

Research Article

A skills training model integrated with entrepreneurship for sustainability: Design and evaluation study

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The purpose of the current study is to design, implement and evaluate a pedagogical model for skill training integrated with entrepreneurship for sustainability. In this regard, the nature of sustainability, entrepreneurship and integrated skill training, as well as the models of sustainability and entrepreneurship training developed in the literature were first examined. Then, the proposed model was defined as the “Skills Training Integrated with Entrepreneurship for Sustainability” model. The study group consists of fourth-year pre-service science teachers. The study, conducted using the design-based research method, consists of three stages: “exploration, design and implementation.” Through these stages, a document analysis, the design of the model and the training framework aligned with the model and a pilot study were carried out, respectively. Thematic, descriptive and content analyses were used to analyze the qualitative data collected through the document analysis and interview forms. The model designed in the study defines the competency areas required for integrated skill training for sustainability to be used in the undergraduate education of pre-service science teachers, while the developed training framework demonstrates learning-teaching practices compatible with these competency areas. In this context, the study is considered to be important for the literature on science education and sustainability. It is recommended that the training model designed in the study can be used as a moderator variable in the preparation and evaluation of green entrepreneurship activities related to sustainability issues, in determining instructors’ pedagogical competencies and in observing their development over time.

Keywords: Design-based research; Integrated skill training; Pedagogical entrepreneurship; Pre-service science teachers; Sustainability literacy

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1. Introduction

Environmental, economic and socio-cultural problems related to sustainability are increasing every day. Among the scenarios awaiting humanity by 2050 are an aging population, changing consumption habits, an increase in the number of people living in urban areas and their health problems, the negative effects of global events felt on basic needs and competition for natural resources (Fošner, 2025). Such serious challenges threatening sustainability in different sectors, for example, agriculture, transportation, health, industry, and education, require urgent solutions and this can be achieved through sustainable development [SD].

SD is a process that aims to develop while preserving limited resources, preparing a future with living conditions that can meet the new needs of people (Garg, 2015). Based on the components of

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fair economic growth, environmental protection, and respect for human rights, SD includes social and economic progress that promotes equity and preserves the environment. Therefore, the economy, nature, and society are interconnected (Dempsey et al., 2011; Gupta & Dharwal, 2022). In addition to these three interrelated dimensions, culture is proposed as an essential component of sustainability (Murray & Cotgrave, 2007). In this context, goals such as human rights, cultural diversity, and global citizenship are closely linked to the socio-cultural dimension of sustainability (Decamps, 2017). To achieve SD in all these dimensions, education from early childhood to higher education plays a crucial role.

Education for sustainability contributes to the development of the knowledge, skills, values, attitudes, and behaviours necessary to build a culture of sustainability, solve and take action on unsustainable problems (Fošner, 2025; United Nations [UN], 2015). Education also provides individuals need to develop skills that promote sustainability to put it into practice in real life. The common skills required for sustainability include action orientation, collaboration, systems thinking, future and values thinking (Wiek et al., 2011), critical thinking, decision-making, and creativity (UN, 2015). Along with these skills, sustainability literacy [SL] also emerges as a significant competency area. SL is defined as the set of skills necessary for the transition to sustainable living (Winter & Cotton, 2012). If an individual has knowledge about sustainability, tends to think critically or solve problems related to sustainability, and behaves in ways that are compatible with sustainability, then the individual is considered to be sustainability literate (Nolet, 2009). Individuals with SL skills are expected to evaluate current sustainability-related issues in society, develop creative and innovative ideas to address the problems, decide on the most functional idea and observe the impact of the idea by implementing it To raise individuals with all these competencies, it is essential to integrate entrepreneurship into the sustainability education because entrepreneurship is a crucial area for a sustainable future. Entrepreneurship, which plays a key role in supporting SD Goals (UN, 2015), naturally focuses on the development of more efficient, innovative and sustainable processes and products (Horisch, 2016). Therefore, it is considered that entrepreneurship can be a source of solutions for environmental, social and economic problems related to sustainability (Hall et al., 2010). Accordingly, it is understood that entrepreneurship and sustainability are two interrelated themes.

When the literature on entrepreneurship and sustainability is considered together, it becomes clear that higher education and undergraduate programs play an important role in training entrepreneurial generations and teachers who take responsibility in SD. How sustainability and entrepreneurship education are understood and implemented is of great importance (Seikkula-Leino et al., 2021) because sustainability and entrepreneurship, unlike content knowledge, emphasize competencies that require action. Studies examining the challenges faced by teachers in SD and entrepreneurship education (Akyürek & Şahin, 2013; Borg et al., 2012; Sağdıç, 2013) commonly identify teachers' lack of knowledge and professional competencies, as well as the absence of example educational practices, as major issues. The European Commission (2011) also emphasizes the gap between implementing entrepreneurship education for sustainability in schools and providing this education to pre-service teachers in higher education. So, it is emphasised that studies on "sustainability" are limited in the entrepreneurship literature, and the relationship between entrepreneurship and sustainable development is not sufficiently understood (Hall et al., 2010; Hermann & Bossle, 2020). Additionally, it is notable that the relationship between entrepreneurship and sustainable development is mostly addressed within the field of economics (e.g., Gupta & Dharwal, 2022). Based on the findings, it is necessary to integrate sustainability and entrepreneurship education into undergraduate teacher education programs and to develop good practice models (Seikkula-Leino et al., 2021). Besides, the findings highlight the need to provide pre-service training for teachers who will develop their individual and professional entrepreneurial competencies in sustainability education. Today, the need to educate young graduates who adopt sustainability and are equipped with sustainability and entrepreneurship skills is becoming increasingly important. In achieving this, teachers' sustainability literacy skills

and entrepreneurial competencies play a key role. In this context, the curricula prepared in our country according to the holistic education approach aim for integrated skills instruction by presenting content and conceptual skills together with literacy skills (Ministry of National Education [MoNE], 2024). Given that entrepreneurship is an inclusive type of skill and that the field of “skill-based sustainability education” is a new area of study today (e.g., Uslu, 2024), the emphasis on skills training integrated with entrepreneurship becomes prominent. So, it is understood that there is a need for studies that integrate the theme of sustainability into skills training integrated with entrepreneurship.

When models developed on sustainability and entrepreneurship skills in literature are examined, Sposab and Rieckmann (2024) propose the necessity of a holistic competency development approach that integrates cognitive, affective, and behavioural competencies. Montes-Martínez and Ramírez-Montoya (2020) emphasise that defining a pedagogical model involving the development of entrepreneurial teacher skills is important for educational institutions. In addition, a research gap is highlighted regarding the development of skills to support sustainability in education (Fuchs, 2024). Besides, a significant shortcoming is the lack of practical testing of instructional frameworks developed for integrating entrepreneurial skills into sustainability education (Hermann & Bossle, 2020; Lans et al., 2014). Similarly, the lack of implementation of sustainable entrepreneurship interventions is among the notable findings (Diepolder et al., 2021). Therefore, there is a need for a comprehensive pedagogical model that meaningfully integrates the sustainability skills with pedagogical competency frameworks and that provides methodological approaches, techniques, and practices for developing and assessing these competencies.

Based on all the above-mentioned needs, the current study aims to present an integrated pedagogical model for integrated skills training for sustainability. In this study, both the “competency areas necessary for contributing to sustainability” and the “professional competency areas required for the lesson design relating to skill-based teaching of sustainability” were defined. Moreover, the study developed a training framework that includes the teaching-learning process, demonstrating how the competency areas in the model can be developed in teacher education undergraduate programs. Then, to evaluate the impact of the training framework in teacher education, a pilot implementation of the learning and teaching practices developed in alignment with the framework was carried out on pre-service science teachers. The study is important in that it presents a training model simultaneously encompassing the themes of teacher competencies, sustainability and skills training integrated with entrepreneurship and a training framework based on the model. The training framework is also of particular importance as it provides a conceptual guide to designing learning modules for teaching sustainability based on skills integrated with entrepreneurship. It is intended that the implementation of a comprehensively designed training framework-aligned with competency areas, teaching-learning approaches, and assessment techniques-will contribute to filling the gap in the literature regarding how the integration of entrepreneurial skills into sustainability education can be practically achieved. At the same time, the study is expected to meet a need in the field by enabling pre-service teachers to comprehensively demonstrate their competencies in teaching skills related to sustainability issues. In this context, the following research questions are defined:

RQ 1) What are the cognitive and practical competency areas that pre-service teachers should possess in the process of skills training integrated with entrepreneurship for sustainability?

RQ 2) How should skills training integrated with entrepreneurship for sustainability be implemented in teacher training?

2. Literature Review

A comprehensive review of the literature on sustainability competencies and integrating entrepreneurship into sustainability helps clarify the research context, identify research gaps, and support the development of a skills training model that integrates sustainability with entrepreneurship.

2.1. Sustainability Competencies

Today, sustainability has become a prominent concept across various disciplines, including the environment, agriculture, health, technology, industry, tourism, and education. In all areas, the common goals of sustainability are to protect nature, ensure equality and economic welfare, promote social justice, and support cultural diversity (Besong & Holland, 2015). In this context, the United Nations Sustainable Development Goals (UN, 2015) present a vision to ensure environmental, social, cultural, and economic development, protect people and the planet, find solutions to global problems, and promote sustainability. Within this vision, education emerges as a crucial tool in achieving the Sustainable Development Goals (UNESCO, 2020, 2025). This is because education for sustainable development [ESD] aims to develop the knowledge, skills, attitudes, and values that enable individuals to make conscious decisions for the benefit of themselves and society and to act accordingly to create a sustainable life now and in the future (Combes, 2005; Zhang et al., 2020). At the same time, ESD aims to equip people of all ages with the cognitive, socio-emotional, and behavioral competencies needed to address sustainability-related issues that affect society and the world (UNESCO, 2025). The sustainability competencies emphasized in these aims are defined as a set of cognitive and practical skills, attitudes, and ethical values used to cope with a situation related to sustainability (Cebrián & Junyent, 2015). These competencies also enable individuals to undertake tasks not only in relation to real-world sustainability challenges but also in seizing sustainability opportunities (Brundiers et al., 2010).

Sustainability competencies, which play a crucial role in promoting sustainability, must be developed at all educational levels from early childhood to adulthood (Bianchi et al., 2022; Vesterinen & Ratinen, 2024). To achieve this, it becomes necessary to integrate and implement sustainability competencies and a competency-based approach into curricula within the scope of ESD (Mogensen & Schnack, 2010; Wiek et al., 2011). Various countries have adapted their curricula to support the development of sustainability competencies and have initiated model development efforts through competency frameworks (Sposab & Rieckmann, 2024). When the literature on sustainability competency frameworks and model development is examined, it is noteworthy that studies focus on different educational levels. For instance, Wiek et al. (2011) developed a flower model explaining the teaching and learning of sustainability competencies at the primary school level. The center of the flower emphasizes collaboration skills, highlighting the interaction between teachers and students, while the petals consist of "systems thinking, futures thinking, strategic thinking, and values-based thinking" skills. It is emphasized that all of these competency areas are interrelated. In the sustainability competency frameworks developed by Sposab and Rieckmann (2024) for secondary education, the main trends include critical and creative thinking, systems thinking, futures thinking, action competence, communication, planning-implementation and reflection, problem-solving, and collaborative decision-making skills. Jegstad and Sinnes (2015) developed a model for implementing ESD in the field of chemistry at the high school level. The model is designed to plan and evaluate education for sustainable development through the chemistry curriculum. It consists of five components: "chemical content knowledge, chemistry in context, the distinctiveness and methodological character of chemistry, ESD competences, and lived ESD." These components are visualized with an elliptical shape representing their application at different levels. The first three components are specific to the subject of chemistry, while the remaining components are related to teaching and learning activities focused on chemistry. Additionally, the "ESD competencies" component of the model includes problem-solving, critical thinking, creativity, systems thinking, futures thinking, action competence, normative competence, collaboration, and communication skills.

Unlike the examples above, the higher education level plays a significant role in contributing to the development of the sustainability field and pedagogical competencies through its roles in "teaching, research, and social responsibility" (Garcia-Rico et al., 2021; Setó-Pamies & Papaoikonomou, 2020). When examining the sustainability competency frameworks developed for higher education, a notable model proposed by Redman and Wiek (2021) for faculty members,

students, and practitioners stands out. This model integrates general competencies (creativity, critical thinking), professional competencies (communication, project management), and disciplinary competencies, and it adds three new competencies (internalization, implementation, and integration) to the widely used sustainability competencies (systems thinking, futures thinking, normative, strategic, interpersonal). Similarly, Besong and Holland (2015) present a framework that integrates sustainability competencies with attitudes, abilities, and behaviors in higher education. This framework also aims to evaluate sustainability competencies with an action-oriented approach. Lenziardi et al. (2025) developed a value-oriented competency model for academics in higher education within the framework of ESD and corporate social responsibility [CSR]. This model encompasses the competencies of academics as individuals, within educational institutions and society, and as educators. In addition, studies on sustainability competencies for pre-service teachers have emphasized the role of experiential practices. For example, methodologies such as interdisciplinary workshops, project-based learning (Albareda-Tiana et al., 2018; Paristiowati et al., 2022), and the living-lab approach (Kadji-Beltrán, 2024) have been shown to enhance both sustainability competencies and professional competencies in pre-service teachers.

Considering the competency frameworks structured for different educational levels, it is understood that differences stem from the social, environmental, economic, and cultural contexts of sustainability (Laurie et al., 2016; Sposab & Rieckmann, 2024). It is also noted that the ESD competencies mentioned are often limited strictly to sustainability in the models. In this context, the integration of entrepreneurial skills into sustainability is considered important. Therefore, the relationship between entrepreneurship and sustainability is discussed in a separate section below.

2.2. Integrating Entrepreneurship into Sustainability

It is important to have the necessary competencies to deal with the social, ecological and economic problems that are waiting to be solved through Sustainable Development Goals (Lans et al., 2014). When considering sustainability-specific areas of competence, entrepreneurship emerges as a core skill area that promotes identifying local and global sustainability problems, developing relevant knowledge and skills, and taking action toward solutions.

Entrepreneurship requires individuals to recognize threats to the environment, economy, and society, and to transform their knowledge and skills into entrepreneurial action (Hermann & Bossle, 2020). To generate entrepreneurial action, a set of domain-specific, social, and personal skills is needed—these constitute entrepreneurial competencies (Tittel & Terzidis, 2020). Individuals who acquire entrepreneurial competencies can significantly contribute to the achievement of sustainable development goals by addressing urgent issues such as poverty, hunger, global warming, irresponsible production and consumption, environmental pollution, and biodiversity loss while also generating new business ideas and creating economic and social value (Shepherd & Patzelt, 2017). Thus, the process of identifying and utilizing opportunities to solve social, environmental, and economic problems highlights the importance of entrepreneurial skills for sustainability (Wyness et al., 2015).

In literature, entrepreneurial skills are not explicitly defined within sustainability education competence frameworks. Common areas of competence shared by sustainability education and entrepreneurship education include interdisciplinarity, inquiry, problem-solving, and collaboration. However, studies in which these competencies are developed within programs or courses remain limited (Hermann & Bossle, 2020; Wiek et al., 2011). For instance, Lans et al. (2014) proposed a competence framework linking entrepreneurship and sustainability education, emphasizing the necessity of solving complex problems, innovation and creativity, individual engagement, exploration and implementation, interaction, and collaboration. Mindt and Rieckmann (2017) emphasized the need to combine collaborative, experiential, transformative, and real-life-based teaching methods used in sustainability and entrepreneurship education to develop sustainability oriented entrepreneurial competencies. Hermann and Bossle (2020) proposed a teaching framework for integrating entrepreneurial skills into sustainability education in higher

education. This framework includes components such as educational focus (target audience, institutions, education domain), learning and teaching approaches (active learning, real-world learning), collaboration with external stakeholders (actors and practices, community, capacity-building), and thematic areas (innovation and design, entrepreneurship and ecosystem support, corporate and organizational aspects). The framework does not explicitly list competencies, but it references systems thinking, anticipatory thinking, interdisciplinary work, and problem-solving as integrated competencies within active and real-world learning approaches. Moreover, entrepreneurship is proposed as an additional competency area to be targeted in sustainability education. It is also recommended that this framework be integrated into course design across different undergraduate and graduate programs. Diepolder et al. (2021) conducted document analysis to identify the competency areas that entrepreneurs need in order to solve sustainability-related problems. For their analysis, they examined three frameworks developed in the literature: the competence framework for sustainable entrepreneurship (Ploum et al., 2017), the core competencies for sustainability-oriented entrepreneurship (Biberhofer et al., 2019), and the process-oriented sustainability entrepreneurship competence framework (Foucrier & Wiek, 2019). They compared these hierarchical, categorical, and process-based frameworks and concluded that competencies such as systemic, anticipatory, normative, strategic, and interpersonal thinking were common across all frameworks.

When these studies are considered, it becomes evident that there is a lack of alignment between sustainability and entrepreneurship education programs in higher education. Entrepreneurial skills and sustainability competencies are often neglected, and there is a shortage of pedagogical approaches suited to undergraduate programs that integrate sustainability and entrepreneurship (Hermann & Bossle, 2020; Wyness et al., 2015). Therefore, there is a gap in the field for a pedagogical model that demonstrates how entrepreneurial skills are integrated, implemented, developed, and assessed within sustainability education.

3. Method

3.1. Research Design

In the current study, which aims to develop a pedagogical model for skills training integrated with entrepreneurship for sustainability, a design-based research [DBR] model was used, which is one of the qualitative research approaches.

DBR refers to a systematic research method that aims to cyclically analyze, design, develop and implement an educational intervention, such as a model, program, material or strategy and is used to validate and improve the intervention in a real-world setting (Anderson & Shattuck, 2012; Design-Based Research Collective, 2003). Among the reasons for choosing design-based research as the appropriate methodology in the current study are the novelty and uncertainty of the pedagogical integration of entrepreneurship and sustainability themes and the existence of deficiencies in teacher competencies and teaching materials required during the process of teaching sustainability and developing related skills. The current study, designed in alignment with a general model applied for DBR in education (McKenney & Reeves, 2018), was completed in three stages.

a. Research, analysis and discovery stage: At this stage, document analysis was conducted on training frameworks developed for sustainability and entrepreneurship to identify the problem through a needs analysis. In this context, topics such as education for sustainability, entrepreneurship education, skills training integrated with entrepreneurship and teacher competencies were examined. Considering this review, the needs analysis was conducted, and pre-service teachers were determined as the target population.

b. Design and construction stage: The design is decided upon to find answers to the research questions. As a result of the document analysis conducted in this context, a model and a training framework compatible with the model were designed to identify and develop the pedagogical content competencies of pre-service teachers for skills training integrated with entrepreneurship

for sustainability [STIE-S]. With this model, conclusions regarding which skills need to be developed were reached. Expert opinions were obtained from three academics specialized in science education for the proposed model and the training framework developed within the scope of the model.

c. Implementation, evaluation and reflection stage: The pilot study of the educational practices prepared in accordance with the model was conducted with the study group in six class hours. The information regarding the educational practices is presented in Table 1.

Table 1

STIE-S activities

<i>Time</i>	<i>Name of the application</i>	<i>Targeted skills</i>
6 class hours	STIE-S activities	Entrepreneurial skill, domain-specific and sustainable living skills.

The STIE-S activities in Table-1 consist of practices carried out under the themes of ‘sustainability, sustainable living spaces, and sustainable technologies.’ Within the theme of sustainability, the activities include conducting scenario exercises on the changing world over time, exploring global and local sustainability issues through video and documentary analyses, creating an idea pool consisting of innovative solutions and presenting a business plan for an association to be established on sustainability activities. Within the theme of sustainable living spaces, the activities involve designing sustainable city plans, building partnerships for ecological villages via drama, creating disaster-resistant miniature structures, developing mobile application ideas for sustainable transportation, and generating projects on smart transportation. Within the theme of sustainable technologies, the activities consist of conducting patent research on green technologies, analysing the sustainability features of future technologies through SWOT analysis, and developing projects and advertising campaigns for clean production technology. At the end of the pilot study of these educational practices, the opinions of the pre-service teachers about the activities carried out within the framework of the STIE-S model were obtained.

3.2. Study Group

During the “research, analysis and discovery” stage of the design, the aim was to examine graduate theses and journal articles for the development of a pedagogical model along with a training framework. A total of 33 documents were evaluated as a result of purposive searches based on the criteria defined in the document analysis form. Of these documents, 27 are articles and 6 are theses; 22 of them are focused on the theme of sustainability, while 11 are focused on the theme of entrepreneurship.

The study also aimed to validate the training framework designed in accordance with the model developed following the document analysis. The study group for the “implementation, evaluation and reflection” stage of the study conducted for this purpose consisted of 10 fourth-year pre-service science teachers attending a state university in Konya, Turkey. The reason for conducting the study on pre-service science teachers is that they will implement sustainability and skill-based science teaching, emphasized in the renewed 2024 middle school science curriculum, in real classroom settings. In forming the study group, attention was paid to ensuring diversity in terms of “entrepreneurship and sustainability experience, gender, and academic achievement”. Of the 10 pre-service teachers who participated in the study on a volunteer basis, 6 are female and 4 are male. Three pre-service teachers enrolled in the entrepreneurship course, and four participated in the sustainability training. The participating pre-service teachers had varying levels of academic achievement. In terms of academic achievement based on the 4.00 grading system, three students had a GPA below 2.00, four students had a GPA between 2.00 and 3.00 and three students had a GPA above 3.00. The reasons for selecting fourth-year undergraduate students for the study include their completion of numerous theoretical and practical courses and their being able to

apply the knowledge and skills they had acquired from these courses in their internship schools. The pre-service teachers were coded as PT1, PT2, ... PT10.

3.3. Data Collection

DBR requires diversity in the data collection process, as it includes various stages. These studies often begin with a literature review to construct the initial design and continue with the application of qualitative or quantitative tools to evaluate the design (Orrill et al., 2003; Reigeluth & Frick, 1999). Accordingly, document analysis and interview forms constituted the data collection tools in the current study. Scientific publications accessed during the model design stage of the study were reviewed as documents. In addition, interview forms were prepared for experts and pre-service teachers. Detailed information about the data collection tools, their characteristics and administration processes are provided in the following.

3.3.1 Document analysis form

A form for document analysis was prepared to identify the competency areas of the STIE-S model and the training framework and teaching-learning practices compatible with these areas. In this form, the review criteria were identified as the themes of "education for sustainability", "entrepreneurship education", "skills training integrated with entrepreneurship" and "teacher competencies/pedagogical content knowledge". Studies on these themes were accessed through the Web of Science, Science Direct, Google Scholar, ULAKBİM, SOBİAD and YÖK Thesis databases. In selecting the documents, attention was paid to ensuring they were accessible thesis and article studies published between 2008 and 2024 in Turkish and English, with a focus on sustainability, in-service and pre-service teacher training, models, curricula, training frameworks and teacher competency development through applied research.

3.3.2. Structured interview form-E

During the design stage of the study, experts (E) were consulted using a structured interview form sent by e-mail for their opinions on the developed STIE-S model and training framework. The interviews were conducted with three experts specialized in the field of science education. Two of the experts are male, and one is female, and each of them works in a different city. One expert, in addition to science education, specialises in entrepreneurship education; another focuses on sustainability education; and the third conducts studies in the field of integrated skills training. For each question in the interview form, they were requested to respond using the categories "Sufficient", "Partially Insufficient" and "Insufficient." Examples of the interview questions asked of the experts are provided below.

Q1) How appropriate is the model in terms of incorporating the elements of entrepreneurship?

Q2) How appropriate is the model in terms of incorporating the dimensions of sustainable development?

Q3) How appropriate is the model in terms of incorporating the targeted entrepreneurship and integrated skills?

Q4) How appropriate is the model in terms of including the basic and professional competencies required for integrated skills training?

Q5) How appropriate is the training framework of the model in terms of including the components of PCK and demonstrating variety in teaching and learning practices?

Q6) What are your opinions about the applicability of the training framework?

3.3.3. Focus group interview form-PSTs

In the evaluation stage of the study, focus group interviews were conducted to determine the opinions of pre-service science teachers [PSTs] on the educational practices carried out in compliance with the STIE-S model. Two researchers specialized in the field of science education provided their opinions regarding the semi-structured interview questions. The average duration allocated for the pilot interview conducted with the 10 PSTs participating in this study was 30

minutes. The interviews were recorded using an audio recorder with the consent of the PSTs. Examples of the questions asked of the pre-service teachers are provided below.

Q1) What do you think about the suitability of the activities for undergraduate level?

Q2) What do you think about the consistency of the activities with the curriculum?

Q3) What do you think about the compatibility of the activities with the target learning outcomes?

Q4) What do you think about the scope and diversity of the teaching methods and techniques used during the implementation of the activities?

Q5) What do you think about the appropriateness of the measurement and evaluation methods used to evaluate the performance during the activities?

Q6) What are your experiences during the implementation of the activities?

3.4. Data Analysis

The analysis method for each data collection tool is provided in the following.

3.4.1. Document analysis

Document data were analyzed using thematic analysis. Thematic analysis is a method for systematically organizing, identifying and interpreting themes within a data set (Braun & Clarke, 2006). In the current study, structures such as “model, course content, curriculum, training framework” in the documents analyzed were described as themes. The data belonging to the themes were examined in terms of their similarities and differences, and structural qualities were classified as categories and codes. In this way, an understanding of the pedagogical structures developed in each document was gained and the relationships between the structures were observed.

3.4.2. Analysis of the interview data

Descriptive and content analysis methods were used in the analysis of qualitative data collected from the experts and pre-service teachers through interviews. For descriptive analysis, the data were organised and displayed in an arranged form according to a determined conceptual structure (Miles et al., 2014). For content analysis, the following process was followed: the preparation phase (selecting the unit of analysis), the organising phase (open coding, creating and reorganising categories, and abstraction), and the reporting phase (describing results through categories and themes (Elo & Kyngäs, 2008). The interview data were coded independently by two researchers of this study, both of whom are experts in science education. The agreement coefficient between the expert coders was calculated as 91% for the expert data and 89% for the data from the pre-service teachers. These values represent a high level of agreement (Miles & Huberman, 1994), meaning that the analysis was reliable. In addition, to increase the validity of the analysis, direct quotations from the pre-service teachers' and the experts' opinions are presented.

3.5. Validity and Reliability of the Research

In the current study, validity and credibility were ensured primarily through document analysis, which provided direct access to relevant literature and thereby established the theoretical foundation of the proposed pedagogical model and educational framework. Indeed, Lincoln and Guba (1985) suggest that ensuring reference adequacy involves verifying preliminary findings by comparing them with archived data. In addition to documents, data triangulation was achieved through focus group interviews. In the literature, the use of multiple data collection methods is recommended to enhance validity and data richness (Lincoln & Guba, 1985; Silverman, 2013). So, expert opinions were obtained from purposefully selected academics regarding the proposed model, educational framework, and interview form. These experts work in various fields, including science education, entrepreneurship, sustainability, and skills training, and are based in different provinces. Based on these expert views, the selection of pre-service teachers for the implementation of the educational framework aligned with the model was carried out, considering

volunteerism and accessibility. Furthermore, attention was paid to ensuring diversity among the pre-service teachers in terms of academic achievement, gender, and experiences related to entrepreneurship and sustainability. Accordingly, fourth-year pre-service teachers were purposefully selected as they had completed most of their subject-matter and pedagogical courses. In a study exploring a specific experience, it is appropriate for the researcher to interview individuals who have lived that experience. Therefore, purposive sampling of participants who are directly connected to the research topic plays a crucial role in ensuring the study's validity and transferability.

During the implementation process of the present study, instructional modules were conducted directly by the researcher, and the participating pre-service teachers were closely observed. Detailed information regarding the aim and procedures of the study was provided to the participants, and their questions were individually addressed. Indeed, spending sufficient time with participants and engaging in prolonged interaction allows the researcher to build trust, which helps prevent misunderstandings and adds credibility to the research content (Lincoln & Guba, 1985; Patton, 2015). Because a detailed description of the context strengthens the study's transferability (Lincoln & Guba, 1985), focus group interviews were audio-recorded with member checking and fully transcribed. Independent coding of the data was carried out by the researchers at various times and locations. Then, an alignment between the researcher's interpretations and participants' statements was assessed through participant verification. Inter-coder agreement and participant checking were employed to enhance the dependability and credibility of the study (Lincoln & Guba, 1985; Merriam, 2009; Miles & Huberman, 1994). In the analysis, participant identities were kept confidential and coded as PT. The results were reported in detail and supported with direct quotations from participant statements. According to Merriam (2009), through all these efforts (e.g., comparing the findings with similar and contrasting results, etc.), the consistency and confirmability, that is reliability of the research, were strengthened.

4. Results

This section includes the results obtained from the document analysis and interview data.

4.1. Results from the Document Analysis Regarding the STIE-S Model

The findings from the analysis of documents obtained from a literature review conducted on sustainability in the teacher training process, conducted to determine the competency areas and pedagogical practice types in the STIE-S model, are shown in Table 2.

When Table-2 is examined in terms of sustainability-themed models developed for the education of teachers and pre-service teachers in higher education, it is seen that the models are aimed at determining "educational frameworks, curricula, course programs, units and competency areas". It is remarkable that the model names are associated with sustainability, SD and SL. It is also observed that the model definitions are created in an integrated manner with pedagogical approaches and skill types, such as the "design thinking model" and the "inquiry-based model".

In the models developed for competency areas, types of skills in the "cognitive, affective, and behavioural dimensions" are emphasized, along with knowledge structures such as "content, pedagogy and PCK" aimed at teaching these skills. Among the thinking skills, sustainability-specific thinking skills such as "systems thinking" in particular, as well as "strategic thinking", "values thinking" and "futures thinking", come to the forefront. The models include various pedagogical approaches and innovative teaching practices both inside and outside the classroom aimed at developing these skills. In the STIE-S model, the findings from the analysis of documents obtained through a literature review on "entrepreneurship education" conducted to identify competency areas and pedagogical practices are presented in Table 3.

Table 2

Competency areas and application types in sustainability-themed models

<i>Study and Theme</i>	<i>Category</i>	<i>Code</i>
Sleurs (2008)		
Teacher competencies for SD education	Cognitive Affective Behavioural	Teaching: Information Reflection: Systems thinking, emotions, values, ethics Networking: Action
Burns (2011)		
Pedagogical model for SL	Content Process Perspective Context	Content knowledge Educational interventions Thinking skills Interaction of society with geographical location
UN Economic Commission for Europe (2011)		
Educator competencies in education for SD	Knowledge Skill Behaviour	Holistic approach Anticipating change Ensuring transformation
Archambault et al. (2012)		
Sustainability science lesson for teachers	Content knowledge Thinking skills SL Conscious citizenship Technology use Content production	Setting learning objectives Materials analysis Creating story content with technology Reviewing content with experts Correcting content based on feedback Offering innovative activities
Bertschy et al. (2013)		
Professional action competencies for SD education	Competency dimensions Competency areas	Motivation, belief-values, self-regulation, professional knowledge Pedagogical, content, pedagogical content, institutional, consultancy knowledge
Warren et al. (2014)		
Sustainability training framework	Strategic thinking Systems thinking Values thinking Futures thinking	Inquiry, project, puzzle, action plan Games, case studies, models, discussion Asking questions, discussing, role-playing A scenario, developing story endings, keeping a journal, conducting macro-history work
Karaarslan (2016)		
Education model for sustainability	Systematic thinking skills	Awareness, making sense, adapting to life
Giangrande et al. (2019), Lozano et al. (2017), and Wiek et al. (2011)		
Sustainability education competencies	Thinking skills and competencies	Systemic, critical and anticipatory thinking, Strategic and normative competence, Collaboration, self-awareness, Integrated problem solving
Scherak and Rieckmann (2020)		
Competencies for SD	Content knowledge Pedagogic content knowledge Skill	Knowledge of sustainability concepts and dimensions Curriculum knowledge integrating sustainability; Learning outcomes knowledge; Preparing lesson plans according to individual differences Critical thinking, collaboration, communication
Qureshi (2020)		
Curriculum model for sustainable life	Content Process Results	Transportation, consumption, recycling Content design (experiential learning) Sustainable living skills
Helmi and Herliani (2021)		
Sustainability design thinking model	SL Design thinking Systems, values, futures, strategic, critical thinking Creative problem solving	STEM approach Prototype construction, testing Developing empathy Defining, generating ideas

Table 2 continued

<i>Study and Theme</i>	<i>Category</i>	<i>Code</i>
Brandt et al. (2021) Sustainability competencies training syllabus	SD goals	
	Skills Futures, values, systems, strategic, reflective thinking	Activities Scenario, video, performance assignment, out-of-school learning, discussion, teamwork
Elster (2022) Inquiry-based teacher training course for SL	Information module	Biodiversity, climate change, soil
	Sustainability skills module	Decision making, action, value creation, systems thinking, discussion
	Didactic module	Role playing, games, questioning, trips, experiments, discussion
	Implementation and evaluation module	Implementation of educational materials in real classrooms
Yağmur (2022) SD model	Content knowledge Pedagogic content knowledge	SD, footprint, environment, recycling Orientations, curriculum, student, teaching strategies, assessment knowledge
Şen and Oktay (2023) Educational framework for sustainability	Skills Discussing, analyzing, critical thinking	Learning-teaching practices STEM approach, cooperative learning method, out-of-school learning
Chinedu et al. (2023) Vocational-technical teacher training curriculum for SL	Learning outcomes	Ethical practices, needs analysis, problem solving, sustainability knowledge
	Teaching competencies Pedagogical approaches	Knowledge, skills and characteristics Case study, problem-based, collaborative, inquiry, place-based learning, simulation, conference
	Strategies for integrating sustainability into education	Sustainability vision, educational competencies, R&D, extracurricular activities, staff development, responsibilities, courses
Uslu and Özdemir (2023) Sustainable living skills framework	Critical thinking	Questioning, noticing and predicting contradictory situations
	Problem solving	Identifying, finding solutions, testing
	Analytical thinking	Understanding and analyzing the reasons
	Systemic thinking	Recognizing the natural system and systemic transformation
	Anticipatory thinking	Predicting outcomes, developing new scenarios
	Communication and collaboration	Establishing a model of cooperation and communication with actors
İnam (2024) Curriculum for SD	Cognitive process	Lifelong learning, vocational training, teacher knowledge in SD education, policy development
Koçulu (2024) SD goals unit	Systems thinking skills, and ethical reasoning	Learn: Cognitive learning Think: Socio-emotional learning Move: Behavioural learning

Table 3

Competency areas and types of practices in entrepreneurship and pedagogical entrepreneurship themed models

<i>Study and Theme</i>	<i>Category</i>	<i>Code</i>
Mwasalwiba (2010) An integrated progression model for entrepreneurship education	Education “about, for and through” entrepreneurship	Creating value, addressing the problem, communicating with institutions, acting on curriculum knowledge, speaking business language, creating sustainable enterprises
Gibb (2011) and Hannon (2006) Dimensions of pedagogical entrepreneurship	Entrepreneurial learner	Possessing entrepreneurial characteristics
	Entrepreneurial teacher	Developing entrepreneurial learner traits
	Entrepreneurial curriculum Entrepreneurial learning environment	Objectives, content, learning-teaching process, assessment Innovative, action-based, democratic, creative, collaborative, social, independent
Rasmussen and Nybye (2013) Progression model for entrepreneurship education	Movement	Initiation, collaboration, value creation
	Creativity Attitude	Idea, solution generation, applied knowledge Self-confidence, ethical principles, dealing with uncertainty
	Environment	Culture, market and economy
Paloniemi and Belt (2015) Integration model for entrepreneurship education	Entrepreneurship skills	Creating opportunities, business idea, creating a business plan
	Entrepreneurship education	Offering opportunities, learning and teaching
	Education process	Structuring learning and teaching
Deveci and Beşoluk (2022), Tarhan (2020) Elements of entrepreneurship education	Business idea generation	Creative, innovative thinking, seeing opportunities, collaboration, problem solving, business planning
	Finance	Resource management, risk taking, cost analysis
	Product design and production	Teamwork, determining product quality
	Promotion and marketing	Communication, self-confidence, self-efficacy, defining product and market, marketing plan, advertising
	Investment and sustainability	Problem solving, futuristic thinking, leadership, networking, governance
Samanci (2021) Content and professional knowledge related to entrepreneurship skills of PTs	Conceptual knowledge	The economic, social, and cultural foundations of entrepreneurship, The importance of being creative and utilizing technology in entrepreneurship, The process of establishing and acquiring a business, The importance of product design
	Professional knowledge	Definition of entrepreneurial skills, Characteristics of individuals possessing these skills, Design of activities to develop entrepreneurial skills, Design of tools for measuring and evaluating entrepreneurial skills

Table 3 continued

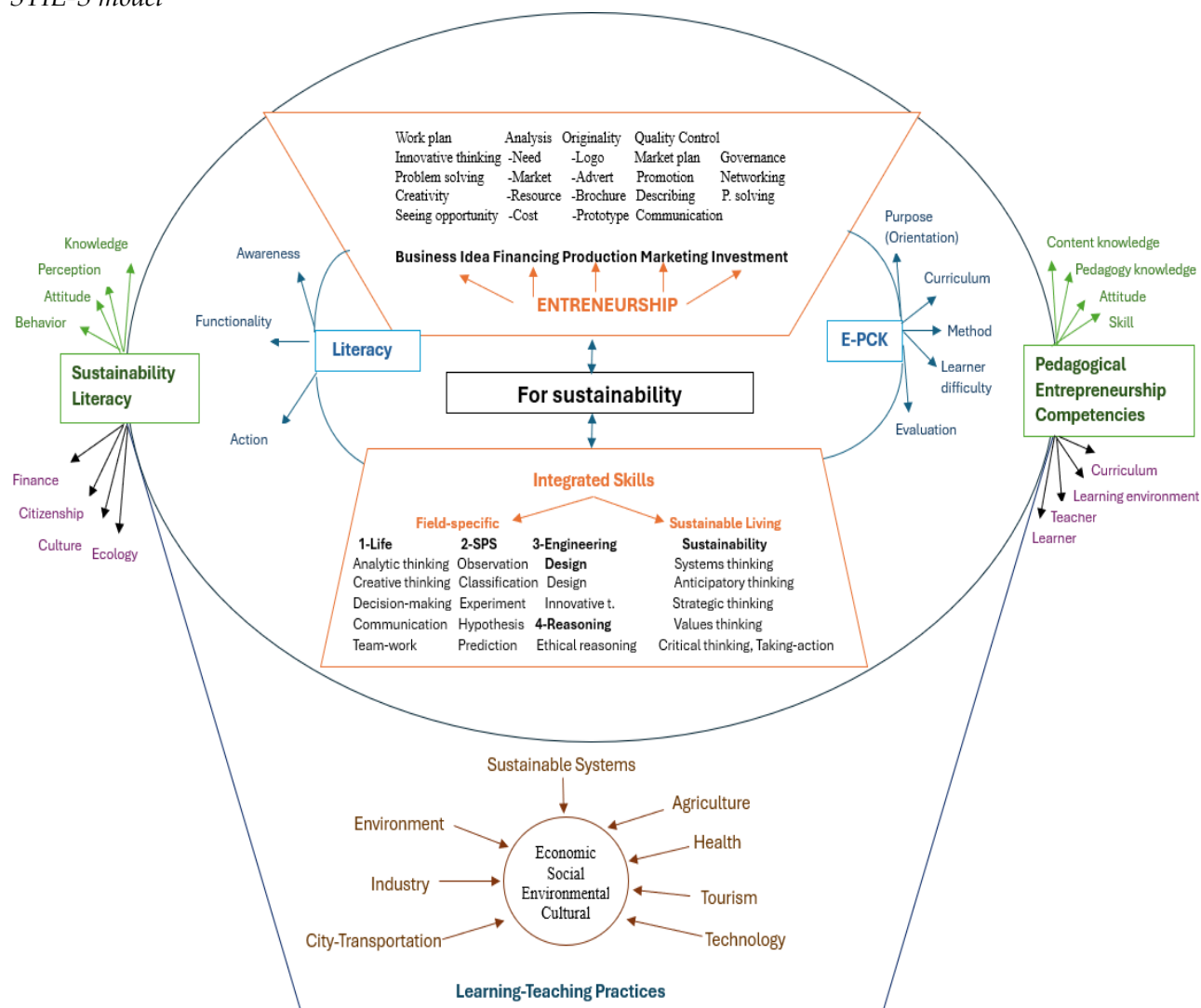
<i>Study and Theme</i>	<i>Category</i>	<i>Code</i>
Kirman Bilgin and İnaltekin (2022)		
Integrated entrepreneurship education for PTs	Entrepreneurship education	KOSGEB entrepreneurship training
	Entrepreneurship education in science	Creativity, innovation in entrepreneurship, design, interaction with the environment, relationship between science and business ideas
	Business plan exhibition	Entrepreneur and business information, marketing, production, management and financial plan
Slišāne (2023)		
The conceptual framework of pedagogical entrepreneurship	Conceptual dimension	Leadership, professional autonomy, proactivity, problem solving
	Personal skills	Flexibility, pedagogical knowledge, professional reflection commitment, strategic vision, risk taking
	Social skills	Communication, using resources, social innovation, value creation
Kocayığit (2024)		
Entrepreneurship curriculum for teachers	Dimensions	Activities
	Entrepreneurship concepts, Need for achievement, Self-confidence, Locus of control, Risk-taking tendency, Innovation and creativity	Lecture, question and answer, analogy, case study, mind and concept mapping, drama, brainstorming, perspective development, modelling, acrostic, group work, research and investigation, problem- and scenario-based learning, project, story creation, station, field trip, on-the-job learning

Examining Table-3 in terms of entrepreneurship-themed models and studies on the pedagogy of entrepreneurship reveals that models have been developed for the “integration of entrepreneurship into education, curriculum, and course design” to determine the “content knowledge and professional competencies” specific to entrepreneurial skills. It is seen that the concept of pedagogical entrepreneurship, its dimensions and conceptual framework related to the teaching of entrepreneurial skills have been defined. In addition, among entrepreneurial skills, “business idea generation, financial analysis, product design, production, promotion and marketing, investment and sustainability” skills come to the forefront. Among the prominent entrepreneurial skills are “problem solving, analysis, communication and collaboration, teamwork, decision making, leadership, self-confidence and risk-taking”, while among the thinking skills, “creative, analytical, futuristic and innovative thinking” come to the forefront. The models include a variety of classroom and out-of-school learning and teaching practices selected in accordance with the nature of entrepreneurship to develop these skills. Among these practices, the methods of “on-the-job learning, field trips-observation-interviews and problem- design- and project-based teaching” are emphasized.

As a result of analyzing the documents obtained from a literature review on the themes of sustainability and entrepreneurship, the STIE-S model was designed. In the model, the competency areas required for the STIE-S model were identified. The STIE-S model structured within the current study is presented in Figure 1. In the STIE-S model proposed in Figure 1, the knowledge and competency areas necessary for developing skills integrated with entrepreneurship in the context of sustainability were identified.

The core competency areas identified in the model are sustainability literacy and pedagogical entrepreneurship. The sub-competency areas identified in the model are entrepreneurship, skills integrated with entrepreneurship, pedagogical content knowledge specific to entrepreneurial skills [E-PCK] and literacy.

Figure 1
STIE-S model



The sub-skills of the entrepreneurial skill targeted for development include “business idea generation, financial management, production-design, promotion-marketing and investment.” The integrated skills aimed at development alongside entrepreneurship were classified as domain-specific and sustainable living skills. Among the domain-specific skills are “scientific process, life, engineering design and reasoning skills”. Among the sustainable living skills are sustainability-specific systems thinking, strategic thinking, futures thinking and values-based thinking, along with problem-solving, critical thinking and skills for taking action. Within the framework of this model, a learning module to be prepared aims to develop at least two different types of skills alongside entrepreneurship in teaching any sustainability topic to pre-service teachers.

The E-PCK component in the model aims to develop knowledge related to the objectives and goals specific to entrepreneurial skills, curriculum, teaching methods and techniques, learner difficulties and measurement and evaluation. Moreover, among the skills targeted for development in the model are literacy skills for sustainability at the levels of awareness, functionality and action.

The sustainability literacy and pedagogical entrepreneurship core competency areas specific to this model aim to develop knowledge, perception, attitudes and behaviours in thematic areas such as sustainable systems, environment, industry, city, health, tourism, agriculture and technology.

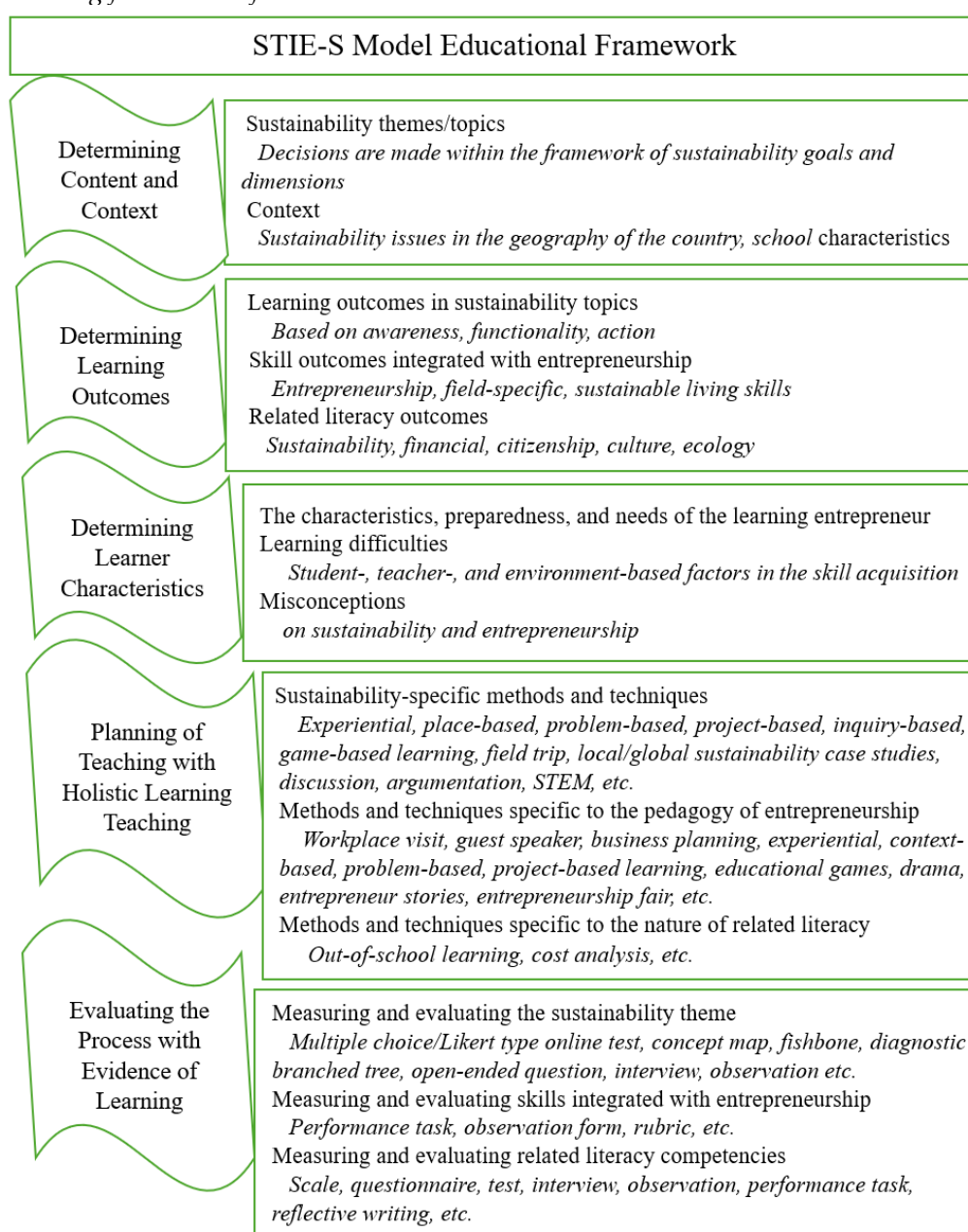
When the environmental, social, cultural and economic dimensions of sustainable development topics are considered, ecology, financial, global citizenship and cultural literacy, along with sustainability literacy, are interconnected competency areas.

Under pedagogical entrepreneurship competencies, the development of subject knowledge, pedagogical knowledge, skills and attitudes specific to the teaching of entrepreneurial skills is targeted. The components of pedagogical entrepreneurship competency areas include knowledge of curriculum, learning environments, and the characteristics of entrepreneurial learners and teachers.

According to the proposed model, the identified knowledge areas influence the instructor's pedagogical competencies and interact with each other. Accordingly, a training framework compatible with the model was developed to enhance the competency areas identified in the model. The training framework of the STIE-S model, developed as a result of the document analysis on the themes of sustainability and entrepreneurship, is as presented in Figure 2.

Figure 2

Training framework of the STIE-S model



The training framework in Figure 2 based on the STIE-S model was structured within the context of the subcomponents of PCK (Magnusson et al., 1999). These subcomponents were renamed to align with the program components developed based on the Türkiye Century Education Model (MoNE, 2024). For example, within the PCK components, knowledge of the goals and objectives of science teaching (science teaching orientation) has been adapted as content and context knowledge; curriculum knowledge as knowledge of learning outcomes; and assessment knowledge as knowledge of learning evidence.

Each of the knowledge components within the framework has been defined in terms of the necessary educational practices, integrated skills related to sustainability and entrepreneurship and related literacy competencies. In this context, the sustainability topics for which skills training will be provided are first identified to develop a learning module aligned with the STIE-S model-based training framework. When selecting topics, the goals of sustainable development, as well as the characteristics of the local geography and the school, should be taken into consideration. Thematic topics in various fields that contribute to national sustainability can be selected. Next, the goals and objectives of skills training for sustainability are determined. In this context, learning outcomes related to sustainability are determined in alignment with the 12th Development Plan (Presidency of Strategy and Budget, 2023) and the curriculum. At the same time, at least two types of skills intended to be developed alongside the “entrepreneurship” skill are identified and the corresponding skill outcomes are defined. Furthermore, the types of literacy and learning outcomes related to the nature of the topic and skills to be taught are identified. To help learners achieve these learning outcomes, particularly in terms of entrepreneurial characteristics, their readiness, learning difficulties and needs are identified. Learning-teaching activities (sample activity in Appendix 1) based on a holistic educational approach are prepared in accordance with the individual differences of the learners. For this purpose, teaching methods and techniques specific to sustainability and entrepreneurship are determined. Moreover, innovative pedagogical approaches are utilized to develop sustainability literacy as well as other literacy skills. Finally, process- and product-oriented constructivist multiple measurement and evaluation tools are selected and implemented to determine whether learners have achieved the learning outcomes related to the themes of sustainability, skills and literacy. With this proposed training framework, the integration of sustainability topics with entrepreneurship as well as other domain-specific and sustainable living skills can be effectively ensured.

4.2. Results from the Interviews Conducted about the STIE-S Model

Findings obtained from the interviews conducted with the experts and pre-service teachers are presented below under separate headings.

4.2.1. Results obtained from the interviews conducted with the experts about the model and training framework

The findings obtained through the analysis of the responses of three academics who are experts in the field of science education regarding the suitability of the model and its training framework are shown in Table 4.

When Table 4 is examined, it is seen that the experts mostly found the model appropriate in terms of “suitability for purpose, including the elements of entrepreneurship, the dimensions of sustainable development, integrated skills and necessary competency areas”. It is also understood that the experts indicated the training framework is appropriate in terms of “applicability, the scope and diversity of learning and teaching practices and the inclusion of PCK components”. Direct quotations from the experts regarding the model and its educational framework are as presented in the following.

Table 4

Findings from the analysis of experts' responses to the interview form

Criteria	Frequency (f)		
	Sufficient	Partially	Insufficient
Model			
Suitability for purpose	3	-	-
In terms of including the elements of entrepreneurship	2	1	-
In terms of including the dimensions of sustainable development	2	1	-
In terms of including integrated skills	3	-	-
In terms of including the competency areas required for integrated skills training	3	-	-
Training Framework			
In terms of containing PCK components	3	-	-
In terms of the scope and diversity of learning and teaching practices	2	1	-
Applicability (teacher and student characteristics, alignment with the curriculum, school context, etc.)	2	1	-

Model and training framework are related to the curriculum and suitable for a holistic educational structure. Developments like this, which contribute to the literature, are promising (E1).

The types of entrepreneurship in the model can be specified as social, commercial and eco-entrepreneurship. Associating entrepreneurship with solving sustainability issues is appropriate. The educational framework serves as a guide for those who will develop activities. In addition, it adequately includes the components of the curriculum. Different teaching methods and techniques can be integrated. The teacher who decides on the method needs to possess all these competencies. It is important to adapt this training to teachers' in-service needs (E2).

New dimensions of sustainability, such as technology, can also be added to the model. As it stands, it is quite comprehensive in terms of skills. The applicability of the training framework may vary depending on the time allocated for the targeted learning outcomes (E3).

When the experts' direct quotations are examined, it is seen that the experts suggest new components and dimensions could be added to the model. They also state that the training framework is applicable provided that the time allocated for the learning outcomes is adhered to. Experts who emphasize the importance of teacher competencies and entrepreneurship skills in learning and teaching practices also believe that the model and training framework will contribute to the field, as they are consistent with the holistic educational approach included in curricula and serve as a guide for educators.

4.2.2. Results from the pre-service teachers' opinions regarding educational practices developed in alignment with the model

The findings obtained through the analysis of the opinions expressed by the pre-service teachers regarding educational practices implemented in compliance with the model are presented in Table 5.

When Table 5 is examined, it appears that the pre-service teachers mostly found the educational practices appropriate in terms of "learner level, consistency with the curriculum and methods, techniques and evaluation". Some pre-service teachers stated that some practices need correction in terms of "comprehensibility and implementation duration". Moreover, in terms of the experience lived, most pre-service teachers found the implementation process efficient, while some noted difficulties. Pre-service teachers expressed various opinions regarding the educational practices. One participant stated, "The performance tasks and the questions in the activity should be easier" (PT1), while another suggested that "the prepared content should also include guidance on how planning should be done" (PT3). In addition, it was recommended that "the methods used

Table 5

Findings from the analysis of pre-service teachers' responses to the interview form

Theme	Category		
	Appropriate <i>f</i>	Needs correction <i>f</i>	Should be removed <i>f</i>
Appropriateness to the learner level	10	-	-
Comprehensibility for learner	7	3	-
Consistency with the curriculum	10	-	-
Compatibility with learning outcomes	10	-	-
Diversity of teaching methods	9	1	-
Suitability of measurement and evaluation method	10	-	-
Applicability (duration etc.)	5	4	1
	<i>Efficient</i>	<i>Challenging</i>	<i>No idea</i>
In terms of the experience lived	7	2	1

in the activity can be diversified; for example, group work techniques or argumentation can be added" (PT4). Some participants emphasized time-related issues, noting that "since the tasks are broad, additional time should be allocated for the activity" (PT5) and "completing the task within the specified time is difficult; therefore, removing similar activities is suggested" (PT6). Another participant mentioned, "we had difficulty preparing the work plan and identifying the problem, so providing a sample plan and a problem scenario beforehand would make it easier" (PT7). Despite these challenges, several pre-service teachers considered the process beneficial, remarking that "overall, it was a comprehensive and efficient activity that required creativity" (PT2, PT8, PT9, PT10).

When these opinions of the pre-service teachers are examined, it is seen that the activities need to be simplified in terms of duration and content and that example work plans, instructions and sustainability dimensions related to the activities should be provided more clearly. The changes made to the learning module activities after the pilot implementation, considering the opinions of the pre-service teachers, are as follows: The time allocated for activity implementations was revised and adjusted to fit within four weekly class hours. Accordingly, similar and time-consuming activities were designated as alternative activities, allowing teachers flexibility in their implementation. The argumentation method was incorporated into the activities. Disadvantages were also incorporated together with the data supporting the advantages of the topic to encourage discussion. Such activities were adapted for group work. Since the implementation process of the activity is explained in detail in the teacher's guidebooks, the student guides include shorter versions. Instructions indicating whether the activities should be carried out individually or in groups were also added. Unclear and difficult question statements were revised to be more understandable. In the business idea development activities, instead of providing students with a predefined problem, they were encouraged to discover sustainability-related issues.

5. Discussion and Conclusion

The current study focuses on the first two stages of a three-stage research project. In the first stage, a literature review was conducted to identify the dimensions of sustainability and entrepreneurship education. As a result of the literature review, a pedagogical model was developed for the holistic integration of sustainability into skills training and a training framework was proposed for the implementation of the model. In the second stage of the study, a pilot implementation of the educational activities developed in alignment with the training framework was conducted with pre-service science teachers.

Based on the importance of entrepreneurial activities for sustainable development in solving local and global crises, this study initially integrated entrepreneurial skills into the sustainability theme. Then, based on the findings of the literature review on sustainability-themed studies, the

aim was to define the “competency areas necessary to contribute to sustainability” as well as the “professional competency areas required for designing lessons focused on teaching sustainability”. Thus, it was decided that the model developed would be skill-oriented. Entrepreneurship skills, which are compatible with the nature of sustainability, were selected as the central skill area to be developed because they play a crucial role in solving sustainability problems and implementing sustainability initiatives.

The literature review revealed that models and training frameworks based on inquiry-based approaches (Elster, 2022), design thinking (Helmi & Herliani, 2021) and sustainable thought structures (Warren et al., 2014) have been developed for sustainability. According to Montes-Martínez and Ramírez-Montoya (2020), defining a pedagogical model that includes the development of entrepreneurial teacher skills is of fundamental importance for educational institutions. Therefore, the STIE-S model is original in that it places entrepreneurship skills at its core. Entrepreneurship skills alone are certainly not sufficient for the implementation of sustainability. Today, “skill-based sustainability education” emerges as a new field of study (e.g., Uslu, 2024). In this context, entrepreneurship skills must be effectively integrated with sustainability-related thinking and life skills. The skills integrated with entrepreneurship are domain-specific and sustainable living skills. Among the domain-specific skills are “scientific process, life, engineering design, and reasoning skills” (MoNE, 2018, 2024), while sustainable living skills include sustainability-specific systemic, strategic, futures-oriented and values-based thinking frameworks (Warren et al., 2014), as well as problem-solving, critical thinking and action-taking skills (Nolet, 2009). In a study examining teachers’ entrepreneurial behaviours for sustainability (Saygın et al., 2024), the importance of integrating entrepreneurship and creativity skills into sustainable educational practices is emphasized. In curricula, it is suggested that subject-area skills be integrated with literacy skills. The STIE-S model is also structured within an integrated skills education framework and is important both for being skill-oriented and for simultaneously encompassing sustainability and entrepreneurship.

The proposed model defines the personal and professional competency areas that pre-service teachers should possess for an effective integrated skills education process in sustainable development topics. The professional competency areas include skill-specific PCK, pedagogical entrepreneurship competencies and sustainability literacy, while the individual competency areas encompass literacy, entrepreneurship and integrated skills. The knowledge and understanding in the areas identified in the proposed model directly influence the pre-service teachers’ pedagogical entrepreneurship competencies and sustainability literacy, while these areas also interact with each other. In other words, in the proposed model, all the knowledge areas expected of the pre-service teachers interact, resulting in a holistic outcome.

Pedagogical models developed to date have revealed the knowledge domains that a teacher should possess, primarily focusing on traditional content knowledge and its instruction (e.g., Major & Palmer, 2002, 2006). Examining studies on developing topic-specific models reveals a model that defines the pedagogical knowledge domains a teacher must possess for teaching socio-scientific issues (Han Tosunoğlu & İrez, 2019). However, these models prove insufficient identifying the skill areas required for education in issues with a systematic and complex nature, such as sustainability. Therefore, the current study addresses a need in the literature by identifying the competency areas required for new-generation pre-service teachers to provide integrated skill instruction in sustainability themes.

As seen in the model, entrepreneurship is a central concept that influences and encompasses other model components in order to understand and implement sustainability because the entrepreneurship skills aimed to be developed include the following: “generating business ideas, securing financing, designing products, marketing and investing” (Tarhan, 2020). In the teaching of such skills, skill-specific PCK comes to the forefront. In research focused on the development of PCK conducted so far, the trend is moving from general PCK towards skill-specific PCK (Aydın Günbatar, 2019). A notable study in the literature focuses on the development of pre-service

teachers' PCK regarding the teaching of systems thinking skills, which are considered essential for sustainable development (Rosenkränzer et al., 2017). Building on this, E-PCK was identified as the core professional competency area of the model, specifically for teaching the entrepreneurship skills that are at the centre of the STIE-S model. The subcomponents of E-PCK were named in alignment with Magnusson's PCK components (1999).

In the teaching of entrepreneurship skills, entrepreneurship pedagogy gains importance. The uncertainty regarding how entrepreneurship skills should be developed within educational institutions has led to the emergence of the concept of "pedagogical entrepreneurship" (Peltonen, 2015). In order to equip students with entrepreneurial skills, it is necessary to establish an entrepreneurial and innovative school culture and learning environment, define the entrepreneurial roles of both teachers and students and design and implement an entrepreneurial curriculum (Gibb, 2011; Hannon, 2006). It is important that the educators have pedagogical entrepreneurship competencies, including "knowledge, attitude, subject matter expertise and pedagogical knowledge" in order to achieve the goals of skills-based education. Our STIE-S model supports all these components.

Within the STIE-S model, the thematic contexts in which competency areas are intended for identification and development were selected in alignment with the goals of sustainable development. These themes include "sustainable systems, environment, education, health, agriculture, technology, tourism, cities and transportation". Indeed, the literature suggests that entrepreneurship education should be given through integration into curricula, courses and subjects (Deveci, 2016; Tarhan, 2021; Uçar, 2020). Within this context, the training framework and learning-teaching activities developed in alignment with the model were structured around thematically determined sustainability topics. The incorporation of sustainability as a fundamental element in the science curriculum, along with the inclusion of units aimed at developing sustainability-related thinking and life skills, demonstrates that the model is highly compatible with the curriculum. Indeed, science teaching carried out through sustainability topics aims to train entrepreneurial individuals who have an understanding and awareness of sustainability, develop solutions to problems, act with social responsibility and contribute to national development through this awareness and experience (MoNE, 2024).

It is also important that the training of teachers and pre-service teachers is compatible with the curricula developed for preschool, primary, middle and high school levels since curricula prepared based on a holistic education approach include sustainability units on certain thematic topics. Among the integrated skill types listed under systems literacy, sustainability literacy stands out as especially important for achieving the learning outcomes of these units. The development of sustainability literacy skills, however, will only be possible with sustainability-literate teachers who actively implement these curricula. At this point, it is important that they possess cognitive, affective and behavioural characteristics at the levels of awareness, functionality and action. Therefore, in the model designed in the study, sustainability literacy is included with its dimensions and levels.

Sustainability literacy is also a concept related to different literacy skills. Since the STIE-S model is developed with a focus on sustainability and entrepreneurship, sustainability literacy is associated with financial, cultural, civic and ecological literacies. Furthermore, the social, environmental, economic, and cultural dimensions of sustainability in the model form the source of this association. In the literature, the model developed by Campbell et al. (2021) on sustainability literacy is limited to the environmental dimension of sustainability and critical media literacy. Similarly, the construction education curriculum design proposed by Cotgrave and Kokkarinen (2010) is limited to environmental topics. In the model developed in the current study, alongside the environmental dimension, the economic, social and cultural dimensions are described and the relationship between various types of literacy and sustainability literacy is emphasized. Indeed, findings in the literature, such as the association of cultural diversity and global citizenship goals with the socio-cultural, ecology, economy dimensions of sustainability

(Decamps, 2017; Özdemir, 2007) support the STIE-S model in terms of its association with different types of literacy.

The competency areas in the model have a general and flexible structure allowing them to be addressed both inside and outside of school environments. The key component in these learning and teaching practices is pre-service teachers who are the teachers of the future. Therefore, in the integrated skills teaching process, the knowledge areas that pre-service teachers must possess and how these knowledge areas are related to each other are important. Structuring learning and teaching during the integration process of entrepreneurship education is important in the Entrepreneurship and Education Integration Model (Paloniemi & Belt, 2015). In this context, a “training framework” aimed at developing the competency areas in the STIE-S model was designed in the study. The designed training framework consists of five dimensions: “content and context, learning outcomes, learner characteristics, learning and teaching practices and evaluation”. In the models and training frameworks developed for similar purposes in the literature, Qureshi (2020) proposes a model for teaching students sustainable living and developing sustainability literacy skills, which includes the dimensions of “content, process and outcomes”. Chinedu et al. (2023) identified four key curriculum components for sustainability literacy in vocational and technical education. These components are learning outcomes for sustainability literacy, teaching competencies, pedagogical approaches and instructional strategies. The sustainability pedagogy model proposed by Burns (2011) to develop sustainability literacy consists of the dimensions of content, process, perspective, and context. The graduate course program developed by Elster (2022) for sustainability literacy consists of four modules: knowledge, didactics, application and evaluation. The training framework developed in compliance with the STIE-S model includes all dimensions proposed in the literature.

The training framework with all its dimensions includes pedagogical practices that support the competency areas defined in the model. In other words, the training framework includes specific instructional methods aimed at developing skills integrated with entrepreneurship. In the literature, it is recommended that pre-service teachers engage with sustainability ideas to develop their sustainability literacy, focus on examples through case studies that demonstrate how sustainability education is implemented, follow learning materials such as articles and participate in out-of-school project activities (Nolet, 2009). Developing environmentally friendly skills and behaviours requires participatory and active teaching and learning methods. Pedagogical approaches that promote sustainability skills include project- and problem-based learning, collaborative, experiential, place-based, holistic and research-based learning, and critical discussion. These methods motivate students to take action regarding sustainability (Evans, 2019; Kollmuss & Agyeman, 2002; Seikkula-Leino et al., 2021). Moreover, among the commonly preferred instructional methods in entrepreneurship education are problem- and project-based learning, case-based learning, experiential learning, simulation games, guest speakers, field trips and observations and institutional visits (Rodrigues, 2023; Selanik Ay & Acar, 2016; Sirelkhatim & Gangi, 2015). The training framework developed in the current study includes these instructional methods recommended in the literature. As a result, the STIE-S model and the training framework are comprehensive.

The expert opinions received regarding the proposed model and the training framework in the study were found to be positive and it was concluded that they are appropriate and functional in terms of criteria such as clarity, applicability and consistency with the curriculum. This framework enables pre-service teachers to relate sustainability topics to real life, develop the knowledge, skills, attitudes and actions necessary to generate business ideas by solving local or global sustainability problems, apply their sustainability literacy skills in practice and assess their performance. Apart from these, considering expert recommendations, the suggestion to add new dimensions of sustainability, such as “technology,” as well as types of entrepreneurship (social, commercial, eco-entrepreneurship, etc.), has come to the forefront. It was decided to integrate into the model the sustainability dimensions highlighted in the literature- “economic, social,

environmental, and cultural.” Since a technology-themed one-week learning module was developed, the emphasis on technology in sustainability is addressed in depth within the activities of this learning module. Accordingly, the emphasis on technology in the model stands out in the teaching and learning practices section. In addition, entrepreneurship is included in the proposed model as a skill domain. This model, designed to develop entrepreneurship skills through sustainability topics in teacher education, incorporates pedagogical field competencies; therefore, the specific types of entrepreneurship mentioned in expert opinions were not included separately.

It is important to train teachers who will create a long-term impact on the future (Deveci & Seikkula-Leino, 2018). In this context, teacher education should be more greatly considered as a way to raise a new generation of entrepreneurs and sustainable thinkers, increase quality of life and welfare and implement global strategies (Seikkula-Leino et al., 2021). In this connection, in the second stage of the study, teaching-learning modules for the STIE-S model were designed for the teacher education program and a pilot implementation of one module was conducted with pre-service science teachers. Considering the views of pre-service teachers, it is emphasised that the activities need to be adjusted in terms of their feasibility for learners within the allocated time. The themes implemented in the pilot study- “sustainability, sustainable living spaces, and sustainable technologies”- are distinct learning modules consisting of various activities. Therefore, it was decided that each theme-specific learning module would be implemented weekly, with four class hours per week allocated to the activities in each module. However, it was observed that pre-service teachers experienced difficulties in implementing and understanding entrepreneurship-oriented activities that required technical knowledge, such as business planning and establishing an association. To address this, it was decided to provide pre-service teachers with exemplary resources demonstrating how to prepare a business plan or carry out association-establishment activities, and to encourage them to review these materials in advance. Accordingly, for activities requiring preliminary preparation, such as observation, interviews, and research, pre-service teachers will be expected to complete their preparations outside of school, enhance their readiness levels, and present their performance tasks in class. In line with another suggestion by the pre-service teachers, sustainability dimensions (social, environmental, economic, etc.) were explicitly integrated into the activity prompts. For the recommendation of making the activity instructions clearer, teacher guides were developed. Within this framework, explanations and directions for activity implementation will be provided by the instructor based on these guides. Moreover, contrary to the suggestions for removing similar activities from the learning modules, it was decided that the instructor would select appropriate and applicable activities among the similar ones, depending on factors such as “grade level, context, school characteristics, and student profiles.” At the same time, although pre-service teachers requested that a ready-made problem situation be provided when developing a business idea or solution proposal, considering the undergraduate level, they were instead expected to identify the problem themselves to recognise sustainability-related issues. One of the other important findings of the study is that the learning module, prepared in alignment with the model and training framework, was found to be effective and conducive by the pre-service science teachers in developing sustainability skills integrated with entrepreneurship and the competencies to impart these skills. In this context, the study is important for science education and sustainability literature with its processes of model design, implementation and evaluation.

6. Limitations and Implications for Future Research

The STIE-S model and training framework proposed in the study have a flexible structure. Although the model and training framework in this study are integrated with the theme of sustainability, researchers can adapt the model and framework to various sustainability topics across different disciplines, focusing on teaching different skills. The pedagogical approaches that promote the competency areas identified in the model can be diversified within the educational framework.

Pre-service teachers can use the STIE-S model to evaluate themselves regarding which knowledge and skill areas they need to possess in their teaching. The STIE-S model can be used to observe how the specified competencies change over time and can also be applied in studies aimed at developing assessment tools in this field.

The implementation of the STIE-S model and training framework is limited to a small number of pre-service teachers. The same model implementation can be repeated with a larger sample of in-service teachers. In addition, the model and training framework can be used as a guide for preparing and evaluating in-service training content and lesson plans for teachers.

Longitudinal studies can be conducted on the impact of the knowledge, skills and pedagogical practices offered by the STIE-S model and training framework in addressing global and local sustainability issues.

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Data Availability: Due to the qualitative nature of the research and to protect participant confidentiality, the datasets (e.g., interview transcripts and internal documents) are not publicly available. However, anonymized excerpts and additional methodological details are available from the corresponding author upon reasonable request.

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References

- Akyürek, Ç., & Şahin, Ç. (2013). Evaluation of elementary teachers' entrepreneurship skills. *EKEV Academy Journal*, 17(57), 51-68.
- Albareda-Tiana, S., Vidal-Raméntol, S., Pujol-Valls, M., & Fernández-Morilla, M. (2018). Holistic approaches to develop sustainability and research competencies in pre-service teacher training. *Sustainability*, 10(10), 3698. <https://doi.org/10.3390/su10103698>
- Anderson, T., & Shattuck, J. (2012). Design-based research: A decade of progress in education research? *Educational Researcher*, 41(1), 16-25. <https://doi.org/10.3102/0013189X11428813>
- Archambault, L., Hartwell, L., Frisk, E., & Hale, A. (2012, March). Developing sustainability literacy among preservice teachers through web-based learning. In P. Resta (Ed.), *Proceedings of Society for Information Technology & Teacher Education International Conference- SITE 2012* (pp. 83-87). Association for the Advancement of Computing in Education. <https://www.learntechlib.org/p/39542>.
- Aydın Günbatar, S. (2019). *Pedagojik alan bilgisinin kategorize edilmesi ve güncel çalışmalar* [Categorization of pedagogical content knowledge and current studies]. In Ş. Uluçmar Sağır (Ed.), *Teoriden uygulamaya pedagojik alan bilgisi* [Pedagogical content knowledge from theory to practice] (pp. 159-177). Pegem Academy.

- Bertschy, F., Künzli, C., & Lehmann, M. (2013). Teachers' competencies for the implementation of educational offers in the field of education for sustainable development. *Sustainability*, 5(12), 5067-5080. <https://doi.org/10.3390/su5125067>
- Besong, F., & Holland, C. (2015). The dispositions, abilities and behaviours (DAB) framework for profiling learners' sustainability competencies in higher education. *Journal of Teacher Education for Sustainability*, 17(1), 5-22. <https://doi.org/10.1515/jtes-2015-0001>
- Bianchi, G., Pisiotis, U., & Cabrera Giraldez, M. (2022). *GreenComp-The European sustainability competence framework*. European Training Foundation. https://openspace.etf.europa.eu/system/files/2022-03/Cabrera%20Giraldez_GreenComp_2.pdf
- Biberhofer, P., Lintner, C., Bernhardt, J., & Rieckmann, M. (2019). Facilitating work performance of sustainability-driven entrepreneurs through higher education: The relevance of competencies, values, worldviews and opportunities. *The International Journal of Entrepreneurship and Innovation*, 20(1), 21-38. <https://doi.org/10.1177/1465750318755881>
- Borg, C., Gericke, N., Höglund, H.O., & Bergman, E. (2012). The barriers encountered by teachers implementing education for sustainable development: Discipline bound differences and teaching traditions. *Research in Science & Technological Education*, 30(2), 185-207. <https://doi.org/10.1080/02635143.2012.699891>
- Brandt, J.O., Barth, M., Merritt, E., & Hale, A. (2021). A matter of connection: The 4 Cs of learning in pre-service teacher education for sustainability. *Journal of Cleaner Production*, 279, 123749. <https://doi.org/10.1016/j.jclepro.2020.123749>
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77-101. <https://doi.org/10.1191/1478088706qp0630a>
- Brundiers, K., Wiek, A., & Redman, C.L. (2010). Real-world learning opportunities in sustainability: from classroom into the real world. *International Journal of Sustainability in Higher Education*, 11(4), 308-324. <https://doi.org/10.1108/14676371011077540>
- Burns, H. (2011). Teaching for transformation: (Re)designing sustainability courses based on ecological principles. *Journal of Sustainability Education*, 2, 1-16. https://pdxscholar.library.pdx.edu/elp_fac/20/
- Campbell, C., Lacković, N., & Olteanu, A. (2021). A "strong" approach to sustainability literacy: Embodied ecology and media. *Philosophies*, 6(1), 14. <https://doi.org/10.3390/philosophies6010014>
- Cebrián, G., & Junyent, M. (2015). Competencies in education for sustainable development: Exploring the student teachers' views. *Sustainability*, 7(3), 2768-2786. <https://doi.org/10.3390/su7032768>
- Chinedu, C. C., Saleem, A., & Wan Muda, W. H. N. (2023). Teaching and learning approaches: Curriculum framework for sustainability literacy for technical and vocational teacher training programmes in Malaysia. *Sustainability*, 15(3), 2543. <https://doi.org/10.3390/su15032543>
- Combes, B. P. Y. (2005). The United Nations decade of education for sustainable development (2005-2014): Learning to live together sustainably. *Applied Environmental Education & Communication*, 4(3), 215-219. <https://doi.org/10.1080/15330150591004571>
- Cotgrave, A.J., & Kokkarinen, N. (2010). Developing a model promoting sustainability literacy through construction curriculum design. *Structural Survey*, 28(4), 266-280. <https://doi.org/10.1108/02630801011070975>
- Decamps, A. (2017). *Analysis of determinants of a measure of sustainability literacy*. Global Education Monitoring Report 2017/8, Accountability in education: Meeting our commitments. <https://unesdoc.unesco.org/ark:/48223/pf0000259581>
- Dempsey, N., Bramley, G., Power, S. & Brown, C. (2011). The social dimension of sustainable development: Defining urban social sustainability, *Sustainable development* 19(5), 289-300. <https://doi.org/10.1002/sd.417>
- Design-Based Research Collective. (2003). Design-based research: An emerging paradigm for educational inquiry. *Educational Researcher*, 32(1), 5-8. <https://doi.org/10.3102/0013189X032001005>
- Deveci, İ. (2016). *The development, implementation and evaluation of entrepreneurship training modules integrated with the middle school science curriculum* (Publication no. 445151) [Doctoral dissertation, Bursa Uludağ University]. Council of Higher Education Thesis Center.
- Deveci, İ., & Beşoluk, Ş. (2022). Disiplinlerarası fen öğretimi ve girişimcilik [Interdisciplinary science teaching and entrepreneurship]. In H.Ş. Ayvaci, & M. Ergun (Eds.). *Disiplinlerarası fen öğretimi* [Interdisciplinary science teaching] (pp. 116-143). Pegem Academy.
- Deveci, I., & Seikkula-Leino, J.A. (2018). Review of entrepreneurship education in teacher education. *Malaysian Journal of Learning and Instruction*, 15, 105-148. <https://doi.org/10.32890/mjli2018.15.1.5>

- Diepolder, C.S., Weitzel, H., & Huwer, J. (2021). Competence frameworks of sustainable entrepreneurship: A systematic review. *Sustainability*, 13(24), 13734. <https://doi.org/10.3390/su132413734>
- Elo, S., & Kyngäs, H. (2008). The qualitative content analysis process. *Journal of Advanced Nursing*, 62(1), 107–115. <https://doi.org/10.1111/j.1365-2648.2007.04569.x>
- Elster, D. (2022, July). Promoting sustainability literacy in science education. In L. Gomez Chova (Ed.), *Proceedings 14th International Conference on Education and New Learning Technologies* (pp. 181-187). IATED. <https://doi.org/10.21125/edulearn.2022.0059>
- European Commission. (2011). *Entrepreneurship education at school in Europe: National strategies, curricula and learning outcomes*. Eurydice, EU Publications Office. <https://data.europa.eu/doi/10.2797/80384>
- Evans, T.L. (2019). Competencies and pedagogies for sustainability education: A roadmap for sustainability studies program development in colleges and universities. *Sustainability*, 11(19), 5526. <https://doi.org/10.3390/su11195526>
- Fošner, A. (2025). Sustainability literacy as a key to a better future: A look at higher education. *Sustainability*, 17, 987. <https://doi.org/10.3390/su17030987>
- Foucrier, T., & Wiek, A. (2019). A process-oriented framework of competencies for sustainability entrepreneurship. *Sustainability*, 11(24), 7250. <https://doi.org/10.3390/su11247250>
- Fuchs, M. (2024). Green skills for sustainability transitions. *Geography Compass*, 18(10), e70003. <https://doi.org/10.1111/gec3.70003>
- Garcia-Rico, L., Martínez-Muñoz, L. F., Santos-Pastor, M. L., & Chiva-Bartoll, O. (2021). Service-learning in physical education teacher education: A pedagogical model towards sustainable development goals. *International Journal of Sustainability in Higher Education*, 22(4), 747-765. <https://doi.org/10.1108/IJSHE-09-2020-0325>
- Garg, A. (2015). Green marketing for sustainable development: An industry perspective. *Sustainable Development*, 23(5), 301-316. <https://doi.org/10.1002/sd.1592>
- Giangrande, N., White, R.M., East, M., Jackson, R., Clarke, T., Saloff-Coste, M., & Penha-Lopes, G. (2019). A competency framework to assess and activate education for sustainable development: Addressing the UN sustainable development goals 4.7 challenge. *Sustainability*, 11(10), 2832. <https://doi.org/10.3390/su11102832>
- Gibb, A. (2011). Concepts into practice: meeting the challenge of development of entrepreneurship educators around an innovative paradigm. *International Journal of Entrepreneurial Behaviour and Research*, 17(2), 146-65. <https://doi.org/10.1108/13552551111114914>
- Gupta, M., & Dharwal, M. (2022). Green entrepreneurship and sustainable development: A conceptual framework. *Materials Today: Proceedings*, 49, 3603-3606. <https://doi.org/10.1016/j.matpr.2021.08.148>
- Hall, J.K., Daneke, G.A., & Lenox, M.J. (2010). Sustainable development and entrepreneurship: Past contributions and future directions. *Journal of Business Venturing* 25(5), 439-448. <https://doi.org/10.1016/j.jbusvent.2010.01.002>
- Han Tosunoğlu, Ç., & İrez, S. (2019). A pedagogical model for teaching socioscientific issues. *Journal of Higher Education and Science*, 9(3), 384-401. <https://doi.org/10.5961/jhes.2019.340>
- Hannon, P.D. (2006). Teaching pigeons to dance: Sense and meaning in entrepreneurship education. *Education & Training*, 48(5), 296-308. <https://doi.org/10.1108/00400910610677018>
- Helmi, M.H., & Herliani, E. (2021). Developing sustainability literacy through STEM learning: A review. *SEAQIS Journal of Science Education*, 1(1), 36-43. <https://doi.org/10.58249/sjse.v1i1.23>
- Hermann, R.R., & Bossle, M.B. (2020). Bringing an entrepreneurial focus to sustainability education: A teaching framework based on content analysis. *Journal of Cleaner Production* 246, 119038. <https://doi.org/10.1016/j.jclepro.2019.119038>
- Horisch, J. (2016). Entrepreneurship as facilitator for sustainable development. *Administrative Sciences*, 6(1), 4. <https://doi.org/10.3390/admsci6010004>
- İnam, B.Ö. (2024). *Designing a program for education for sustainable development for teacher candidates* (Publication no. 905642) [Doctoral dissertation, Ankara University]. Council of Higher Education Thesis Center.
- Jegstad, K.M., & Sinnes, A.T. (2015). Chemistry teaching for the future: A model for secondary chemistry education for sustainable development. *International Journal of Science Education*, 37(4), 655-683. <https://doi.org/10.1080/09500693.2014.1003988>
- Kadji-Beltrán, C. (2024). Enhancing sustainability teaching competence in preschool teacher education using living labs. *Sustainability*, 16(7), 2781. <https://doi.org/10.3390/su16072781>

- Karaarslan, G. (2016). *Science teachers as ESD educators: An outdoor ESD model for developing systems thinking skills* (Publication no. 439199) [Doctoral dissertation, Middle East Technical University]. Council of Higher Education Thesis Center.
- Kirman Bilgin, A., & İnaltekin, T. (2022). Investigating the effectiveness of integrated entrepreneurship education. *Education and Science*, 47(210), 139-160. <http://dx.doi.org/10.15390/EB.2022.10888>
- Kocayigit, A. (2024). *The effect of entrepreneurship curriculum on the primary teachers' entrepreneurship tendencies* (Publication no. 895163) [Doctoral dissertation, Muğla Sıtkı Koçman University]. Council of Higher Education Thesis Center.
- Koçulu, A. (2024). *Development and implementation of the sustainable development goals unit: Exploring students' systems thinking skills and ethical reasoning* (Publication no. 883004) [Doctoral dissertation, Yıldız Technical University]. Council of Higher Education Thesis Center.
- Kollmuss, A., & Agyeman, J. (2002). Mind the gap: Why people act environmentally and what are the barriers to pro-environmental behaviour. *Environmental Education Research*, 8(3), 239-260. <https://doi.org/10.1080/13504620220145401>
- Lans, T., Blok, V., & Wesselink, R. (2014). Learning apart and together: Towards an integrated competence framework for sustainable entrepreneurship in higher education. *Journal of Cleaner Production*, 62, 37-47. <https://doi.org/10.1016/j.jclepro.2013.03.036>
- Laurie, R., Nonoyama-Tarumi, Y., Mckeown, R., & Hopkins, C. (2016). Contributions of education for sustainable development (ESD) to quality education: A synthesis of research. *Journal of Education for Sustainable development*, 10(2), 226-242. <https://doi.org/10.1177/0973408216661442>
- Lenziardi, R., Méxas, M. P., Lucas, M., & Sá, P. (2025). Enhancing teacher competences in education for sustainable development (ESD): A value-oriented framework. *Journal of Teacher Education for Sustainability*, 27(1), 6-32. <https://doi.org/10.2478/jtes-2025-0002>
- Lincoln, Y. & Guba, E. (1985). *Naturalistic inquiry: Establishing trustworthiness*. Beverly Hills.
- Lozano, R., Merrill, M.Y., Sammalisto, K., Ceulemans, K., & Lozano, F.J. (2017). Connecting competences and pedagogical approaches for sustainable development in higher education: A literature review and framework proposal. *Sustainability*, 9(10), 1889. <https://doi.org/10.3390/su9101889>
- Magnusson, S., Krajcik, J. & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining pedagogical content knowledge: The construct and its implications for science education* (pp. 95-132). Kluwer Academic.
- Major, C., & Palmer, B. (2002). Faculty knowledge of influences on student learning. *Peabody Journal of Education*, 77(3), 138-162. https://doi.org/10.1207/S15327930PJE7703_8
- Major, C.H. & Palmer, B. (2006). Reshaping teaching and learning: The transformation of faculty pedagogical content knowledge. *Higher Education*, 51, 619-647. <https://doi.org/10.1007/s10734-004-1391-2>
- McKenney, S., & Reeves, T. (2018). *Conducting educational design research*. Routledge.
- Merriam, S.B. (2009). *Qualitative research: A guide to design and implementation*. Jossey-Bass.
- Miles, M., & Huberman, A.M. (1994). *Qualitative data analysis: An expanded sourcebook*. Sage.
- Miles, M.B., Huberman, A.M., & Saldaña, J. (2014). *Qualitative data analysis: A methods sourcebook*. Sage.
- Mindt, L., & Rieckmann, M. (2017). Developing competencies for sustainability-driven entrepreneurship in higher education: A literature review on teaching and learning methods. *Teoría de la Educación*, 29(1), 129-159. <https://doi.org/10.14201/teoredu281>
- Ministry of National Education [MoNE]. (2018). *Fen bilimleri dersi öğretim programı (ilkokul ve ortaokul 3, 4, 5, 6, 7 ve 8. sınıflar)* [Science course curriculum primary and secondary school 3rd, 4th, 5th, 6th, 7th and 8th grades]. MoNe. <https://mufredat.meb.gov.tr/>
- Ministry of National Education [MoNE]. (2024). *Türkiye yüzyılı maarif modeli ortak metni* [Common text for Türkiye century education model curriculum]. <https://tymm.meb.gov.tr/ortak-metin>
- Mogensen, F., & Schnack, K. (2010). The action competence approach and the 'new' discourses of education for sustainable development, competence and quality criteria. *Environmental Education Research*, 16(1), 59-74. <https://doi.org/10.1080/13504620903504032>
- Montes-Martínez, R., & Ramírez-Montoya, M.S. (2020). Educational and social entrepreneurship of future teachers in the framework of open education and sustainable development. In F. J. García-Peñalvo (Ed.), *Eighth International Conference on Technological Ecosystems for Enhancing Multiculturality* (pp. 1020-1025). Association for Computing Machinery. <https://doi.org/10.1145/3434780.3436622>
- Murray, P.E., & Cotgrave, A.J. (2007). Sustainability literacy: The future paradigm for construction education?. *Structural survey*, 25(1), 7-23. <https://doi.org/10.1108/02630800710740949>

- Mwasalwiba, E.S. (2010). Entrepreneurship education: A review of its objectives, teaching methods, and impact indicators. *Education+Training*, 52(1), 20–47. <https://doi.org/10.1108/00400911011017663>
- Nolet, V. (2009). Preparing sustainability-literate teachers. *Teachers college record*, 111(2), 409–442. <https://doi.org/10.1177/016146810911100207>
- Orrill, C.H., Hannafin, M.J., & Glazer, E. M. (2003). Disciplined inquiry and the study of emerging technology. In D.H. Jonassen (Ed.), *Handbook of research for educational communications and technology* (pp. 335–353). Routledge.
- Özdemir, O. (2007). A new environmental education perspective: Education for sustainable development. *Education and Science*, 32(145), 23–39. <https://educationandscience.ted.org.tr/article/view/738>
- Paloniemi, K., & Belt, P. (2015). Mismatch in teachers' ontological conception of entrepreneurship education. In J. C. Sanchez-Garcia (Ed.), *Entrepreneurship education and training* (pp. 313–334). IntechOpen Textbooks.
- Paristiwati, M., Rahmawati, Y., Fitriani, E., Satrio, J.A., & Putri Hasibuan, N.A. (2022). Developing preservice chemistry teachers' engagement with sustainability education through an online project-based learning summer course program. *Sustainability*, 14(3), 1783. <https://doi.org/10.3390/su14031783>
- Patton, M.Q. (2015). *Qualitative research & evaluation methods: Integrating theory and practice*. Sage.
- Peltonen, K. (2015). How can teachers' entrepreneurial competences be developed? A collaborative learning perspective. *Education+Training*, 57(5), 492–511. <https://doi.org/10.1108/ET-03-2014-0033>
- Ploum, L., Blok, V., Lans, T., & Omta, O. (2017). Toward a validated competence framework for sustainable entrepreneurship. *Organization & environment*, 31(2), 113–132. <https://doi.org/10.1177/10860266176970>
- Presidency of Strategy and Budget. (2023). 12th development plan (2024–2028). <https://www.sbb.gov.tr/kalkinma-planlari/>
- Qureshi, S.M.Q. (2020). Learning by sustainable living to improve sustainability literacy. *International Journal of Sustainability in Higher Education*, 21(1), 161–178. <https://doi.org/10.1108/IJSHE-01-2019-0001>
- Rasmussen, A., & Nybye, N. (2013). Entrepreneurship education: Progression model. *Young Enterprise*, 25(3), 1–17. <https://www.ffe-ye.dk/media/44723/Progression-model-English.pdf>
- Redman, A., & Wiek, A. (2021). Competencies for advancing transformations towards sustainability. *Frontiers in Education*, 6, 1–11. <https://doi.org/10.3389/feduc.2021.785163>
- Reigeluth, C.M., & Frick, T.W. (1999). Formative research: A methodology for creating and improving design theories. In C.M. Reigeluth (Ed.), *Instructional-design theories and models* (pp. 633–651). Routledge.
- Rodrigues, A.L. (2023). Entrepreneurship education pedagogical approaches in higher education. *Education Sciences*, 13(9), 940. <https://doi.org/10.3390/educsci13090940>
- Rosenkränzer, F., Hörsch, C., Schuler, S., & Riess, W. (2017). Student teachers' pedagogical content knowledge for teaching systems thinking: Effects of different interventions. *International Journal of Science Education*, 39(14), 1932–1951. <https://doi.org/10.1080/09500693.2017.1362603>
- Sağdıç, A. (2013). *A closer look into Turkish elementary teachers regarding education for sustainable development* (Publication no. 350152) [Master's thesis, Middle East Technical University]. Council of Higher Education Thesis Center.
- Samanci, B. (2021). *Revealing third year prospective science teachers' professional and conceptual knowledge regarding entrepreneurship skill* (Publication no. 671041) [Master's thesis, Kafkas University]. Council of Higher Education Thesis Center.
- Saygın, M., Say, S., Öztürk, İ.Y., Gülden, B., & Kaplan, K. (2024). A step towards sustainable education: Does an entrepreneurial teacher nurture creativity? *Sustainability*, 16(18), 7948. <https://doi.org/10.3390/su16187948>
- Scherak, L., & Rieckmann, M. (2020). Developing ESD competences in higher education institutions-Staff training at the University of Vechta. *Sustainability*, 12(24), 10336. <https://doi.org/10.3390/su122410336>
- Seikkula-Leino, J., Jónsdóttir, S.R., Håkansson-Lindqvist, M., Westerberg, M., & Eriksson-Bergström, S. (2021). Responding to global challenges through education: entrepreneurial, sustainable, and pro-environmental education in Nordic teacher education curricula. *Sustainability*, 13, 12808. <https://doi.org/10.3390/su132212808>
- Selanik Ay, T., & Acar, Ş. (2016). Views of classroom teachers about the acquisition of entrepreneurial skills. *Electronic Journal of Social Sciences*, 15(58), 960–976. <https://doi.org/10.17755/esosder.258829>
- Şen, A.İ., & Oktay, Ö. (2023). Sürdürülebilir kalkınma hedefleri ışığında yükseköğretim ve STEM eğitimi [Higher education and STEM education in the light of sustainable development goals]. In U. Çevik, E. Şahin (Eds.), *Sürdürülebilir kalkınma ve STEM eğitimi* [Sustainable development and STEM education] (pp. 249–272). Nobel.

- Seto-Pamies, D., & Papaoikonomou, E. (2020). Sustainable development goals: A powerful framework for embedding ethics, CSR, and sustainability in management education. *Sustainability*, 12(5), 1762. <https://doi.org/10.3390/su12051762>
- Shepherd, D. A., & Patzelt, H. (2017). Researching entrepreneurs' role in sustainable development. In D.A. Shepherd, H. Patzelt (Eds.). *Trailblazing in entrepreneurship: Creating new paths for understanding the field* (pp. 149-179). Springer.
- Silverman, D. (2013). *Doing qualitative research: A practical handbook*. Sage.
- Sirelkhatim, F., & Gangi, Y. (2015). Entrepreneurship education: A systematic literature review of curricula contents and teaching methods. *Cogent Business & Management*, 2(1), 1052034. <https://doi.org/10.1080/23311975.2015.1052034>
- Sleurs, W. (2008). Competencies for ESD (education for sustainable development) teachers: A framework to integrate ESD in the curriculum of teacher training institutes. Comenius 2.1 CSCT-project. *American Psychologist*, 53(4), 449-455. https://ue4sd.glos.ac.uk/downloads/CSCT_Handbook_11_01_08.pdf
- Slišāne, A. (2023, March). Conceptualization of pedagogical entrepreneurship: Theory and results of qualitative research. In L. G. Chova, C. G. Martinez, & J. Lees (Eds.), *INTED Proceedings-17th International Technology, Education and Development Conference* (pp. 2856-2864). IATED. <https://doi.org/10.21125/inted.2023.0788>
- Sposab, K. & Rieckmann, M. (2024). Development of sustainability competencies in secondary school education: A scoping literature review. *Sustainability*, 16, 10228. <https://doi.org/10.3390/su162310228>
- Tarhan, M. (2020). *Girişimcilik pedagojisine giriş* [Introduction to entrepreneurship pedagogy]. Pegem Academy.
- Tarhan, M. (2021). *Girişimcilik becerisinin kazandırılmasında farklı yaklaşımlar* [Different approaches in the acquisition of entrepreneurship skills]. Nobel.
- Tittel, A., & Terzidis, O. (2020). Entrepreneurial competences revised: Developing a consolidated and categorized list of entrepreneurial competences. *Entrepreneurship Education*, 3(1), 1-35. <https://doi.org/10.1007/s41959-019-00021-4>
- Uçar, S. (2020). *Girişimcilik eğitimi temel eğitimden öğretmen eğitimine genel bakış* [Entrepreneurship education: An overview from primary education to teacher education]. Academician.
- United Nations [UN]. (2015). Transforming our world: The 2030 agenda for sustainable development. *Sustainable Development Goals*. <https://sustainabledevelopment.un.org/post2015/transformingourworld/publication>
- United Nations Economic Commission for Europe [UNECE]. (2011). *Learning for the future: Competences in education for sustainable development*. UNECE Steering Committee on Education for Sustainable Development. <https://unece.org/info/Environment-Policy/Education-for-Sustainable-Development/pub/3098>
- United Nations Education, Scientific, and Cultural Organization (UNESCO). (2020). *Education for sustainable development: A roadmap*. <https://doi.org/10.54675/YFRE1448>
- United Nations Education, Scientific, and Cultural Organization (UNESCO). (2025). *What do you need to know about education for sustainable development?* <https://www.unesco.org/en/sustainable-development/education/need-know>
- Uslu, S. (2024). *Acquisition of sustainable life skills through sustainability education* (Publication no. 865639) [Doctoral dissertation, Muğla Sıtkı Koçman University]. Council of Higher Education Thesis Center.
- Uslu, S., & Özdemir, O. (2023). Life skills framework for sustainability education. *The Journal of Buca Faculty of Education*, 57, 1996-2011. <https://doi.org/10.53444/deubefd.1302801>
- Vesterinen, M., & Ratinen, I. (2024). Sustainability competences in primary school education—a systematic literature review. *Environmental Education Research*, 30(1), 56-67. <https://doi.org/10.1080/13504622.2023.2170984>
- Warren, A., Archambault, L., & Foley, R.W. (2014). Sustainability education framework for teachers: Developing sustainability literacy through futures, values, systems, and strategic thinking. *Journal of Sustainability Education*, 6(4), 23-28. <https://susted.com/>
- Wiek, A., Withycombe, L., & Redman, C.L. (2011). Key competencies in sustainability: A reference framework for academic program development. *Sustainability Science*, 6, 203-218. <https://doi.org/10.1007/s11625-011-0132-6>
- Winter, J. & Cotton, D. (2012). Making the hidden curriculum visible: Sustainability literacy in higher education. *Environmental Education Research*, 18(6), 783-796. <https://doi.org/10.1080/13504622.2012.670207>

- Wyness, L., Jones, P., & Klapper, R. (2015). Sustainability: What the entrepreneurship educators think. *Education+ Training*, 57(8/9), 834-852. <https://doi.org/10.1108/ET-03-2015-0019>
- Yağmur, Z.İ. (2022). Examination of science teachers' subject matter and pedagogical content knowledge regarding sustainable development (Publication no. 784668) [Master's thesis, Düzce University]. Council of Higher Education Thesis Center.
- Zhang, T., Shaikh, Z. A., Yumashev, A. V., & Chląd, M. (2020). Applied model of e-learning in the framework of education for sustainable development. *Sustainability*, 12(16), 6420. <https://doi.org/10.3390/su12166420>

Appendix 1. Sample Activity and Activity Plan from the Learning Module

Activity Plan

Activity Name: We Are Establishing an Association on Sustainability!

Grade Level: Undergraduate

Purpose of the Activity: To raise awareness about entrepreneurship-focused sustainability practices, promote the dissemination of sustainable activities and gain various skills.

Learning Outcome: Prepares a work plan for establishing an entrepreneurial association in the field of sustainability.

Target Skills: Entrepreneurship (business idea, financing, design, promotion), integrated life skills (analytical, creative and innovative thinking, communication, and collaboration), sustainable life skills (values-based thinking, strategic thinking).

Dimensions of Sustainability: Environmental, socio-cultural

Components of Sustainability Literacy Processes: Awareness and functionality

Implementation Stages According to the STIE-S Model Educational Framework

Content and Context Stage: The theme of sustainability is determined. Based on the sustainability activities of international NGOs, the need to increase the number and dissemination of associations in our country that operate through civil initiatives and voluntary entrepreneurship is identified.

Learning Outcomes Stage: Learning outcomes for sustainability, skills, and literacy are determined.

Sustainability Learning Outcome: Gaining competence in accessing and understanding knowledge on sustainability (awareness level) and creating content for sustainability activities (functionality level).

Entrepreneurship-integrated Skills Outcome: Development in entrepreneurship, field-specific, and sustainable life skills.

Associated Literacies: Development of sustainability, cultural, and ecological literacy.

Learner Characteristics and Challenges Stage: The readiness and experiences of pre-service teachers in entrepreneurship and sustainability are explored through Q&A. While performing the association-establishing task, areas where pre-service teachers face difficulties are observed.

Teaching and Learning Practices Stage: The methods and techniques include project-based learning, cooperative learning, business planning, and Q&A.

Learning Evidence and Evaluation Stage: Self and peer assessment forms, an analytic rubric for the association-establishing performance task are used. In addition, reflective writing and interviews are recommended.

Through this sample implementation, pre-service teachers' sustainability literacy skills are evaluated at the levels of awareness and functionality in terms of creating sustainability activities. In addition, during the business planning process (cost analysis, team building, logo design, research, highlighting originality, and promotion), the development of entrepreneurship-specific domain knowledge and pedagogical content competencies (such as teaching methods and assessment knowledge) is monitored.

Sample Activity

We Are Establishing an Association on Sustainability!

Yesterday, while walking in the park, we ran into one of our professors from school. The professor, whose work on sustainability I've read, seemed a bit distracted. When I asked why, he said he was currently busy due to SUYED activities. Then he asked me, "Have you heard of SUYED?" With a surprised look, I could only say no. Smiling, he began to explain:

... I began to think about establishing an association. I realized that what we were writing remained limited to academic circles and students. However, sustainability should be an initiative that concerns the entire society and needs to be promoted across all segments. What we lack, I believe, is "voluntary and civil initiative". This gap was the trigger for the idea of founding an association in my country. Together with my student, we prepared the bylaws and established our association. It is called SUYED - the Association for Sustainable Life Education - the first voluntary civil organization in Turkey in this field. We need to work much more in this area. The more we increase our numbers and expand our impact, the better.

As can be understood, in the process of transitioning to sustainability in our country, we need to make progress through civil organizations to raise public awareness and spread sustainable practices. For this, important responsibilities fall on you young people. So, let's get to work!

Task 1: As a team, you will establish a new association focused on sustainability. After completing your task, you will present as a team. During the planning phase of establishing your association, pay attention to the following topics:

Work Plan for Establishing an Association

Name of the association:

Purpose of the establishment of the association:

Association members and their duties:

Incomes and expenses of the association:

Characteristics of the association:

Logo/brand of the association:

Strengths and weaknesses of the association:

Our commonalities with and differences from other associations:

Sustainability activities planned in the association (social, cultural, ecological, technological, and economic activities):

Task 2: You are required to prepare and present a short film/documentary introducing this association and its activities in order to increase your visibility on social media. Don't forget that the short film should emphasize your goals related to sustainability.

Note: Before starting the work plan, please examine as an example the website (<https://suyed.com.tr/>). Please note that you will be evaluated according to the criteria listed in the rubric below.

Association Project Evaluation Rubric

Criteria	Yes (3)	Partly (2)	No (1)	Explanation
Both tasks were completed on time.				
The project portfolio was submitted completely.				
All team members actively participated in the presentation.				
All stages of the business plan were clearly stated.				
The association project serves the purpose of sustainability.				
The association activities aim to raise public awareness.				
The association was promoted with an advertisement/introductory video.				
A project idea different from other associations was proposed.				
The promotional video includes original ideas.				