 629–656.

Huang, C. C., Li, S. P., Lai, J. C. M., Chan, Y. K., and Hsieh, M. Y. (2023). Research on the international sustainable practice of the Taiwanese food and agricultural education law under the current global food security challenges. *Foods* 12:2785. doi: 10.3390/foods12142785

Idzni, S. I., and Chia, K. S. (2021). A supervisory and control system for indoor lettuce farming. *Int. J. Integr. Eng.* 13, 249–259. doi: 10.30880/ijie.2021.13.01.022

Ishida, H. (2018). The history, current status, and future directions of the school lunch program in Japan. *Jpn. J. Nutr. Diet.* 76, S2–S11. doi: 10.5264/eiyogakuzashi.76.S2

Iun, U. G., Lau, K. G., Li, S. A., and Kao, C. Y. (2005). "A study on implementation of Southern-Min Taiwanese tone Sandhi system. A study on implementation of Southern-Min Taiwanese tone Sandhi system," in the *19th Pacific Asia Conference on Language, Information and Computation, Vol. 19* (Tokyo: Waseda University), 119–130.

Jumaidin, R., Abdul Rahman, A., Sapuan, S., and Rushdan, A. (2024). Effect of sugarcane bagasse on thermal and mechanical properties of thermoplastic cassava starch/beeswax composites. *Phys. Sci. Rev.* 9, 1–15. doi: 10.1515/psr-2022-0047

Kane, D. (2006). *The Chinese Language: Its History and Current Usage*. North Clarendon, VT: Tuttle Publishing.

Kimura, A. H. (2011). Food education as food literacy: privatized and gendered food knowledge in contemporary Japan. *Agric. Hum. Values* 28, 465–482. doi: 10.1007/s10460-010-9286-6

Kingsley, J., Egerer, M., Nuttman, S., Keniger, L., Pettitt, P., Frantzeskaki, N., et al. (2021). Urban agriculture as a nature-based solution to address socio-ecological challenges in Australian cities. *Urban For. Urban Green.* 60:127059. doi: 10.1016/j.ufug.2021.127059

Kioupi, V., and Voulvoulis, N. (2019). Education for sustainable development: a systemic framework for connecting the SDGs to educational outcomes. *Sustainability* 11:6104. doi: 10.3390/su11216104

Kokotsaki, D., Menzies, V., and Wiggins, A. (2016). Project-based learning: a review of the literature. *Improv. Sch.* 19, 267–277. doi: 10.1177/1365480216659733

Kolb, A. Y., and Kolb, D. A. (2009). Experiential learning theory: a dynamic, holistic approach to management learning, education and development. *SAGE Handb. Manage. Learn. Educ. Dev.* 7, 42–68. doi: 10.4135/9780857021038.n3

Kolb, D. A. (1984). *Experiential Learning: Experience as the Source of Learning and Development*. Englewood Cliffs, NJ: Prentice Hall, Inc.

LaCharite, K. (2016). Re-visioning agriculture in higher education: the role of campus agriculture initiatives in sustainability education. *Agric. Human Value* 33, 521–535. doi: 10.1007/s10460-015-9619-6

Laird, S. (2013). Bringing educational thought to public school lunch: Alice waters and the edible schoolyard. *J. Thought* 48, 12–27.

Lau, S. H., and Tsai, W. T. D. (2020). A comparative study of how and why in Taiwan Southern Min and Mandarin Chinese. *Lang. Linguist.* 21, 254–284. doi: 10.1075/lali.00055.sen

Lee, C. M., Lee, C. H., and Popuri, S. (2020). Perspective of environmental education in Taiwan: current status of implementation. *J. Environ. Sci. Manage.* 23, 83–95. doi: 10.47125/jesam/2020_1/09

Lee, W. (2023). Everyday democracy and civic agriculture: the case of a CSA organization in Taiwan. *Innov. Soc. Sci.* 1, 44–69. doi: 10.1163/27730611-bja10009

Lehrer, N. (2024). An immersive, comparative approach to experiential learning in food studies education. *Agric. Hum. Values* 41, 61–73. doi: 10.1007/s10460-023-10466-y

Lieblein, G., Breland, T. A., Østergaard, E., Salomonsson, L., and Francis, C. (2007). Educational perspectives in agroecology: steps on a dual learning ladder toward responsible action. *NACTA J.* 51, 37–44.

Lin, K. H. (2017). *The practice of alternative agro-food network – a case study of the food and farming education in Longdu Elementary School*. (Master's thesis). National Sun Yat-sen University, Kaohsiung, Taiwan.

Liu, J., Zhao, Y., Si, X., Feng, G., Slik, F., and Zhang, J. (2021). University campuses as valuable resources for urban biodiversity research and conservation. *Urban For. Urban Green.* 64:127255. doi: 10.1016/j.ufug.2021.127255

Liu, J. C. E., and Kan, T. Y. (2024). A comprehensive review of environmental, sustainability and climate change curriculum in Taiwan's higher education institutions. *Int. J. Sustain. High. Educ.* 25, 375–389. doi: 10.1108/IJSHE-01-2023-0019

Mabon, L., Shih, W. Y., and Jou, S. C. (2023). Integration of knowledge systems in urban farming initiatives: insight from Taipei Garden City. *Sustain. Sci.* 18, 857–875. doi: 10.1007/s11625-022-01196-x

Mensah, J. (2019). Sustainable development: meaning, history, principles, pillars, and implications for human action: literature review. *Cogent Soc. Sci.* 5:1653531. doi: 10.1080/23311886.2019.1653531

Monville-Oro, E., Angeles-Agdeppa, I., Baguilat, I. P., Gonsalves, J., and Capanzana, M. V. (2020). "Linking school gardens, school feeding, and nutrition education in the Philippines," in *Agrobiodiversity, School Gardens and Healthy Diets*, eds. D. Hunter, E. Monville-Oro, B. Burgos, C. N. Rogel, B. Calub, J. Gonsalves, et al. (New York, NY: Routledge), 62–76.

Mun, E. G., Lee, Y. E., and Cha, Y. S. (2023). The globalization of bibimbap: focusing on the diversity of modernization of bibimbap. *J. Ethn. Foods* 10:39. doi: 10.1186/s42779-023-00195-2

National Taiwan University (2008). *NTU at 80 Going for the Top 100: National Taiwan University 80th Anniversary Special Edition*. Taipei: National Taiwan University Press.

Ohly, H., Gentry, S., Wigglesworth, R., Bethel, A., Lovell, R., and Garside, R. (2016). A systematic review of the health and well-being impacts of school gardening: synthesis of quantitative and qualitative evidence. *BMC Public Health* 16:286. doi: 10.1186/s12889-016-2941-0

Orr, D. W. (1994). *Earth in Mind: On Education, Environment, and the Human Prospect*. Covelo: Island Press.

Owens, T. L. (2017). Higher education in the sustainable development goals framework. *Eur. J. Educ.* 52, 414–420. doi: 10.1111/ejed.12237

Ozer, E. J. (2007). The effects of school gardens on students and schools: conceptualization and considerations for maximizing healthy development. *Health Educ. Behav.* 34, 846–863. doi: 10.1177/1090198106289002

Parr, D. M., and Trexler, C. J. (2011). Students' experiential learning and use of student farms in sustainable agriculture education. *J. Natural Resour. Life Sci. Educ.* 40, 172–180. doi: 10.4195/jnrlse.2009.0047u

Pisarn, P., Kim, M. K., and Yang, S. H. (2020). A potential sustainable pathway for community-supported agriculture in Taiwan: the consumer perspective in a farmers' market. *Sustainability* 12:8917. doi: 10.3390/su12218917

Purvis, B., Mao, Y., and Robinson, D. (2019). Three pillars of sustainability: in search of conceptual origins. *Sustain. Sci.* 14, 681–695. doi: 10.1007/s11625-018-0627-5

Ratcliffe, M. M., Merrigan, K. A., Rogers, B. L., and Goldberg, J. P. (2011). The effects of school garden experiences on middle school-aged students' knowledge, attitudes, and behaviors associated with vegetable consumption. *Health Promot. Pract.* 12, 36–43. doi: 10.1177/1524839909349182

Reisner, B. A., Pate, C. L., Kinkaid, M. M., Paunovic, D. M., Pratt, J. M., Stewart, J. L., et al. (2020). I've been given copus (classroom observation protocol for undergraduate stem) data on my chemistry class... now what? *J. Chem. Educ.* 97, 1181–1189. doi: 10.1021/acs.jchemed.9b01066

Reynolds, R. (2008). *On Guerrilla Gardening: A Handbook for Gardening Without Boundaries*. London: Bloomsbury.

Richards, J. C., and Pun, J. (2023). A typology of English-medium instruction. *RELC J.* 54, 216–240. doi: 10.1177/0033688220968584

Rickinson, M. (2001). Learners and learning in environmental education: a critical review of the evidence. *Environ. Educ. Res.* 7, 207–320. doi: 10.1080/13504620120065230

Rosman, N. Z. I. B., and Jamaludin, N. S. (2022). "Biochar and chicken manure compost," in *Handbook of Biodegradable Materials*, eds. G. A. M. Ali and A. S. H. Makhlouf (Cham: Springer International Publishing), 1243–1274.

Russo, A., and Cirella, G. T. (2019). Edible urbanism 5.0. *Palgrave Commun.* 5, 1–9. doi: 10.1057/s41599-019-0377-8

Sachs, J. D. (2012). From millennium development goals to sustainable development goals. *Lancet* 379, 2206–2211. doi: 10.1016/S0140-6736(12)60685-0

Sachs, J. D., Schmidt-Traub, G., Mazzucato, M., Messner, D., Nakicenovic, N., and Rockström, J. (2019). Six transformations to achieve the sustainable development goals. *Nat. Sustain.* 2, 805–814. doi: 10.1038/s41893-019-0352-9

Safri, N. A. M., Zainuddin, Z., Zulkifle, I., Azmi, M. S. M., Fudholi, A., and Ruslan, M. H. (2020). Temperature performance of a portable solar greenhouse dryer with various collector design. *Sains Malays.* 49, 2539–2545. doi: 10.17576/jsm-2020-4910-19

Sardeshpande, M., Rupprecht, C., and Russo, A. (2021). Edible urban commons for resilient neighbourhoods in light of the pandemic. *Cities* 109:103031. doi: 10.1016/j.cities.2020.103031

Sartison, K., and Artmann, M. (2020). Edible cities–an innovative nature-based solution for urban sustainability transformation? An explorative study of urban food production in German cities. *Urban For. Urban Green.* 49:126604. doi: 10.1016/j.ufug.2020.126604

Sehar, A., Akbar, M., Poulova, P., Vasudevan, A., and Huang, T. (2025). Understanding the drivers of pro-environmental attitude in higher education institutions: the interplay of knowledge, consciousness, and social influence. *Front. Environ. Sci.* 12:1458698. doi: 10.3389/fenvs.2024.1458698

Shamsuri, N. A., Hamsan, M. H., Shukur, M. F., Alias, Y., Halim, S. N. A., Aziz, S. B., et al. (2024). Enhancing EDLC applications with [BMIM] BF4-integrated cellulose gel electrolyte for sustainable energy storage. *J. Energy Storage* 75:109559. doi: 10.1016/j.est.2023.109559

Sharma, S., Lishika, B., and Kaushal, S. (2023). Soil Quality indicators: a comprehensive review. *Int J. Plant Soil Sci.* 35, 315–325. doi: 10.9734/ijpss/2023/v35i224139

Shen, Y. M., Wong, Y. Y., and Huang, C. C. (2023). Conversion of a specialized course into liberal education in an English-medium instruction environment through experiential learning: a case study in the course of vegetable diseases. *J. Scholarsh. Teach. Learn.* 3, 1–28. doi: 10.7007/JSoTL.202309_3(3).0001

Shih, M., Li, G. Y., and Chang, W. S. (2021). Keeping things normal during an uncommon time: a lesson from National Taiwan University. *J. Teach. Learn. Technol.* 10, 103–116. doi: 10.14434/jotlt.v9i2.31470

Smith, M. K., Jones, F. H., Gilbert, S. L., and Wieman, C. E. (2013). The Classroom Observation Protocol for Undergraduate STEM (COPUS): a new instrument to characterize university STEM classroom practices. *CBE Life Sci. Educ.* 12, 618–627. doi: 10.1187/cbe.13-08-0154

Srisai, P., Lin, H. C., Liu, C. C., Zeng, F. J., Yang, Y. C., and Chou, W. M. (2023). Thermostable ficin from jelly fig (*Ficus pumila* var. awkeotsang) latex: purification, identification and characterization. *J. Sci. Food Agric.* 103, 846–855. doi: 10.1002/jsfa.12196

Stains, M., Harshman, J., Barker, M. K., Chasteen, S. V., Cole, R., DeChenne-Peters, S. E., et al. (2018). Anatomy of STEM teaching in North American universities. *Science* 359, 1468–1470. doi: 10.1126/science.aap8892

The Open Door (2024). *Garden to Table Program*. Available at: https://theopendoorpantry.org/garden-to-table-program (accessed July 15, 2024).

Tseng, K. H., Yang, T. H., Chen, P. Y., Chien, H., Chen, C. F., and Hung, Y. C. (2022). Exploring the feasibility of mitigating flood hazards by an existing pond system in Taoyuan, Taiwan. *Drones* 7:1. doi: 10.3390/drones7010001

UNESCO (2012). *International Standard Classification of Education (ISCED) 2011*. Montreal, QC: UNESCO Institute for Statistics.

Usmansyah, D., Rasyid, Y., and Ridwan, S. (2019). Needs analysis on Indonesian language learning materials about agriculture for foreign speakers. *J. Educ. Learn.* 13, 155–162. doi: 10.11591/edulearn.v13i1.7408

Van Bruggen, A. H., Gamliel, A., and Finckh, M. R. (2016). Plant disease management in organic farming systems. *Pest Manag. Sci.* 72, 30–44. doi: 10.1002/ps.4145

Van den Bogerd, N., Dijkstra, S. C., Seidell, J. C., and Maas, J. (2018). Greenery in the university environment: students' preferences and perceived restoration likelihood. *PLoS ONE* 13:e0192429. doi: 10.1371/journal.pone.0192429

Van den Branden, K. (2016). The role of teachers in task-based language education. *Annu. Rev. Appl. Linguist.* 36, 164–181. doi: 10.1017/S0267190515000070

Van den Branden, K., Van Gorp, K., and Verhelst, M. (2009). *Tasks in Action: Task-Based Language Education from a Classroom-Based Perspective*. Newcastle: Cambridge Scholars Publishing.

Vasilescu, R., Barna, C., Epure, M., and Baicu, C. (2010). Developing university social responsibility: a model for the challenges of the new civil society. *Proc. Soc. Behav. Sci.* 2, 4177–4182. doi: 10.1016/j.sbspro.2010.03.660

Viana, C. M., Freire, D., Abrantes, P., Rocha, J., and Pereira, P. (2022). Agricultural land systems importance for supporting food security and sustainable development goals: a systematic review. *Sci. Total Environ.* 806:150718. doi: 10.1016/j.scitotenv.2021.150718

Wade, R. (2008). Education for sustainability: challenges and opportunities. *Policy Pract. Educ. Sustain. Dev.* 6, 30–48.

Wadumestrige Dona, C. G., Mohan, G., and Fukushi, K. (2021). Promoting urban agriculture and its opportunities and challenges—a global review. *Sustainability* 13:9609. doi: 10.3390/su13179609

Wagner, A. L., Keusch, F., Yan, T., and Clarke, P. J. (2019). The impact of weather on summer and winter exercise behaviors. *J. Sport Health Sci.* 8, 39–45. doi: 10.1016/j.jshs.2016.07.007

Waida, Y., and Kawamura, M. (2022). "Japanese school lunch and food education," in *School Food, Equity and Social Justice*, eds. D. Ruge, I. Torres, and D. Powel (London: Routledge), 171–186.

Wang, P. C., Huang, J. W., and Lee, D. C. (2023). Participation in intergenerational food and agriculture education programs effectively promotes place attachment. *Int. J. Environ. Res. Public Health* 20:4616. doi: 10.3390/ijerph20054616

Wang, W. S. (1973). The Chinese language. *Sci. Am.* 228, 50–63. doi: 10.1038/scientificamerican0273-50

Wezel, A., Bellon, S., Doré, T., Francis, C., Vallod, D., and David, C. (2009). Agroecology as a science, a movement and a practice. A review. *Agron. Sustain. Dev.* 29, 503–515. doi: 10.1051/agro/2009004

Willer, H., and Lernoud, J. (2019). *The World of Organic Agriculture Statistics and Emerging Trends 2019*. Frick: Research Institute of Organic Agriculture (FiBL) and IFOAM – Organics International.

Wu, M. Y. (2018). *An initiative of campus supported agriculture (CampuSA) at Chung Yuan Christian University* (master's thesis). Chung Yuan Christian University, Taoyuan, Taiwan. doi: 10.6840/cycu201800107

Wu, P. H. (2022). How local education empowers rural development: a case study of Meinong. *Taiwan. J. Soc.* 71, 1–56.

Yang, J. C. C. (2023). "University social responsibility in Taiwan: diverse goals and interdisciplinary learning," in *Transformation of Higher Education in the Age of Society 5.0: Trends in International Higher Education*, eds. R. Yamada, A. Yamada, and D. E. Neubauer (Cham: Springer International Publishing), 145–157.

Yerokhin, S. M., Lin Feuer, Y. S., and Sassen, R. (2024). Biodiversity preservation in German higher education institutions: existing approaches, challenges and future developments. *Int. J. Sustain. High. Educ*. doi: 10.1108/IJSHE-12-2023-0608. [Epub ahead of print].

Zheng, Z. W., and Chou, R. J. (2023a). Promoting the development of edible landscapes in suburban areas with place branding—a case study in Taiwan. *Land* 12:1237. doi: 10.3390/land12061237

Zheng, Z. W., and Chou, R. J. (2023b). The impact and future of edible landscapes on sustainable urban development: a systematic review of the literature. *Urban For. Urban Green.* 84:127930. doi: 10.1016/j.ufug.2023.127930

Zhou, Y., Wei, C., and Zhou, Y. (2023). How does urban farming benefit participants? Two case studies of the garden city initiative in Taipei. *Land* 12:55. doi: 10.3390/land12010055

Zuppinger-Dingley, D., Schmid, B., Petermann, J. S., Yadav, V., De Deyn, G. B., and Flynn, D. F. (2014). Selection for niche differentiation in plant communities increases biodiversity effects. *Nature* 515, 108–111. doi: 10.1038/nature13869