

Promoting Technical Education on Waste Management and Recycling Through Interactive E-Learning Platforms

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Abstract. A lack of proper waste management, primarily due to the extremely high rate of waste generation, has catastrophic implications for the environment, economy, and public health. To combat this issue, more emphasis needs to be placed on campaigning among citizens, along with sensitizing students and professionals through special seminars on proper waste recycling and management methods. The creation and dissemination of sophisticated instructional websites that educate learners about advanced recycling processes and environmental technology are the primary concerns of this paper. The idea aims to make learning a sophisticated process more accessible by consolidating various tools, such as videos, live online labs, games, and standalone teaching sessions, which would render learning intricate topics both entertaining and straightforward. Including competitive elements through the presentation of puzzles or virtual simulations provides further enjoyment while also enhancing information retention and promoting self-directed learning responsibility. Furthermore, experiential training in waste sorting and material recovery will always provide apprentices with an opportunity to practice outside the classroom setting, complemented by the added advantage of in-depth theoretical knowledge. The flexible setting promotes self-guided discovery objectives, accommodating all types of learners, including school-age children and working adult jobholders from various industries. This approach enables individualized paths for every user, enhancing satisfaction rates for a specific intended goal and increasing skill sets within a zero-formulation framework. Declining information deficits among individuals began with the adoption of eco-friendly solutions that enable all to adopt balanced, holistic priorities, actively influencing a healthier way of life and the well-being of society, thereby sustaining a paradigm. The initial outcome from users in test groups showed enhanced knowledge, enhanced awareness, and a higher desire to engage in recycling activities. The study considers the potential of e-learning as a robust support for various training skills in waste management education in support of achieving global sustainability goals.

1 Introduction

The increasing issue of ineffective waste recycling and disposal is the result of extensive environmental degradation and depletion of natural resources [1]. Industrialization, urbanization, and rising consumerism have been significant contributors to global waste generation [12]. Ineffective waste collection is the source of pollution, health issues, and economic losses. For this purpose, there is a need to implement effective waste and recycling management to promote sustainable environmental protection and resource preservation [14]. Though it is a dominant issue, limited data exist on waste and recycling management training, with students, experts, specialists, and the community showing less interest in it [15]. Traditional schools often lack practical

learning equipment, such as workshops, which hinders the acquisition of necessary skills among most students. This, in turn, contributes to a lack of awareness of quality waste management and recycling schemes [4].

Online learning websites create a gap-filling window through interactive programs with customized educational requirements presented by students with a shallow understanding of intricate issues in waste management [3].

Sites designed for such an objective can be utilized to support the education provided to these students through multimedia content, simulation animations, and virtual labs, thereby enhancing their understanding. This research focuses on technical education in waste recycling and management [9]. They can offer outstanding value by fostering technical proficiency, promoting continued practice, and cultivating green habits through their

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adaptable, extendable, and student-centric strategies in various areas of society. These digital learning devices have become not only unavoidable for knowledge updating but also essential for active participation in global waste management efforts [2]. With innovative learning methods, it becomes a feasible possibility for people and communities to contribute towards a clean and green future.

Key Contributions

- The research proposes an e-learning system intended to provide technical training on recycling and waste management as interactive multimedia, simulations, and gamification strategies.
- The platform successfully bridges the knowledge gap by providing individualized learning experiences tailored to various learners, including students, professionals, and community members.
- The suggested methodology demonstrates the potential of interactive e-learning in facilitating experiential learning and skill acquisition in waste management, thereby promoting circular economy practices and sustainable behaviors.

This research study is categorized into five major sections to provide a sequential outline of the research. Section one provides the context, necessity, and motivation for propelling technical education in waste management and recycling, with a focus on the significance of interactive e-learning platforms.

2 Literature Survey

A number of learning theories are used to support the design of the interactive e-learning platform in terms of creating a pedagogical approach. The Cognitive Theory of Multimedia Learning (CTML) justifies using videos and simulations and implies that learners will be more productive in case the information is presented in both visual and verbal form. The theory based on self-determination (SDT) is applicable to integrating the aspects of gamification since it increases intrinsic motivation through the opportunities of autonomy, competence and relatedness. Also, Experiential Learning Theory (ELT) is the basis of the application of virtual labs, whereby learning in real life scenarios and reflection is of essence. These theories underpin the methods of delivery of the content, not to mention, it goes hand in hand with the objectives of the improvement of the engagement, retention, and motivation of the learners.

Education in waste management and recycling has been identified as an essential component of environmental sustainability [5]. Several research studies have highlighted the importance of education in raising awareness and improving waste-handling measures among the public and communities [10]. Conventionally, conventional classroom approaches are not as flexible and interactive as needed to impact a large base of people effectively. Current studies suggest that interactive e-learning environments can mitigate these shortcomings by providing accessible, self-guided, and engaging learning processes. Interactive games, virtual simulations, and multimedia technologies have proved to enhance learners'

practical skill development and learning retention. E-learning environments also contextualize advanced concepts within real-world scenarios, which facilitates the learner's understanding of principles in waste management [6]. Research has also highlighted the importance of integrating technology into the teaching of vocational subjects that focus on eco-friendly practices. For instance, environmental awareness and applicable skills have been developed through virtual courses on waste segregation, composting, recycling, and resource recovery [8]. Furthermore, research confirms that e-learning resources can serve diverse populations, including school students, technicians, and other community members, regardless of their geographic location. This aspect makes such resources best suited for imparting comprehensive training in waste disposal [13]. With all these developments, there is a lack of holistic integration of interactive e-learning tools for technological education on recycling and waste management [7][11].

3 Methodology

The system that was proposed with the waste management and recycling education was created by the iterative model of design, including the ongoing feedback of the learners in case of the different test runs. To make the site appealing to users and more effective in terms of learning, the platform incorporates a combination of multimedia tools, i.e., instructional videos, interactive simulations, quizzes, and real-time feedback to attract the attention of users. Its development was a methodological process that used such technologies as HTML5, JavaScript, Unity to simulate, and PHP to integrate back-end. This enabled the development of a flexible user-friendly interface which reacts to unique learning requirements. Through the course of development, the usability, accessibility and content personalization were to be given special attention to serve the various learner demographics. The architecture of the system is developed to provide scalability, interactivity, and the powerful backend which is used to process data and provide feedback in real-time.

The evaluation of the existing educational frameworks and e-learning paradigms concerning waste recycling and waste management, it becomes evident that traditional modalities are capable of facilitation of content presentation but fail to provide individual learning, real-time assessment and adaptive feedback capabilities. To overcome these shortcomings, this study presents a new high-end interactive e-learning system, which involves smart analysis of learners and dynamic delivery of content coupled with inclusion of game modules that provide more interactive and memorability.

Mathematical Formulations:

In the platform, to analyze and assess learner performance with content delivery tailored to each user, the following algorithms are implemented:

Learner Engagement Score (LES):

$$LES = \frac{V + I + Q}{T} \times 100 \quad (1)$$

Where in equation (1):

- V = NumberNumber of video modules completed
- I = NumberNumber of interactive modules completed
- Q = NumberNumber of quizzes attempted
- T = Total available modules

Knowledge Retention Index (KRI):

$$KRI = \left(\frac{C}{A}\right) \times 100 \quad (2)$$

Where in equation (2):

- C = Correct answers in assessments
- A = Total assessment questions attempted

The Knowledge Retention Index measures how effectively a learner utilizes and retains knowledge acquired from a specific platform. It relies on the performance of the learner in the quizzes or tests where the correct number of answers is compared to the number of attempts taken. This assessment provides a rough estimate of the ability of the learner to comprehend the subject in question, their ability to recall and practice useful ideas. High test scores demonstrate good retention and comprehension, while low test scores highlight the need to revisit or relearn the material.

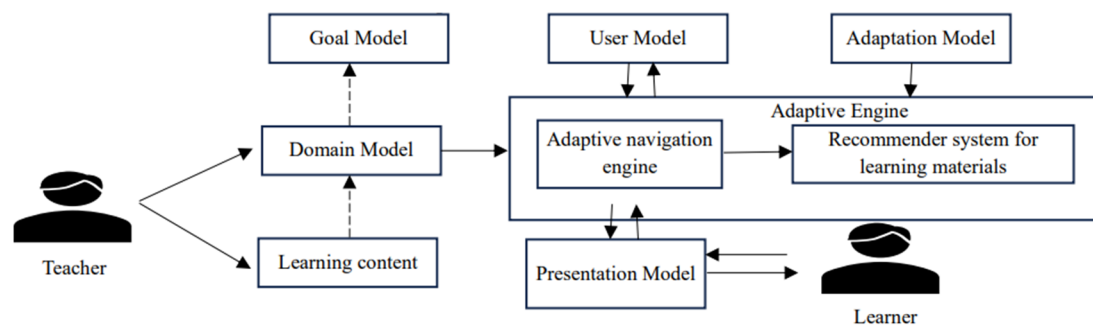


Figure 1. System Architecture of the Proposed Interactive E-Learning Platform

Figure 1 demonstrates the design of the suggested interactive e-learning system, which is supposed to contribute to the improvement of technical training in waste management and recycling. The teacher begins by initiating the process and offering the instructional material on the subject matter of waste management. Structured and presented within the domain model, with the alignment in mind that would serve the goals established in the goal model, the content continues.

The adaptation engine is the core component, as it adapts the learning process. It utilizes the input from the user model, which maintains the learner's profile and progress, and the adaptation model input, which specifies how the learning content needs to be adapted to personal requirements.

4 Results And Discussion

The 100 respondents were enlisted to participate in the study through online advertisement and partnership with the local universities. The participants were split into two groups whereby; one group took the proposed e-learning system and the other was subjected to traditional strategies of learning about waste management. The research was carried out within 8 weeks during which the participants underwent activities in the form of interactive simulations, quizzes and video tutorials. The demographic information of the participants including age, occupation and previous experience in waste management comprises the following: 60 %t of the respondents were students with the age group of 18-25, 25 %t was working professionals of the waste management and environmental industry and the remaining 15 %t was

community based who had limited background information on the waste management practices. This demographic distribution will guarantee that there is a variety in the number of participants, which will give to insight on the participation of various groups to the educational material.

The interactive e-learning platform suggested was tested with 100 learners, comprising students, technical staff, and the general public. The main aim was to determine the engagement, knowledge retention, and satisfaction of the learners with the platform compared to the traditional learning procedures. The Learner Engagement Score (LES) and the Knowledge Retention Index (KRI) were used as the measure of the learner performance, as described in the above section. The findings indicated that the online interactive learning platform significantly enhanced learners' engagement and comprehension of waste management and recycling concepts.

Figure 2 gives a comparison of the engagement behavior of the learners between the traditional teaching methods and the proposed interactive e-learning platform. The findings show that the suggested method aroused a higher degree of involvement among 87% however, the traditional practices aroused among 62%. This is mainly due to the fact that the proposed platform will include videos, simulations, quizzes, and instant feedback. These traits promote interaction and active participation and imagination in learners which would otherwise not be the same with traditional approaches. The outcomes reveal that interactive e-learning provides a better platform of engaging the learners especially in provision of technical education on recycling and waste management.

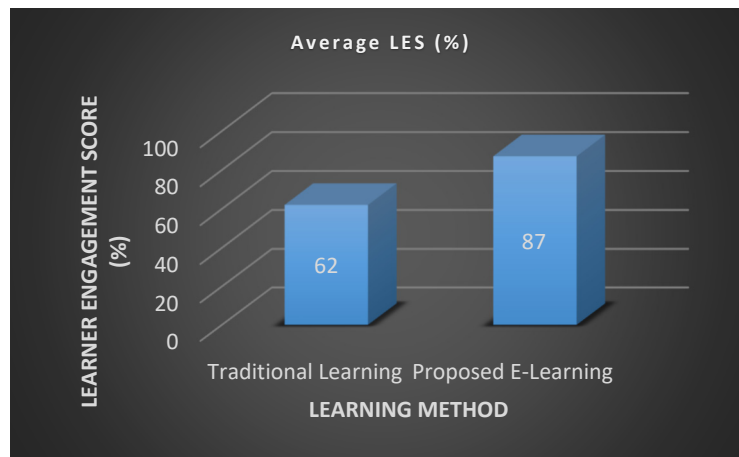


Figure 2. Comparison of Learner Engagement Scores (LES) Between Traditional and Proposed E-Learning Approach

5 Conclusion

This underscores the need to integrate interactive e-learning systems for facilitating technical education, waste management and recycling. The growing amounts of waste and strife for sustainability require interactive affordability and hands-on learning. The above-mentioned e-learning system has the potential to surpass the shortcomings of traditional face-to-face teaching through instructional material that is not only interactive but also provides adaptive pathways, along with instant assessment. As was seen in previous examinations, students showed greater retention of knowledge and active participation when using the interactive platform. In this instance, students utilizing asynchronous instruction appreciated varying degrees of control over content access which resulted in widened inclusion, enhanced efficiency and motivation towards self-paced mastery in technical education.

Reference

1. Debrah, J. K., Vidal, D. G., & Dinis, M. A. P. (2021). Raising awareness on solid waste management through formal education for sustainability: A developing countries evidence review. *Recycling*, 6(1), 6.
2. Orhorhoro, E. K., Atuma, E. V., & Adeniyi, A. S. (2016). Design and Fabrication of Compression Molding Machine for Plastic Waste Recycling in Nigeria. *International Academic Journal of Innovative Research*, 3(2), 48–67.
3. Al-Samarraie, H., Teng, B. K., Alzahrani, A. I., & Alalwan, N. (2018). E-learning continuance satisfaction in higher education: a unified perspective from instructors and students. *Studies in higher education*, 43(11), 2003-2019.
4. Aghaei, S. S., & Jahed-Motlagh, M. R. (2018). Feedback Linearizing Control for Recycled Wastewater Treatment. *International Academic Journal of Science and Engineering*, 5(1), 145–153. <https://doi.org/10.9756/IAJSE/V5I1/1810013>
5. Tanjung, A., Rachman, I., & Matsumoto, T. (2024). The impact of environmental education, knowledge, and facility on pre-service teachers' intention toward waste separation and recycling on campus: teacher education institution in Indonesia case study. *Journal of Material Cycles and Waste Management*, 26(6), 3917-3927.
6. Hafezieh, M., Seidgar, M., Alizadeh Osalou, Zh., Nekoueifard, A., Ghara, K., Mohebbi, F., & Rezaei, M. M. (2024). Mechanization impact of improvement of some quality indicators of wastewater in rainbow trout culture dualpurpose farms in Markazi Province of Iran. *International Journal of Aquatic Research and Environmental Studies*, 4(2), 1-17. <http://doi.org/10.70102/IJARES/V4I2/1>
7. Ferronato, N., & Torretta, V. (2019). Waste mismanagement in developing countries: A review of global issues. *International journal of environmental research and public health*, 16(6), 1060. <https://doi.org/10.3390/ijerph16061060>
8. M. Krsmanović, S. Šušnjar, J. Golijanin, A. Valjarević, GIS Based Vulnerability Assessment of Illegal Waste Disposal – Case Study East Sarajevo. *Archives for Technical Science* 2(27), 63–76 (2022). <https://doi.org/10.7251/afts.2022.1427.063K>
9. Martin, F., & Bolliger, D. U. (2018). Engagement matters: Student perceptions on the importance of engagement strategies in the online learning environment. *Online learning*, 22(1), 205-222. <https://doi.org/10.24059/olj.v22i1.1092>
10. Yogamadhavan, V. K., & Mannayee, G. (2024). An Evaluation of Various Deep Convolutional Networks for the Development of a Vision System for the Classification of Domestic Solid Street Waste. *Journal of Internet Services and Information Security*, 14(2), 268-283. <https://doi.org/10.58346/JISIS.2024.I2.017>
11. Allesch, A., & Huber-Humer, M. (2023). A brief glance on global waste management. In *Minerals and Waste* (pp. 227-258). Cham: Springer International Publishing.

12. B. Juneja, S. Deepak, R.D.V. Babu, A. Tomar, Design of Sustainable Approaches for Pharmaceutical Waste Management in Household Settings. *Natural Engineering Sciences* **10**(1), 162–175 (2025). <https://doi.org/10.28978/nesciences.1642307>
13. Sun, J. C. Y., & Rueda, R. (2012). Situational interest, computer self-efficacy and self-regulation: Their impact on student engagement in distance education. *British journal of educational technology*, *43*(2), 191-204. <https://doi.org/10.1111/j.1467-8535.2010.01157.x>
14. Vasquez, E., & Mendoza, R. (2024). Membrane-Based Separation Methods for Effective Contaminant Removal in Wastewater and Water Systems. *Engineering Perspectives in Filtration and Separation*, 21-27.
15. Lobos, A., & Babbitt, C. W. (2013). Integrating emotional attachment and sustainability in electronic product design. *Challenges*, *4*(1), 19-33.