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Impact of Food Geography Education on Competency and Sustainable Food Actions: A Conceptual SDG-Aligned Model

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Abstract

This study explores the impact of food geography education on developing food geographer competencies and enhancing food sustainability action intentions through a conceptual model aligned with Sustainable Development Goals (SDGs). The theoretical framework integrates Boyatzis's competency model and the Theory of Planned Behavior to evaluate how educational interventions influence psychological, social, and environmental factors. The study adopts a process-oriented research design, utilizing a qualitative literature review to identify core tasks of food geographers and link these tasks to specific SDG domains. Competencies such as geospatial technology application, sustainable agriculture advocacy, community engagement, and sustainable food education are mapped to critical SDGs, including SDG 2 (Zero Hunger), SDG 12 (Responsible Consumption and Production), and SDG 15 and 14 (Life on Land and water). The findings highlight the diverse roles of food geographers, including sustainability advocates, geospatial analysts, and community coordinators, showcasing their impact on food systems and sustainability practices. The study identifies 19 critical competencies, categorized into clusters such as Geospatial Technology and Monitoring, Sustainable Agriculture, and Community Coordination, essential for addressing complex food system challenges. Moreover, the study successfully conceptualizes a research model to investigate the impact of food geography education on student competencies for food sustainability actions and sustainability action intentions, offering a structured approach for future empirical studies. The study provides practical implications for curriculum development, instructional strategies, and professional development programs, emphasizing the need for a holistic approach that integrates education, policy, and community engagement.

Keywords: Competency Development, Food Geography Education, Food Sustainability, Sustainable Development Goals (SDGs).

Introduction

Food sustainability action integrates environmental, social, and economic goals to ensure long-term food security. In Europe, initiatives like the Science-Based Targets initiative (SBTi) drive net zero and waste reduction, though challenges remain (1). Reducing food waste through tools like the Food Waste Reduction Action Guide supports SDG 12 (2). Hybrid governance and policy reforms embed ethics and biodiversity goals (3, 4). Education fosters collaboration and critical skills for sustainable transitions (5). Inter-sectoral collaboration is vital but hindered by siloed approaches (6). Despite progress, harmonized frameworks, supportive policies, and stakeholder engagement are needed for truly sustainable food systems.

Food literacy, which includes the knowledge, skills, and attitudes necessary to make informed food choices and manage food resources responsibly, plays a crucial role in reducing food loss and waste. By enhancing individuals' understanding of food systems—from production and storage to consumption and disposal—food literacy empowers consumers to plan meals, store food properly, and creatively use leftovers, thereby minimizing avoidable waste. Educational programs that develop food literacy, such as food mapping and community-based initiatives, also foster critical thinking about the environmental and ethical implications of food waste. This supports SDG 12 by not only reducing waste at the consumer level but also encouraging sustainable consumption habits that ripple through households, schools, and communities (7, 8).

Food geography education fosters food sustainability by equipping individuals with knowledge to understand complex food systems. Integrating geographical, cultural, and socio-

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economic perspectives helps promote sustainable practices. Programs like the Geography of Food Summer School emphasize intercultural learning and responsibility (9), while experiential methods such as foodscape mapping address equity and inclusion (10, 11). Community-based initiatives like Think&EatGreen@School and Brazil's PNAE link education with local food systems and support small producers (12, 13). Challenges include cultural diversity and access, requiring cross-cultural learning and participatory approaches (9, 14). Addressing structural inequities is key to inclusive, sustainable food systems.

Food geography education holds a distinct position from food systems, agroecology, and geographical literacy education. While food systems focus on structure and policy (15), and agroecology emphasizes sustainable farming and justice (16), food geography integrates geospatial tools, socio-cultural analysis, and competency-based learning. Unlike geographical literacy, which centers on spatial awareness, food geography prepares learners for roles like geospatial analysts and community food coordinators. Its interdisciplinary, applied framework aligns with the SDGs, combining spatial reasoning, cultural context, and sustainability action. This specialization fosters academic inquiry and equips students for careers in sustainability, education, and policy-making (17, 18).

The professional development of food geographers requires interdisciplinary expertise across geography, food science, and social sciences. Challenges include integrating cultural, economic, and environmental perspectives, as seen in culinary geography's rise in tourism education (19), and limited GIS curriculum support and data access (20). Navigating sub-disciplinary divides and balancing theoretical with applied research is also critical (21). Rapid changes in the food industry demand adaptive, interdisciplinary strategies, though traditional academic structures hinder progress (19, 22). Opportunities arise through initiatives like the EDGE project, which promotes workforce competencies and supports career readiness for geography graduates (23), driving innovation and impact.

Food geography education significantly influences sustainable food action intentions by addressing psychological, social, and environmental factors through experiential learning and knowledge integration (9). It enhances knowledge and awareness of sustainable food systems, fosters pro-environmental motivations, and builds self-efficacy aligned with sustainable practices (7, 24). Socially, community-based initiatives like Think&EatGreen@School promote food citizenship and social norms supporting sustainability (12). While intercultural exchanges broaden perspectives (9). Environmentally, education increases awareness of food choices' ecological impacts and promotes local, agroecological practices (25, 26). However, translating intention into action requires addressing cultural differences, resource availability, and structural barriers through a holistic approach combining education, policy, and community engagement (25).

Food geography education fosters food geographer competence by integrating cultural, environmental, and socio-economic dimensions into the learning process, enhancing students' understanding of global food networks and equipping them with skills to address sustainability and cultural identity challenges (27). Program like "Geography of Food" highlight the importance of cultural awareness and sustainable food value chains through experiential learning and practical skills development (9). Innovative pedagogical approaches, including e-learning, field trips, and mapping exercises, deepen students' engagement and foster competence in addressing food system complexities (28, 29). However, challenges such as integrating diverse backgrounds and maintaining methodological clarity in traditional geography education must be addressed to maximize its educational impact (9).

While food geography education supports sustainability intentions and competence development, a key research gap remains in identifying specific competencies for food geographers and evaluating the impact of educational interventions. Existing studies address psychological, social, and environmental factors (7, 9) and integrate cultural, environmental, and socio-economic dimensions. However, there is no comprehensive framework or empirical model linking education to competence and sustainable action. Initiatives like Think&EatGreen@School show promise (12), but their long-term effects on behavior and professional readiness across diverse contexts are unclear. This study aims to

define core competencies and develop a model to assess education's impact on sustainability intentions.

Theoretical Framework

The theoretical framework of this study is anchored in interdisciplinary theories of Food geography education and competency-based learning. It integrates competency model. This posits that underlying individual characteristics drive superior performance in specific roles, with the Sustainable Development Goals (SDGs) as a global sustainability paradigm. The framework draws on food geography education theories to address food system complexities. These theories collectively emphasize the role of education in fostering competencies that align with SDG targets. The integration of psychological constructs, including self-efficacy and pro-environmental motivation, further grounds the framework in behavioral theory, highlighting how knowledge and skills translate into sustainability intentions (7, 30, 31).

To deepen the educational foundation of the framework, essential learning theories are also integrated. Kolb's Experiential Learning Theory emphasizes the cyclical process of concrete experience, reflective observation, abstract conceptualization, and active experimentation, which is particularly relevant to field-based activities like food mapping and community engagement embedded in food geography education (32). Mezirow's Transformative Learning Theory highlights the role of critical reflection in challenging existing assumptions and fostering shifts in worldview, aligning well with the intercultural and justice-oriented goals of sustainable food education (33). Furthermore, the sustainability competencies proposed by Wiek including systems thinking, anticipatory competence, normative competence, strategic competence, and interpersonal competence — provide a comprehensive framework for assessing the capabilities developed through food geography education (34). These theories collectively enhance the model by linking pedagogical approaches with the cognitive, affective, and behavioral transformations required for sustainability action.

Conceptual Framework

This conceptual framework evaluates how food geography education fosters core competencies and enhances sustainability action intentions. It integrates Boyatzis's competency-based model, Ajzen's Theory of Planned Behavior, Kolb's Experiential Learning, Mezirow's Transformative Learning, and Wiek's sustainability competencies (30, 33–35). Boyatzis structures key competencies, while Ajzen explains how attitudes and norms shape intentions. Kolb and Mezirow offer pedagogical insights for transformative learning, and Wiek supports systems thinking and strategic planning. Together, these theories form a rigorous, practical model. By aligning competencies with SDGs, the framework assesses how food geography education influences both competence development and sustainable action intentions (7).

Methodology

Research Design

The proposed research design outlines a structured approach to developing competencies in food geography education, emphasizing a process-oriented methodology. The initial stage involves conducting Qualitative Literature Review of Tasks. This is to identify the fundamental tasks of food geographers, which serve as the foundation for competency development. This foundational understanding is crucial for aligning educational content with the practical demands of the field. Peer-reviewed literature was identified, selected, and evaluated. Reference work was established using Google Scholar, SCOPUS and WOS (the broadest database for academic studies). Additional verification was conducted through other academic databases, but no further relevant sources were identified. Studies were sourced using search terms such as: *"Food Geographer," "Food Geography," "Food Geographer in SDG,* and *"Food Geographies in Urban and Rural Contexts."* The most relevant studies were selected based on criteria including a precise definition of the term, publication date of 2010 or later, and studies that provided a synthesis of existing literature. The final collection included the following peer-reviewed studies (36). Firstly, each source was then analyzed as Food geographer tasks.

The second stage focuses on linking food geographers' tasks with relevant Sustainable Development Goals (SDGs). The integration of SDGs into food geography education ensures that learners not only acquire sustainability competencies but also develop a holistic

perspective on global sustainability challenges (15). By mapping the work of food geographers to specific SDG domains, educators can create targeted learning outcomes that align with global sustainability priorities, such as food security, responsible consumption, and environmental conservation. The methodological process of linking food geographers' tasks with corresponding Sustainable Development Goals (SDGs) involved a systematic approach combining qualitative content analysis and framework synthesis. Initially, core tasks of food geographers—such as geospatial technology and monitoring, sustainable food production systems, sustainable agriculture practices, community engagement, and workforce capacity building—were identified through a comprehensive literature review. These tasks were then mapped to relevant SDGs by aligning specific SDG objectives and targets with the expected outcomes of each task. Justifications for each linkage were based on empirical evidence and theoretical support, demonstrating measurable contributions to specific SDG targets. An expert review process validated the task-to-SDG connections, followed by iterative refinement to ensure the framework's practical applicability in educational and policy contexts. This approach established a robust framework that highlights the significant role of food geographers in advancing global sustainability objectives.

The next step is to outline the specific competencies required for food geographers. These competencies encompass a blend of knowledge, skills, and attitudes necessary for effective practice in the field. This stage involves a thorough synthesis and mapping of competencies, integrating theoretical frameworks with practical skills needed in food geography. A qualitative literature review of competencies required for food geographers highlights a multidimensional skill set essential for supporting Sustainable Development Goals (SDGs). The methodological process involved identifying, selecting, and evaluating peer-reviewed literature through comprehensive searches on academic databases such as Google Scholar, using targeted keywords including "food geographer," "geospatial technology," "sustainable agriculture," "geographical indications," and "SDGs in food systems." The most relevant sources were chosen based on criteria such as clear definition of competencies, recent publication (post-2010), and contributions to existing literature synthesis. The selected studies were systematically analyzed, and competencies were categorized into five clusters: Geospatial Technology and Monitoring Competence, Geographical Indication Competence, Sustainable Food Education Competence, Community Food Systems Coordination Competence, and Sustainable Agriculture Advocacy Competence. These competencies enable food geographers to integrate geospatial technologies, promote sustainable food systems, and foster socio-economic growth through education and community engagement. As agricultural geospatial analysts, they utilize Geographic Information Systems (GIS) and remote sensing to optimize agricultural productivity and biodiversity conservation (36, 37). As geographical indication analysts, they apply Geographical Indications (GIs) to enhance food product quality and sustainability (18). In educational roles, they build capacity and promote sustainable practices among food professionals (38). As community coordinators, they engage stakeholders to boost socio-economic development and integrate local food policies (39). Lastly, as sustainable agriculture advocates, they drive environmentally friendly practices, reduce chemical use, and support climate action (36). This synthesis emphasizes how food geographers' diverse roles, identified through a structured literature review process, contribute to global efforts in food security, sustainability, and resilience.

The synthesis and mapping process is a critical phase where competencies are categorized and aligned with educational objectives. This step involves creating a competency matrix that bridges the gap between academic learning and real-world applications. The matrix not only outlines the competencies but also provides a roadmap for curriculum development, instructional strategies, and assessment methods that support competency-based education.

Finally, the framework culminates in conceptualizing the impact of food geography education on students' competencies and their intention to engage in food sustainability actions. This conceptualization involves evaluating how educational interventions influence learners' abilities and their willingness to apply these

competencies in practical, sustainability-oriented contexts. The process-oriented approach ensures a dynamic interplay between education and practice, ultimately contributing to the broader goal of promoting sustainable food systems through well-informed and competent food geographers.

Lastly, a structured framework synthesis was applied to develop a new competency structure for designing curricula and courses in food geography education. The design protocol, adapted from (40). Then incorporates a systematic approach to ensure the relevance and applicability of competencies in food geography programs. The following criteria guided the competency structure development:

The development of the framework involved several key steps to ensure its relevance and academic rigor. First, competencies identified through the literature were clearly defined and standardized to avoid generic definitions or redundancies, ensuring that they are specific to food geography and aligned with the goals of Sustainable Development Goals (SDGs) implementation. Second, the framework sought to address gaps in the literature by identifying unestablished roles and overlooked competencies within food geography education, thereby introducing new perspectives grounded in both academic and practical discourse. Third, a practice-oriented approach was adopted by mapping core functions and competencies directly linked to real-world food geography practices—such as geospatial technology application, geographical indication analysis, community food systems coordination, and sustainable agriculture advocacy—thus avoiding the mere listing of disconnected skills. Finally, by drawing on core competencies from related disciplines, the framework promotes interdisciplinary learning and aligns food geography education with broader educational and professional debates on competency development.

To assess the impact of food geography education, a conceptual research model was developed using insights from entrepreneurship education studies and findings from the qualitative literature review (41). As shown in Figure 1, the model evaluates the impact of food geography education through the measurement of perceived food geography competency and intentions to engage in food sustainability actions. This model provides a practical and theoretical foundation for assessing how well food geography education prepares students with the necessary competencies and motivates them towards sustainable practices.

Results

Tasks—What Does a Food Geographer Do?

As shown in Figure 2, food geographers play a crucial role in achieving Sustainable Development Goals (SDGs) by integrating geospatial technologies and geographical indications to enhance food security, sustainability, and socio-economic growth. Their core tasks include acting as agricultural geospatial analysts, where they utilize geospatial technology such as GIS and Earth observation data to map and monitor soil and crop conditions, optimizing agricultural productivity and biodiversity conservation (36, 37, 39, 42). As geographical indication analysts, food geographers promote the use of Geographical Indications (GIs) to ensure quality and authenticity in sustainable food production systems, contributing to economic growth and social sustainability, exemplified by Parmigiano Reggiano cheese and Mishima Potato in Japan (18, 43). They also take on the role of sustainable agriculture advocates, integrating sustainable agriculture and bio-economy practices to increase yields, preserve biodiversity, and reduce chemical usage, which supports SDG targets related to food security and environmental sustainability (36). Additionally, as community food system coordinators, food geographers engage local communities to drive socio-economic growth and create sustainable urban and rural systems, leveraging technology infrastructure to enhance initiative effectiveness (39). Lastly, as sustainable food education coordinators, they contribute to workforce capacity building by mapping workforce contributions to SDGs, conducting workshops, and increasing awareness among food professionals, promoting a collaborative approach to sustainable development (38). Through these multifaceted roles, food geographers are instrumental in addressing global challenges such as hunger, malnutrition, and environmental sustainability, demonstrating their integral role in SDG implementation.

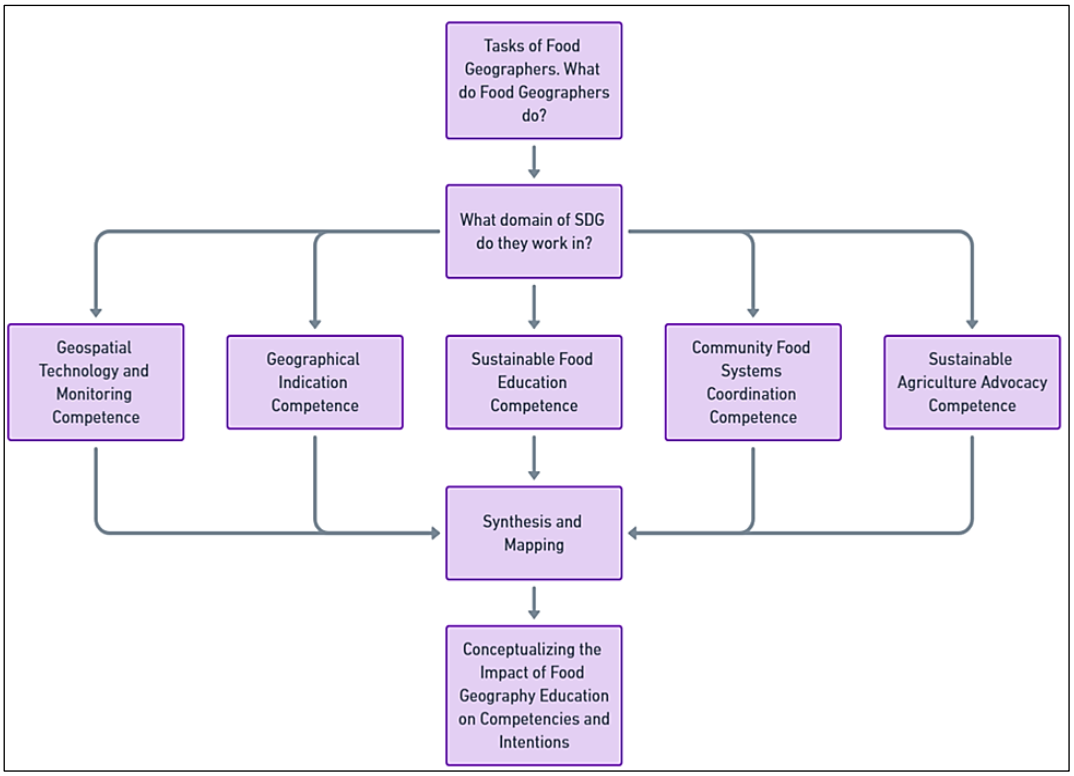

Figure 1: Overview of Research Design Adapted from "A Process-Oriented Framework of Competencies for Sustainability Entrepreneurship" (33)

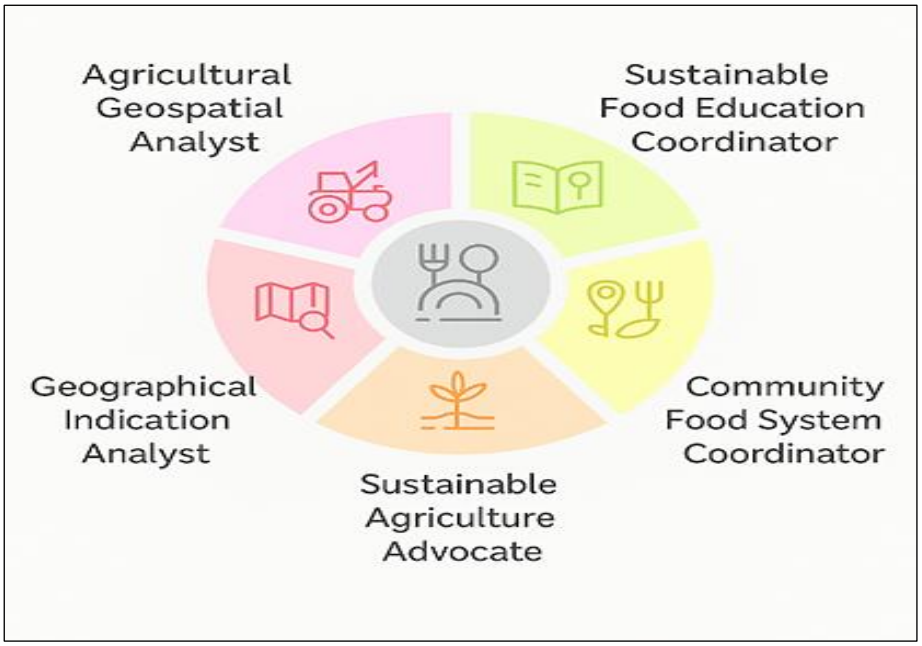

Figure 2: The Roles of a food Geographer

Which Domain of SDG can they Work?

Table 1 shows that food geographers play a pivotal role in achieving Sustainable Development Goals (SDGs) through their diverse tasks, each aligned with specific SDG targets. By utilizing geospatial technology and monitoring, including geospatial data and GIS applications, food geographers contribute to SDG 15 and 14 (life on land and water) by conserving biodiversity and to SDG 13 (Climate Action) by monitoring climate trends. Through sustainable food production systems, particularly by promoting Geographical Indications (GIs), they support SDG 12 (Responsible Consumption and Production) by

advocating responsible food sourcing and SDG 8 (Decent Work and Economic Growth) by enhancing economic growth and fair trade practices. In sustainable agriculture practices, food geographers integrate bio-economy methods that boost food production while maintaining biodiversity (SDG 15 and 14) and improving food security through reduced chemical use (SDG 2 - Zero Hunger). Additionally, their work in community engagement and socio-economic growth helps build sustainable cities and communities (SDG 11) and reduces inequalities (SDG 10) by fostering inclusive socio-economic development. Lastly, by focusing on workforce capacity building, food geographers align educational efforts with SDG 4 (Quality Education) and strengthen global partnerships for sustainability (SDG 17) through stakeholder collaborations. This strategic linkage not only enhances food systems but also ensures holistic contributions to global sustainability goals.

Table 1: Food Geographers' Task and Corresponding SDGs

Food Geographers' Task	Corresponding SDG(s)
Geospatial Technology and Monitoring (Utilization of Geospatial Data and Earth Observation and GIS)	SDG 15 and 14 (Life on Land and water) and SDG 13 (Climate Action)
Sustainable Food Production Systems (Geographical Indications - GIs)	SDG 12 (Responsible Consumption and Production) and SDG 8 (Decent Work and Economic Growth)
Sustainable Agriculture Practices	SDG 2 (Zero Hunger) and SDG 15 (Life on Land)
Community Engagement and Socio-Economic Growth	SDG 11 (Sustainable Cities and Communities) and SDG 10 (Reduced Inequalities)
Workforce Capacity Building	SDG 4 (Quality Education) and SDG 17 (Partnerships for the Goals)

Competencies—What Are Food Geographers Capable of?

Competency refers to the underlying characteristics of an individual that lead to superior performance in specific jobs or situations (30). Similarly, it is proposed two conceptual frameworks for developing competency models (44): Validated Competency Models and Starting-from-Scratch Competency Models. The Validated Competency Model builds upon an existing model, incorporating generic competencies that apply to broad roles and tasks with minimal specialized skills. This approach is particularly useful in professions where diverse duties and roles require adaptable competencies. Our competency framework for food geographers is organized into five distinct blocks, aligning with the core roles identified earlier. These roles include expertise in geospatial technology and GIS, advocacy for sustainable agricultural practices, facilitation of community-driven initiatives, and mapping workforce contributions to SDGs through capacity-building workshops. Much of the reviewed literature highlights the generic abilities required for these roles, emphasizing the need for competencies that support food security, sustainability, and socio-economic growth. We believe that a comprehensive competency framework tailored to different contexts will enhance its universal applicability, providing a robust model for food geographers to excel in varied professional environments (45).

As shown in Table 2, food geographers play a vital role in sustainable agricultural management by leveraging geospatial technology and monitoring techniques to map and analyze soil and crop conditions. Their core competencies include integrating multiscale geospatial data, applying advanced remote sensing techniques, and utilizing Geographic Information Systems (GIS) for spatial analysis. These skills enable them to conduct exploratory spatial data analysis, optimize crop production, and support sustainable agricultural practices (46). Additionally, food geographers are proficient in remote sensing for mapping agricultural land use, predicting crop yields, and monitoring soil stress using spectral reflectance data and indices like NDVI and SAVI (47). They effectively integrate Internet of Things (IoT) devices with GIS for real-time soil health monitoring and timely decision-making (48). Their expertise in precision agriculture allows them to

make data-driven management decisions by identifying soil and crop performance variabilities (49). Furthermore, food geographers contribute to climate change adaptation and resource management by modeling crop growth under various climate scenarios and managing water resources in areas susceptible to drought or flooding (50).

Table 2: Competencies of Food Geographer in Geospatial Technology and Monitoring

Competence Area	Behavioral Focus	Literature Source
Integration and Analysis of Geospatial Data	Integrating multiscale geospatial data (e.g., satellite imagery, soil datasets, hydrological data) to monitor crop growth and soil conditions.	(46)
Application of Remote Sensing and GIS	Mapping agricultural land use, predicting crop yield, and monitoring crop and soil stress using remote sensing and GIS.	(47–49)
Utilization of IoT and Real-Time Monitoring	Integrating IoT devices with GIS for real-time soil health monitoring and data-driven decision-making.	(48)
Decision-Making and Precision Agriculture	Using geospatial technologies and machine learning for precision agriculture, optimizing input use, and enhancing crop stress monitoring.	(49)
Climate Change Adaptation and Resource Management	Modeling crop growth under climate scenarios, managing water resources, and predicting crop water demand.	(50)

As demonstrated in Table 3, food geographers who utilize Geographic Indications (GIs) and Geographic Information Systems (GIS) play a critical role in promoting sustainable food production by integrating spatial data with traditional agricultural practices. Their competencies include understanding GIs as intellectual property, assessing their economic and social impacts, and aligning GIs with Sustainable Development Goals (SDGs) through Codes of Specifications and sustainability indicators (51–53). In GIS proficiency, food geographers excel in spatial data analysis, precision agriculture techniques, and evidence-based decision-making to optimize soil fertility and manage agricultural resources efficiently (54, 55). Additionally, they demonstrate collaborative and participatory skills by engaging with GI stakeholders and managing collective reputations through effective coordination and community empowerment (51, 56). These integrated competencies enable food geographers to contribute to economically viable and environmentally sustainable food systems.

Table 3: Competencies of Food Geographers in GIs and GIS for Sustainable Food Production

Competence Area	Behavioral Focus	Literature Source
Knowledge of GIs as Intellectual Property	Understanding GIs as intellectual property, recognizing legal frameworks and agreements such as WTO-TRIPS and WIPO Lisbon agreement.	(51)
Ability to Assess Economic and Social Impacts	Evaluating the economic benefits of GIs, assessing market	(51, 53)

	access, value distribution, and potential social inequalities.	
Integration with Sustainable Development Goals (SDGs)	Linking GIs to SDGs by promoting good practices in Codes of Specifications (CoS) and aligning with public goods and sustainability indicators.	(18, 51)
Spatial Data Analysis	Using GIS to collect, store, analyze, and visualize spatial data for soil management, crop yield estimation, and monitoring patterns.	(18)
Precision Agriculture Techniques	Implementing precision agriculture techniques using GIS to optimize soil fertility and manage resources sustainably.	(55)
Evidence-Based Decision Making	Applying GIS for informed decision-making, providing relevant information for farm management and sustainability practices.	(54, 55)
Engagement with Stakeholders	Facilitating participatory processes with GI producers, associations, and stakeholders to empower communities and support sustainable food systems.	(51, 56)
Management of Collective Reputation	Coordinating and managing the collective reputation of GIs to ensure value realization across the value chain and territory.	(56)

As shown in Table 4, Food geographers advocating for sustainable agricultural practices that reduce chemical usage and preserve soil health possess vital competencies in promoting environmental sustainability and agricultural productivity. These include a deep understanding of sustainable agricultural practices such as organic farming, integrated pest management, and crop rotation, which enhance soil health by promoting biodiversity and nutrient cycling (57, 58). They are skilled in soil health management, leveraging organic amendments and advanced technologies like precision farming and remote sensing to optimize resource use and improve soil conditions (16). Additionally, food geographers play a critical role in policy advocacy, engaging with policymakers to support sustainable practices and educating farmers and consumers about soil health benefits (57, 58). Their competencies also include fostering collaboration with researchers, practitioners, and agricultural communities, enhancing knowledge sharing, and creating effective, context-specific solutions for soil management (16, 58).

Table 4: Competencies of Food Geographers Advocating for Sustainable Agricultural Practices

Competence Area	Behavioral Focus	Literature Source
Understanding of Sustainable Agricultural Practices	Knowledge of sustainable practices such as organic farming, integrated pest management, and crop rotation	(57)

	to minimize chemical inputs and promote soil health.	
Soil Health Management	Understanding physical, chemical, and biological soil properties, using organic amendments like compost and green manures to enhance soil fertility.	(59)
Integration of Technology and Innovation	Utilizing precision farming, remote sensing, and AI technologies to monitor soil health and optimize agricultural resource use.	(16)
Policy Advocacy and Education	Engaging with policymakers to promote incentives for sustainable practices and educating farmers and consumers on environmental benefits.	(58)
Collaboration and Interdisciplinary Approach	Collaborating with researchers, practitioners, policymakers, and agricultural communities to develop effective soil health management strategies.	(16, 58)

As depicted in Table 5, food geographers play a critical role in fostering community-driven initiatives that support socio-economic growth and promote sustainable urban and rural systems. Their competencies include leveraging social economies through practices like bartering, gifting, and self-provisioning, which contribute to food security and community development by emphasizing cooperation over competition (60). They support community self-organization by facilitating grassroots innovation and social learning, helping initiatives adapt to local needs and societal challenges (61). Additionally, food geographers integrate local food policies with spatial planning to enhance food system resilience, employing methodologies such as Living Labs to develop governance strategies and reclaim abandoned land (62). They bridge urban-rural divides by promoting community-led initiatives and supporting alternative food networks that address food insecurity with ecological sustainability goals ("Towards a Post-Growth Food System", 2022 (63). Finally, food geographers contribute to sustainable local food systems by integrating environmental considerations into social economies, advancing equity within sustainability, and fostering collaborative governance approaches (64).

Table 5: Competencies of Food Geographers in Facilitating Community-Driven Initiatives

Competence Area	Behavioral Focus	Literature Source
Understanding and Leveraging Social Economies	Recognizing the value of bartering, gifting, and self-provisioning in social economies to support food security and community development.	(60)
Fostering Community Self-Organization	Supporting grassroots innovation, promoting social learning, and aiding communities in navigating	(61)

	limited resources and power dynamics.	
Integrating Local Food Policies and Spatial Planning	Developing synergies between rural and urban areas through local food policies, spatial planning, and governance experimentation.	(62)
Bridging Urban-Rural Divides	Facilitating community-led initiatives to shift power relations, enhance food sovereignty, and promote ecological sustainability.	(63)
Promoting Sustainable Food Systems	Bridging sustainability and social economy to advance equity, support collaborative governance, and strengthen rural livelihoods.	(63)

Table 6 shows that food geographers contribute significantly to achieving the Sustainable Development Goals (SDGs) by mapping workforce contributions to sustainability initiatives and conducting workshops to build capacity among food professionals. Their key competencies (Table 5) include a deep interdisciplinary knowledge of food systems' environmental, social, and economic dimensions, enabling them to tackle challenges related to food security, sustainability, and public health (65, 66). They possess strong mapping and analytical skills to identify prioritized SDGs and align food-related activities with global sustainability goals (38). Food geographers also excel in facilitation and communication, using workshops and training programs to enhance awareness and engagement in sustainable practices (38, 67). Innovative strategies such as blended learning and international exchange programs, like the Geography of Food Summer School, are employed to foster intercultural understanding and support the development of sustainable food value chains (17). Ultimately, their focus on capacity building and competence development ensures the advancement of food system transformation through tailored professional development and transdisciplinary research practices (65).

Table 6: Competencies of Food Geographers in Mapping Workforce Contributions to SDGs

Competence Area	Behavioral Focus	Literature Source
Interdisciplinary Knowledge	Understanding environmental, social, and economic dimensions of food systems to address challenges related to SDGs such as food security and sustainability.	(65, 66)
Mapping and Analytical Skills	Mapping workforce contributions to SDGs, analyzing prioritized goals, and evaluating alignment of activities with SDGs.	(38)
Facilitation and Communication	Facilitating workshops to enhance participants' understanding of SDGs and boosting confidence in aligning work with global goals.	(38, 67)

Workshops and Training Programs	Designing and conducting workshops that focus on food systems' relevance to SDGs through expert-led seminars and interactive sessions.	(38, 68)
Blended Learning and International Exchange	Utilizing blended learning and international exchanges to enhance intercultural understanding and problem-solving for sustainable food chains.	(17)
Capacity Building and Competence Development	Emphasizing capacity building and competence development through tailored programs and promoting transdisciplinary research practices.	(65)

Synthesis and Mapping

The synthesis and mapping process involved extracting 5 clusters of the competencies, behavioral focuses, and literature sources and categorizing them under relevant competence areas. Common themes such as geospatial technology, sustainable agricultural practices, community-driven initiatives, and workforce contributions to SDGs were identified (Table 7). Similar competencies were synthesized into unified competence areas, and a structured framework was created by aligning competencies with their behavioral focuses and literature sources. During the mapping process, duplicates were identified and merged to maintain a concise and non-redundant compilation. Overlapping competencies, such as "Precision Agriculture Techniques" and "Integration of Technology and Innovation," were merged, and related competencies like "Engagement with Stakeholders" and "Facilitation and Communication" were combined for streamlined representation. Unique competencies were carefully retained, ensuring no critical information was lost.

Table 7: Competencies of Food Geographers and Literature Sources

	Competencies	Literature Sources
1.	Integration and Analysis of Geospatial Data	(46)
2.	Application of Remote Sensing and GIS	(47–49)
3.	Utilization of IoT and Real-Time Monitoring	(48)
4.	Decision-Making and Precision Agriculture	(54)
5.	Climate Change Adaptation and Resource Management	(50)
6.	Knowledge of GIs as Intellectual Property	(51, 52)
7.	Ability to Assess Economic and Social Impacts	(51, 53)
8.	Integration with Sustainable Development Goals (SDGs)	(18, 51)
9.	Spatial Data Analysis and Precision Agriculture Techniques	(54, 55)
10.	Engagement with Stakeholders and Management of Collective Reputation	(51, 56)
11.	Understanding of Sustainable Practices	(57, 58)
12.	Soil Health Management	(59)
13.	Integration of Technology and Policy Advocacy	(58)
14.	Collaboration and Interdisciplinary Approach	(16)
15.	Understanding Social Economies and Fostering Self-Organization	(60, 61)

16.	Integrating Local Food Policies and Bridging Urban-Rural Divides	(62, 63)
17.	Promoting Sustainable Food Systems	(64)
18.	Interdisciplinary Knowledge and Analytical Skills	(38, 65, 66)
19.	Facilitation, Training, and Capacity Building	(17, 38, 68)

Conceptualization of a Research Model to Evaluate the Impact of Food Geography Education on Students' Food Geography Competencies and Food Geography Food Sustainability Intention

The research model is developed to investigate the impact of geography education on fostering food geographers' or students' intention to engage in food sustainability actions, it is essential to consider the influence of psychological, social, and environmental factors. Food geography education enhances psychological factors by increasing knowledge and awareness of sustainable food systems (17), strengthening motivations and pro-environmental intentions (7), and boosting self-efficacy and sustainable identity formation (24, 31). Socially, educational programs promote community engagement and influence social norms (12). Support intercultural exchange to broaden perspectives (17). And empower communities to make informed food choices (51, 52). Environmentally, integrating sustainability into education raises awareness of the environmental impacts of food choices (25). Leverages experiential learning to embed sustainable practices (25). And emphasizes local and agroecological practices to reduce food miles (26).

As shown in Figure 2, the proposed research model is created to investigate the impact of geography education on fostering food geographers' or students' competencies for engaging in food sustainability actions, it is crucial to integrate cultural, environmental, and socio-economic dimensions into the learning process. Food geography education enhances competencies such as the integration and analysis of geospatial data (46). Application of remote sensing and GIS (47–49). And utilization of IoT and real-time monitoring (48). Additionally, it strengthens decision-making and precision agriculture skills (54). As well as promotes climate change adaptation and resource management (50). By emphasizing competencies like engagement with stakeholders (50, 45). Promoting sustainable practices (57, 58). And fostering interdisciplinary collaboration (16). Food geography education equips students to address contemporary challenges such as sustainability and cultural identity. These competencies enable students to contribute effectively to food sustainability actions, bridging theoretical knowledge with practical applications (17).

Overall, the model can investigate the impact of food geography education on fostering food geographers' or students' competencies and intention to engage in food sustainability actions, it is essential to consider the influence of psychological, social, and environmental factors alongside the development of specific competencies. Food geography education plays a pivotal role in integrating geographical perspectives with food studies, enabling learners to understand the complexities of food systems, including production, distribution, consumption, and sustainability (8). This educational approach enhances psychological factors by increasing knowledge and awareness of sustainable food systems (17). Strengthening pro-environmental motivations, and building self-efficacy and sustainable identity (7, 24, 31). Socially, it fosters community engagement, shapes social norms, and empowers communities to make informed choices (8, 12). Environmentally, it raises awareness of the impacts of food choices (25). Promotes experiential learning (25). And supports local agroecological practices (26). By equipping students with 19 critical competencies—ranging from geospatial data analysis to promoting sustainable food systems (46, 64). Thus, food geography education not only prepares individuals to meet the demands of the evolving job market but also empowers them to actively contribute to food sustainability actions through a well-rounded and multidisciplinary skill set (17).

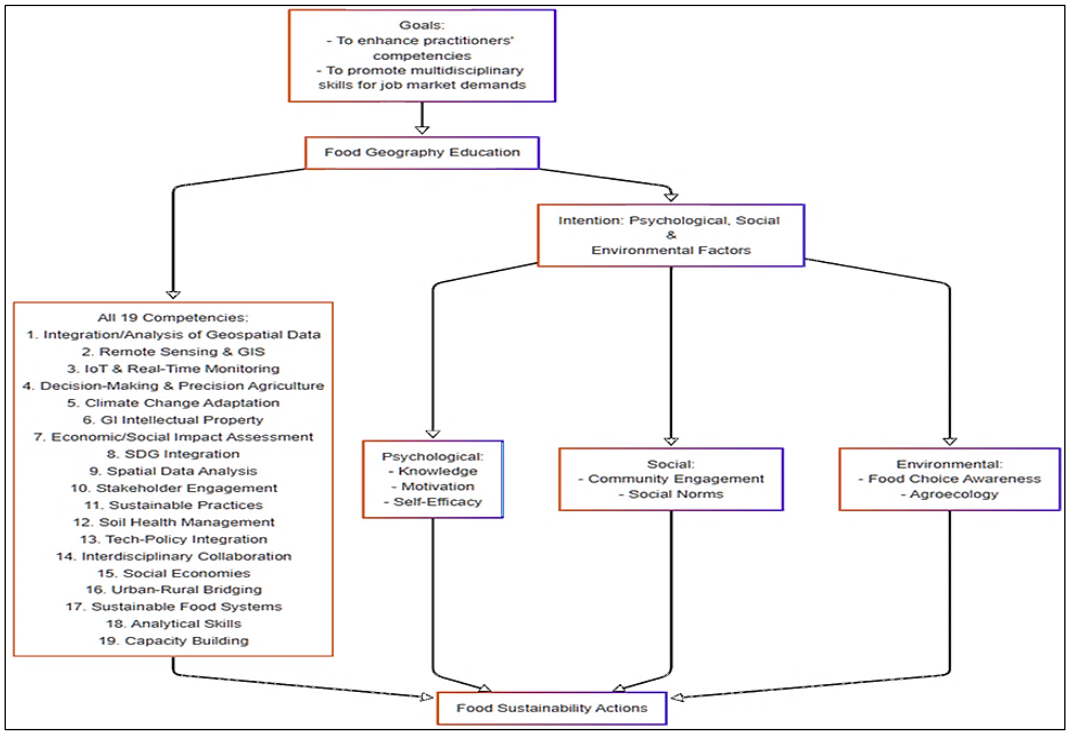

Figure 3: Conceptual Model of Food Geography Education Impact on Competency Development and Food Sustainability Actions

Discussion

This study conceptualizes a robust research model to investigate how food geography education fosters food geographer competencies and enhances food sustainability action intentions by integrating competency development frameworks with behavioral theories. The model is grounded in Boyatzis's competency model, which outlines the development of specific competencies through a process-oriented approach, and the Theory of Planned Behavior (35). This explains how educational interventions influence psychological, social, and environmental factors to drive sustainable behaviors (24, 31). By mapping educational strategies such as experiential learning, community-based projects, and intercultural exchanges to competency clusters including geospatial technology, sustainable agriculture advocacy, and community systems coordination, the model establishes clear linkages between learning outcomes and Sustainable Development Goals (SDGs) (17, 18). The conceptual framework not only evaluates the direct impact of education on competence development but also examines how enhanced competencies translate into sustainability action intentions through increased awareness, motivation, and self-efficacy (7). This holistic approach enables a multidimensional analysis of how food geography education contributes to systemic change in food systems, offering insights for curriculum development, policy formulation, and community engagement (25).

Food geographers play diverse and critical roles in achieving food sustainability goals by leveraging their unique competencies in various domains such as sustainability advocacy, geospatial analysis, and community coordination. As sustainability advocates, food geographers promote sustainable agricultural practices, integrating bio-economy methods that enhance food production while preserving biodiversity and reducing chemical use, which supports Sustainable Development Goal (SDG) 2 (Zero Hunger) and SDG 15 and 14 (Life on land and water) (36). In their role as geospatial analysts, they utilize advanced tools such as Geographic Information Systems (GIS) and remote sensing to map and monitor agricultural landscapes, contributing to biodiversity conservation and climate action, aligning with SDG 13 (Climate Action) and SDG 15 and 14 (Life on land and water) (37). Additionally, as community coordinators, food geographers engage local communities in socio-economic development initiatives, fostering sustainable urban and rural systems and promoting equity and

inclusion, which directly impacts SDG 10 (Reduced Inequalities) and SDG 11 (Sustainable Cities and Communities) (39). Through these multifaceted roles, food geographers not only address complex food system challenges but also facilitate the integration of local knowledge with scientific insights, thereby creating resilient food systems that align with global sustainability objectives (38). The study's findings reinforce the importance of food geography education in equipping future professionals with these competencies, enabling them to contribute effectively to systemic change in food systems through evidence-based practices and community-driven approaches.

The development of the new 19 competencies in food geography education is crucial for equipping learners with the necessary skills to address complex challenges related to food systems and sustainability. These competencies, categorized into five clusters—Geospatial Technology and Monitoring, Geographical Indications, Sustainable Agriculture, Community Coordination, and Workforce Capacity Building—provide a comprehensive skill set that aligns with evolving industry demands and Sustainable Development Goals (SDGs) (18, 36). By fostering expertise in areas such as geospatial data analysis, sustainable agriculture advocacy, and community systems coordination, food geography education prepares students for diverse roles, including agricultural geospatial analysts, community coordinators, and sustainable food education coordinators (38, 39). These competencies enable food geographers to integrate technological innovations, promote environmentally sustainable practices, and empower communities through education and policy advocacy. Importantly, aligning these competencies with SDG targets enhances the role of food geographers in contributing to global food security, responsible consumption, and biodiversity conservation (17, 25). As the field of food geography continues to evolve, the adoption of a competency-based approach ensures that educational programs remain relevant and impactful, ultimately driving systemic change towards sustainable food systems.

Food geography education significantly influences the intentions to engage in food sustainability by addressing key psychological, social, and environmental factors that drive sustainable behaviors. The integration of experiential learning, community-based projects, and intercultural exchanges within educational programs fosters knowledge, motivation, and self-efficacy, which are critical psychological drivers of sustainability intentions (7, 17). By enhancing awareness of sustainable food systems, educational initiatives such as the Geography of Food Summer School and Think&EatGreen@School promote pro-environmental motivations and support the development of a sustainability-oriented identity (11, 12). Socially, community learning and participatory activities strengthen social norms around sustainable practices and empower students to influence their communities positively (25). Additionally, education that incorporates the planetary health framework and agroecological practices raises environmental awareness, embedding sustainable practices into everyday experiences (25, 26). The use of theoretical models, including Boyatzis's competency model and the Theory of Planned Behavior, provides a structured approach to understanding how educational interventions can shift attitudes and perceived behavioral control, effectively translating sustainability awareness into actionable intentions (24, 31). Ultimately, food geography education not only builds competencies but also creates a strong foundation for sustained engagement in food sustainability actions.

The study's findings are well-supported by the theoretical framework, which integrates (30) competency model and the Theory of Planned Behavior (35) to explain how food geography education influences food geographer competencies and food sustainability action intentions. Boyatzis's model emphasizes that individual characteristics, including knowledge, skills, and attitudes, drive superior performance in specific roles, aligning with the study's identification of key competencies such as geospatial technology application, community engagement, and sustainable agriculture advocacy (18, 36). The Theory of Planned Behavior further elucidates how educational interventions enhance psychological, social, and environmental factors, thereby translating knowledge and competencies into sustainable behaviors (7, 17). Conceptually, the research model demonstrates how food geography education as a multidimensional intervention not only fosters competence development but also strengthens pro-

environmental motivations, self-efficacy, and social norms that support sustainability intentions (24, 31). By bridging theoretical insights with practical educational strategies, this study highlights the critical role of a structured competency framework and behavioral theories in achieving sustainable food systems through education (25).

The conceptualization of a research model to investigate the impact of food geography education on student competencies for food sustainability actions and sustainability action intentions has significant implications for both academic research and practical applications. The model provides a structured framework that links educational interventions with the development of specific competencies, including geospatial technology, sustainable agriculture advocacy, and community systems coordination, which are crucial for addressing complex food system challenges. By aligning the research model with Boyatzis's competency model and the Theory of Planned Behavior, the study not only evaluates how educational programs enhance competencies but also examines how these competencies influence students' intentions to engage in sustainable food actions. This approach offers educators, curriculum developers, and policymakers a valuable tool for assessing the effectiveness of educational strategies in promoting sustainable practices. Additionally, the conceptual model facilitates future empirical studies by providing clear metrics for evaluating both competence development and behavioral intentions, supporting the design of longitudinal studies to measure long-term impacts on professional readiness and systemic change in global food systems. This model emphasizes the need for a holistic approach that integrates education, policy, and community engagement, contributing to achieving Sustainable Development Goals (SDGs) through well-informed and competent food geographers.

Lastly, the implementation of this model within educational institutions can occur through multiple entry points. At the national level, curriculum designers can integrate food geography as a cross-disciplinary theme within sustainability, science, or citizenship education, aligning with SDGs and sustainability competencies. In teacher education programs, this model can serve as a framework for training educators in experiential, place-based, and competency-based pedagogies that promote systems thinking and food sustainability. NGOs and community organizations may adopt this model in youth programs or community education initiatives, using participatory activities like food mapping, community gardening, or food waste audits to build food literacy and sustainability action competencies. By engaging these various actors—policy makers, teacher educators, and community leaders—food geography education can be scaled and contextualized, enhancing its relevance and impact across diverse educational and social contexts.

Conclusion

This study highlights the critical role of food geography education in developing competencies and enhancing food sustainability action intentions, contributing significantly to achieving Sustainable Development Goals (SDGs). By integrating Boyatzis's competency model and the Theory of Planned Behavior, the study offers a structured approach to understanding how educational interventions influence psychological, social, and environmental factors that drive sustainable behaviors. The identification of 19 critical competencies, categorized into Geospatial Technology and Monitoring, Sustainable Agriculture, and Community Coordination, underscores the diverse roles of food geographers in addressing complex food system challenges. The study successfully conceptualizes a research model to investigate the impact of food geography education on student competencies for food sustainability actions and sustainability action intentions, offering a structured approach for future empirical studies.

Although this study presents a theoretical conceptualization, the model is explicitly designed for future empirical validation. It serves as a structured foundation for designing longitudinal and intervention-based studies that can assess the effectiveness of food geography education programs in developing student competencies and motivating sustainable food actions. Thus, future research should apply this model using mixed methods, such as pre- and post-intervention assessments, case studies, or structural equation modeling, to empirically examine the pathways

between educational interventions, competency development, and sustainability intentions. This empirical application will not only test the model's validity but also provide data-driven insights for refining curricula and policymaking in sustainability education.

To evaluate the proposed model, mixed-method approaches can be employed. Quantitative techniques such as pre- and post-intervention surveys using validated instruments (e.g., sustainability competency self-assessments, food literacy scales, and behavioral intention questionnaires based on the Theory of Planned Behavior) can measure changes in knowledge, attitudes, and behaviors. Structural Equation Modeling (SEM) can be used to test the relationships between educational inputs, competencies, and behavioral outcomes. Additionally, qualitative methods such as reflective journals, interviews, and classroom observations can provide insights into learners' transformative experiences and contextual factors influencing behavioral change. Combining these methods ensures a comprehensive evaluation of both competency development and the psychosocial processes that lead to sustainability action.

To enhance the impact of food geography education, students should actively participate in experiential learning opportunities, including field trips, community projects, and international exchanges, to build practical skills and gain a comprehensive understanding of food systems, prioritizing the development of core competencies in geospatial technology, sustainable agriculture, and community engagement to enhance professional readiness and contribute to sustainability goals. Teachers are encouraged to implement innovative teaching strategies that blend theoretical frameworks with real-world experiences, utilizing e-learning, case studies, and participatory methods to foster critical thinking, problem-solving skills, and support diverse learning needs, emphasizing competency-based education for multidisciplinary roles in food geography. Policy makers should develop policies that support competency development in education, ensuring adequate resources, infrastructure, and opportunities for practical learning, while promoting collaboration among educational institutions, industry stakeholders, and communities to create supportive environments for sustainable food practices. Future research should focus on longitudinal studies to assess the long-term impacts of food geography education on professional readiness and sustainability actions, contributing to systemic change in global food systems and enhancing food security, responsible consumption, and biodiversity conservation.

Abbreviation

None.

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Conflict of Interest

The authors declare no conflict of interest.

Ethics Approval

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