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Review Article

Curricula Transformations and Alternative Pedagogical Approaches for Sustainable Agriculture and Environment

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Abstract

Alternative pedagogical approaches and curriculum transformations are crucial for promoting sustainable agriculture and environmental education. Conventional pedagogical approaches to teaching these subjects often rely on lecture-based methods and rote learning, which can limit students' engagement and critical thinking skills. Alternative pedagogical approaches, such as transdisciplinary education, experiential learning, problem-based learning, project-based learning, and hybrid learning, offer opportunities for student-centered and hands-on learning experiences. These pedagogical methods allow students to utilize their knowledge and skills in addressing real-life problems and projects, resulting in increased involvement and a deeper level of learning, enhancing comprehension of sustainable agriculture and the environment. Additionally, curriculum transformations that integrate agriculture sustainability and environmental education across disciplines and provide interdisciplinary experiences can support a more holistic understanding of these complex and interrelated issues. The integration of innovative alternative pedagogical tools and curriculum changes within the realm of sustainable agriculture and environmental education is crucial in fostering the development of future researchers, farmers, and policymakers, who possess the necessary skills and knowledge to tackle the intricate challenges of promoting sustainability in agriculture and the environment.

Keywords: Education; Food security; Curriculum; Sustainable agriculture

Introduction

Food security is a global concern that impacts every individual. Historically, attempts to boost productivity and crop yields have resulted in environmental degradation, loss of biodiversity and the decline of ecosystem services, disproportionately and/or affecting populations vulnerability (Rehman *et al*. 2022). The food chain has a profound impact on the enviroment, primarily through the emission of CO_2 and wastage of food resources (Acevedo *et al*. 2018; Tubiello *et al*. 2022). Around one-third of the food produced for human consumption is either lost or wasted on a global scale, which amounts to a staggering 1.6 billion tons of food and accounts for approximately 8% of global greenhouse gas emissions. Global agri-food system emissions accounted for 16.5 billion metric tonnes (Gt CO_2 eq.yr^{-1}), representing 31% of total anthropogenic emissions, with emissions from on-farm production processes at 7.2 Gt CO_2 eq. yr^{-1}, land use change at 3.5 Gt CO_2 eq. yr^{-1} and pre- and post-production processes at 5.8 Gt CO_2 eq. yr^{-1} (Tubiello *et al*. 2022). The production of unconsumed food not only has severe environmental consequences but also put immense pressure on biodiversity, accounting for more than 20% of global biodiversity loss. Moreover, it occupies nearly 30% of agricultural land globally (Losses and Waste 2011). Food production systems heavily rely on natural resources such as soil, water, energy, etc. for various activities including fertilization, processing, packaging, transportation, and cooling. These activities have signficant environmental implications on a global level, contributing to issues such as loss of biodiversity, soil degradation, deforestation, greenhouse gas emissions and air and water pollution. The ongoing loss of biodiversity remains a major factor in food production (Eastwood *et al*. 2021). Climate change manifests through variable precipitation, increased droughts and floods and negatively affects food production. It disrupts the availability of vital natural resources like soil and water, causing substantial alterations to the conditions for food and industrial production in certain regions. Presently, extreme weather events and the increasing prevalence of climate

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associated diseases in plants and animals remain challenges to food production, with the impact expected to intensify in the future (Polańska *et al*. 2022).

Addressing the challenges associated with global food and nutrition security, it is crucial for the research community to actively participate in generating knowledge, promoting innovation and collaborating with society, with an ultimate aim of establishing a more robust food system (Abecassis *et al*. 2018). Capacity building and raising awareness play pivotal roles in effective dissemination of knowledge from researchers to farmers and other stakeholders (Abecassis *et al*. 2018; Polańska *et al*. 2022). The needs analysis has indicated a clear requirement for education and professional programs that align with the strategic goals of the WHO European action plan for food and nutrition policy. These programs should encompass areas such as protecting the integrity of the food chain, preventing and controlling foodborne contamination, and effectively managing food safety (Polańska *et al*. 2022).

One effective approach to address the challenges of sustainable agriculture and the environment is to focus on pedagogy and curriculum transformation in order to produce well-trained and well-acquainted human resources (HR), who can bring real change in these areas. Pedagogy encompasses the process of teaching, learning, understanding, and experiencing the connections between food, health, pleasure, agriculture, family and community, culture, and the environment. Sumner (2013) highlighted the importance of utilizing critical food pedagogies in adult education as a way to address issues of sustainability in current food systems and to create comfort in lifestyles. The pedagogical and curriculum transformation is necessary for tackling challenges to sustainable agriculture and the environment because it helps to ensure that students are educated about sustainable practices and are acquainted with the knowledge and skills needed for their future implementation. This includes understanding the interconnectedness of food systems, ecology and social equity, and being able to apply this understanding to make informed decisions about land management and resource use. Incorporating sustainable agriculture and environmental education into the curriculum can help to raise awareness and encourage engagement in these issues among students, which is important for promoting sustainable practices in the long term. By emphasizing the importance of HR in bringing about change in sustainable agriculture and the environment, this article aims at to identify the most effective and promising pedagogical approaches and curriculum transformations for teaching and their potential impact on the promotion of sustainable agriculture and the environment. It also describes the importance of interdisciplinary and holistic approaches to teach about sustainable agriculture and the environment, which includes the integration of social, economic, and environmental aspects in order to produce well-trained and well-acquainted HR.

Sustainability, agriculture and environment

The notion of sustainability or sustainable development has become increasingly important in policymaking since the Brundtland Report was published in 1987. The word sustainable or sustainability has been derived from the Latin word “sustinere” which means to maintain, sustain, support, and endure. The term “sustinere” transitioned from Latin to old French as “sostenir” and eventually become “soutenir” in modern French. It entered the English language as the verb “to sustain” during the Early Modern Period, as evidenced by its use in John Evelyn’s renowned forestry treatise, Sylva, published in 1664 (Evelyn 1975). The adjective “sustainable” gained widespread usage much later, with the Oxford English dictionary documenting its common usage in 1965 (Caradonna 2014).

The concept of sustainability

The concept of “sustainability” has its roots in forestry, where it refers to the principle of never taking more from a forest than it produces in new growth (Fig. 1; Hopwood *et al*. 2005). Hans Carl von Carlowitz in 1713 coined the term “Nachhaltigkeit” in German, which conveys the concept of sustainability (Barkemeyer *et al*. 2014). His book “*Sylvicultura Oeconomica*” introduced the idea of sustainability as an economic concept more than 300 years ago. The concerns about maintaining soil fertility among early farmers, and the preservation of prey by our Palaeolithic predecessors reflect early instances of sustainability awareness. The concept of stewardship and care for future generations has been long established. However, the Brundtland Report's concept of sustainability is ambiguous, which masks the complexity of sustainability (Redclift 2005). In 1849, the concepts of sustainability, such as calculating forest rotation periods (sustained yield) and managing fisheries (maximum sustainable yield), were empirically applied (Vavra 1996).

The term "sustainability" has been the subject of extensive discussion and has a wide range of definitions due to its ambiguity and increasing importance in the development of national and international policies (Wiersum 1995; Wilderer 2007). In 1804, Georg Ludwig Hartig, a German forestry researcher, defined sustainability as the use of forests to the maximum extent possible while ensuring that future generations enjoy the same benefits as the current one. The terms "sustainability" and "sustainable development" together have nearly 300 definitions.

Sustainable development is widely recognized to encompass three key components: economic, social and environmental (Elkington and Rowlands 1999). Renewable clean energy is an obvious example of sustainability, with solar and wind energy being just a few examples. Sustainable agriculture is another critical component of sustainable development, as it seeks to meet society's present needs while preserving natural resources for future generations. Factually,

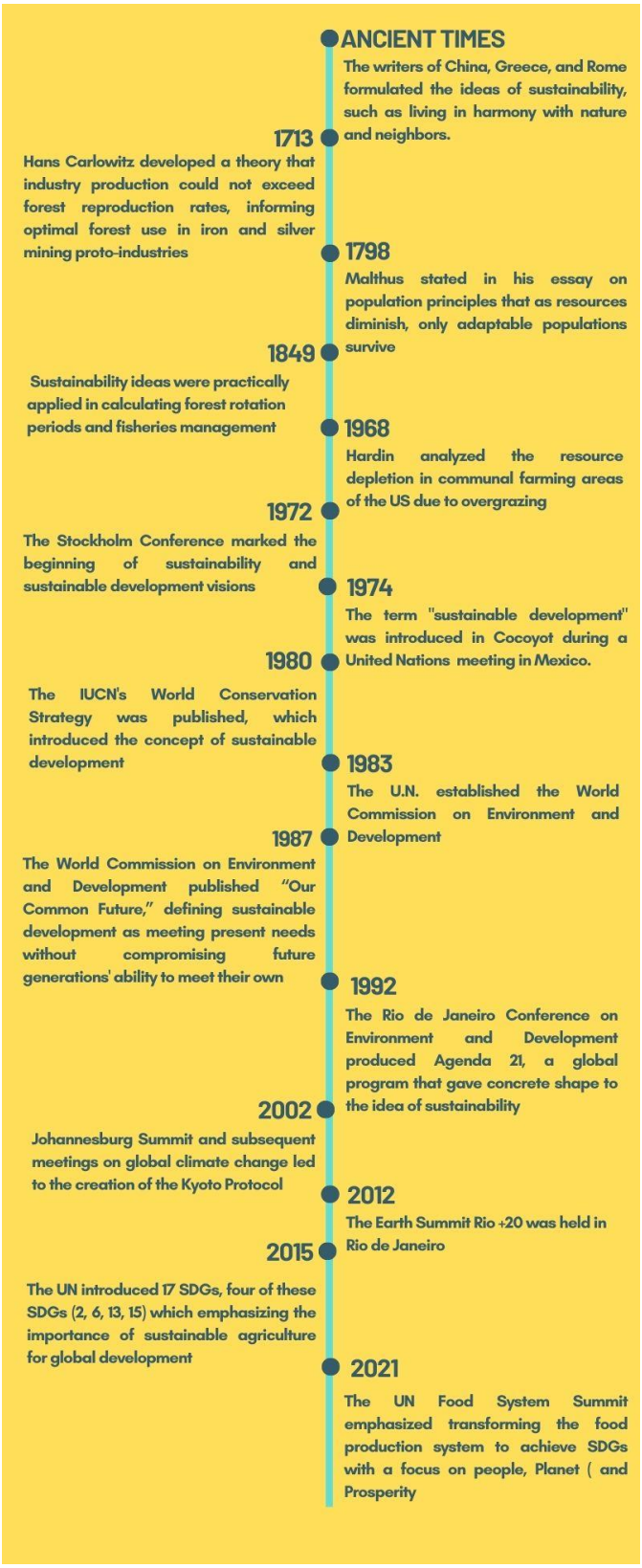

Fig. 1: Evolution of Sustainability and Its Application to Agriculture and Environment: A Timeline
UN= United Nations; IUCN= International Union for the Conservation of Nature

sustainable agricultural practices strive to safeguard the environment, enhance the Earth's natural resources, and preserve and enhance soil fertility while increasing profitable farm income and promoting environmental stewardship.

The United Nations (UN) has been instrumental in advancing the concept of sustainability through a series of international meetings, including the Conference on the Human Environment in Stockholm in 1972 (Fig. 1; García and Vergara 2000). Recognizing the importance of environmental concerns, the UN established the World Commission on Environment and Development, UN in 1983, which released the influential document "Our Common Future" in 1987, providing a comprehensive definition of sustainable development (Imperatives 1987). Subsequent global conferences on environmental issues, such as the UN Conference in Rio de Janeiro in 1992 on Environment and Development, the Johannesburg Summit in 2002, and the Earth Summit Rio +20 in 2012 (Koroneos and Rokos 2012), further reinforced the significance of sustainability in global policy discussions.

To emphasize the role of sustainable agriculture in promoting global development, the UN adopted Sustainable Development Goals (SDGs) in 2015, which have influenced research practices in this field (Janker *et al*. 2018). To achieve four out of the 17 SDGs, the agriculture sector must play a crucial role. One proposed solution to transform the current food production system is by implementing practices that promote a sustainable agrosystem approach. This approach can promote regenerative agriculture, reverse biodiversity loss, improve soil health, and support community well-being (Shahmohamadloo *et al*. 2022). However, it remains unclear how international political discussions have influenced the scientific discourse on sustainable agriculture and how this concept is interpreted in these discussions.

Agricultural sustainability

Interest in agriculture and food sustainability may be attributed to environmental concerns that gained prominence during the 1950s and 1960s. Today's sustainability concerns center on the need to create agricultural practices and technologies that (i) do not harm the environment, recognizing its crucial role in farming, (ii) are feasible and attainable for farmers and (iii) increase food productivity while concurrently generating positive impacts on environmental resources and services. Sustainability and resilience are principles that are incorporated into agricultural systems. Different expressions suggest that some agricultural systems are more sustainable than the ones that are currently in use (Clements and Shrestha 2004; Gliessman 2005). The fundamental principles of sustainability encompass: (i) integrating biological/ecological processes, including nitrogen fixation, nutrient cycling, soil regeneration, competition, allelopathy, predation, and parasitism into food production systems; (ii) minimizing the utilization of non-renewable inputs that pose harm to the environment or to the well being of farmers and consumers; (iii) harnessing the knowledge and skills of farmers to enhance self-reliance and reduce reliance on costly external inputs; and (iv) leverage collective capacities to foster collaboration in addressing common agricultural and natural resource challenges, such as for pest management, watershed conservation, irrigation practices, forest management, and access to credit. However, the concept of sustainable agriculture does not imply rejecting certain technology or methods on the basis of philosophy. Technology is expected to offer some sustainability advantages if it increases farmer output while posing minimal environmental impact. A common characteristic of agricultural systems that emphasizes these concepts is their multifunctionality within economies and landscapes (Dobbs and Pretty 2004; Pretty 2008).

Education for sustainable agriculture and environment

Higher education, including formal academic programs, has a significant role in promoting sustainability in agriculture and the environment (UNESCO 2014). A recent study in Latin America found that university students had a positive attitude toward sustainable agriculture (SA) and an adequate level of knowledge on the subject (Gabela *et al*. 2022). The study suggests that integrating sustainable agriculture principles into agricultural education can enhance attitudes and knowledge of learners regarding SA. This can be achieved by incorporating sustainable agriculture into the curriculum and supplementing it with experiential learning opportunities, which can enhance profitability, risk reduction and resilience. Furthermore, future research should examine other variables that could influence attitudes and knowledge related to SA, including teachers' attitudes and knowledge towards SA, educational approaches and environmental behavior (Gabela *et al*. 2022). Other examples of formal education in sustainable agriculture and the environment include degree programs in sustainable agriculture or environmental studies. These programs offer students with a solid understanding of sustainable agriculture principles, environmental management practices, and relevant economic and social matters. They cover a wide range of topics including organic farming, conservation of natural resources, and integrated pest management (UNESCO 2014). Formal education, particularly higher education, can produce well-trained and well-acquainted human resources who can bring real change in sustainable agriculture and the environment.

In addition to formal education, non-formal education such as workshops and extension programs plays a pivotal role in advancing sustainable agriculture and environment awareness. Extension services are a type of non-formal education that can be used to transfer knowledge from researchers to farmers and other stakeholders in the agri-food industry. Such programs provide opportunities for farmers and agricultural workers to learn about sustainable farming practices and the latest agricultural technologies. This approach can also be effective in raising awareness about the benefits of sustainable agriculture and creating community engagement in sustainable food production. For instance, in

Uruguay, Siembras Project has had significant reach and impact. The objective of this community program focused on health, coexistence and development, with the aim of fostering local community sustainability and promoting harmonious living practices. The program involved more than 23,000 children aged 3–12 years old from participating towns, along with around 6,000 families and 700 educators associated with children's educational institutions. Its primary focus was to provide education and foster community awareness regarding health, local organic food production, citizenship and sustainable development (UNESCO 2012).

Training and education for sustainability in agriculture and the environment can comprehend a wide range of topics and can be provided through various types of educational programs. Some key areas of focus for education in this field may include the followings:

1. Non-chemical and regenerative farming practices: This can include instruction on techniques such as cover cropping, crop rotation and the use of natural fertilizers and pesticides.
2. Conservation of natural resources: Topics such as soil and water conservation, as well as biodiversity preservation, may be covered in sustainable agriculture education.
3. Integrated pest management: This may include instruction on the use of biological control methods, as well as the reduction or elimination of chemical pesticides.
4. Social and economic aspects of sustainable agriculture: Education in this area may include instruction on food systems, food security, and the role of sustainable agriculture in community development.
5. Climate change and sustainable agriculture: Understanding the impacts of climate change on agriculture and how to adapt to it
6. Plant genetic resource conservation: Education on plant genetic resource conservation can help promote the conservation and sustainable use of plant genetic resources, which are essential for maintaining genetic diversity in crop species and ensuring long-term food security.
7. Crop and food diversification: Instruction on crop and food diversification can help promote the use of diverse and resilient crop varieties that are adapted to different growing conditions and can help increase food security and promote sustainable farming practices.
8. Introduction to neglected and underutilized resilient crops: Education on neglected and underutilized resilient crops can help promote the use of resilient crop varieties that are adapted to harsh growing conditions such as drought, salinity, or poor soil, etc., and can help increase food security and promote sustainable agriculture.
9. Precision agriculture: Instruction on precision agriculture can help promote the use of advanced technologies, such as remote sensing, GIS, and precision farming equipment, to optimize agricultural production while minimizing environmental impact.
10. Education for sustainable agriculture and the environment can be provided through a variety of educational programs, such as:

a. Formal degree programs in sustainable agriculture or environmental studies.
b. Non-formal education programs, such as workshops, training programs, and extension programs.
c. Online education, such as MOOCs, online courses, and webinars.
d. The education needed for sustainable agriculture and environment is multidisciplinary, it includes knowledge of agriculture, ecology, biology, climatology, economics, sociology, political science and other related fields.

Curriculum transformations for sustainable agriculture and environment

In higher education, there has been an increasing focus on the curriculum in recent years, particularly in relation to comprehensive institutional curriculum renewal (Hicks 2018). However, within the domain of sustainable agriculture and the environment, the need for curriculum transformations has become increasingly apparent. The challenges facing agriculture and food systems are intensifying, and traditional approaches to education and training are no longer adequate. As a result, initiatives around the world have been launched aimed at transforming curricula and developing new educational programs that better prepare students for the multifaceted nature of sustainability in agriculture (Šūmane *et al*. 2018). One such initiative is the pan-European MSc program "Sustainable Food Systems Engineering, Technology and Business" (FOOD4S 'food force') 2020–2026 (2029). The program objective is to transfer knowledge, expertise, and best practices in developing nations, as an essential model leading to social, environmental and economic sustainability in food systems (Polańska *et al*. 2022).

A pedagogical approach that is rooted in the values places deliberate emphasis on the fundamental principles that underpin diverse agricultural and food systems, as well as their governance. It considers these values when designing educational strategies and creating meaningful experiences in various educational settings, acknowledging the individual beliefs and perspectives held by the learners (Galt *et al*. 2012). This approach is particularly important for sustainable agriculture, which requires new knowledge and learning processes. Informal farmer knowledge and learning practices can play a crucial role in constructing alternative pathways toward sustainability (Šūmane *et al*. 2018).

The findings of 11 case studies conducted as a part of the RETHINK research program revealed that farmers highly regard the local experiential knowledge, recognizing its practical, personal, and contextual significance. The study identifies various approaches to integrating different forms of knowledge, including synthesizing knowledge from different sources, farmer networking, promoting cooperation between researchers and farmers as co-generators of knowledge and establishing multi-actor knowledge networks. The

integration of this knowledge into the agriculture curriculum will be helpful in producing well-equipped human resources, which can help in implementing sustainable agriculture practices for food security and ecosystem functioning (Šūmane *et al*. 2018).

The UN Decade of Education for Sustainable Development framework stresses the importance of providing high-quality education for sustainable development. This necessitates adopting a multi-methodical approach that combines various pedagogical approaches (Lozano *et al*. 2019). This approach encourages students to actively participate and engage in critical thinking and reflect upon their learning. To achieve this, it is imperative to develop new curricula that move away from passive learning and embrace transformative learning, incorporating new content, forms of knowledge, and learning processes. These curriculum transformations are critical if we are to build a more sustainable future for agriculture and food systems and prepare students to meet the complex challenges of sustainable agriculture and environment and engage with the diverse range of stakeholders involved in these systems (Šūmane *et al*. 2018; Polańska *et al*. 2022).

Several studies have underlined the significance of developing critical pedagogy education curricula that incorporate the knowledge and practices of subsistence farmers to address climate change and sustainability concerns. Govender (2019) documented the experiences and perceptions of seven Black South African subsistence farmers from a qualitative multi-case study. He observed resilience by farmers in issues like water conservation, pest management, and indigenous knowledge. The study recommends integrating the knowledge and practices of subsistence farmers into education curricula and forming partnerships with the farming community to foster a critical pedagogy.

Alternative pedagogical approaches for sustainable agriculture and environment

The art and science of teaching and learning is called pedagogy (Murphy 2003; Trott *et al*. 2020). The selection of a pedagogical approach relies on various factors including the educational environment, the instructor's skills and experience, the backgrounds, and interests of individual students, and the teaching goals (Table 1; Freitas and Oliver 2006). This is important to note that the transfer of knowledge and skill development are the major objectives of any pedagogical approach. This is why, in addition to traditional lecturing, a variety of approaches should be used in seats of higher learning of agriculture to enhance the learning process and enhance the transfer of knowledge and skill development aimed at the sustainability of agriculture and the environment (Fig. 2; Lozano *et al*. 2019). The potential alternative pedagogical approaches for the sustainability of agriculture and environment, include transdisciplinary education, active learning, problem-based learning and experiential learning (Fig. 2; Table 1), etc. are discussed below.

Transdisciplinary education

This approach involves learning and research that integrates knowledge and expertise from multiple disciplines to address complex problems related to sustainability in agriculture and the environment. The goal of transdisciplinary education is to provide a comprehensive understanding of the interconnections between different domains and to develop solutions that are informed by multiple perspectives and disciplines. This type of learning seeks to overcome the limitations of traditional, single-disciplinary approaches and to promote collaboration, integration and holistic problem-solving (Fig. 2).

The modern food system is facing challenges in simultaneously attaining food security and environment sustainability. A fragmented approach to addressing these issues in universities is hindering food system transformation. North American institutes of higher education have developed novel programs in sustainable food system education (SFSE) to provide students with the necessary knowledge, skills and attitudes to address the intricate challenge to food systems. A signature pedagogy for SFSE has been proposed based on the analysis of SFSE programs, which includes an interdisciplinary approach, systems thinking, experiential learning and engagement in collective action initiatives. This framework aims at to encourage further dialogue and advancement in the theory and practice of SFSE (Valley *et al*. 2018). In the context of sustainable agriculture and environment, transdisciplinary strategy may involve bringing together experts from fields such as agronomy, ecology, social sciences, economics and policy to address issues such as food security, biodiversity conservation and sustainable land use (Table 1).

Outcome-based learning

The outcome-based learning (OBL), or outcome-based education (OBE) system is a teaching and learning method that combines diverse teaching methods to facilitate students in attaining the specified learning outcomes (Fig. 2; Katawazai 2021). This is different from the conventional education system as it involves three components including the theory of education, a well-structured educational framework and a distinct approach to instructional practice (Killen 2007). The OBE helps the institutions to assess the students based on the pre-designed learning outcomes and warrants the students to develop new skills to enable them to compete in the global market.

Experiential learning

This approach emphasizes hands-on, practical learning experiences, such as working on a farm or participating in conservation projects. This type of learning can help students to better understand and apply sustainable agriculture and environmental principles in real-world contexts (Fig. 2).

Table 1: Alternative pedagogical approaches for sustainable agriculture and environment education

Approach	Examples	Advantages	Challenges	Reference
Trans disciplinarity education	A program that combines ecology, agronomy, sociology, economics, and policy to understand and address the challenges of sustainable food systems	Addresses complex issues from multiple angles, providing a more comprehensive solution. Enhances the students' ability to collaborate and communicate effectively. Focuses on finding solutions to real-world problems	Involves extensive collaboration and coordination among multiple disciplines, which can be time-consuming Encounters challenges in integrating multiple perspectives and finding common ground Difficulties in implementing interdisciplinary programs in traditional academic structures	Hansson and Polk (2018) Jahn *et al.* (2022)
Experiential learning	Students work on a farm, participate in conservation projects, or create their own sustainable agriculture project	Enhances student engagement and motivation Fosters practical skills and knowledge relevant to sustainable agriculture and the environment Promotes critical thinking and problem-solving skills Provides real-world context for learning and helps students understand the relevance of course content to their lives Encourages collaboration, teamwork, and community building	Can be resource-intensive and requires coordination with community partners and stakeholders Can be challenging to assess student learning and measure the impact of experiential learning activities Requires careful planning and preparation to ensure that learning experiences are meaningful, relevant, and aligned with course outcomes	Backman *et al*. (2019)
Place-based education	Students conduct research on local environmental or agricultural issues, or participate in sustainable agriculture and environmental projects in their local communities.	Builds connections between students and their local communities Promote and encourage a profound emotional reconnection with nature, environment, land and the oneself Allows students to apply their knowledge and skills in real-world scenarios.	Requires community partnerships and engagement.	Bonnett (2003)
Service learning	Students work in teams on projects that address local sustainable agriculture and environmental issues, such as developing a community garden or creating a conservation plan for a local park.	Promotes students self efficacy, self esteem, compassion across several dicipline, scial responsible knowledge Provide opportunity to apply their knowledge and skills in real-world scenarios while also making a positive impact on their communities.	Requires community partnerships and engagement.	Williamson (2017); Long and Gummelt (2020)
Problem based learning	Students working in teams to address a challenge such as developing a plan for water conservation in local agriculture practices	Promotes critical thinking and problem-solving skills. Encourages active student engagement. Relevant and practical learning experiences. Fosters collaboration and teamwork. Supports student learning and understanding of complex issues.	Need substantial planning and preparation time for educators The open-ended nature of the problem can be difficult for students Some students may not have the necessary skills or knowledge to fully participate. Assessing student learning can be difficult	Abbey *et al*. (2017); Thakur *et al*. (2021);
Project based learning	Students working in teams to design and implement a sustainable farming project, such as a community garden, using sustainable agriculture practices.	Encourages critical thinking and problem-solving Relevant and practical learning experiences Encourages student engagement and motivation. 3. Supports the development of skills such as project management and collaboration	Significant planning and preparation time required for educators. Student assessment can be difficult Some students may struggle with the open-ended nature of the project. Balancing the learning goals with the practical requirements of the project can be challenging.	Wei *et al*. (2009); Wróblewska and Okraszewska (2020)
Hybrid learning	Students learn about sustainable farming practices through online coursework and then apply their knowledge through hands-on experiences at a community garden or on a local farm.	Offers flexibility for students, allowing them to work at their own pace. Supports personalized and differentiated learning. Enhances student engagement through a variety of learning experiences. Allows for real-time, interactive learning experiences.	Balancing the benefits of both online and in-person learning Ensuring the quality of online materials and experiences Addressing the potential for disparities in access to technology and resources Maintaining student engagement and motivation in both online and in-person environments Incorporating assessment and evaluation that effectively measures student learning in both contexts	Means *et al*. (2013); Gillett-Swan (2017)

Traditional classroom teaching may not always align with conventional agricultural systems and practices. Instead, these enable the students to understand the sustainability of farming and the ecosystem at large through on-farm projects and sessions (Kassam *et al*. 2022).

Parr and Trexler (2011) investigated students' perspectives on the efficacy of teaching methods in sustainable agriculture and food systems, the incorporation of their experiences on student farms into their academic curriculum and the motivations behind their engagement in student farm activities. Their results indicated a preference for a combination of classroom and practical learning, confirming the importance of experiential education. A community of learners was established between the students

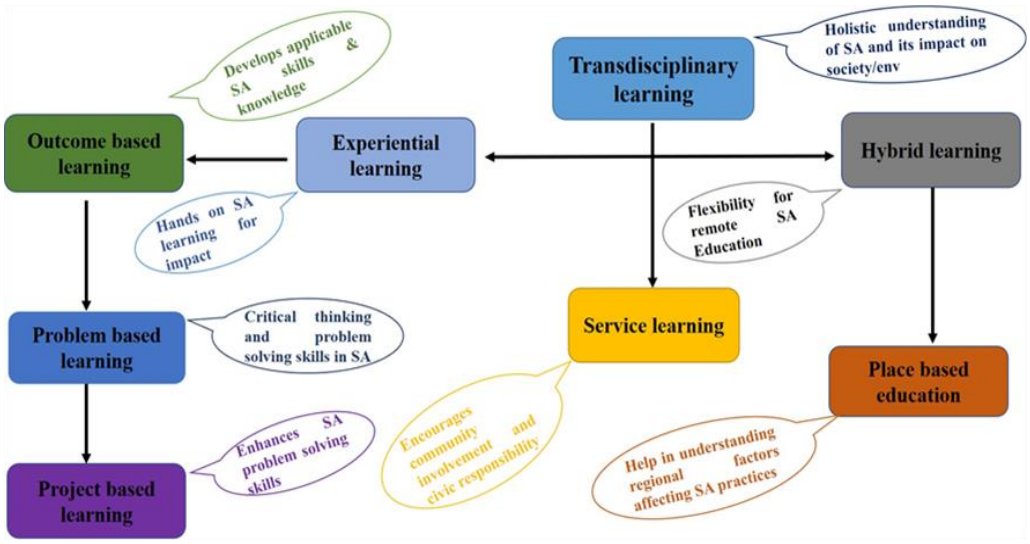

Fig. 2: Alternative pedagogical approaches for sustainable agriculture and environment

and instructors, leading to the co-creation of knowledge. Students were driven by a sense of empowerment and alignment with their values through practical learning; suggesting that student farms are a viable means of fostering experiential learning in sustainable agriculture and food systems programs at land-grant colleges.

Problem-based learning

This approach focuses on learning through active problem-solving, where students work in groups to analyse and solve real-world challenges pertaining to sustainable agriculture and the environment. For instance, Abbey *et al*. (2017) evaluated the impact of problem-based learning (PBL) on the advancement of students' attitudes and skills in horticulture education. The students were assigned two complex problems, which involved producing fresh baby greens for a catering event and seedlings for a grower. The active engagement in PBL resulted in the development of positive attitudes and the acquisition of professional, practical, affective and social skills. Students showcased leadership qualities, critical thinking abilities, and conflict management skills in their presentations and reports. High quality problem-based tasks were found to be critical in stimulating and elaborating prior knowledge, developing epistemic curiosity, and establishing a relevant semantic framework. The PBL process was also found to enhance cognitive and emotional intelligence, creativity, social skills, and employability. Krzic *et al*. (2015) evaluated the effectiveness of PBL in a Sustainable Soil Management course at the University of British Columbia (UBC) Farm. The integration of the UBC Farm case provided students with hands on activities and teamwork with farm managers and staff, resulting in stimulating and impactful experiences. The PBL approach employed in this course may serve as a model for a postsecondary soil science curriculum, supporting student learning and facilitating natural resource management. The PBL approach, known for its focus on intricate interdisciplinary challenges is widely recognized as a proficient approach to education for sustainable development (Brundiers and Wiek 2013). This approach enables students to cultivate critical thinking and problem-solving abilities, while also empowering them to apply their knowledge of agriculture and environmental sustainability in real-world contexts.

Project-based learning

This approach emphasizes student-cantered learning and focuses on student-led projects that encourage innovation and creativity. This approach facilitates the practical application of student's knowledge and skills in real-world scenarios, fostering the development of crucial abilities such as communication, teamwork and leadership (Table 1). In a recent study on the effectiveness of Project-based learning (PjBL) and PBL in students' capacity to diversify seaweed products, Muhammad *et al*. (2021) observed that PjBL had a stronger impact on fostering learning skills, and students taught with PjBL demonstrated a great ability to diversify seaweed products compared to those taught with PBL. The interaction between learning strategies and skills significantly impacts students' ability to diversify seaweed products (Muhammad *et al*. 2021). In a study conducted by Cazorla-Montero *et al*. (2019) on the use of project-based learning in the field of Sustainable Development Planning in postgraduate programs in Spain, a mixed methods approach was employed to evaluate student and staff perceptions of the implementation of the program. Their findings showed that the program emphasized the importance of comprehensive thinking and intellectual coherence, experiential learning,

and the developement of personal and interpersonal skills as crucial factors for attaining success in sustainable projects, programs, and portfolios. The results of the study highlight the effectiveness of the PjBL approach for imparting knowledge on sustainable development planning in postgraduate programs. The implementation of PjBL in an Environmental Education course demonstrated a positive effect on students' attitudes towards understanding environment. It was considered advantageous as it fostered creativity, encouraged research, and provided lasting learning. No gender disparities were detected. The students reported that PjBL aided their comprehension of environmental issues and enabled them to play a more proactive role in resolving these problems (Genc 2005).

Service learning

This approach combines traditional classroom learning with service projects that address community needs related to sustainable agriculture and environment. This can help students to apply their knowledge and skills in real-world contexts while also making a meaningful and beneficial influence on their communities (Table 1; Fig. 2). The University of Southern Maine implemented a service-learning project to address food waste, environmental stewardship, food insecurity, and climate change with the collaboration of three courses. Thirty students worked with 14 community partners to decrease food waste and its environmental impact, forming multidisciplinary teams to assess, learn, explore, create, and present plans. The project aligns with the university's dedication to climate change education and provides students with valuable hands-on learning opportunities that benefit the community (Picardy *et al*. 2021). Projects can be developed using a service-learning or community-oriented strategy, in which the community plays the role of client and receives the project report upon completion (Fourie 2003). The challenges faced by all parties involved in both models include faculty reluctance to teach due to high workload and uncertain impact on tenure and promotion, students' lack of knowledge about self-directed learning expectations and community partners' difficulty in collaborating with academic researchers (Brundiers *et al*. 2010).

Place-based education

This approach focuses on a specific place or community for teaching and learning. This can include working on projects that address local environmental or agricultural issues and can help build connections between students and their local communities (Table 1; Fig. 2). Grover and Gruver (2017) studied the impact of regional factors on the management decisions of smallholder farmers in East Central Indiana with a goal to promote sustainability in the environment, society and economics. The study used qualitative research methods, including semi-structured interviews conducted with 15 key informants and 33 farmers. The results showed several challenges hindering sustainable farm management, such as market constraints, regulatory factors, time constraints, and limited access to education. These results emphasized the importance of local circumstances in influencing agricultural policies and community outreach efforts (Grover and Gruver 2017). The place-based education approach recognizes the significance of local context in decision-making and recognizes the unique environmental, social and economic factors that impact agriculture in specific regions (Sonnino *et al*. 2016). By focusing on the specific needs and challenges of a particular area, a place-based approach can provide targeted support and resources to farmers, leading to more sustainable farming practices (Kiesel *et al.* 2022). This approach also promotes the use of local resources and knowledge, which can increase the overall effectiveness of agricultural initiatives and ensure that they are culturally and socially appropriate. Overall, place-based education provides a comprehensive framework for addressing agriculture sustainability and environmental concerns in a way that is tailored to the needs of local communities.

Hybrid learning

The pandemic (COVID-19) caused a significant transformation in the delivery of education. The conventional method of in-person learning has been replaced by online learning, necessitating rapid adjustments by higher education institutions (HEIs) to adapt to this unprecedented shift (Barrot *et al*. 2021; Mpungose 2023). In order to ensure the uninterrupted progress of teaching and learning, HEIs must transition to flexible modes of teaching and learning. This involves recalibrating the curriculum, providing faculty with necessary skills and resources, upgrading infrastructure, implementing strategic plans, and conducting comprehensive evaluations of all program aspects (Dayagbil *et al.* 2021). While online teaching has historically not been a conventional choice for curriculum in SA, however the COVID-19 pandemic promoted the use of online tools for teaching and learning. However, online teaching should be used as supplementary resources rather than the primary mode of instruction in sustainable agriculture programs. Consequently, adjustments to the curriculum need to be made to accommodate online classes. This includes availability of infrastructure for online education, selecting platforms that facilitate class participation and discussion, sorting course materials, and ensuring seamless connectivity, etc. are to be taken into account while revising the curriculum. In addition, there is a growing recognition among academicians that future education needs in this field include management and ICT skills as integral parts (Baptista *et al.* 2021).

In conclusion, these pedagogical approaches are more interactive and engaging, and offer students the opportunity to apply of their knowledge, skills and creativity to real-world problems. These approaches facilitate students to attain a comprehensive understanding of sustainable agriculture and

the environment, develop a sense of responsibility towards natural resources and be more prepared to face the challenges of the future.

Conclusion

Sustainable agriculture and environmental education are crucial in higher education institutions. It requires a shift from traditional teaching methods to innovative learning environments and curricula that excel beyond traditional academic boundaries. This transformation should incorporate pedagogical approaches such as transdisciplinary education, outcome-based learning, experiential learning, hybrid learning, and service learning. These pedagogical approaches are essential in helping students to understand the interrelations among evolving agri-food systems and environmental, economic and social dimensions. Furthermore, they empower students to assume responsible, productive and innovative roles as informed citizens in a dynamic and ever-changing global landscape. The importance of training and equipping human resources to match the changing needs cannot be overlooked. Therefore, the inclusion of program goals that promote the removal of barriers between fields, universities, scientists, farms and farmers, and the convergence of science and practice is imperative in shaping the educational journey of students. The change in pedagogy and curriculum transformation can lead to well-trained and well-acquainted human resources who can engage with diverse stakeholders involved in these systems and help build a more sustainable future for agriculture and food systems. Therefore, it is imperative that higher education institutions take a proactive approach to revise their curricula and teaching methods to promote sustainable agriculture and environmental education.

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Author Contribution

AR collected the literature, prepared the first draft, and revised the manuscript; KJ edited and improved the manuscript; MF conceptualized the idea, edited and improved the manuscript.

Conflicts of Interest

Author declares no conflict of interest.

Data Availability

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