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Article

# Integrating Contemporary Technologies in Education: Empowering Youth for Sustainable Future through New Literacies

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**Abstract:** The quasi-experimental study examines the role of contemporary technologies, such as artificial intelligence and humanoid robots, in enhancing sustainability education for future teachers, emphasizing their impact on shaping sustainable beliefs in future generations. Involving 112 pre-service teachers, the research compares various contemporary and traditional learning methods. Pre- and post-test evaluations were conducted to assess changes in participants' understanding of sustainability concepts and the variability of their responses. Results reveal significant improvements in sustainability awareness, with methods involving humanoid robots showing higher response variability. The study also identifies the development of new literacies crucial for effectively utilizing advanced technologies in promoting environmental sustainability. While artificial intelligence and humanoid robots match the efficacy of traditional methods, they notably engage young educators more effectively in sustainability topics. These findings highlight the need to integrate such technologies into educational framework to deepen the understanding of environmental issues and prepare youth for future challenges. However, further research is required to explore long-term effects and broader demographics. The research contributes significantly to educational technology and sustainability in education, showcasing the transformative potential of incorporating contemporary technologies in educational settings.

**Keywords:** contemporary technology; education; empowering youth; humanoid robots; new literacies; sustainability

## 1. Introduction

The rise of the internet and advanced technologies, such as artificial intelligence (AI) and robotics, has radically transformed our approach to education and learning. This development not only offers young people new educational opportunities but also plays a crucial role in shaping a sustainability-oriented future, which is essential for the preservation of our planet. The capability of AI to stimulate human behavior (Duan et al., 2019), along with the increasing role of humanoid robots (HR) perceived as embodied social agents in education [4], signals a new era in teaching and learning. This approach to education not only enhances learning experiences but also enables young individuals to actively engage in complex discussions about sustainability and environmental protection. This article explores how advanced technology, including AI-driven platforms such as ChatGPT and HR, contributes to empowering youth for active participation in sustainability initiatives and developing the necessary skills and knowledge to confront future environmental challenges.

## 2. Advanced Technologies in Sustainability Education

In the context of sustainability education, advanced technologies such as AI and robotics enable young people to explore and understand the complexity of environmental challenges. Recent research underscores the significant role of AI and robotics in augmenting educational outcomes, enhancing the understanding of sustainability issues, and contributing to the achievement of the Sustainable Development Goals (SDGs). For instance, the role of AI in achieving the SDGs highlights both the potential benefits and drawbacks of AI in relation to society, economy, and environment, emphasizing the necessity for ethical considerations and democratic control in the development and application of AI technologies [34]. Additionally, the impact of robotics and autonomous systems on meeting the SDGs has been explored, revealing how these technologies could facilitate the achievement of SDGs through innovation and efficiency improvements, albeit with potential risks that need to be carefully managed [33]. Furthermore, a meta-analysis on the effectiveness of humanoid robots in improving learning outcomes provides evidence of a moderate but significantly positive effect of HR on students' learning outcomes, offering insights into how HR interventions can be beneficial in various educational settings [47].

Specifically, AI-driven chatbots have emerged as effective tools for engaging students in dialogues on intricate subjects, including those pertaining to environmental sustainability [25]. The application of HR in education, particularly those integrated with AI capabilities, presents a unique interactive experience [35]. Such technologies are adept at simulating human-like interactions, proving to be exceptionally beneficial in scenarios where engagement and personalized learning are pivotal. The use of HR in educational settings is an emerging field of study. These robots, often integrated with AI capabilities like those provided by ChatGPT, offer a unique interactive experience that can enhance learning about sustainable practices. Their ability to simulate human-like interactions makes them particularly effective in scenarios where engagement and personalization are crucial for learning outcomes.

The application of AI technologies in education has significantly impacted learners' understanding of sustainability issues. Studies such as those conducted by [34] on the role of AI in achieving the SDGs and the effectiveness of HR in improving learning outcomes [47] provide evidence of AI's potential to enhance educational outcomes and promote a deeper understanding of sustainability challenges. These technologies not only facilitate innovative educational approaches but also enable a more interactive and engaging learning environment that can lead to improved comprehension of complex sustainability issues.

For instance, AI can analyze and provide feedback on students' understanding of energy conservation practices, offering tailored advice and resources to deepen their knowledge [48]. Comparative research indicates that technology-enhanced learning methods, including the use of AI and robotics, often outperform traditional educational approaches in terms of student engagement, motivation, and learning outcomes, particularly in the context of sustainability education [21]. These studies [21,40] underscore the potential of integrating advanced technologies to better prepare students for addressing future learning challenges.

To bridge the gap between the potential of AI and robotics in environmental education (EE) and the practical application in classrooms, it's crucial to highlight the mechanisms through which these technologies facilitate learning. AI-driven platforms and HR offer dynamic, interactive experiences that can simulate real-world environmental challenges, making abstract concepts tangible. These technologies also enable personalized learning paths, adapting in real-time to the student's progress and understanding, thus enhancing engagement and efficacy. Furthermore, incorporating AI and robotics into curriculum design encourages a multidisciplinary approach, blending computer science, environmental studies, and critical thinking skills. This seamless integration of advanced technologies into education underscores the transformative potential of AI and robotics in crafting a more sustainable future, encouraging ongoing research and curriculum development to fully harness their educational benefits [32].

The integration of AI-driven platforms like ChatGPT and HR into EE has the potential to revolutionize how environmental topics are taught and learned. By leveraging the interactivity,

engagement, and personalization afforded by these technologies, educators can better prepare students to tackle future environmental challenges with innovative solutions. The promise of these technologies in enhancing sustainability education underscores the need for continued exploration and integration of advanced technologies in educational settings, thus avoiding that advanced technologies are simply added to other topics with being truly integrated [13].

AI and robotics not only enhance the understanding of sustainability topics but also establish new learning paradigms. Advanced technologies, such as AI and robotics, not only transform educational paradigms but also enable young people to develop innovative approaches to addressing environmental issues. The development of these technologies in education strengthens the capacity of young people to become leading innovators or sustainability initiatives. These interactive and personalized approaches are key to fostering deeper awareness and responsibility among the youth. This leads to the next critical element in sustainability education, the role of EE, which also emphasizes the importance of deeper understanding and responsible action, but through a different approach.

### **3. Literacies for Integrating Advanced Technologies in Education**

In a world where technology is constantly advancing, new forms of literacy enable young people to effectively tackle technological and environmental challenges. These new literacies include understanding and utilizing advanced technologies, which are crucial for empowering youth in developing and implementing sustainable strategies. With the evolution of new technologies, there has emerged a spectrum of new literacies [5,31], bringing forth questions that extend beyond the traditional definition of literacy [41]. These literacies are not limited to traditional forms of communication but encompass diverse forms of expression and understanding necessary in an interactive, connected, and multimedia-rich world. Modern media enable readers to become lifelong learners and engage in global competition [28]. These new forms of literacy include not only the ability to read and write but also the capacity to comprehend, utilize, and critically evaluate a variety of information and communication technologies. This approach to literacy paves the way for more comprehensive and adaptable learning, essential for successful navigation in an ever-changing technological environment [10], necessitating new methods, environments, and assessment methods in educational settings [37].

The primary goal of new literacies is to better prepare learners for a society with few constants and involving artifacts, social interactions, procedures, routines, and practices that are almost unimaginable today. Examining emerging literacies provides helpful steppingstones for considering how and why current literacy practices are evolving and new ones are appearing now, as well as why some are staling the same and what can be done about it [23]. Such new literacies are characterized as flexible, multimodal, and consistent with social behaviors in all places, times, and dimensions [9].

The concept of new technologies is formulated to align with the evolution of contemporary technologies [10]. Emerging literacies directly related to interaction with advanced technologies such as AI and HR. These technologies require understanding and skills that surpass traditional knowledge, and in an environment where technological innovations have become commonplace, new literacies have become crucial for successful individual functioning in society. They have become necessary and essential in the learning and teaching process. The ability to use and understand contemporary technologies is no longer just an additional skill but a fundamental tool for acquiring, analyzing and applying knowledge. Therefore, new literacies have become the foundation for developing the ability to solve complex problems and exercise critical judgment, particularly important in the context of preparing youth for future challenges, where they will need to effectively use technology while maintaining a critical and ethical perspective.

In the context of new literacies, it is imperative that educational systems respond to the challenges and opportunities brought by contemporary technologies. The European Commission, in response to these needs, has developed the Digital Competence Framework for Citizens (DigComp), which comprehensively outlines the key skills and knowledge required for effective use of digital technologies [46]. The DigComp framework identifies five essential areas of digital competence:

information and data literacy, communication and collaboration, digital content creation, safety, and problem solving. This framework details the competencies necessary for successful and competent functioning in a digitally transformed world, aligning with the concept of new literacies that promote adaptability, multimodality, and consistency with social behaviors. These new approaches to literacy lay the groundwork for developing the ability to address complex problems and exercise critical judgment, which is especially vital in preparing young people for future challenges where they must effectively use technology while maintaining a critical and ethical perspective.

Educational technologies, such as AI-driven platforms and HR, can serve as key tools in developing these literacies. By integrating these technologies into educational processes, we not only improve the accessibility and quality of learning but also equip young individuals with the skills necessary for active participation in addressing global environmental challenges. It is particularly important that these technologies are utilized in a manner that promotes critical thinking, creativity, and ethical awareness, thereby shaping youth not only as technologically proficient individuals but also as responsible citizens capable of creating a sustainable future. This paper explores key questions related to the effectiveness and effect of advanced technologies in youth education, with a special focus on young preservice teachers, in shaping sustainable practices and awareness.

#### **4. Advanced Technologies in Environmental Education**

Advanced technologies and environmental education (EE) together form a powerful tool for empowering youth to become key players in sustainable development. While advanced technologies, such as AI and robotics, provide innovative methods for learning about sustainability, EE focuses on developing a deeper understanding of the impacts of human behavior on the environment and the significance of long-term environmental responsibility. This combination of approaches – advanced technologies together with traditional and innovative educational strategies – shapes a comprehensive approach to teaching and learning about sustainability. Amidst the global changes taking place in the world and the growing awareness that we have only one planet to protect and preserve for human life, there has been a recent and growing shift in the research on environmental sustainability, while it is important to remember that efforts to integrate environmental awareness into education have been present for more than 50 years [19]. Many are aware of the need to include such topics in the school curriculum. This has led to the emergence in recent decades of so-called *environmental education* (EE), which has become a major area within the curriculum at a time when we are becoming increasingly aware of the impact of people's actions on the planet. EE is a specific type of education that links the changing concern for the environment (where it also refers to issues related to environmental care) and the way we define and promote EE. An important aspect of such education, which has gained prominence particularly in recent years, is the growing concern about events related to human behavior and impacts on the environment. Support for an educational approach such as EE has therefore increased [20]. This is also important because EE does not only address aspects of immediate environmental improvement but is also concerned with improvement in the long term, which is particularly important if we are to produce responsible individuals who will treat the environment in which they live in a good way. This is especially significant when discussing environmental content because current environmental issues not only present a compelling chance to alter education and the way that humans interact with the natural world, but they also necessitate further study in order to find a lasting solution [7,43].

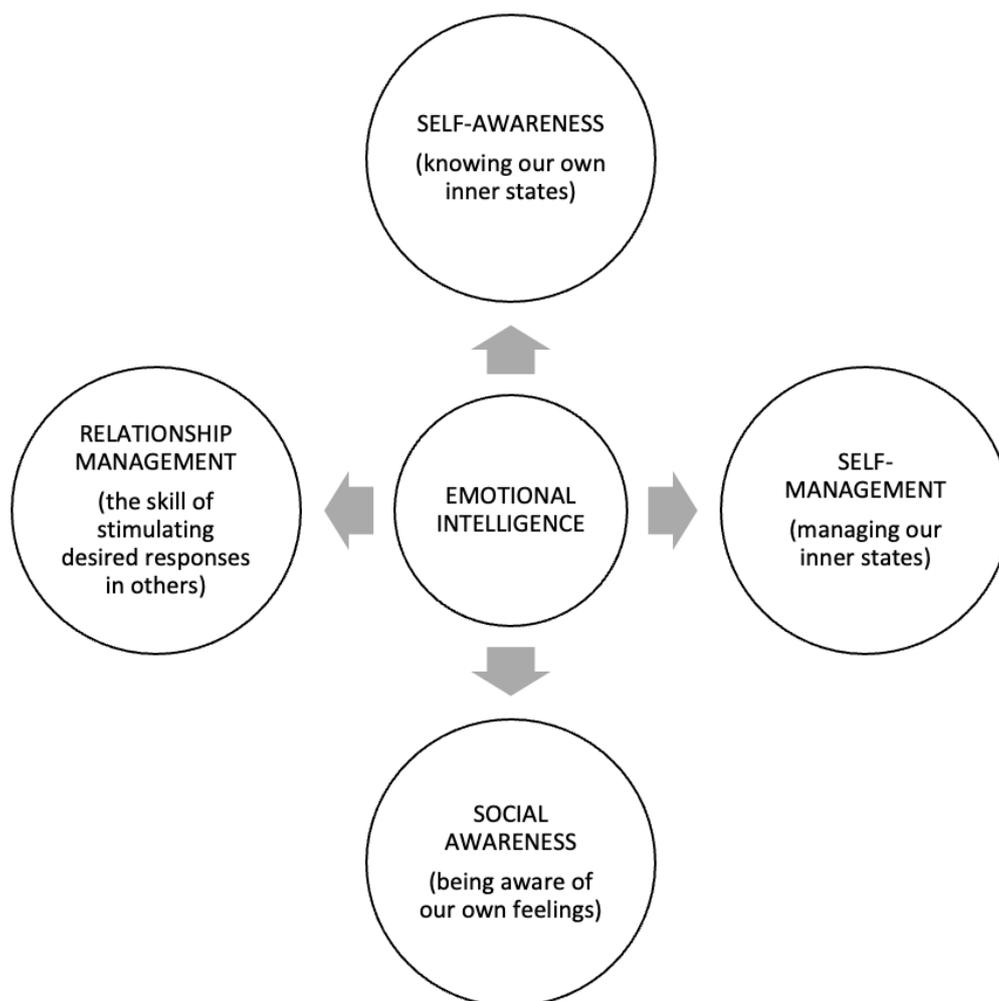
Considering the significant integration of contemporary technologies into education, learning strategies have evolved, showing a marked shift towards exploratory and problem-based learning. These types of teaching methods are particularly suitable for teaching about environmental issues, sustainability and promoting environmental awareness [2]. Education fundamentally emphasizes the importance of knowledge acquisition, but in modern learning environments, the development of social competences is also increasingly important. These should play a key role in promoting environmental awareness if we are to change people's consciousness. The key question is whether these competences can be increased [18]. With the emergence of new forms and methods of teaching and learning, we have moved towards a learner-centered approach. Instruction is more

individualized and tailored to the individual, which can be a key difficulty in promoting the wider importance of environmental awareness. This is because differentiation of teaching reduces social skills, which, alongside social awareness, are key to the field of environmental issues [1,6,44].

If we want to promote environmental awareness among younger people, we need to understand the concept of proprioception. It is a field that deals with the self-observation of people's thoughts, which leads us to a point of self-awareness. In practice, this means that through proprioception, people are able to perceive their own movement or become aware of it. When people are able to do this, it means that we are also able to change our own mindset and our own actions, and this is particularly crucial in changing people's environmental awareness and promoting the perception that we can do the most to save the planet. Proprioception can be used to change individual consciousness. In fact, we can achieve a different, specific way of thinking, which is key in environmental awareness [1].

Proprioception (Figure 1) is also inextricably linked to emotional intelligence, which can play an important role in topics such as environmental awareness and sustainability. Emotional intelligence is inextricably linked to four factors: *self-awareness* (knowledge of one's own internal states), *self-management* (managing our internal states), *social awareness* (awareness of one's own feelings), and *relationship management* (the skill of encouraging desired responses in others) [18], where it is important to realize that it makes sense to start the process of proprioception stimulation at as young an age as possible.

The SDGs may be significantly influenced in a good way by young people. They make up around 30 % of the global population, and long-term prosperity depends heavily on their involvement in local affairs and the ensuing impact they have. Senior decision-makers have consistently disregarded the significance of youth empowerment and inclusion, and youngsters have been disregarded across the board in the socio-political and economic spheres. This necessitates a careful analysis of how to give young people the credit they deserve by allowing them to actively participate in decision-making at all pertinent levels, keeping in mind that these choices have an impact on both their present and future lives [39]. School can be the place to achieve this, as the educational process starts at a younger age (around 6 years old). It is therefore important to start EE in the lower grades of primary school. It would make sense to include EE-related topics in the school curriculum already then. Given these insights, it becomes particularly crucial to educate young, future educators, who will teach in the lower grades of primary school, and who are in the process of learning and sharing their future teaching philosophies. Educating these aspiring teachers about sustainability and environmental issues in the context of contemporary educational environment engages them as key stakeholders in this field. This approach integrates modern technologies and focus on the capability of emotional intelligence of the youngest participants in education, which can play a significant role in fostering pro-environmental attitudes among young people [3,38].



**Figure 1.** Emotional intelligence, as part of proprioception, plays an important role in promoting environmental awareness.

## 5. Research Objectives

This study aims to evaluate the effectiveness of contemporary educational technologies in enhancing young people's understanding of environmental sustainability, with a particular focus on young future teachers. The study focuses on identifying the effects of integrating contemporary technologies versus traditional educational approaches on sustainability-related learning outcomes. The aim is to ascertain the effect of such educational tools in shaping environmental awareness and pedagogical strategies among young future educators, with an emphasis on identifying crucial new literacies vital for the effective utilization of advanced technologies in empowering youth towards a sustainable future.

To gain a comprehensive understanding, the following research questions were formulated:

RQ1: How effective are advanced technologies, including generative language models, humanoid robots, and online information searching, compared to traditional learning methods like book study, lecture-based teaching, and peer discussion, in enhancing young people's awareness of their contributions to environmental sustainability and the creation of a sustainable future?

RQ2: What effects do various learning methods have on the variability of responses among young individuals, especially future teachers, in terms of their ability to shape and transmit sustainable values and practices, and what role do advanced technologies play in this?

RQ3: Which specific new literacies, knowledge, skills and attitudes are essential for young individuals, particularly young future educators, to successfully utilize advanced technologies in contributing to environmental sustainability and shaping a sustainable future?

## 6. Materials and Methods

The subsequent sections elaborate on the study's methodology to provide a clear understanding of the sustainability education research.

### 6.1. Study Participants and Procedure

The sample for the study is purposive and convenience-based, consisting of pre-service teachers aged 19 to 24 years, enrolled in the Elementary Education program at the Faculty of Education of one of the Slovenian universities. The selection of a sample of young future teachers is of crucial importance for understanding the impact of advanced technologies in education about sustainability. Their unique role as mediators of knowledge and influencers on future generations makes their perspectives and experiences extremely important for research and development of sustainable educational strategies. Understanding how these technologies affect their awareness and readiness to lead sustainable initiatives is essential for designing effective approaches to empower youth for a sustainable future. The study engaged 112 participants, with 95 actively exploring sustainable practices, while 17 participants withdrew, citing either a lack of interest in sustainability or resistance to integrating new technologies in education.

The quasi-experimental study [12] was grounded in the integration of new technologies in research-based learning on the topic of sustainability. Both qualitative and quantitative research methods were employed based on the results. Prior to the intervention, participants individually responded to an open-ended question: "How can I contribute to improving environmental sustainability?". This was followed by group work, where participants explored the research question in six different ways, while the control group did not explore the topic.

Participants were divided into seven groups within the study program, each group comprising approximately an equal number of individuals. Within these groups, participants were further randomly assigned into pairs or trios, based on their method of researching the theme of sustainability. Participants were limited to 15 minutes to explore the topic. For clarity, the breakdown of tasks and groups is presented in the form of a table (Table 1).

**Table 1.** Participant Allocation by Research Method with Detailed Group Instructions.

Research Method	Group Instruction	N (groups)	N (participants)
ChatGPT 3.5*	Use ChatGPT to explore how you can contribute to improving environmental sustainability. Be curious, ask questions, and look for new ideas. Consider the potential solutions and approaches suggested by ChatGPT, and critically evaluate them. Reflect on how the chatbot's feedback can contribute to your impact on environmental sustainability.	6	17
Humanoid Robot*	Explore the theme using a humanoid robot integrated with ChatGPT 3.5. First, familiarize yourself with the robot's operation, then ask it questions to explore how you can improve environmental sustainability. Be curious and look for new ideas. Reflect on how the robot's feedback can contribute to your impact on environmental sustainability. Critically evaluate the information obtained.	6	17

Google**	Use Google as your primary research tool to explore how you can contribute to improving environmental sustainability. When searching for information, use the internet reciprocal teaching method. Ensure to verify the credibility of sources, and compare different views on sustainability. Reflect on how the gathered information can contribute to your impact on environmental sustainability.	6	17
Books Available in School Library	Borrow books in the school library to explore how you can contribute to improving environmental sustainability. Conduct an in-depth study and explore different aspects of sustainability. Reflect on how the gathered information can contribute to your impact on environmental sustainability.	5	15
Frontal Teaching Method	Participate in the class where I, as the teacher, will present the theoretical foundations. Engage actively, think critically, and stay focused on the topic.	6	17
Group Exploration Through peer Discussion	Explore the theme of sustainability through conversation and discussion. Share your experiences and ideas, encourage creative thinking, and exchange opinions to gain new insights, without using technological tools. Reflect on how the new information can contribute to your impact on environmental sustainability.	6	15
Control Group	As part of the control group, you will not directly explore the theme of sustainability. Instead, during the research period, engage in other activities that are independent of the theme of sustainability and new technologies.	6	15

\*The groups possess knowledge and skills for working with chatbots [22]. \*\* Participants are familiar with the method from their regular academic obligations. The Internet Reciprocal Method was developed by [26].

This study leverages the AlphaMini robot, integrated with OpenAI's ChatGPT, as a cutting-edge tool for sustainability education. The AlphaMini, known for its humanoid design and capability to engage in complex interactions, was enhanced with four key AI models to facilitate a seamless educational experience in the Slovenian language. These models include speech synthesis, speech recognition, a chatbot interface for ChatGPT integration, and voice activity detection. Each component plays a crucial role in enabling the robot to understand and communicate effectively with users, thereby making sustainability education more interactive and engaging. The speech synthesis model allows the AlphaMini to articulate responses in clear, natural Slovenian, making the educational content accessible and understandable. Concurrently, the speech recognition model enables the robot to accurately interpret spoken Slovenian, ensuring a smooth two-way communication flow. These models are foundational for creating an interactive learning environment where participants can freely converse with the robot about sustainability topics. By integrating the chatbot functionality with ChatGPT, the AlphaMini was equipped to engage in detailed discussions about sustainable energy. This setup allowed the robot to access a vast repository of information on sustainability, which it could then communicate in an educational context. The integration facilitates dynamic, informative conversations, where learners can ask complex questions and receive knowledgeable answers that foster a deeper understanding of sustainability. The voice activity detection model is crucial for the robot to identify when a participant is speaking, allowing for more

natural and responsive interactions. This technology ensures that the AlphaMini can recognize speech inputs accurately, minimizing errors and enhancing the overall user experience. The customization of the AlphaMini with these AI models enabled it to function as an effective educational tool, particularly in the context of sustainability education. The robot's ability to understand and speak Slovenian opened up new possibilities for engaging young learners in discussions about sustainable energy practices. Through interactive dialogues, the AlphaMini could convey complex concepts in an accessible manner, encouraging learners to think critically about their environmental impact and the importance of sustainable practices. This innovative educational approach underscores the potential of integrating advanced technologies, like ChatGPT with humanoid robots, to foster engaging, informative, and impactful learning experiences. By leveraging the AlphaMini robot and custom AI technologies, this study offers insights into using technology to promote sustainable energy awareness among young learners.

After completing the research phase, where participants employed various methods to study the theme of sustainability, they were asked to respond again to the initial question: *"How can I contribute to improving environmental sustainability?"*. This repeated reflection was crucial for assessing how different research methods effected the participants' understanding and perception of sustainable practices. Analyzing the responses provided insight into how educational strategies and the use of various tools contribute to the development of knowledge and awareness of environmental issues. Additionally, it enabled the evaluation of the effectiveness of new technologies methods in promoting critical thinking and active engagement of participants in the topic of sustainability.

During the research process, four researchers conducted systematic observations to assess the role of 21 competences, defined by [46] in the Digital Competence Framework for Citizens. The DigCompEdu model has already proven to be useful for the scientific analysis of digital competencies [11]. These observations took place in an educational setting where participants worked with various advanced and traditional learning methods. The researchers utilized qualitative observation techniques and note-taking to document the interactions of participants with educational tools. A particular focus was placed on observing if and how individual employed basic knowledge, skills and attitudes according to DigiComp 2.2. The process of researchers' observation involved a thorough analysis of the observations and recorded notes, enabling the researchers to assess which specific competences participants utilized in their work. The findings from these observations were then systematized and quantified in the form of table showing a cross-section of all skills identified by all participating researchers, showcasing the usage of different types of knowledges, skills and attitudes according to the chosen learning or teaching methods. The table includes a detailed analysis of the application of individual competences across various modes of work. In addition to observing which competencies participants developed, the study also focused on the extent to which these identified competencies were represented. The competencies according to the DigComp 2.2 framework encompass elements that can be fully developed in digital environments. However, certain knowledge, skills, and attitudes can also be partly cultivated in analog learning environments. In such cases, the competencies are not referred to as defined by DigComp 2.2, but rather to basic or foundational knowledge skills, and attitudes. These foundational elements, although not specifically digital, lay the groundwork for the further development towards fully-fledged digital competencies. Understanding and developing these fundamental elements is crucial for bridging the gap between analog and digital learning, thus facilitating a more holistic and balanced educational experience.

## 6.2. Measures

In line with the main goal of the research, a written method was used for data collection, where participants responded to a pre-prepared question on a paper, both before and after the intervention. The collected responses were then analyzed to understand the effect of various technological approaches and traditional methods on the sustainability practices and awareness of young people and to examine the effects of different methods on the variability of participants' responses.

The responses received were classified within the following categories:

- Carbon footprint reduction (use of public transport, walking, cycling, reducing car usage, use of electric vehicles).
- Sustainable usage and recycling (recycling of waste, use of products for multiple uses, reducing plastic usage, buying second-hand clothes).
- Resource conservation (saving water and electricity, turning off lights, closing water during tooth brushing).
- Sustainable food and agriculture (buying locally produced food, growing own food, using natural fertilizers, reducing meat consumption).
- Awareness and education (educating others about sustainability, training on sustainability topics, participating in cleaning actions, supporting sustainable organizations).
- Energy efficiency and renewable sources (using renewable energy sources, energy-efficient devices, digitalization to reduce paper usage).
- Sustainable waste management (composting, proper waste segregation, reducing food waste).

Once categorized, responses were analyzed to determine common themes and variances in participants' understanding of sustainability. This analysis was instrumental in identifying the effect of different learning methods on participants' perceptions and knowledge.

Through a process of observation, the researchers identified new literacies, knowledge, skills and attitudes are essential to successfully utilize contemporary technologies in contributing to environmental sustainability and shaping a sustainable future. The observed knowledge, skills and attitudes are identified in Table 2 based on the definition of [46].

**Table 2.** Knowledge, Skills and Attitudes According to Key Components of Digital Competence\*.

Information and data literacy	Communication and collaboration	Digital content creation	Safety	Problem solving
Browsing, searching, and filtering data, information and digital content <sup>(1)</sup>	Interacting through digital technologies <sup>(4)</sup>	Developing digital content <sup>(10)</sup>	Protecting devices <sup>(14)</sup>	Solving technological problems <sup>(18)</sup>
Evaluating data, information and digital content <sup>(2)</sup>	Sharing through digital technologies <sup>(5)</sup>	Integrating and re-elaborating digital content <sup>(11)</sup>	Protecting personal data and privacy <sup>(15)</sup>	Identifying needs and technological responses <sup>(19)</sup>
Managing data, information and digital content <sup>(3)</sup>	Engaging in citizenship through digital technologies <sup>(6)</sup>	Copyright and licenses <sup>(12)</sup>	Protecting health and well-being <sup>(16)</sup>	Creatively using digital technologies <sup>(20)</sup>
	Collaborating through digital technologies <sup>(7)</sup> Netiquette <sup>(8)</sup> Managing digital identity <sup>(9)</sup>	Programming <sup>(13)</sup>	Protecting the environment <sup>(17)</sup>	Identifying digital competence gaps <sup>(21)</sup>

\*Specific knowledge, skills and attitudes are numbered to show the results in Table 11.

The study assessed both comprehensive competencies developed in digital environments as per the DigComp 2.2 framework and fundamental knowledge, skills and attitudes cultivated in analog settings, laying the groundwork for a nuanced understanding of educational measures in both digital and analog learning contexts. Accordingly, the study introduced two distinct measures, with 'fundamental' covering fundamental knowledge, skills, and attitudes developed in analog learning environments and 'comprehensive' focusing on specific digital competencies outlined in the DigComp 2.2 framework [46].

### 6.3. Data Analysis

Responses were gathered immediately before and after the intervention to assess the change in participants' perspectives. Each response was anonymized and logged into a secure database for analysis. It was ensured that the anonymity of responses was maintained throughout the study to uphold ethical standards and participant confidentiality. Prior to the analysis, the obtained responses were reviewed and, where necessary, further anonymized, thereby maintaining the integrity and confidentiality of the collected information. The responses were organized according to the research method employed by each group. Subsequently, the responses were categorized into different categories based on the given answers. This process of qualitative coding involved assigning individual text segments to relevant categories, which facilitated the identification of patterns and themes. The data were quantified, providing a statistical foundation for the findings.

To compare differences in pre- and post-test results based on the participants' work methods, a repeated measures ANOVA was used due to its suitability for comparing the same participants across different conditions over time. This was crucial to understand how participants' perceptions evolved pre- and post-intervention. In the analysis of within-subject effects, the Greenhouse-Geisser correction was used to adjust degrees of freedom in the F-test. This was a crucial adjustment to account for potential violations of sphericity in the repeated measures ANOVA, thereby assuring the accuracy of p-values and the reliability of conclusions. The Bonferroni test was chosen for its conservative nature in correcting for multiple comparisons, thereby reducing the likelihood of false positive findings.

To discern specific differences among various research methods following the ANOVA, a post-hoc Tukey HSD (Honestly Significant Difference) test was used for pairwise comparisons between groups when ANOVA indicated significant differences. It was used to control the Type I error rate across multiple comparisons. The Tukey HSD test provided mean differences, standard errors, significance levels, and 95% confidence intervals for each pair of research methods. This approach was crucial in identifying statistically significant differences between specific pairs of research methods, ensuring the conclusions drawn from these comparisons were statistically sound.

Building on the systematic observations conducted by the researchers, the subsequent data analysis process was meticulously structured to ensure the integrity and validity of the findings. Following the completion of the observation phase, the researchers embarked on a comprehensive coding procedure. This involved categorizing the data based on the key components of digital competence (Table 2). The coding process was guided by predefined criteria aimed at identifying distinct patterns of components of digital competence use among the participants. A thematic analysis was conducted on the coded data to extract meaningful insights. This allowed for the identification of prevalent trends and unique instances of literacy usage, providing a nuanced understanding of how different literacies were applied in various educational contexts. The quantification of these findings was carefully executed to maintain statistical rigor. Frequency analysis was used to determine the prevalence of each literacy type across different learning methods, and cross-tabulation helped in understanding the relationships between observed knowledge, skills, and attitudes. The final step involved the synthesis of these quantitative insights into a comprehensive table, which effectively illustrates the spectrum of observed components of digital competence in diverse educational settings. This table serves as a visual representation of the complex interplay between advanced teaching tools and the development of new literacies among youth, thus contributing valuable empirical evidence to the field of educational technology and sustainability education.

## 7. Results

In this chapter the results of the study are presented, focusing on the different effects of various learning methods on participants' comprehension and application of environmental sustainability concepts.

### 7.1. Comparative Analysis of Pretest and Posttest Scores Across Learning Methods

To assess how different learning strategies affect participants' understanding and application of environmental sustainability, the analysis is centered around the comparison of diverse educational approaches, encompassing contemporary technologies as well as conventional methodologies including book study and frontal teaching. Utilizing ANOVA, this part of the research seeks to unravel the subtleties in learning outcomes attributed to these distinct pedagogical strategies. The emphasis is laid on discerning the effectiveness and influence of each method, aiming to provide a comprehensive understanding of their role in fostering participants' understanding of sustainability (Table 3).

**Table 3.** Mean Scores and Standard Deviations by Learning Method for Pretest and Posttest.

Test	Source of learning	Mean	Std. Deviation	N
Pretest	ChatGPT	4.00	.756	15
	Humanoid Robot	4.31	1.195	16
	Google	4.36	1.598	14
	Books	3.91	1.044	11
	Peer Discussion	3.50	1.834	12
	Frontal Teaching	3.60	1.404	15
	Control Group	4.50	1.834	12
	Total	4.03	1.410	95
Posttest	ChatGPT	9.93	2.915	15
	Humanoid Robot	11.81	6.921	16
	Google	11.29	5.165	14
	Books	6.64	2.942	11
	Peer Discussion	7.17	2.980	12
	Frontal Teaching	8.60	4.579	15
	Control Group	5.50	2.780	12
	Total	8.95	4.850	95

The results of repeated measures ANOVA with a Greenhouse-Geiser correction show that there are statistically significant changes in the pre- and post-test results among all participants groups, regardless of the method used to explore the topic ( $F(36.218, 8.697) = 26,938, p < .001$ ). This means that general progress was recorded over time, but it does not indicate that this progress was specific to individual methods of work.

Significant differences in standard deviations between groups were observed in the pretest and posttest. Before the intervention, the standard deviations between groups were similar, indicating a comparable level of individual responses. After the intervention, the standard deviations increased, especially in groups using humanoid robots ( $SD = 6.921$ ) and Google ( $SD = 5.165$ ), indicating a greater number of responses after the intervention. However, the Bonferroni post-hoc test did not show statistically significant differences between the groups in average results, as indicated by p-values greater than .05. The exception was the comparison between the groups using humanoid robots and the control group, where the p-value was on the verge of statistical significance ( $p = .05$ ), suggesting a possible difference between the groups but caution is needed in interpreting the results, as the p-value is very close to the conventional threshold for statistical significance. The confidence intervals for the average differences between groups overlapped, further indicating that there were no significant differences in outcomes between the methods of work. Although these findings do not support the existence of statistically significant differences, it is important to emphasize that the Bonferroni test, due to its conservatism, increases the value of type II errors, meaning that real differences between groups may not have been detected.

## 7.2. Effect of Learning Methods on Response Variability

This chapter aims to explore the effect of various learning methods on the variability of responses. The focus is on assessing how different approaches to task execution manifest in the diversity of response quality and consistency. ANOVA is employed to systematically dissect these relationships. Emphasis is placed on the importance of understanding the efficacy and influence on different work methods, both for theoretical knowledge and practical application.

### 7.2.1. Effect of Learning Methods on Carbon Footprint Category Response Variability

The results of ANOVA revealed a statistically significant difference among the work methods,  $F(6, 88) = 2.607$ ,  $p = .023$ . This indicates that participant responses varied significantly depending on the employed work method. Additionally, the intercept of the model was statistically significant,  $F(1, 88) = 224,565$ ,  $p < .001$ , underscoring the overall relevance of the model. The R-squared ( $R^2$ ) for the ANOVA model was approximately .0381, suggesting that about 3.81 % of the variability of the results. This relatively small percentage of explained variability suggests that while statistically significant difference among work method were found, they account for only a small portion of the overall variability in participant responses. Most research methods did not show statistically significant differences in average responses, except for the comparison between the groups using humanoid robots and books, where a statistically significant difference was found ( $p = .020$ ). Detailed results are provided in Table 4.

**Table 4.** Mean Scores and Standard Deviations by Learning Methods for Carbon Footprint Variability of Answers.

Method	Pretest		Posttest	
	Mean	Std. Deviation	Mean	Std. Deviation
ChatGPT	1.13	.352	1.20	.414
Humanoid Robot	.69	.602	.69	.602
Google	1.21	.802	1.36	.929
Books	1.55	1.215	1.64	1.362
Peer Discussion	.75	.622	.92	.515
Frontal Teaching	1.00	.000	1.20	.414
Control Group	.83	.718	.83	.718

A post-hoc Tukey HSD results indicated a significant difference was noted between Humanoid Robots and Books categories, with a mean difference of  $-0.90$ ,  $SE = 0.270$ ,  $p = .020$ , and a 95% confidence interval ranging from  $-1.72$  to  $-0.09$ . For all other pairs of work methods, the p-values were higher than 0.005, indicating no statistically significant differences between these methods. Other work methods did not exhibit statistically significant differences.

### 7.2.3. Effect of Learning Methods on Sustainable Usage and Recycling Category Response Variability

Regarding the effect of ANOVA results indicate that while model's intercept was statistically significant,  $F(1, 88) = 233.426$ ,  $p < .001$ , suggesting the overall model's relevance, there were no statistically significant differences among the work methods,  $F(6, 88) = 1.752$ ,  $p = .118$ . This implies that the variations of learning methods as defined in the study did not significantly affect the average outcomes. The R-squared ( $R^2$ ) value of approximately .107 for the ANOVA model indicates that around 10.7 % of the total variability in the dependent variable is explained by differences in work methods. This findings suggest that while the selected work methods provide some explanation for the variability in outcomes, the majority of the variability remains unexplained, as detailed in Table 5.

**Table 5.** Mean Scores and Standard Deviations by Learning Methods for Sustainable Usage and Recycling Variability of Answers.

Method	Pretest		Posttest	
	Mean	Std. Deviation	Mean	Std. Deviation
ChatGPT	1.27	1.100	2.60	1.352
Humanoid Robot	2.12	.719	2.63	.885
Google	1.36	.633	3.71	1.326
Books	1.36	1.286	1.73	1.191
Peer Discussion	1.25	1.422	2.00	2.045
Frontal Teaching	1.07	.961	2.00	1.813
Control Group	1.58	1.240	1.58	1.240

For detailed breakdown of the mean scores and standard deviations across different learning methods, Table 4 presents these metrics for both pretest and posttest. The data in Table 4 illustrate the variability in responses, offering further insights into the nature of the answers provided by participants under each method.

#### 7.2.4. Effect of Learning Methods on Resource Conservation Category Response Variability

Statistical significance of the effect of different learning methods on the measured variable was confirmed by ANOVA as the results demonstrate statistically significant differences among learning methods,  $F(6, 88) = 3.568$ ,  $p = .003$ . Furthermore, the model's intercept proved to be statistically significant as well,  $F(1, 88) = 201.338$ ,  $p < .001$ , signifying the model's overall importance. The R-squared ( $R^2$ ) value for the ANOVA model was approximately 0.196, suggesting that about 19.6% of the variability in the dependent variable can be attributed to differences in the learning methods. This finding highlights the moderate importance of the chosen work methods in explaining the variability in participant responses. Table 6 presents the mean scores and standard deviations for both pretest and posttest across different learning methods, providing a comprehensive view of the data.

**Table 6.** Mean Scores and Standard Deviations by Learning Methods for Resource Conservation Variability of Answers.

Method	Pretest		Posttest	
	Mean	Std. Deviation	Mean	Std. Deviation
ChatGPT	1.13	.834	1.73	.884
Humanoid Robot	.31	.602	1.69	1.138
Google	.36	.497	.93	.616
Books	.45	.522	.64	.505
Peer Discussion	.50	.522	.83	.389
Frontal Teaching	.73	.458	1.27	.704
Control Group	.83	.718	.83	.718

The post-hoc Tukey HSD test revealed that while most learning methods did not exhibit statistically significant differences in average responses, a notable exception was observed. A significant difference was identified between the groups using humanoid robots and books with a mean difference of  $-.90$ ,  $SE = .020$ , and a 95 % confidence interval spanning from  $-1.72$  to  $-.09$ . However, for all other comparisons among learning methods, the p-values exceeded  $.05$ , indicating no significant differences between these methods.

#### 3.2.5. Effect of Learning Methods on Sustainable Food and Agriculture Category Response Variability

The effect of various learning methods on sustainable food agriculture was explored using ANOVA. The ANOVA results revealed a statistically significant intercept,  $F(1, 88) = 38.578$ ,  $p < .001$ , confirming the overall significance of the model within the realm of sustainable food agriculture

education. However, differences among the specific work methods were not statistically significant,  $F(6, 88) = 1.110$ ,  $p = .363$ , suggesting that, as per the study's design, these varied methods did not significantly effect the average learning outcomes in this particular area of sustainability. The R-squared ( $R^2$ ) value for the model was approximately 0.0704, indicating that roughly 7.04% of the total variability in the dependent variable is accounted for by differences in work methods. While this points to a minor influence of these methods on learning outcomes in sustainable food agriculture, the majority of variability in responses remains unexplained by these methods. The detailed results are presented in Table 7.

**Table 7.** Mean Scores and Standard Deviations by Learning Method for Sustainable Food and Agriculture Variability of Answers.

Method	Pretest		Posttest	
	Mean	Std. Deviation	Mean	Std. Deviation
ChatGPT	.20	.561	.60	.737
Humanoid Robot	.00	.000	.13	.342
Google	.14	.535	.57	1.016
Books	.18	.405	.82	.874
Peer Discussion	.17	.389	.33	.651
Frontal Teaching	.27	.458	.67	.816
Control Group	.42	.515	.42	.515

Table 6 confirms the uniformity in learning outcomes across different methods in the context of sustainable food agriculture.

#### 7.2.6. Effect of Learning Methods on Awareness and Education Category Response Variability

A variance analysis (ANOVA) was conducted to assess the influence of different learning methods on the measured variable, focusing on the effect of these methods in awareness and education. The ANOVA results revealed that, while the model's intercept was statistically significant,  $F(1, 88) = 73.603$ ,  $p < .001$ , highlighting the model's overall importance, differences among the learning methods did not reach statistical significance,  $F(6, 88) = 2.037$ ,  $p = .069$ . This suggests that the various work methods, as defined in this study, did not significantly effect the average outcomes. The R-squared ( $R^2$ ) of the model was approximately 0.1219, indicating that around 12.19% of the total variability in the dependent variable is accounted for by differences in work methods. Although this reveals a certain degree of influence exerted by the selected methods, it also indicates that a significant portion of outcome variability remains unexplained by these methods. Table 8 illustrates these findings by presenting mean scores and standard deviations by learning methods, which did not demonstrate statistically significant variations in outcomes for awareness and education.

**Table 8.** Mean Scores and Standard Deviations by Learning Methods for Awareness and Education Variability of Answers.

Method	Pretest		Posttest	
	Mean	Std. Deviation	Mean	Std. Deviation
ChatGPT	.00	.000	1.93	.704
Humanoid Robot	.44	.892	.69	.946
Google	.57	.646	1.14	1.231
Books	.09	.302	.18	.603
Peer Discussion	.33	.651	1.42	.900
Frontal Teaching	.13	.352	.93	1.163
Control Group	.50	.905	.50	.905

### 7.2.7. Effect of Learning Methods on Energy Efficiency and Renewable Sources Category Response Variability

An ANOVA was used to assess how various learning approaches affected the variety of answers on renewable energy sources and energy efficiency. The model's intercept was statistically significant,  $F(1, 88) = 64.046$ ,  $p < .001$ , according to the ANOVA results, confirming the model's overall significance. Significant variations were discovered between the learning approaches,  $F(6, 88) = 4.172$ ,  $p < .001$ , indicating that the chosen learning approaches had different effects on the results. The R-squared ( $R^2$ ) of the model was approximately 0.2215, indicating that about 22.15% of the total variability in the dependent variable could be explained by the differences in learning methods. This percentage of explained variability signifies a substantial effect of the chosen methods on the variability of the results, implying that these methods had statistically significant different effects on the measured variable in this study. The results in Table 9 underscore the significance of the voice of learning methods on outcomes related to energy efficiency and renewable sources.

**Table 9.** Mean Scores and Standard Deviations by Learning Methods for Energy Efficiency and Renewable Sources Variability of Answers.

Method	Pretest		Posttest	
	Mean	Std. Deviation	Mean	Std. Deviation
ChatGPT	.00	.000	.60	.507
Humanoid Robot	.25	.447	.87	.619
Google	.21	.426	.79	.975
Books	.09	.302	.09	.302
Peer Discussion	.17	.389	.42	.515
Frontal Teaching	.07	.258	.06	.507
Control Group	.00	.000	.00	.000

Further analysis using a post-hoc Tukey HSD test was performed for pairwise comparisons among different learning methods following the ANOVA. The Tukey HSD test results revealed a significant difference was observed between "Humanoid Robot" and "Books," with a mean difference of -0.47,  $SE = 0.140$ ,  $p = .019$ , and a 95% confidence interval from -0.90 to -0.05. There was also a significant difference between "Humanoid Robot" and "Control Group,"  $M = -0.56$ ,  $SE = 0.137$ ,  $p = .002$ , with a 95% confidence interval from -0.98 to -0.15. A significant difference was also noted between Google and control group,  $M = -0.50$ ,  $SE = 0.141$ ,  $p = .011$ , with a 95% confidence interval from -0.93 to -0.07. For all other pairs of learning methods, p-values were above .05, indicating no significant differences between these methods. These findings suggest that while certain learning methods demonstrated statistically significant differences, others did not exhibit such variations. Particularly noteworthy are the significant differences observed between "Humanoid Robot" and both "Books" and the "Control Group," suggesting that these methods had varying effects in the context of the study.

### 7.2.8. Effect of Learning Methods on Sustainable Waste Management Category Response Variability

For variability of the answers regarding a sustainable waste management among groups, A variance analysis (ANOVA) was conducted. The results indicate that that the model's intercept was statistically significant,  $F(1, 88) = 51.959$ ,  $p < .001$ , underscoring the model's overall importance. However, no statistically significant differences were observed among the learning methods,  $F(6, 88) = 0.654$ ,  $p = .686$ , suggesting that the methods did not differ significantly in their average outcomes. The R-squared ( $R^2$ ) for this model was approximately 0.0427, indicating that only about 4.27% of the total variability in the dependent variable is explained by differences in learning methods. This minor proportion of explained variability implies that while the model was statistically significant, the learning methods collectively did not significantly influence the variability of results. These findings,

detailed in Table 10, demonstrate a consistent level of response across different methods, with no single method proving distinctly more effective in this specific context.

**Table 10.** Mean Scores and Standard Deviations by Learning Methods for Sustainable Waste Management Variability of Answers.

Method	Pretest		Posttest	
	Mean	Std. Deviation	Mean	Std. Deviation
ChatGPT	.27	.458	.40	.507
Humanoid Robot	.50	.632	.50	.632
Google	.50	.650	.79	.893
Books	.18	.405	.36	.809
Peer Discussion	.33	.492	.50	.522
Frontal Teaching	.33	.488	.53	.516
Control Group	.33	.492	.33	.492

### 3.3. The Role of New Literacies in Empowering Youth for a Sustainable Future with Advanced Technology

Building upon the systematic observations and comprehensive data analysis, this chapter addresses the pivotal role of new literacies in empowering youth for a sustainable future through advanced technology. The observations highlight the importance of new literacies in advanced learning environments, emphasizing how advanced technologies require diverse literacies from young individuals. These competencies equip individuals, particularly those preparing for careers in education, with the necessary skills and knowledge for effective contributions to environmental sustainability. The analysis extends beyond identifying which competencies were developed, also examining the degree to which these competencies, as per DigComp 2.2 framework, were represented in both digital and analog learning environments, differentiating between fully developed digital competences and foundational knowledge, skills, and attitudes (Table 11).

**Table 11.** Knowledge, Skills and Attitudes as per the Digcomp 2.2 Model Across Various Learning Methods.

Method of Learning	Identified Competencies	Competency Depth
ChatGPT	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21	Comprehensive
Humanoid Robot	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21	Comprehensive
Google	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21	Comprehensive
Books	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21	Fundamental
Peer Discussion	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21	Fundamental
Frontal Teaching	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21	Fundamental
Control Group	None	Non-applicable

The analysis of the results shown in Table 10 reveals significant insights into how different learning methods influence competency development according to the DigComp 2.2 framework. Methods involving contemporary technologies such as ChatGPT, HR, and Google show a comprehensive depth of competency engagement across all 21 competencies, indicating that these digital environments foster a broad and in-depth development of new-literacies. This comprehensive engagement suggests that technologies not only facilitate the acquisition of a wide range of digital

competencies but also promote their integration in a way that deeply embeds these knowledge, skills, and attitudes in the learning process. On the other hand, methods involving traditional forms of learning, without contemporary technologies, contribute to the development of the same competencies but generate fundamental knowledge, skills, and attitudes, serving as key foundation for the development of more advanced digital competencies. This approach confirms that traditional learning methods are essential for establishing fundamental elements that enable the holistic development of digital competencies, thereby providing a solid base for further digital learning and growth.

## 8. Discussion

The study supplements existing literature by exploring contemporary approaches in sustainability and EE, incorporating technologies such as generative language models and HR. Analyzing pre- and post-test results revealed that these technologies are at least as effective as traditional teaching methods, and in some circumstances, contemporary technologies proved more effective (RQ1). This is particularly encouraging for EE in the context of the research by [8], which suggests that new technologies not only transform teaching and learning methods but also the ideas, concepts, and objectives of education, especially relevant in the era of Industry 4.0 [30]. Notably, the use of HR showed promising results, with statistically significant changes in response variability (RQ2), indicating a potentially greater effectiveness of these methods compared to traditional approaches. This complements existing studies [36,42], highlighting the impact of digital technologies on educational experiences and the engagement of youth in the context of adopting sustainable development goals. While AI and HR matched the efficacy of traditional methods, they notably engaged young educators more effectively in sustainability topics.

The integration of advanced technologies in education is particularly suitable for educating about environmental awareness and can significantly contribute to the development of digital competencies and new literacies (RQ3), which are crucial for effective engagement in sustainability. Working with contemporary technologies, specifically with generative language models, HR, and online research, significantly develops and realizes all competencies as defined by the DigComp 2.2 strategy [46]. A significant finding of the study is also that traditional approaches in education establish and strengthen the foundations of competencies as defined by DigComp 2.2, demonstrating the interconnectedness of these competencies, which are upgraded from traditional approaches to learning sustainability into contemporary learning environments.

Education plays a crucial role in empowering youth for sustainable future. The interplay of literature review [4,38] and obtained results confirms the importance of educating young, future teachers for the use and understanding of the impact of advanced technologies in sustainability education, as their unique role as knowledge mediators and influencers of future generations makes their perspectives and experiences extremely important for researching and developing sustainable education strategies.

When interpreting the results, some limitations must be considered. The sample is limited to a group of young future teacher from a Slovenian university, which may affect the general validity of the findings. A more diverse sample in terms of geographical, cultural, and educational background could provide more representative results. The research used a quasi-experimental approach, limiting the ability to establish causal links between the learning methods used and sustainability awareness. Additionally, the study focuses primarily on short-term effects, meaning that the long-term impacts of using contemporary technologies on sustainability awareness and behavior were not examined.

Future research should focus on the long-term effects of contemporary technologies on sustainability education. Their unique role as mediators of knowledge and influencers on future generations make their perspectives and experiences extremely important for researching and developing sustainable educational strategies. Understanding how these technologies impact their awareness and readiness to lead sustainable initiatives is essential for designing effective approaches to empower youth for a sustainable future.

In the context of global efforts to achieve sustainable goals, this research is particularly relevant as promoting awareness and understanding of environmental sustainability among young is crucial to ensuring that future generations are able to effectively respond to environmental challenges. The role of educational technologies is particularly important in the era of digitalization, where technological advancements offer new opportunities for innovative and engaged learning. This is especially relevant in the context of global education, where approaches that go beyond traditional methods and include technological innovations are needed to promote active and critical learning.

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