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Research Article

From Bites to Bytes: Fostering Sustainable Food Practices through E-Learning and Pedagogical Psychology

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ABSTRACT

This paper explores the integration of online learning platforms as a means to address Sustainable Development Goal (SDG) 12.3, which aims to halve global food waste by 2030, aligning with Goals 1, 2, 9, 10, 11, 13, 14, and 15. Focusing on transformative pedagogical practices and technological advancements, the study investigates the efficacy of e-learning in fostering sustainable behaviors, specifically relating to the management of food waste. By analyzing the implementation of artificial intelligence algorithms within online learning environments, personalized guidance and feedback are provided to learners, facilitating informed decision-making in sustainable food practices, achieving SDGs 4 and 8. Additionally, the paper examines the implications of online learning on diverse age groups, ranging from primary school to young adults, highlighting the importance of tailored educational approaches in promoting sustainable habits. Through a comprehensive exploration of educational strategies and technological innovations, this study contributes to the discourse on leveraging digital platforms to advance sustainability agendas in education.

Keywords: behavioral intention, e-education, household food waste, motivation.

I. INTRODUCTION

The United Nations Member States have embraced the 2030 Agenda for Sustainable Development, which outlines 17 key Sustainable Development Goals (SDGs). These goals are vital for fostering progress across economic, social, and environmental domains globally [1]. Among these, Goal 12.3 specifically aims to halve food waste by 2030, while also contributing to the realization of several other interconnected goals, which focus on feeding populations, mitigating climate change, and reducing environmental harm.

To achieve this goal, each union and country develops its own laws and regulations for its implementation, thus food waste prevention is hierarchically prioritized worldwide. This approach is the most challenging of all hierarchy stages because it depends on human behavior. The factors that influence wasteful behavior are summarized in the Wasteful Behavioral Framework (WBF) [2]. WBF categorizes influences into several areas: Psychological Factors (such as attitudes, perceived behavioral control, knowledge of food waste, involvement in FW, habits, and emotions), Norms (both social and personal), and Situational Factors (such as urbanization levels and litter perception). Additionally, Demographics and Socioeconomic Status (SES) factors play a role, including age, education level, household composition, gender, and income. The WBF also tracks the stages of household food waste management, from planning and purchasing to storage, consumption, and disposal [2].

A major barrier to sustainable food waste management is a general lack of consumer knowledge [3]. Although various measures, such as advertisements and public information campaigns, have been implemented, there is often insufficient data to determine whether the content (whether positive, negative, or shocking) effectively influences behavior in the long term [4]. In 2023, the EU Consumer Food Waste Subgroup and the European Consumer Food

Waste Forum evaluated different approaches, concluding that improving educational initiatives—such as multi-faceted programs in schools, kitchen skill guidelines, and personalized feedback supported by technology—can significantly enhance food waste prevention efforts [5].

Online learning platforms provide immersive learning environments for sustainable development education. These laboratories simulate real life, allowing users to actively participate in simulations related to sustainable food waste management. Enhanced with artificial intelligence algorithms, the platform can offer customized guidance. By analyzing user interactions, these algorithms are thought to provide personalized recommendations and feedback, enhancing participants' ability to make informed decisions in simulations of sustainable food practices [6]-[8].

II. E-LEARNING DEVELOPMENT PEDAGOGICAL PSYCHOLOGY

Remote learning rapidly evolved during the COVID-19 pandemic, as educational institutions were forced to adopt it urgently, often with minimal preparedness [9]. Remote learning has both drawbacks and advantages.

Advantages include reduced transportation costs, time savings, and increased accessibility to education [9].
Drawbacks of remote learning have been identified [9],[10]:

1. Some students experience physical discomfort: headaches, neck pain, red eyes, and backaches.

2. Some students experience psychological discomfort while learning remotely: this includes reduced socialization, lack of interaction sensations, and the absence of immediate feedback on their progress, which is a crucial aspect of the learning process.

3. Issues with electricity or internet connections can disrupt the learning process.

For students to embrace e- learning effectively, a positive attitude from educators is necessary. This positive attitude is shaped by influencing student behavior in online environments through two framework models: the Technology Acceptance Model (TAM), which focuses on technology acceptance, and the Theory of Planned Behavior (TPB), which examines individual behavior [11]. According to the TAM, when technology is perceived as easy to use and useful, it fosters a positive attitude toward remote learning. In the TPB, individual intentions influence the formation of positive attitudes, existing subjective norms, and perceived control over behavior. This is a crucial finding indicating that subjective norms are positively related to the intention to use remote learning. This can be interpreted as the influence of family, friends, or other social groups on a student's intention to use remote learning, including in virtual classrooms [11],[12].

Research indicates two distinct age groups for educating sustainable food waste managment: primary school [13] and young adults e-education [14].

III. PRIMARY SCHOOL SUSTAINABILITY DEVELOPMENT E-EDUCATION

The first potential education age is the primary school stage, which is approximately from 8 to 12 years old. This age group is highlighted in the EU Food Forum [5]. Long-term results are believed to be better if training is introduced in elementary schools to educate the younger generation [13]. Firstly, youths are usually unaware of the problem and do not know how to reduce waste, separate it, or avoid it. Secondly, they often do not understand the value of food and, when provided with general information, choose to purchase another product based on their perceptions.

To conduct training in this age group, it is important to include Sustainable Development Education in school programs. In 2019, UNESCO adopted the global action program "Education for Sustainable Development 2030", advocating for the integration of sustainability education into teaching practices to meet global objectives [15]. The implementation of this program is planned by incorporating training content into the following core subjects: geography, biology, chemistry, and geology [16]. However, integration faces its challenges, not only related to children's specific psychological behavior but also to their attitudes towards sustainable development education. Three main groups of obstacles have been identified: students do not perceive themselves as members of society and are not familiar with a sustainable lifestyle; students do not see themselves as individual members of society, but rather as followers of teacher instructions; and the implementation of sustainable development is limited in the teaching process [17].

To effectively integrate training in the elementary school age group, it is essential to overcome barriers using Cambourne's conditions for effective learning [18]:

1. Immersion: Provide children with an environment where various social groups are involved in sustainability issues, such as at school, at home, or in other groups. This will not only create a sense of participation in the social community but also foster curiosity and interest in a sustainable lifestyle. The student's microsystem, which includes teachers, parents, books, and classroom activities, and the macrosystem, which includes education policy, economics, social relations, and culture, together create the environment [19].

2. Demonstration: Explain existing ecological problems and their impact on the environment and ecology. Using artificial intelligence laboratories, it would be possible to visualize problems, their impact, and the need for sustainable living. This could be done in the form of games or animations. It is also important to explain the value of food and the life cycle to help students understand why to choose sustainable options.

3. Hope and expectations: Create a positive environment by promoting innovation. Artificial intelligence can serve as a place where children can experiment, collaborate with virtual teachers, and share experimental data.

4. Responsibility: Foster a sense of responsibility in children. Students should be perceived as full members of society, and artificial intelligence will take on a consultant role rather than just a leader.

5. Employment: Encourage children to take risks, make mistakes, and learn from them as part of a natural learning process. With the help of artificial intelligence, create simulations or games where decisions need to be made, risks taken, and lessons learned from the results.

6. Application: Provide opportunities for students to apply their knowledge and skills in real-life situations, promoting sustainable behavior. These could be practical tasks supported by artificial intelligence.

7. Feedback: Provide regular and constructive feedback to children to promote understanding and skill development. Artificial intelligence will serve as an assistant in feedback because it can analyze behavior, results, and performance effectively.

Using this methodic will allow seamlessly integrate e-education platform with AI into educational process.

IV. YOUTH SUSTAINABILITY DEVELOPMENT EDUCATION

The second potential age group is young people, according to research, this period has been identified as a time when people are self-motivated to change their habits but need information about the problem and potential solutions [14], [20].

If sustainability development education is introduced into higher education, it can follow a similar strategy to the elementary school age group. However, considering the goal of these artificial intelligence laboratories to increase sustainability knowledge levels in this age group, other adaptation methods could be chosen.

During this age, individuals choose career-oriented training to improve their competencies. This year's TOP 10 most demanded competencies include two cognitive skills (analytical and creative thinking), four self-effectiveness skills (resilience, flexibility, and agility; motivation and self-awareness; knowledge and lifelong learning; reliability and attention to detail), two interpersonal sklills (empathy and active listening; leadership and social influence), one leadership skill (quality control), and one technology skill (technological savvy). These competencies are mostly related to entrepreneurship, but the top skills can change every five years depending on technological changes, digitalization, and globalization [21].

The fastest-growing jobs are those related to technology, digitization, and sustainability. The job of a sustainability analyst has experienced a 45% growth in the last five year [21]. However, demand is not always the only factor driving this growth; laws also dictate the need for sustainable competencies. The European Green Deal, including GreenComp, has set requirements for sustainable competency training [22]. This legislation covers not only the development of sustainable skills: sustainable values, nature conservation, collective action and individual initiative, but also business competencies such as systematic thinking, critical thinking, and problem-solving. Online platforms specializing in sustainability development education offer competency training to make people competitive and in-demand in the job market.

In addition to motivators in this age group, personality identification can also be used. Mental well-being and social relationships, which often promote long-term friendships and partnerships, can be crucial in the exploration and clarification of self-identity. Social networks are usually important factors in understanding one's social role and

building self-confidence [23], [24]. Important factors to consider in the social aspect when developing an online training platform include:

1. Social comparison process on social networks: Individuals often compare themselves to others, both positively (benign envy) and negatively (malicious envy). To promote positive comparison, the learning platform could include tools such as visualization of educators' achievements or create learner groups where each participant's achievements are highlighted. Positive behavior can inspire others to adopt sustainable solutions.

2. Online social identity determination: The comparison process influences social identity. Therefore, it is important to provide tools for users to demonstrate their social identity and commitment. A certification system could be introduced for those who want to show commitment, and this certificate could be paid, providing additional value to those who want to obtain it. This could be particularly attractive to bloggers, influencers, and other social media users who want to stand out. Training will be free for those who do not need certification.

3. Multi-factor approach: It is important to note that a person's existing and future sustainable behavior is influenced by many factors, including gender, culture, household size, place of residence, etc. [2]. To ensure an individual approach to sustainable education, it is essential to consider these factors and use artificial intelligence to customize the learning process. This can be explained through surveys, during the learning process, or by incorporating personality tests into the platform, which will also be interesting to users. This personalized approach can help provide effective and appropriate learning materials, taking into account each person's unique characteristics and needs.

V. E-LEARNING ENHANCED WITH AI, ITS INTENTION TO USE

Artificial intelligence algorithms offer personalized learning. By analyzing user interactions, these algorithms provide personalized recommendations and feedback, enabling learners to make informed decisions in simulations of sustainable food practices [6]-[8].

Artificial intelligence integrated into learning platforms develops practical skills essential for real-world application. Users acquire decision-making, critical thinking, and problem-solving skills through practical activities. This helps connect theoretical knowledge with practical application [9]. Furthermore, artificial intelligence enables adaptation and personalized learning, incorporating data analysis, content generation, and student progress tracking [25].

When creating a remote artificial intelligence laboratory [12], several crucial areas must be considered:

1. People have different learning styles, so it is important to use various styles in remote learning, such as visual, textual, and content sharing.

2. Feedback is crucial, so the implementation of a task-oriented dialogue system needs to be explored. These systems can facilitate interaction with students, ask questions about their information, and automatically infer their needs. The dialogue system should be designed to effectively identify student deficiencies and provide appropriate support.

3. Data and privacy security are essential for students to feel safe when using artificial intelligence platforms. If students do not feel secure, they may be reluctant to share ideas, engage in critical thinking, and, in the worst-case scenario, experience fear, hindering the learning process.

4. Designers play a key role in creating an improved virtual laboratory with artificial intelligence. They need to create intuitive and user-friendly interfaces to ensure effective knowledge transfer. Designers also need to address ethical issues related to data privacy, inclusion, and bias in artificial intelligence algorithms to ensure the integrity of the educational experience [6], [25].

5. Cognitive load is also crucial in remote learning. The main problem is extraneous cognitive load arising from the design of remote platforms and individual knowledge required to determine whether it is extraneous load or not [12]. This is important considering that different students have different knowledge levels on the topics they apply new knowledge to.

Incorporating all the factors found to be crucial for e-education into the TAM can provide a robust foundation for understanding the adoption of e-learning platforms. Figure 1 illustrates the integration of influenced factors from the TAM and TPB models into an e-learning platform enhanced with artificial intelligence (AI). For TAM, external factors that affect perceived ease of use and perceived usefulness encompass various aspects such as platform design

(cognitive overload), the utilization of different learning styles, personalized learning with AI, feedback mechanisms, and Cambourne's seven effective learning conditions.

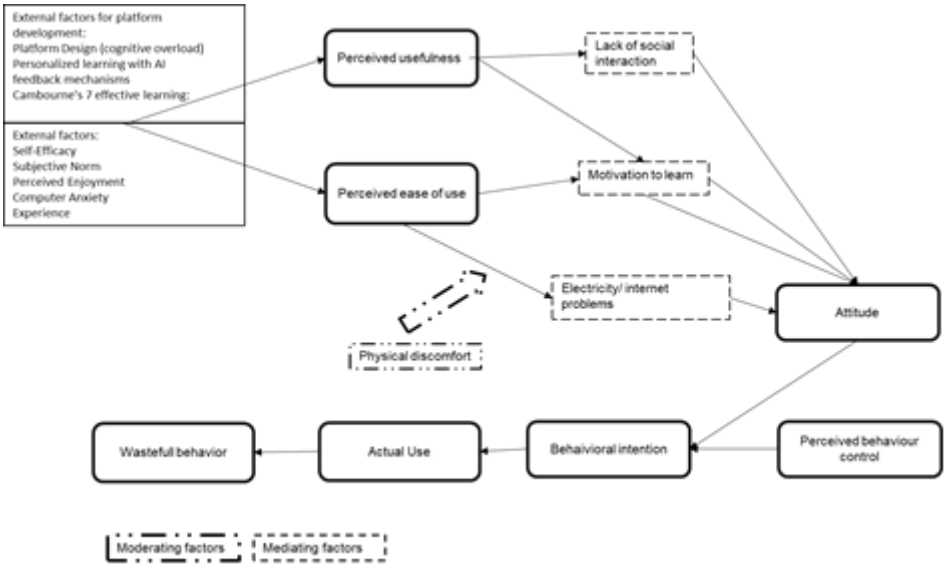

Figure 1. Integrated Factors Influencing Adoption of AI-Enhanced E-learning Platform for Sustainable Food Waste Education: Extending TAM with Additional Influencing Factors

In the context of pedagogy, mediation and moderation play essential roles in understanding users' attitudes and behaviors towards e-learning platforms. Mediating factors, such as interruptions in electricity or internet connectivity during the learning process and individuals' motivation to learn, act as intermediaries between perceived ease of use and attitude, as well as between perceived usefulness and attitude. They help explain how external factors indirectly influence users' perceptions and attitudes towards e-learning platforms.

Moderating factors, on the other hand, such as physical discomfort, can influence the strength or direction of the relationship between perceived ease of use and attitude. Integrating short breaks and opportunities to mitigate attention fatigue strengthens students' focus and learning outcomes. From a pedagogical standpoint, understanding these moderating variables allows educators and platform designers to tailor interventions and adjustments to mitigate potential barriers or enhance facilitators of e-learning adoption.

Furthermore, research has identified several external factors commonly used in TAM concerning e-learning adoption, including self-efficacy, subjective norms, perceived enjoyment, computer anxiety, and experience [26]. This highlights the interconnectedness between external factors in TAM and those from the Wasteful Behavioral Framework (WBF) and the Theory of Planned Behavior (TPB). For example, subjective norms can serve as external factors for TAM, while demographics, socioeconomic status factors, and situational factors contribute to self-efficacy, perceived enjoyment, computer anxiety, and experience. Additionally, the development of personalized learning and platform design is influenced by demographics, SES factors, and situational factors, underscoring the importance of considering these variables in pedagogical practice and e-learning platform design.

CONCLUSION

In conclusion, this study has provided valuable insights into the integration of online learning platforms to address SDG 12.3, aiming to reduce food waste by 50% by 2030, while aligning with various other SDGs. By examining the intersection of transformative pedagogical practices and technological advancements, the efficacy of e-learning in fostering sustainable behaviors, particularly in the context of food waste sustainable management, has been explored.

The analysis of artificial intelligence algorithms within online learning environments has revealed the potential for personalized guidance and feedback, enabling informed decision-making in sustainable food practices and contributing to SDGs 4 and 8. Moreover, the examination of the implications of online learning on diverse age groups underscores the importance of tailored educational approaches in promoting sustainable habits.

By incorporating interconnections with the Technology Acceptance Model (TAM) into the discussion, we gain a comprehensive understanding of the factors influencing attitudes toward using e-educational platforms with AI for addressing food wasteful behavior. It is crucial to understand the primary motivators and foster diverse motivations to ensure engagement, as subjective norms influence both the TAM and TPB models. Establishing a role for social identification fosters a sense of belonging and community among learners, which could enhance user interaction.

Moving forward, further research should explore innovative technological interventions to enhance the effectiveness of e-learning platforms in fostering sustainability. Additionally, investigating the impact of personalized learning and AI-driven feedback mechanisms on learners' attitudes and behaviors towards sustainability will be crucial.

Overall, this study adds to the expanding body of research on sustainability education, emphasizing the potential of digital platforms and artificial intelligence in promoting sustainability initiatives in education, and supporting the achievement of the Sustainable Development Goals**.**

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