

Facing Economic Gap: Assessing the Multidimensional Sustainability Awareness of Pre-Service Science Teachers¹

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Abstract

This study aims to determine the levels of awareness among pre-service science teachers regarding sustainable development. This exploratory study employed a descriptive survey model, with a total of 41 volunteer pre-service teachers in their fourth year of the Science Teaching program at a state university in the Black Sea Region of Türkiye forming the study group. The "Sustainable Development Awareness Scale," a 37-item 5-point Likert-type scale developed by Atmaca et al. (2019), was used as the data collection tool. In the study, the responses of the pre-service teachers to the scale items were analyzed in terms of percentage (%) and frequency (f), and descriptive statistics were used to determine their awareness levels regarding sustainable development. The study's results revealed that pre-service science teachers scored above the average on both the overall scale and its factors. Additionally, it was found that the pre-service teachers' highest average scores were in the "society" factor, while their lowest scores were in the "economy" factor.

Keywords: Sustainable development, awareness, pre-service science teachers, economic sustainability, environmental sustainability, social sustainability.

Introduction

The Industrial Revolution led to large-scale global developments, and the increasing population, combined with implemented economic policies and technological advancements, resulted in increased production, which in turn accelerated the depletion of natural resources. The disruption of the balance between

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production and consumption, along with the development of consumption mechanisms that threaten the equilibrium of nature to meet needs, has led to economic, technological, and social changes with negative environmental impacts (Njoku, 2016).

The transformation of environmental problems into a global issue has made sustainability and sustainable development highly debated topics in recent years. The concept of sustainable development was first introduced in the 1987 Brundtland Report by the United Nations (UN), defined as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). In other words, sustainable development can be described as balancing the protection of future generations' interests with the satisfaction of current human needs (Collin, 2004).

Sustainable development stands as one of the most crucial issues on today's global agenda, having been institutionalized through the Sustainable Development Goals (SDGs) established by the United Nations 2030 Agenda (UN, 2015). Education, particularly SDG 4 (Quality Education), is recognized as both a vehicle and a fundamental component of sustainable development (UNESCO, 2016). By equipping individuals with the knowledge, skills, and values needed for a sustainable future, education contributes to achieving other SDGs (poverty eradication, climate action, gender equality, etc.) (Tilbury, 2011). Furthermore, the Education for Sustainable Development (ESD) approach aims to build more equitable and resilient societies by encouraging individuals to address environmental, social, and economic dimensions holistically (UNESCO, 2017).

Education constitutes the most critical element in forming societies with high sustainability awareness and commitment (McKeown et al., 2002). Education for Sustainable Development enhances the knowledge, values, and skills necessary for individual and collective participation in decision-making processes that improve the quality of life without compromising the future of future generations (Summers et al., 2000). Consequently, positioning education policies at the core and supporting them through lifelong learning perspectives plays a pivotal role in achieving the SDGs.

In light of the increasing importance of sustainability today, determining the knowledge, perceptions, and awareness of both in-service and pre-service teachers—who play a critical role in building societies that adopt sustainable lifestyles—is of paramount significance. A review of the literature on Sustainable Development reveals numerous studies involving teachers and pre-service teachers, including research examining whether high school teachers' perceptions of sustainable development vary according to their subject areas and professional experience (Borg et al., 2014), investigations into pre-service teachers' self-perceived competencies in Education for Sustainable Development (Cebrián & Junyent, 2015), and studies exploring teachers' views on the competencies required for Education for Sustainable Development (Şeker & Aydın, 2021). Further research includes analyses of primary pre-service teachers' competency perceptions (Soysal, 2016), assessments of practising primary teachers' perspectives (Uğraş & Zengin, 2019), and multifaceted studies on the environmental attitudes, behaviours, and sustainable development awareness of pre-service science teachers (Koçulu, 2018). Additionally, studies have investigated pre-service biology teachers' understanding of sustainability and Education for Sustainable Development (Bezeliak et al., 2020), assessed science teachers' (Dal & Okur-Akçay, 2021) and pre-service science teachers' (Atmaca, 2018; Torun, 2024) awareness of sustainable

development, examined pre-service teachers' sustainable development awareness levels and lifelong learning tendencies (Eröz et al., 2023), and explored pre-service social studies teachers' views on sustainable development (Değirmenci & Gül, 2024).

Considering the influence of teachers on society, their role as models for future generations, and their active role in shaping the present and future world, determining future teachers' awareness of sustainable development is vital. Therefore, this study aims to determine the levels of awareness among pre-service science teachers regarding sustainable development.

Method

Research Model and Design

The study employs a quantitative research method. Quantitative research is a methodological approach that relies on statistical data, working with populations and samples, and utilizes probabilistic sampling techniques (Garip, 2023). The research was conducted using a descriptive survey model. Survey models are research designs that aim to describe a past or existing phenomenon or situation as it currently exists (Karasar, 2011).

Study Group

The study group consisted of a total of 41 volunteer pre-service teachers (n = 34 female, n = 7 male) in their fourth year of the Science Teaching program at a state university located in the Black Sea Region of Türkiye.

Data Collection Tools

The "Sustainable Development Awareness Scale," developed by Atmaca et al. (2019), was used. The scale is a 5-point Likert-type instrument comprising three sub-dimensions: "economy" (13 items), "society" (9 items), and "environment" (14 items), along with one control item, totalling 37 items. The minimum score on the scale is 36, and the maximum is 180. The Cronbach's Alpha reliability coefficient for the overall scale was calculated to be 0.91 (Atmaca et al., 2019). In this study, the Cronbach's Alpha reliability coefficient for the overall scale was calculated to be 0.93.

Data Analysis

In the research, the responses given by the pre-service teachers to the scale items were analyzed in terms of percentages and frequencies. Descriptive statistics were used to determine pre-service teachers' levels of awareness regarding sustainable development.

Results

The frequency and percentage distributions of pre-service teachers' responses to the "economy" factor of the Sustainable Development Awareness Scale are presented in Table 1.

When Table 1 is examined, it is determined that more than half of the pre-service science teachers strongly agree that current economic resources should be used efficiently with consideration for future generations (73.2%), that borrowing for development should be done by considering economic balances (51.2%), that economic policies should be designed to reduce poverty and income disparities (56.1%), that economic development should be planned in a way that prevents unemployment (61.0%), that economic policies should be shaped according to sustainable production (61.0%), that economic policies should be formulated in a way that does not destroy

natural resources (68.3%), that environments ensuring the safety of life and property should be created for economic investments (51.2%), and that research and development (R&D) activities should be supported (58.5%). Additionally, it is observed that the majority of the pre-service teachers agree that the production of advanced technology products (48.8%) and investments in the agriculture and livestock sectors (46.3%) are necessary for economic development. On the other hand, nearly half of the pre-service teachers are undecided about prioritizing non-production sectors for economic development (48.8%). The pre-service teachers expressed disagreement with individuals making purchases based solely on their desires and wishes without considering their needs, and with prioritizing practices that yield high profits in the short term in livestock, agricultural, and industrial production.

Table 1.

Frequency and Percentage Distributions of Responses to the "Economy" Factor

	Items	Strongly Agree		Agree		Undecided		Disagree		Strongly Disagree	
		f	%	f	%	f	%	f	%	f	%
Economy	Individuals should shop toward their desires and wishes, without regard for their needs.	2	4.9	9	22.0	8	19.5	12	29.3	10	24.4
	We must use current economic resources with conservation, thinking about future generations.	30	73.2	10	24.4	0	0	1	2.4	0	0
	Debt to be made for development should be made considering economic balances.	21	51.2	17	41.5	2	4.9	1	2.4	0	0
	Economic policies should reduce poverty and income inequality.	23	56.1	17	41.5	0	0	1	2.4	0	0
	Economic development should be planned to prevent unemployment.	25	61.0	16	39.0	0	0	0	0	0	0
	Economic policies should be shaped by sustainable production.	25	61.0	13	31.7	3	7.3	0	0	0	0
	Economic policies should be shaped so as not to destroy natural resources.	28	68.3	13	31.7	0	0	0	0	0	0
	Livestock, agricultural and industrial production should be focused on applications that will generate high profits in the short term (use of GMO products, hormonal animals etc.).	3	7.3	1	2.4	11	26.8	17	41.5	9	22.0

For economic investments, environments that ensure the safety of life and property must be established.	21	51.2	20	48.8	0	0	0	0	0	0
For economic development, non-production sectors should be emphasised.	3	7.3	5	12.2	20	48.8	10	24.4	3	7.3
The production of high-tech products for economic development should be supported.	18	43.9	20	48.8	3	7.3	0	0	0	0
Investments in agriculture and livestock should be supported to promote economic development.	18	43.9	19	46.3	4	9.8	0	0	0	0
Research and development (R&D) studies for economic development should be supported.	24	58.5	16	39.0	1	2.4	0	0	0	0

The frequency and percentage distributions of the responses given by the pre-service teachers to the "society" factor of the Sustainable Development Awareness Scale are presented in Table 2.

Table 2.

Frequency and Percentage Distributions of Responses to the "Society" Factor

	Items	Strongly Agree		Agree		Undecided		Disagree		Strongly Disagree	
		f	%	f	%	f	%	f	%	f	%
Society	Equal opportunities should be offered to individuals in society (women/men, rich/poor, people of different races and religions, etc.).	30	73.2	11	26.8	0	0	0	0	0	0
	For all individuals in society, environments should be created to enable individuals to learn lifelong.	24	58.5	17	41.5	0	0	0	0	0	0
	Individuals should be provided with integrating and enhancing social services (such as nurseries, shelter homes, social assistance foundations etc.).	21	51.2	20	48.8	0	0	0	0	0	0

Access to education and health services should be provided to all individuals in society.	24	58.5	17	41.5	0	0	0	0	0	0
Individuals should be provided with environments that make them feel safe while living.	25	61.0	16	39.0	0	0	0	0	0	0
The interaction of cultures in society should be supported and developed.	23	56.1	18	43.9	0	0	0	0	0	0
The society must take responsibility to keep the well-being of individuals and families above the minimum.	21	51.2	14	34.1	6	14.6	0	0	0	0
Urbanization (city, town, etc.) should be to protect the soul and body health of the society.	24	58.5	17	41.5	0	0	0	0	0	0
The work of governmental and non-governmental organizations involved in activities for the sustainable environment should be supported.	22	53.7	17	41.5	2	4.9	0	0	0	0

When Table 2 is examined, it was determined that pre-service teachers strongly agreed that individuals in society should be provided with equal opportunities (73.2%), environments should be created to facilitate lifelong learning (58.5%), integrative and developmental social services should be offered to individuals to help them integrate with and contribute to society (51.2%), all individuals should have access to education and healthcare services (58.5%), a safe environment should be established where they feel secure in their living areas (61.0%), the interaction and development of different cultures within society should be supported and enhanced (56.1%), society should take responsibility to ensure the welfare of individuals and families is maintained above minimum standards (51.2%), urbanization should occur in a way that protects the mental and physical health of the community (58.5%), and the activities of official and non-governmental organizations working for sustainable environmental practices should be supported (53.7%).

The frequency and percentage distributions of pre-service teachers' responses to the "environment" factor of the Sustainable Development Awareness Scale are presented in Table 3.

Table 3.*Frequency and Percentage Distributions of Responses to the "Environment" Factor*

	Items	Strongly Agree		Agree		Undecided		Disagree		Strongly Disagree	
		f	%	f	%	f	%	f	%	f	%
Environment	Any intervention that damages natural life (wrong use of pesticide, prohibited hunting, etc.) must be punished for the continuation of biological diversity.	24	58.5	12	29.3	5	12.2	0	0	0	0
	The use of public transportation at short distances does not help to maintain atmospheric equilibrium.	11	26.8	7	17.1	4	9.8	11	26.8	8	19.5
	I think that vehicles with the least impact on the degradation of the ecological balance should be preferred when buying one.	21	51.2	16	39.0	4	9.8	0	0	0	0
	Energy-saving products should be preferred in order to use energy sources for a longer time.	26	63.4	15	36.6	0	0	0	0	0	0
	The use of renewable energy sources needs to be widespread to leave a livable world.	27	65.9	14	34.1	0	0	0	0	0	0
	Every individual has responsibility to protect existing resources (water, air, soil, etc.) for future generations to survive ecological problems.	25	61.0	16	39.0	0	0	0	0	0	0
	Industrial establishments should take precautions to protect environmental health and prevent	26	63.4	15	36.6	0	0	0	0	0	0

pollution of natural resources.											
Green areas can be dispensed with for urbanization and industrialization.	1	2.4	5	12.2	3	7.3	8	19.5	24	58.5	
In order to leave a greener world for future generations, responsibility for afforestation and the protection of the trees is the responsibility of each individual.	23	56.1	18	43.9	0	0	0	0	0	0	
I think that each individual has responsibilities in the process of recycling waste so that the raw material resources can be used by future generations.	25	61.0	14	34.1	2	4.9	0	0	0	0	
Wastes should be separated according to their characteristics and reused, so that raw material sources can be used by future generations.	25	61.0	15	36.6	1	2.4	0	0	0	0	
I think that nothing can be done individually to prevent global climate change.	1	2.4	5	12.2	2	4.9	12	29.3	21	51.2	
I think global warming poses a serious threat to the future of our world if cautions are not taken.	25	61.0	16	39.0	0	0	0	0	0	0	
I think that ecological footprint should be minimized for the continuation of the world's livability.	21	51.2	13	31.7	3	7.3	2	4.9	2	4.9	

When Table 3 is examined, it is determined that the majority of pre-service teachers strongly agree that any intervention harming natural life for the continuation of biodiversity should be penalized (58.5%), that vehicles with the least impact on ecological balance should be preferred when purchasing a vehicle (51.2%), and that

energy-saving products should be chosen to enable the more extended use of energy resources (63.4%). Additionally, they agree that the use of renewable energy sources should be expanded to leave a habitable world for future generations (65.9%), that every individual has responsibilities in preserving current resources to prevent future generations from facing ecological problems (61.0%), and that every individual has a role in afforestation efforts and the protection of trees to leave a greener world for future generations (56.1%). They also agree that every individual has responsibilities in the recycling process to ensure that raw material resources can be used by future generations (61.0%) and that industrial establishments should take measures to protect environmental health and prevent the pollution of natural resources (63.4%) and they further emphasized that waste should be separated and evaluated according to its characteristics to ensure that raw material resources can be used by future generations (61.0%). Furthermore, they agree that global warming poses a serious threat to the future of our planet if no action is taken (61.0%) and that our ecological footprint must be reduced to maintain the Earth's habitability (51.2%). On the other hand, more than half of the pre-service teachers strongly disagree that green areas can be sacrificed for urbanisation and industrialisation (58.5%) and that nothing can be done individually to prevent global climate change (51.2%). Additionally, a significant proportion of the pre-service teachers agree that using public transportation for short distances does not contribute to maintaining atmospheric balance.

In the study, to reveal the sustainable development awareness levels of pre-service teachers, scores from the overall scale and all factors were calculated. Descriptive statistical results regarding the sustainable development awareness levels of pre-service teachers are presented in Table 4.

Table 4.

Descriptive Statistical Results Regarding Pre-Service Teachers' Sustainable Development Awareness Levels

	Scale Factors	Number of Items	X	Mode	Median	Range	SD	Min	Max	Possible Min-Max Scores
Factor name	Economy	13	55.48	60.00	55.00	26.00	5.33	38.00	64.00	13-65
	Society	9	41.02	45.00	41.00	9.00	3.93	35.00	45.00	9-45
	Environment	14	61.21	55.00	63.00	7.00	6.40	50.00	70.00	14-70
Sustainable Development Awareness Scale		36	157.73	173.00	159.00	53.00	14.50	124.00	177.00	36-180

When examining Table 4, it is observed that the pre-service teachers scored a maximum of 177.00 and a minimum of 124.00 on the Sustainable Development Awareness Scale, with an arithmetic mean of 157.73. The standard deviation of the obtained scores was determined to be 14.50. When the scores from the sub-dimensions of the scale are examined, it was found that in the "economic sustainability" sub-

dimension, the scores ranged from a minimum of 38.00 to a maximum of 64.00, with an arithmetic mean of 55.48; in the "social sustainability" sub-dimension, the scores ranged from a minimum of 35.00 to a maximum of 45.00, with an arithmetic mean of 41.02. In the "environmental sustainability" sub-dimension, the scores ranged from a minimum of 50.00 to a maximum of 70.00, with an arithmetic mean of 61.21. Additionally, it was determined that the pre-service teachers' average scores for the factors of the Sustainable Development Awareness Scale were highest in the "social sustainability" factor and lowest in the "economic sustainability" factor.

Discussion and Conclusions

The findings obtained from the small sample in this study suggest a potential imbalance in the awareness structure of pre-service teachers, indicating that this issue warrants further investigation with larger and more representative samples. Therefore, the results of this study are considered important not as a reflection of a generalizable fact, but as a valuable hypothesis for future research.

The research results indicate that pre-service teachers scored above the average on both the overall scale and the factors of the Sustainable Development Awareness Scale. The arithmetic mean of the pre-service teachers' scores on the Sustainable Development Awareness Scale was 157.73, indicating a high level of awareness. When studies conducted with pre-service teachers in the literature are examined, similar results have been found (Demirbaş, 2015; Koçulu, 2018; Eröz et al., 2023; Torun, 2024). Similarly, Dal and Okur-Akçay (2021) concluded that science teachers generally have a high level of awareness of sustainable development. Longitudinal data from Germany (Waltner et al., 2020) and systematic reviews from Spain (Pegalajar-Palomino et al., 2021) document a significant rise in pro-sustainability commitment among education students over the last decade. Furthermore, branch-specific studies (Khalid-Malik et al., 2023) corroborate that pre-service science teachers often exhibit higher motivation than those in other disciplines, identifying themselves as primary actors in environmental transformation.

The research results also show that the arithmetic means of the pre-service teachers' scores on the scale's factors are high. However, it was determined that the pre-service teachers achieved their highest average scores in the "society" factor, while their lowest average scores were in the "economy" factor. However, the 'cognitive imbalance' identified in the 'economy' factor reflects a chronic gap in global ESD literature. International analyses (Berglund et al., 2020; Munkebye et al., 2020) have identified economic justice and sustainable production as the least understood pillars across various cultures, from Iceland to Taiwan. This 'economic literacy gap' is further emphasized in the most recent 2025 frameworks (Özdemir-Yılmaz, 2025), highlighting that sustainability remains a fragmented concept without the integration of economic complexities. The study reveals that while pre-service science teachers demonstrate high levels of awareness regarding sustainable development, their relatively lower performance in the economic sustainability dimension is particularly noteworthy. This finding suggests that teacher education programs may not sufficiently emphasize the economic dimension of sustainable development. The comparatively lower scores in economic sustainability indicate that pre-service teachers have not fully internalized this particular aspect of sustainable development. These results strongly underscore the need for a greater emphasis on economic sustainability components in teacher education curricula. Curriculum revision should not only add new courses but

also enrich the content of existing courses with an economic sustainability perspective, ensuring a balanced approach between the three pillars of sustainability: environment, society, and economy.

The lack of depth in economic sustainability awareness identified in this study is consistent with Peretz's (2025) critique, who observes that curricula often treat natural and social/economic domains as separate entities, thereby obscuring the coupled dynamics of real-world problems. Integrating systems thinking is proposed as a vital solution to this fragmentation, as it enables learners to perceive relationships and feedback loops across ecological, technological, and economic dimensions. Moreover, developing 'systems thinking' competencies is essential for pre-service teachers to manage the interrelated components of sustainability. As teachers often struggle to think holistically across monodisciplinary boundaries, teacher education must provide specific methodologies and tools to facilitate this complex cognitive process and help candidates move from a surface understanding to in-depth pedagogical practice (Munkebye et al., 2020). By fostering the ability to bridge scientific and social perspectives, educators can help candidates recognise how economic drivers directly influence environmental states.

A balanced approach to the three pillars of sustainable development—environmental, social, and economic—is crucial for fostering a comprehensive perspective among pre-service teachers (UNESCO, 2017). These findings strongly support the need to revise teacher education curricula to better incorporate the principles of sustainable development. Such revision will not be possible without enriching the content of existing courses with an economic sustainability perspective.

Education is not merely a tool but a cornerstone of societal transformation in achieving sustainable development goals. Education 2030, published by UNESCO (2016), emphasises that quality education (Sustainable Development Goal 4) plays a pivotal role in attaining all other Sustainable Development Goals (SDGs). By enhancing environmental awareness, education contributes to climate action (SDG 13) while fostering social justice (SDG 10) and gender equality (SDG 5), thus helping to build a more inclusive society (UN, 2015). However, this transformation necessitates restructuring teacher training through a sustainability lens. Curricula should be restructured to incorporate interdisciplinary courses and project-based learning approaches that foster systems thinking. A holistic educational approach should be adopted, ensuring that pre-service science teachers can analyse environmental issues while also recognising their economic triggers and social consequences. As McKeown and Hopkins (2003) emphasised, equipping teachers with competencies in sustainability directly affects the quality of knowledge and skills transmitted to students. This requires teachers not only to know the Sustainable Development Goals but also to be equipped with pedagogical skills that allow them to transmit this knowledge through systems thinking and real-world applications.

The change should not be limited to future teachers alone. Continuous, effective professional development programs should be designed and implemented to enhance current teachers' knowledge and awareness. These programs should cover new approaches to sustainability and effective teaching methods. However, these trainings should not be limited to knowledge transfer; they should also equip teachers with 21st-century skills such as systemic analysis, critical thinking, collaboration, and problem-solving. These skills are essential for teachers to teach sustainability-related topics effectively to their students.

Curriculum design must be systematically aligned with the Sustainable Development Goals (SDGs). Tilbury's (1995) seminal work demonstrates that integrating environmental education into curricula significantly increases students' conservation awareness and promotes sustainable lifestyle practices. To achieve meaningful progress, a three-pronged approach is essential: (1) governments and education policymakers must realign school curricula with SDG targets, (2) comprehensive sustainability training programs for teachers should be implemented, and (3) sustainable practices in schools must be actively encouraged. Sustainability should no longer be the subject of specific courses, but rather a principle that permeates every stage of the education system. This requires not only the content but also the pedagogy to be shaped in alignment with the Sustainable Development Goals. This transformation requires the synergistic development of teacher education programs, curriculum reforms, and school-based sustainability initiatives. Only through such integrated efforts can we empower future generations to create a truly sustainable world.

The ultimate message of this research is that awareness alone is not sufficient. The primary goal is to transform this awareness into pedagogical skills that equip students with 21st-century competencies, such as critical thinking, problem-solving, collaboration, and systemic analysis. High awareness does not automatically translate into effective teaching practice. UNESCO's (2017) "Education for Sustainable Development Goals: Learning Objectives" document emphasises that not only knowledge, but also socio-emotional and behavioural learning areas, must be emphasised. Therefore, curriculum reform should address not only "what" will be taught (content) but also "how" it will be taught (pedagogy). Training teachers who can educate for sustainability should be our ultimate goal. This is the most important conclusion the research indirectly points to, but policymakers must clearly focus on it. The disparity between high awareness and instructional readiness constitutes a significant 'knowledge-action gap.' To bridge the identified 'knowledge-action gap,' curriculum reform should move beyond mere knowledge acquisition (ESD1) and emphasise learning processes that foster critical thinking and argumentation (ESD2). Munkebye et al. (2020) highlight that many school projects fail to challenge students cognitively, often omitting the potential of subjects such as ethics, philosophy, and language to foster reflection and critical evaluation of complex sustainability issues. Empirical evidence from the UAE (Al-Naqbi & Alshannag, 2018) and Pakistan (Jamil et al., 2024) suggests that theoretical knowledge does not automatically translate into classroom practice. Bridging this gap requires Professional Action Competence (PACesd), which synthesizes willingness, self-efficacy, and pedagogical content knowledge (Sass et al., 2022). In this context, the TALIS 2024 results highlight a global urgency for teachers to adopt digital tools to manage complex global challenges (OECD, 2025). Integrating Artificial Intelligence (AI) and Information and Communication Technology (ICT) tools, as advocated by Kayaalp et al. (2025) and Cebrián et al. (2021), offers a revolutionary potential to simulate sustainability scenarios and enhance the strategic competencies of future educators.

Recommendations

The results of the study indicate that pre-service science teachers are cognitively and affectively prepared to engage in the sustainability process; however, this readiness remains weak in the economic dimension and is not supported by practical

pedagogical skills. In light of the current findings and the synthesis of international literature, the following recommendations are proposed:

Whole-Institution Approach: Education for Sustainable Development (ESD) should no longer be an add-on course in the curriculum, but rather be transformed into a holistic structure that permeates all science disciplines, as emphasized by Özdemir-Yilmazer (2025) and Hurd & Ormsby (2020).

Systems Thinking and 4C Skills: The curriculum should be enriched with systems thinking tasks to enable candidates to analyze the interaction between economic and environmental systems. Furthermore, "4C" skills (Communication, Collaboration, Critical Thinking, Creativity) (González-Salamanca et al., 2020) should be placed at the center of teacher training.

Systems-Oriented Pedagogical Scaffolding: Following the recommendations of Peretz (2025), teacher training should move beyond one-time activities toward sustained integration of conceptual modelling and visual representations, such as causal-loop diagrams or DPSIR frameworks. These tools allow candidates to externalise their mental models and confront cognitive biases that simplify complex sustainability issues. Furthermore, providing teachers with ready-to-use frameworks and rubrics is essential to reducing the implementation burden and bridging the identified 'knowledge-action gap'.

Economic Sustainability Literacy: For the economic dimension, which is the weakest area for candidates, "sustainable production and consumption" themed modules should be added from the first years of university education to create a "multiplying effect," as suggested by Vega-Cervera and Gallardo-Vazquez (2024).

Action-Oriented Education and Self-Efficacy: To enable candidates to move from 'knowing to doing,' action competencies should be developed through community service applications and project-based learning (Sass et al., 2022; Baena-Morales et al., 2023).

Technological and Artificial Intelligence Integration: In line with the TALIS 2024 vision (OECD, 2025) and the work of Kayaalp et al. (2025), candidates should be equipped with the skills to utilize AI-supported educational technologies to address and teach complex sustainability issues.

Sustainable Lifestyle Role Modeling: In light of Özdemir-Yilmazer's (2025) findings, training programs should incorporate an awareness process that not only transforms the professional knowledge of candidates but also their personal life choices, such as sustainable consumption habits, to ensure they serve as authentic role models.

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