sustainability

MDPI

Article

Liaoning University ChopMelon Net Project: Innovative Research on Sustainable Education Based on Real Social Issues

Xianghui Tian, Jia Liu and Yanlin Tang *

Liaoning School of Marxism, Liaoning University, Chongshan Campus, Shenyang 110031, China; 4022310098@smail.lnu.edu.cn (X.T.); 17320929993@163.com (J.L.)
* Correspondence: tangyanlin@lnu.edu.cn

Abstract: The purpose of this study is to evaluate how the ChopMelon Net online learning platform can contribute to the effectiveness of sustainable education by incorporating real social issues. The core innovation of ChopMelon Net is that it provides a learning environment that connects learners directly to real-world challenges and aims to enhance learners' understanding of sustainable development theory. The study employed the technology acceptance model (TAM), theory of planned behavior (TPB), and knowledge–Behavior gap theory (KBGT) to design the questionnaires and semi-structured interviews in order to comprehensively assess the impact of ChopMelon Net on learners' skill enhancement. The results showed that learners not only showed significant improvement in critical thinking and problem-solving skills after using ChopMelon Net, but also expressed a high level of satisfaction with the educational content and interactive experience provided by the platform. In addition, the study found that ChopMelon Net effectively promoted learners' awareness of the importance of sustainable education and behavioral change through its innovative educational model, which provides important empirical support for future sustainable education practices and the design of online education platforms. This study highlights the importance and effectiveness of incorporating real social issues into the teaching and learning process, with far-reaching implications for sustainable innovation in education.

Keywords: online learning platform; sustainable education; educational innovation; critical thinking; problem-solving skills; user satisfaction

Citation: Tian, X.; Liu, J.; Tang, Y. Liaoning University ChopMelon Net Project: Innovative Research on Sustainable Education Based on Real Social Issues. *Sustainability* **2024**, *16*, 3781. https://doi.org/10.3390/su16093781

Academic Editors: Kittisak Jermsittiparsert, Ismail Suardi Wekke, Oytun Sozudogru and Jamaluddin Ahmad

Received: 9 March 2024
Revised: 26 April 2024
Accepted: 28 April 2024
Published: 30 April 2024

1. Introduction

In the field of education in the twenty-first century, education for sustainable development (ESD) has emerged as a key issue on the global education agenda. UNESCO defines ESD as "education that empowers learners to acquire knowledge, skills, attitudes, and values for sustainable development" [1]. As society becomes increasingly concerned with sustainability issues, education systems face an urgent need to update their content and methods to address these challenges [2,3]. In this context, the purpose of this study is to comprehensively evaluate the effectiveness of the ChopMelon Net online learning platform. As the primary research object, we focus on exploring how the platform can enhance the learning experience of learners by integrating real social issues. In addition, this study looks at several supporting indicators, including learners' improvement in critical thinking and problem-solving skills, learner satisfaction, behavioral intentions, and motivation. This multidimensional assessment approach aims to provide insights into the actual contribution of ChopMelon Net to the promotion of sustainable education goals.

The main innovation of this study is the demonstration of how an e-learning platform can place learners directly in the midst of real-world challenges through a real-life case study that not only focuses on learner skill enhancement, but also more broadly evaluates its impact on learner satisfaction, behavioral intentions, and motivation. In the context of digital education, the choice of assessment tools is crucial to accurately measure learners' critical thinking and problem-solving skills [4,5]. According to Jansen et al. (2017),

questionnaires and interviews proved to be effective tools for assessing the effectiveness of online learning [6]. In this study, the questionnaire and semi-structured interview methods are used to comprehensively understand learners' educational experiences through ChopMelon Net by integrating the application of the technology acceptance model (TAM), theory of planned behavior (TPB), and knowledge–behavior gap theory (KBGT).

This study aims to answer the following primary and secondary questions:

Primary Research Questions:

1. How does ChopMelon Net enhance the learner learning experience by integrating real social issues?

Secondary Research Questions:

1. How do learners rate the effectiveness of ChopMelon Net in enhancing their critical thinking and problem-solving skills?

2. How satisfied are learners with the educational content and interactive experience provided by ChopMelon Net?

3. How does ChopMelon Net influence learners' behavioral intentions and actual behaviors towards sustainable initiatives?

4. What motivations drive learners to use ChopMelon Net and engage in sustainable education activities?

By answering these questions, we expect to propose improvements for the application of e-learning platforms in the field of sustainable education to better meet the needs of future education.

2. Materials and Methods

2.1. Literature Review

2.1.1. Theoretical Foundations and Practical Challenges of ESD

ESD aims to empower learners with knowledge, skills, values, and behaviors about sustainable development through education [7,8]. This covers a wide range of aspects such as environmental protection, economic equity, and social inclusion [9,10]. Literature exploring ESD points out that while the concept has been widely accepted by the international community, there are still challenges in integrating content, innovating pedagogical approaches, and assessing learning outcomes in its practical implementation [11,12].

2.1.2. Real Social Issues in Education

In the current education model, classroom teaching is often based on theoretical knowledge, and students may encounter difficulties in applying their knowledge practically to solve problems. The introduction of real social problems is seen as a way to address this issue [13]. Real social problems refer to issues that have practical significance, complexity, and contextual depth, and they require students to apply interdisciplinary knowledge in the solution process [14]. However, there are many challenges in effectively integrating real social problems into teaching and learning, such as how to select problems with depth and significance, and how to stimulate students' interest in these problems. In recent years, many studies have begun to explore the use of real social issues in education [15,16]. For example, some studies have pointed out that the use of real social problems enhances student engagement and motivation to see a direct connection between learning and the real world [17]. Other studies focus on specific disciplines, such as math, science, and engineering education, to explore how solving real social problems can foster student innovation [18]. Still, other research suggests that interdisciplinary projects on real social problems promote students' ability to work in teams [19]. Further studies have concluded that the approach of using real social problems as educational content is considered to be an effective strategy for increasing learner engagement and learning outcomes [20]. Brown et al. mention that when learners are able to apply what they have learnt to real-world problems, they are more able to comprehend and retain that knowledge [21]. In addition, this approach promotes interdisciplinary learning and provides students with the opportunity to integrate theory with practice [22].

2.1.3. The Importance of Critical Thinking and Problem-Solving Skills

In today's fast-changing world, critical thinking and problem-solving skills are recognized as key skills that learners must possess [23,24]. The literature review emphasized that these skills are essential for students to understand complex problems, evaluate information, make sound decisions, and innovate solutions [25]. Educational research has emphasized that the education system should focus more on the development of skills rather than merely imparting knowledge [26,27]. There are a variety of strategies and methods that are used in educational practice to develop students' critical thinking and problem-solving skills [28]. These methods include discussion-based learning, problem-based learning, case studies, and interdisciplinary projects [29]. Through these interactive and student-centered learning approaches, students can apply their thinking skills in real-world contexts, leading to deeper understanding and improved skills [30]. However, while existing research supports the value of developing these skills in education, further research is needed to explore the most effective instructional strategies and methods [31].

2.1.4. Online Education Platforms and ESD

With advances in technology, online education platforms offer new possibilities for achieving ESD [32,33]. By providing access to a wide range of resources and interactive tools, these platforms create the conditions for personalized learning and distance education [34,35]. However, the literature also identifies challenges with online platforms in terms of content quality, technological accessibility, and learner engagement [36,37].

2.1.5. Applications of ChopMelon Net

ChopMelon Net (Figure 1) is an innovative online learning platform designed to enable learners to gain an in-depth understanding and analysis of the economic, social, and environmental challenges facing the globe by introducing real social issues as pedagogical content, which focuses on combining theoretical knowledge with real-life contexts by providing rich case studies, interactive discussions, and hands-on activities.

Figure 1. ChopMelon Net webpage.

This picture shows the web interface of ChopMelon Net: there is a green logo on the left side of the top, which is a kind of pumpkin plant, and "ChopMelon Net" is written in the middle of it; there are two windows under "ChopMelon Net", the blue icon on the left side is written as "Browse Problems", with a button for "Click to Enter" underneath; on the right side of the page, the green icon is written as "Publish Problems", with the button

for "Click to Enter" underneath, and at the bottom of the page, there is a line of grey text, "Problems set with real problems in real-life scenes of social reality to trigger thinking".

ChopMelon Net integrates real social issues into the education system through a case bank, providing students with intuitive and vivid learning materials. These cases not only cover multiple aspects of sustainable development in different sectors (Figure 2), such as environmental protection, social justice, and economic prosperity, but also focus on the complexity and realism of the issues. In addition to the case bank, ChopMelon Net also provides an interactive discussion platform that encourages exchanges and collaboration among students. Students can post their views, ask and answer questions on the platform, and interact with people from different backgrounds and learning experiences. Such interactions not only promote knowledge sharing and understanding but also help develop students' teamwork and communication skills. In addition, ChopMelon Net also closely integrates learning with real-world problem-solving through practical activities and project tasks. Students can apply what they have learned in practice, come up with innovative solutions, and evaluate their feasibility and impact. This problem-oriented learning approach not only enhances students' interest and motivation in learning but also helps develop their innovative thinking and practical skills.

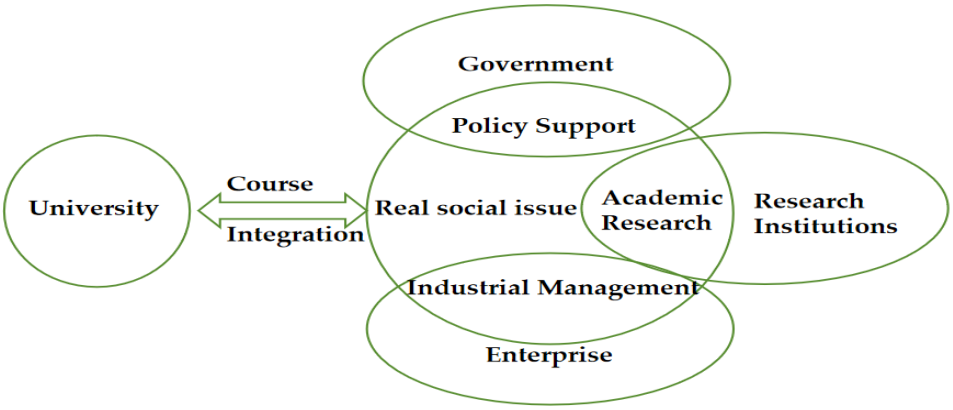

Figure 2. Access to "real social issue" on ChopMelon Net.

2.2. Theoretical Framework

2.2.1. Application of Three Models to Online Learning

In current research on educational technology, the technology acceptance model (TAM) and theory of planned behavior (TPB) are important theoretical frameworks for understanding and predicting users' behavior in accepting and using new technologies. Knowledge–behavior gap theory (KBGT) is used to enable users to accept the technology. There may still be a gap between actual use and optimal utilization of the technology. The three models are employed to analyze how learners accept and use ChopMelon Net, an innovative online learning platform.

TAM theory focuses on perceived usefulness and perceived ease of use, which are considered to be the key drivers influencing users' acceptance and use of new technologies. According to Cheung et al. (2012), if a technology is perceived as useful and easy to use by users, they are more likely to adopt and use it consistently [38].

TPB theory adds the dimension of social influence and behavioral control, which suggests that an individual's behavioral intentions are influenced not only by their attitudes, but also by a combination of subjective norms and perceived behavioral control. Sussman et al. (2019) suggests that if individuals believe they are capable of carrying out a behavior, and that the social group in which they are embedded is supportive of carrying out the behavior, then the likelihood of them carrying out the behavior will increase [39].

KBGT theory explores the idea that even when individuals have sufficient knowledge, their behavior may not reflect that knowledge, and that there is what is known as the "knowledge–behavior gap", which Swart et al. (2012) suggests is often the result of a

number of factors, including lack of motivation, environmental constraints, and a lack of the necessary behavioral skills [40]. In online learning environments, although learners may understand and agree with the importance of the content, actual learning behaviors may be hampered by technological barriers, time management issues, or a lack of self-regulation.

2.2.2. Combination of the Three Models with ChopMelon Net

Figure 3 shows how users form attitudes towards using the platform by perceiving its usefulness (e.g., content quality) and ease of use (e.g., interface design), which in turn affects their intention to use ChopMelon Net, and ultimately their actual participation and interaction on the platform. This model can help us understand and analyze user acceptance and usage of the online sustainability education platform ChopMelon Net, and how to optimize the platform to increase user satisfaction and engagement.

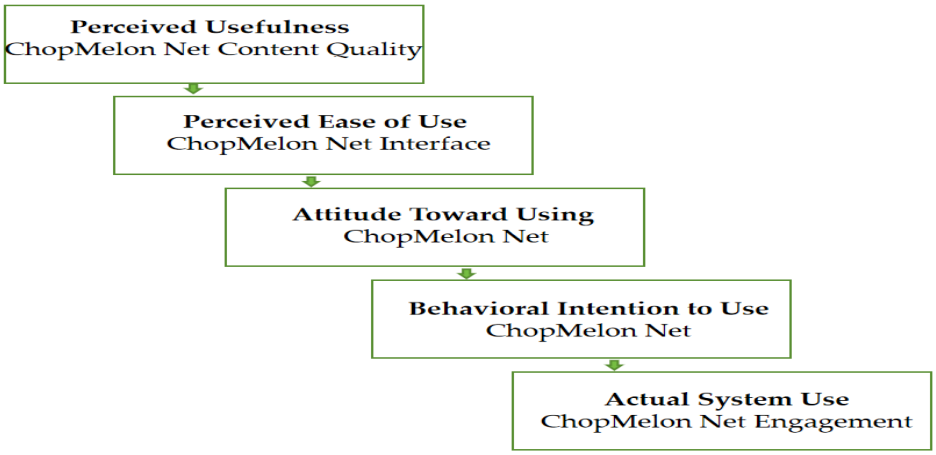

Figure 3. Schematic diagram of the customized technology acceptance model (TAM) applied to the ChopMelon Net.

Figure 4 shows how users' attitudes towards the value of content on ChopMelon Net, community-influenced subjective norms, and perceived behavioral controls on platform usability all work together to influence users' behavioral intentions, and thus their actual behavior towards sustainability actions on the platform. This model allows us to understand users' psychological motivations for engaging with ChopMelon Net and taking sustainability actions. It highlights the multiple dimensions that influence user behavior, including personal attitudes, social influences, and perceived ease of execution. Understanding these factors is essential for designing and optimizing online platforms such as ChopMelon Net in order to promote active user participation and the practice of sustainability behaviors.

Figure 4. Schematic diagram of the theory of planned Behavior (TPB) applied to the ChopMelon Net.

Figure 5 illustrates how the knowledge of sustainability gained through ChopMelon Net, together with the motivations and attitudes influenced by it, and the behavioral skills enhanced through the platform, combine to form a behavioral intention to adopt sustainability practices, which ultimately leads to actual sustainability behaviors. An innovative approach to ESD is proposed by incorporating real social issues into the learning process. The research needs to explore how ChopMelon Net influences learners' knowledge acquisition, skills development, and values formation.

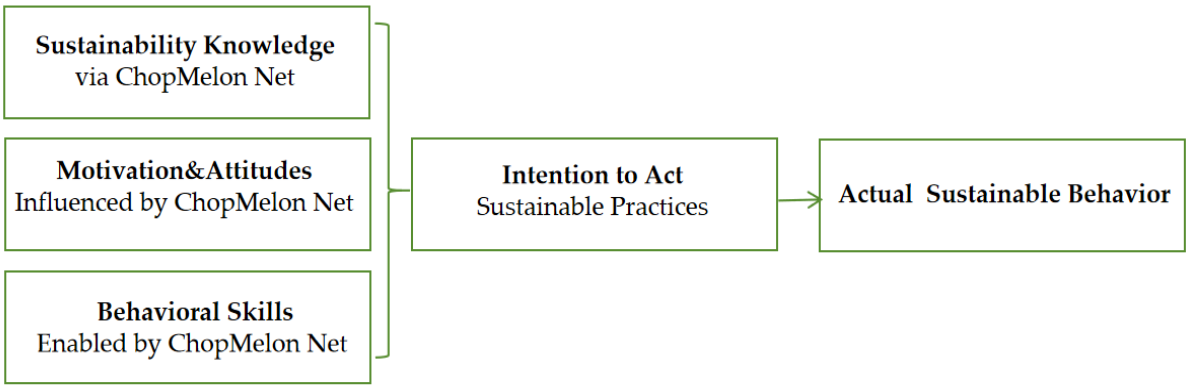

Figure 5. Schematic diagram of knowledge–behavior gap theory (KBGT) applied to the ChopMelon Net.

The combined use of the above three theoretical models not only provides a theoretical foundation for ChopMelon Net as an online education platform, but also comprehensively supports the advancement of sustainable education through real social issues and its positive impact on enhancing learners' critical thinking and problem-solving skills. This practice demonstrates the potential and effectiveness of ChopMelon Net in promoting sustainable education practices and strengthening learners' competencies.

2.3. Research Design

In order to assess learners' critical thinking and problem-solving skills, learning satisfaction, and behavioral intentions, a structured questionnaire was used in this study. The questionnaire consisted of quantitative questions to assess learners' skill enhancement and satisfaction, as well as qualitative questions to gather learner-specific feedback on the platform. Twenty learners who showed a high level of engagement and unique insights in the questionnaire were selected for in-depth interviews to understand their behavioral intentions and deep-rooted motivation for learning.

In particular, critical thinking is defined as the process of being able to apply logical and analytical skills when evaluating information [41–43], a competency that is crucial for learners in their learning activities in ChopMelon Net, enabling them to effectively screen, analyze, and evaluate the various educational contents and real problem cases provided on the platform. Problem-solving skills are defined as the ability to identify problems when faced with challenges and to find and implement effective solutions [44–46], and through ChopMelon Net, learners are confronted with a series of well-designed problems and challenges designed to stimulate and enhance their ability to identify problems and apply the knowledge and skills they have learned to formulate and implement solutions. Learner satisfaction is defined as the overall level of satisfaction of learners with the platform's content, interactions, pedagogical methods, and the technological platform used [47]. Behavioral intention and motivation refer to learners' expectations of behavior and the motivation that drives learners to engage and continue using the learning platform, and the above auxiliary indicators correspond to the corresponding entries in the questionnaire and interviews (See Appendix A for validation of operationalisation of selected indicators). The questionnaire design also made reference to the technology acceptance model (TAM), theory of planned behavior (TPB), and knowledge–behavior gap theory (KBGT) to ensure the comprehensiveness and scientificity of the assessment.

It is worth stating that the questionnaire was used as the main assessment tool in this study. The structure and entries of the questionnaire were based on previous studies by Harms (2017) and Tsai (2020) et al. in which its reliability and validity in similar learning environments were verified in detail [48,49], and professors on campus helped to verify the relevance of the entries and the clarity of the representations. In order to further adapt the questionnaire to the present specific context of the study, the questionnaire was fine-tuned according to the results of the pretest, which involved 30 learners and showed statistically good internal consistency (Cronbach's $\alpha = 0.87$). In addition, to further validate the questionnaire construction, an exploratory factor analysis (EFA) was used. We chose principal component analysis (PCA) as the extraction method and applied the maximum variance method (Varimax) for factor rotation to clearly distinguish the different factors. The results of the analysis showed that all measured items loaded significantly on the expected factors and the eigenvalues of the factors were greater than 1, which supported the hypothesis of the construction of our questionnaire. The first factor contained mainly items related to the technology acceptance model (TAM), while the second factor focused on the theory of planned behavior (TPB). The total explained variance for each factor exceeded 60%.

2.3.1. Questionnaires

1. Sample selection: the study targeted active users of ChopMelon Net, including users of different year groups, educational backgrounds, and geographic locations, to ensure a representative and diverse sample.

2. Sample size: The study invited 200 users to participate in an online questionnaire through the platform's built-in randomization feature.

3. User characteristics:

Age distribution: The sample covered users of different age groups from under 18 to over 50.

Educational background: Educational backgrounds ranged from high school and below to master's degree and above, covering a wide range of educational levels.

Geographic location: participants came from different regions of China, including but not limited to cities such as Beijing, Shanghai, and Shenyang, which ensured the geographical breadth of the findings.

4. Form of distribution:

Online questionnaires (① and ②) were distributed to the target audience through the ChopMelon Net platform and social media channels. (For a detailed questionnaire, see Appendix B).

2.3.2. Interviews

From the 200 users who participated in the online questionnaire, 20 were selected for online semi-structured interviews. These 20 users were selected based on the unique insights they demonstrated in the questionnaire and the diversity of their backgrounds to ensure a broad and in-depth research perspective. Table 1 shows specific information about the 20 interviewees and Table 2 shows the interview guide.

Table 1. Specific information on interviewees.

Number [1]	Gender	Age Range	Educational Background	Occupational Field	Experience with ChopMelon Net [2]	Geographic Location [3]	Note [4]
1	Women	20	Undergraduate	Schoolchildren	6 months	Beijing	New user
2	Men	26	Master's degree student	Teacher	1 year	Shanghai	Regular user
3	Women	36	Polytechnic	Electrical engineer	2 years	Shenyang	Regular user
4	Men	45	Senior high school	Marketing manager	3 months	Chengdu	New user

Table 1. *Cont.*

Number [1]	Gender	Age Range	Educational Background	Occupational Field	Experience with ChopMelon Net [2]	Geographic Location [3]	Note [4]
5	Women	24	Undergraduate	Educational counselor	1 year	Hangzhou	Regular user
6	Men	34	Undergraduate	Schoolchildren	4 months	Xi'an	New user
7	Women	53	Master's degree student	Doctor	2 years	Nanjing	Regular user
8	Men	24	Master's degree student	Editor	1.5 years	Taiyuan	Regular user
9	Women	34	Polytechnic	Photographer	5 months	Chongqing	New user
10	Men	31	Senior high school	Designer	2 months	Tianjin	New user
11	Women	56	Polytechnic	School security	7 months	Harbin	Regular user
12	Women	22	Undergraduate	Cafeteria attendant	2 months	Beijing	New user
13	Men	29	Polytechnic	Hotel manager	2 years	Shanghai	Regular user
14	Women	38	Polytechnic	Accountant	1 year	Shenyang	Regular user
15	Men	41	Senior high school	Social worker	3 months	Chengdu	New user
16	Women	23	Master's degree student	Physiotherapist	3 years	Hangzhou	Regular user
17	Men	35	Undergraduate	Architect	2 months	Xi'an	New user
18	Women	41	Master's degree student	Counselor	3 years	Wenzhou	Regular user
19	Men	28	Polytechnic	Teacher	10 months	Guangdong	Regular use
20	Men	25	Undergraduate	Solicitor	9 months	Shenzhen	Regular user

[1] Number—each participant is numbered for ease of administration and citation. [2] Experience of using ChopMelon Net—the length of time the participant has been using ChopMelon Net to differentiate between new users and regular users. [3] Geographic location—recording the geographic location of the participant to ensure that the study covered perspectives from different areas. [4] Notes—extra information or special notes, such as frequency of use, special experience, or background of the user.

Table 2. Interview guide.

1. Please briefly introduce yourself, including your professional background and how you learnt about ChopMelon Net.
2. How long have you been using ChopMelon Net? Under what circumstances do you usually use it?
3. What type of content or problem are you looking for when you use ChopMelon Net?
4. Can you share a particularly impressive experience with the program? Why did this experience leave a lasting impression on you?
5. Has the use of ChopMelon Net changed the way you view or understand certain issues? Can you provide specific examples?
6. How do you think ChopMelon Net has helped you improve your critical thinking skills? Please share some specific examples or experiences.
7. With regard to problem-solving, has the use of ChopMelon Net helped you to solve problems more effectively? Can you give me some examples?
8. How effective do you think the ChopMelon Net has been in promoting understanding and solving real social problems? In what ways has it done well and in what ways does it need to improve?
9. If you had the opportunity to suggest improvements to ChopMelon Net, what areas would you suggest? Why?
10. Overall, how would you rate the contribution of ChopMelon Net to your personal development, especially in terms of critical thinking and problem-solving skills?
11. Would you recommend ChopMelon Net to others? Why?

3. Results

3.1. Results of the Online Questionnaire One

By analyzing users' self-assessment data on critical thinking skills before and after using ChopMelon Net, we observed significant improvements (Table 3).

Table 3. Self-evaluation data sheet for improvement of critical thinking skills before and after using ChopMelon Net.

Rating Levels	Before Using	After Using
Very low	36	18
Low	53	29
Moderate	69	43
High	38	89
Very high	4	21

Comparative analysis: Before using ChopMelon Net, only 21% of users rated their critical thinking skills as "high" or "very high". After 6 months of using ChopMelon Net, this percentage increased to 55%.

Creating hypotheses:

H0: *There will be no change in the average score of critical thinking skills before and after using ChopMelon Net.*

H1: *The average score of users' critical thinking skills increased after the use of ChopMelon Net.*

The percentage difference between before and after the use of ChopMelon Net is $p_1 - p_2 = 55\% - 21\% = 34\% = 0.34$

Calculate the standard error SE:

$$\mathrm{SE} = \sqrt{\frac{p_1(1-p_1)}{n_1} + \frac{p_2(1-p_2)}{n_2}}$$

$n_1 = n_2 = 200$ is the sample size, yielding SE = 0.0455.

Calculate the test z: $z = (p_1 - p_2)/\mathrm{SE} = 7.4725$.

At z = 7.4725, the *p*-value is very close to 0. Therefore, it can be concluded that a *p*-value of <0.05 indicates that there is a significant change in the percentage of users who consider themselves to be critical thinkers before and after using ChopMelon Net. It can be seen that ChopMelon Net has a significant impact on the improvement of users' critical thinking skills.

By analyzing the self-assessment data on the improvement in users' problem-solving skills before and after using ChopMelon Net, we observed significant improvements (Table 4).

Table 4. Self-evaluation data sheet on improvement of problem-solving skills before and after using ChopMelon Net.

Rating Levels	Before Using	After Using
Very low	36	18
Low	53	29
Moderate	69	43
High	38	89
Very high	4	21

Comparative analysis: Before using ChopMelon Net, about 39% of users considered themselves to be "high" or "very high" in problem-solving skills. After using the platform, this percentage increased to 62%.

Same as above, the hypothesis was established and the standard error SE = 0.0486 was calculated. The test z = 4.732510 was calculated, with a *p*-value of <0.05 indicating that there is a significant change in the proportion of users who consider themselves to be high or very high in problem-solving ability before and after using ChopMelon Net. It can be seen that ChopMelon Net has a significant impact on users' problem-solving abilities.

In addition, we used regression analysis to more precisely analyze the impact of ChopMelon Net on learners' critical thinking and problem-solving skills. Through regression analyses, we found that the use of ChopMelon Net had a significant positive effect on both critical thinking skills and problem-solving skills of the learners.

Table 5 and Figures 6 and 7 show the actual values of the two competency scores versus the values predicted through the regression, and it can be seen that the vast majority of learners made significant improvements in both skills after using ChopMelon Net. However, the explanatory power of the models (R2 = 0.260 and 0.348) suggests that despite being statistically significant, there are other factors that may influence the enhancement of these skills that are not fully captured in the current model. Therefore, future research needs to consider including more variables such as learners' background, previous learning experiences, and personal attitudes towards learning, which may have a significant impact on learning outcomes. In addition, while the regression model in this study provided useful preliminary information, the low level of explanation prompted further optimization of the model to provide a more comprehensive understanding of the various factors that influence learner outcomes.

Table 5. Means and standard deviations of critical thinking skills and problem-solving skills before and after using ChopMelon Net.

Aspect	Before Using	After Using
Critical thinking skills	M = 2.61 SD = 1.05	M = 3.33 SD = 1.13
Problem-solving skills	M = 3.25 SD = 0.97	M = 3.70 SD = 1.02

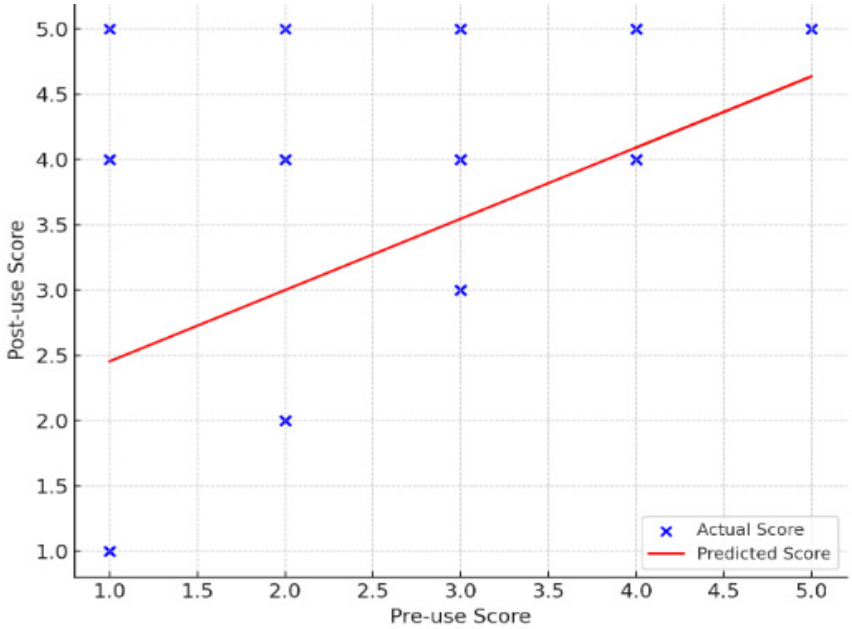

Figure 6. Regression analysis of critical thinking skills. Regression coefficient (slope): 0.546, intercept: 1.907, R^2 (degree of explanation): 0.260. The model explained 25.6% of the variance, suggesting that pre-use critical thinking skills are predictive of post-use skills, but that there are other factors at play as well.

The statistics of the scores of the overall evaluation part of the questionnaire were used to understand the satisfaction of the users with the effectiveness of the use of the ChopMelon Net.

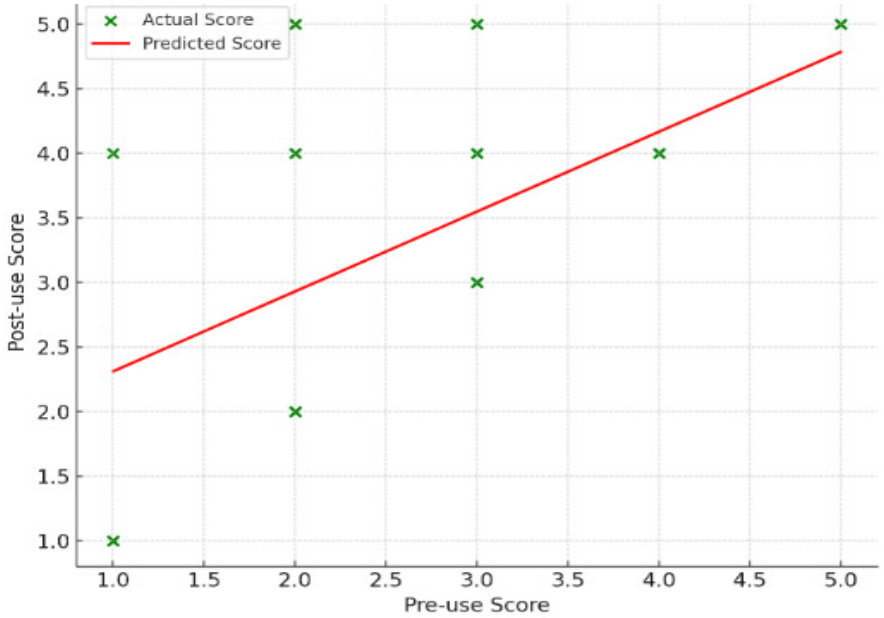

Figure 7. Regression analysis of problem-solving skills. Regression coefficient (slope): 0.619, intercept: 1.692, R^2 (degree of explanation): 0.348. The model explained 34.8% of the variance, indicating that pre-use problem-solving ability was a better predictor of post-use ability.

From Figure 8, we can see that more than half of the users of ChopMelon Net think it is highly effective in helping to understand and solve real social problems (with a score of 80–100), while 19% of them also think that it is effective (with a score of 60–80), showing that most of the users hold a positive and favorable opinion of ChopMelon Net. However, there are also 7% of users who think it is average (with a score of 40–60) and even 6% of users who think it is low (with a score of 20–40). This shows that although most users are satisfied with the effectiveness of ChopMelon Net, there are still some users who have reservations or negative attitudes toward its effectiveness.

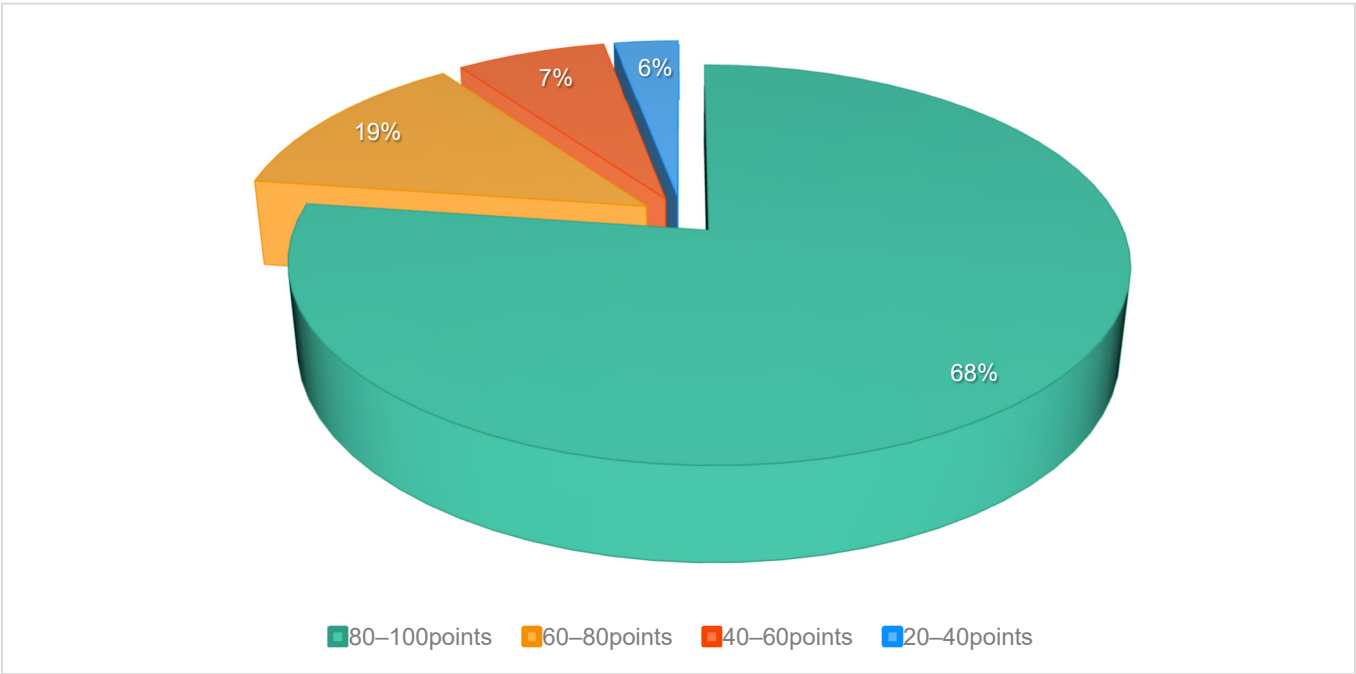

Figure 8. Overall user rating of ChopMelon Net.

The suggestions for improvement made by users were categorized and analyzed. Among them, the speed of updating and the coverage of the platform's content are the most desired improvements, accounting for 30% of the users. They believe that ChopMelon Net needs to update its content in a more timely and comprehensive manner to meet their growing learning needs. Secondly, users hope that the platform can add more interactive and social features, accounting for 25% of the total. They believe this can enhance communication and learning among users and improve learning outcomes. In addition, the platform's user interface and user experience, technical support, and customer service are also the focus of users' attention.

3.2. Results of the Online Questionnaire Two

Based on the feedback collected in the online questionnaire two, we use Pearson's correlation coefficient to analyze the correlation between user satisfaction, behavior change, and knowledge enhancement.

Each cell shows the correlation coefficient between two variables, where 1 indicates a perfect positive correlation and 0 indicates no correlation. As we can see from Figure 9, the correlation coefficients between all variables are above 0.7, which indicates that there is a strong positive correlation between these variables in these data. Such results imply that user satisfaction, knowledge growth, and behavioral change are interrelated in the ChopMelon Net environment.

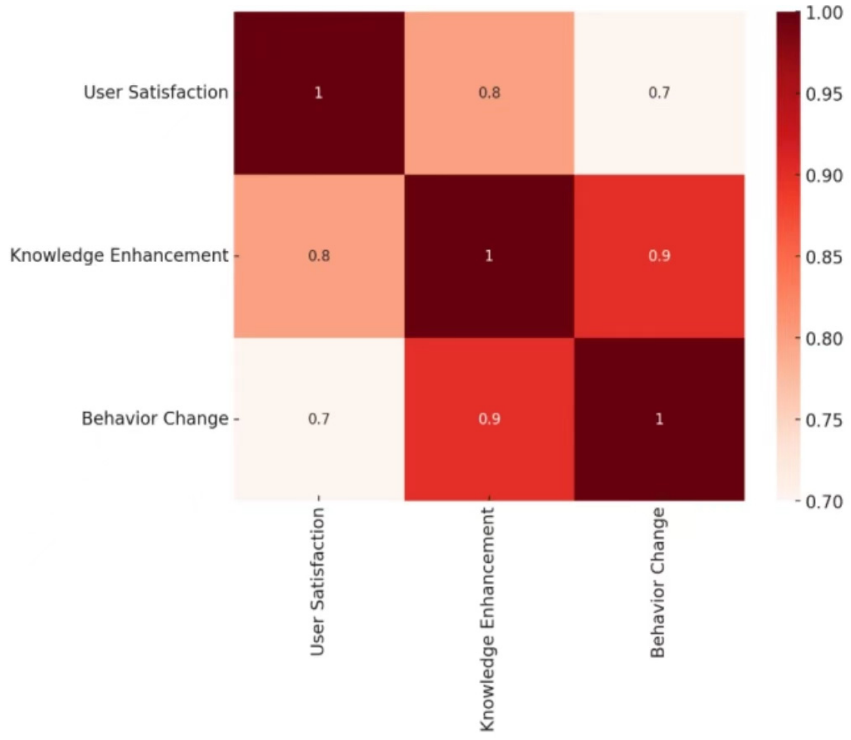

Figure 9. Correlation matrix with strong correlation among variables.

The three scatter plots show the relationship between "knowledge enhancement" and "behavioral change", "user satisfaction" and "knowledge enhancement", and "user satisfaction" and "behavioral change", respectively, as can be seen from the scatter plots.

Figure 10 shows a significant positive correlation between "knowledge enhancement" and "behavioral change", which reveals a key finding that as users' knowledge grows, their behavioral change becomes more pronounced. This phenomenon clearly indicates that ChopMelon Net not only effectively contributes to the growth of users' knowledge, but also leads to a positive behavioral change. This transformation from knowledge to action demonstrates that ChopMelon Net motivates users to apply what they have learned to their daily lives.

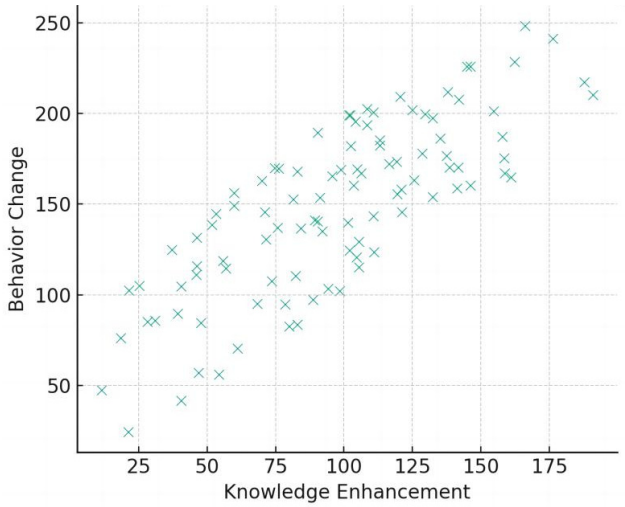

Figure 10. Knowledge enhancement vs. behavior change.

Figure 11 reveals a positive correlation between "user satisfaction" and "knowledge enhancement", suggesting that when users are more satisfied with the platform, their growth in sustainable knowledge is also more significant. This finding suggests that ChopMelon Net has been successful in creating and distributing educational content that meets the learning needs and expectations of its users. This positive feedback loop not only strengthens users' trust and reliance on the platform, but also plays a key role in enhancing their knowledge. High levels of user satisfaction often reflect the ease of use, richness of content, and attractiveness of the platform, and these elements combine to enhance the user's learning experience, making the absorption and understanding of knowledge more effective.

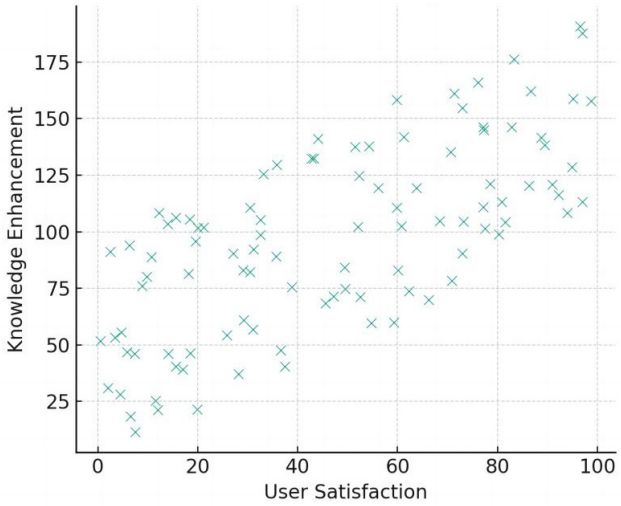

Figure 11. User satisfaction vs. knowledge enhancement.

Figure 12 shows the positive correlation between "user satisfaction" and "behavioral change", suggesting that a high level of user satisfaction with the platform may be closely related to changes in their sustainable behavior. This finding suggests that ChopMelon Net has not only won praise from users for providing high-quality educational content, but has also succeeded in encouraging users to apply what they have learned in real-life situations, leading to real behavioral change. This positive change underlines a key point, the true value of education lies not only in the acquisition of knowledge, but also in the ability to translate that knowledge into concrete action. By increasing user satisfaction, ChopMelon Net effectively bridges the gap between knowledge and action, proving the remarkable

effectiveness of its platform in promoting sustainability education and its practice, and laying a solid foundation for achieving broader social and environmental goals.

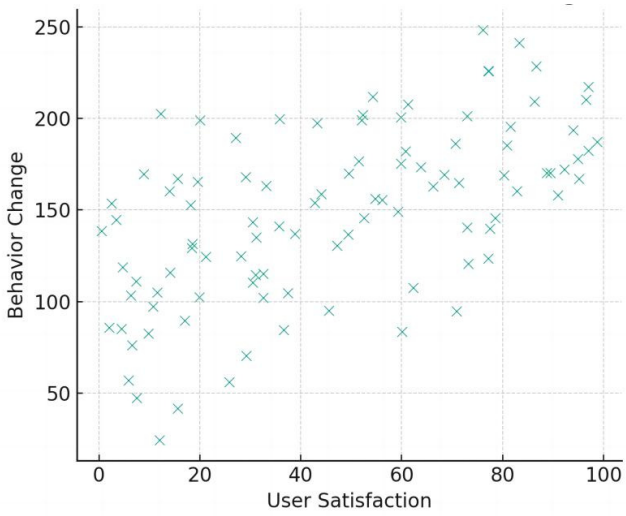

Figure 12. User satisfaction vs. behavior change.

3.3. Results of the Semi-Structured Interviews

Based on the feedback collected from the interviews, we broadly categorized the themes into five parameters: Parameter 1 "improved critical thinking skills"; parameter 2 "user satisfaction"; parameter 3 "increased knowledge"; parameter 4 "behavioral change"; and parameter 5 "improved problem-solving skills". We had 20 interviewers, and each user provided feedback on five different parameters. Since each user responded to each parameter, the total number of responses is 100 (20 users × 5 parameters). (Note: It is important to note that the total number of responses to the data, 190, exceeded the expected 100 (20 users × 5 parameters) due to the fact that the interviews encouraged users to provide multiple levels of feedback on each parameter, i.e., rather than just giving a single satisfaction rating for each parameter, users provided feedback based on different dimensions of the experience (e.g., quality of content, interactive experience, application practices), and therefore multiple ratings were provided.)

We present these responses using stacked bar charts (Figure 13).

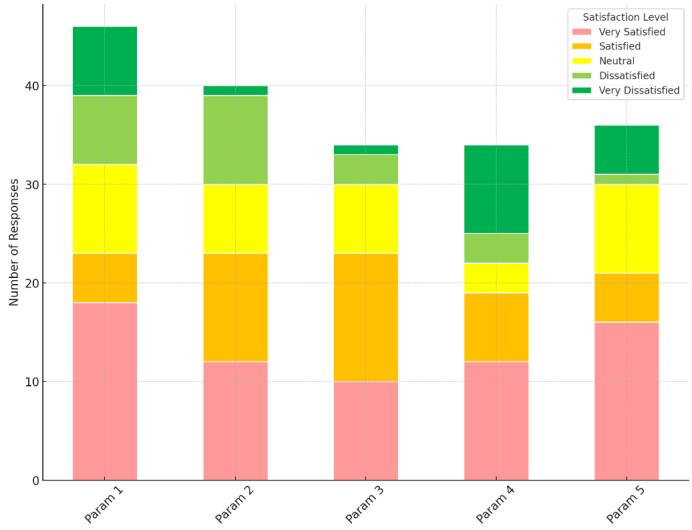

Figure 13. Stacked bar chart showing satisfaction across five parameters. (Note: Each bar represents a parameter, and different colored layers in the bar represent different levels of feedback satisfaction for that parameter).

Parameter 1 "Improved critical thinking skills"

Improved critical thinking skills received a high number of very satisfied ratings (18), but also a relatively high number of unsatisfied (7) and very unsatisfied ratings (7). This suggests that while ChopMelon Net performed well for the majority of users in terms of improving critical thinking skills, there was a certain percentage of users who did not feel the expected improvement, suggesting that the developers need to further review the course content and teaching methods in order to better meet the learning needs of all users.

Parameter 2 "User satisfaction"

Overall user satisfaction ratings of ChopMelon Net are relatively balanced, with very satisfied (12) and satisfied (11) ratings dominating. The high satisfaction ratings indicate that users are generally satisfied with the interface, content, and functionality of ChopMelon Net. The low number of dissatisfied (9) and very dissatisfied (1) ratings point to specific areas of improvement, such as improving interactivity or enhancing the personalized learning experience.

Parameter 3 "Increased knowledge"

In terms of Increased knowledge, user feedback shows a more even distribution of satisfaction, with a preponderance of very satisfied (10) and satisfied (13) ratings. This result suggests that ChopMelon Net has performed well in enhancing users' knowledge related to sustainable development, especially in promoting their ability to understand and respond to real social issues. However, there is still room to further enhance user satisfaction by adapting and enriching the pedagogical content.

Parameter 4 "Behavioral change"

Behavioral change received a relatively high number of very unsatisfactory ratings (9), which may reflect the challenges that users face in applying what they have learned to practical behavior. Although ChopMelon Net is designed to facilitate the practical application of knowledge, users may not be able to adequately demonstrate learned knowledge and skills in practice. This suggests the need to further explore mechanisms to support changes in user behavior, such as providing more practical guidance and case studies.

Parameter 5 "Improved problem-solving skills"

Improvement in problem-solving skills received relatively consistent ratings of very satisfied (16) and satisfied (5), indicating that users generally found ChopMelon Net to be effective in improving problem-solving skills. The high level of user satisfaction reflects ChopMelon Net's success in designing and implementing problem-solving-related courses and activities.

Taken together, ChopMelon Net has demonstrated its potential and effectiveness in enhancing users' critical thinking and problem-solving skills, strengthening knowledge related to sustainable development, and promoting behavioral change. However, it is also evident from the feedback reflected in the different dimensions of user satisfaction that there is room for further optimization and improvement, especially in ensuring that all users experience full learning effectiveness and behavioral change. ChopMelon Net needs to focus in the future on enhancing the personalized and practical nature of the content, as well as on improving the user-friendliness of the technical support and the user interface, so as to improve overall user satisfaction and learning outcomes.

In addition, we derived six sub-themes from the above five thematic parameters, namely, interactive experience and user engagement ①, depth and breadth of knowledge ②, technology acceptance and usage experience③, continuous learning and self-development④, community interaction and learning motivation ⑤, and practical application and behavioral change ⑥.

As can be seen in Figure 14, experience and user engagement ① is the most prominent sub-theme and is the one that has a direct link to all the other sub-themes. This demonstrates that user experience and engagement are the basis for the other learning outcomes, and if

users are not engaged, the other learning outcomes are difficult to achieve. ChopMelon Net enhances user learning experience and engagement by providing interactive and practical questions to engage users, i.e., depth and breadth of knowledge ②. As an educational platform, ChopMelon Net provides content that not only covers multiple domains, but also digs deeper into the knowledge of each domain. User feedback suggests that they are able to deepen their understanding of sustainability topics through ChopMelon Net, which is crucial for solving problems in the real world. Technology acceptance and experience of use ③ concerns how users evaluate the ease of use of the platform and the technology it provides. According to feedback, users' technology acceptance largely determines whether they continue to use ChopMelon Net. The platform needs to ensure that the user interface is user-friendly, and the content is of a high quality to promote long-term user engagement. Continuous learning and self-development ④ considers how users not only gain knowledge on ChopMelon Net, but also how they can achieve self-improvement through continuous learning. The continuous self-development path demonstrates the long-term value of education, especially in terms of critical thinking and problem-solving skills. Community interaction and learning motivation ⑤ shows the motivation that users gain through interaction with others. Community interaction motivates learners to continue exploring and provides support during the learning process, and this community power has a significant impact on learner motivation. Practical application and behavioral change ⑥ is a reflection of how users translate what they have learned into practical action. This demonstrates not only the practicality of the educational content, but also the effectiveness of ChopMelon Net in facilitating user behavioral change, which is particularly crucial for ESD.

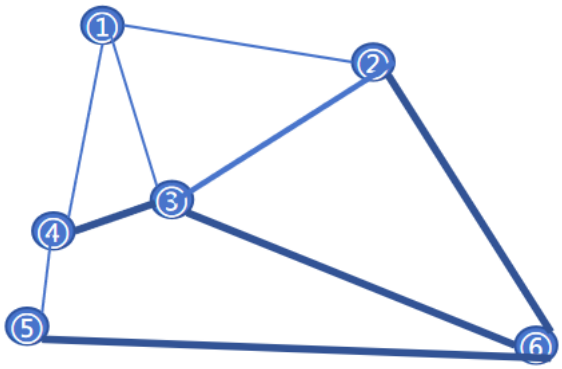

Figure 14. Sub-theme mapping. (Note: The nodes in the graph represent the themes, the edges indicate the associations between these themes, and the width of the edges indicates the strength of the associations or the frequency of mentions.).

4. Discussion

After analyzing the effectiveness of ChopMelon Net as a platform for sustainable innovation, we observed significant positive effects. This is due to the reliability and validity of the questionnaire, and our findings provide empirical support for the educational strategies of online education platforms [50,51]. Future research could consider applying the questionnaire in different learning environments and populations to further validate its broad applicability and flexibility.

The results of this study showed that the use of ChopMelon Net significantly improved users' critical thinking and problem-solving skills, which is consistent with previous research that suggests that integrating real-world problems into instruction is an effective way to improve these skills [52,53]. The complexity and dynamics of real-world problems require learners to use and integrate knowledge from different domains while encouraging them to adopt an active learning attitude [54]. Although the original questionnaire did not directly collect satisfaction data on the quality of content, interactivity, and user-friendliness of the interface, high levels of satisfaction can be indirectly inferred from user behavior and feedback. Users' high-frequency use of the platform and willingness to recommend it

may reflect their positive evaluation of various aspects of ChopMelon Net [55,56]. Future research could explore the direct relationship between these dimensions and learning effectiveness through more detailed investigations.

The ChopMelon Net platform is designed as a series of interactive cases related to real-world challenges. Each case focuses on a specific sustainable development problem, such as climate change, social justice, or economic sustainability, and provides a wealth of background information, key data, and relevant policy analyses to enable learners to fully understand the multidimensionality and complexity of the problem. For example, in a case study on water resources management, learners first experience the current living situation of a community suffering from water scarcity through virtual reality, and then analyze the potential impacts of different water resources management strategies on the community through the tools and data provided by the platform. Learners need to assess the feasibility and sustainability of various solutions, such as rainwater harvesting systems, groundwater reuse, or desalination, and ultimately come up with an integrated management plan. In this process, ChopMelon Net not only provides theoretical knowledge, but also promotes critical thinking and problem-solving skills by simulating real-world situations. Through interactive discussions and collaborative tasks, learners can exchange ideas with peers from different backgrounds and explore complex issues of sustainable development. This case-based learning approach effectively combines abstract sustainable development theory with concrete practice, enabling learners to better understand and address real-world sustainable development challenges.

The above case of ChopMelon Net further confirms the critical role of educational technology in promoting sustainable education [57,58]. By utilizing technology, educators can provide a more diverse and interactive learning experience across the constraints of traditional classrooms [56]. Although this study provides preliminary evidence of the educational effectiveness of ChopMelon Net, there are some limitations. Firstly, the relatively small sample size may affect the generalizability of the results. Second, the lack of data directly measuring the effects of content quality, interactivity, and interface friendliness on learning effectiveness limits our understanding of the role of these factors. Future research should expand the sample size and adopt a more comprehensive questionnaire design in order to delve deeper into how different aspects of online learning platforms affect learning effectiveness [59]. Overall, the case study of ChopMelon Net demonstrates the potential of integrating real social issues into online learning, which has significant positive effects on the development of critical thinking and problem-solving skills. Despite some research limitations, the findings of this study provide valuable insights into the design and evaluation of online education platforms, emphasizing the importance of creating interactive and hands-on opportunities for learners. Future research should further explore how technology can be most effectively utilized to support and enhance the goals of sustainable education [60,61].

5. Conclusions

Liaoning University's ChopMelon Net program has shown significant effectiveness in enhancing sustainable education, mainly due to the innovative integration of real social issues into teaching and learning. In this study, a comprehensive evaluation of the use of the ChopMelon Net platform was conducted through questionnaires and interviews. The results of the analysis of questionnaire one revealed significant improvements in learners' critical thinking and problem-solving skills. By comparing learners' self-assessments before and after participating in the ChopMelon Net platform, we found a positive change, with a large proportion of learners giving higher ratings to their critical thinking and problem-solving skills after the learning process. This was again verified by regression analyses. The analysis of questionnaire two further explored learners' overall satisfaction with the ChopMelon Net platform and the impact of the learning experience on their knowledge growth and behavioral changes. Using Pearson's correlation coefficient analysis, the results show a strong positive correlation between user satisfaction, knowledge growth, and

behavioral change. This suggests that learners are not only satisfied with the platform's educational content and interactive experience, but also that this satisfaction is strongly linked to their knowledge growth and actual behavioral change, thus reinforcing the role of online learning platforms in facilitating the dissemination of the concepts and practices of sustainable education. The analysis of the semi-structured interviews provided deeper insights through stacked bar charts, revealing how learners actually improved their critical thinking, problem-solving skills, user satisfaction, and changes in knowledge behaviors through the ChopMelon Net project. They expanded their understanding of various aspects of sustainable education. Feedback from learners in the interviews also emphasized the importance of community interaction and motivation to learn, while also pointing to some room for improvement, such as the speed of updates and the coverage of the platform's content.

In summary, the ChopMelon Net program has not only successfully enhanced learners' critical skills and knowledge, but also increased their awareness of sustainable development issues through the provision of high-quality educational content and interactive experiences. These findings provide an important empirical basis for how e-learning platforms can more effectively support sustainable education and point the way to future educational practices and research.

In addition, future research should endeavor to expand the sample size and increase the diversity of the sample to ensure the generalizability and transferability of the findings, and the research should also include long-term tracking studies to assess the impact of online learning platforms, such as ChopMelon Net, on users' long-term learning effectiveness and career development. By exploring these research directions, we can develop a deeper understanding of how online educational technologies can best support and enhance the goals of sustainable education, and provide richer insights and evidence for the development and application of educational technologies.

Author Contributions: Conceptualization, J.L.; Methodology, X.T.; Formal analysis, X.T.; Investigation, J.L.; Resources, Y.T.; Data curation, J.L.; Writing—original draft, X.T.; Writing—review & editing, Y.T.; Funding acquisition, Y.T. All authors have read and agreed to the published version of the manuscript.

Funding: The Key Project of Liaoning Provincial Social Science Foundation, China: Grant No. L22AWT015.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

In terms of critical thinking and problem-solving skills, this study used a multi-source data collection strategy. Firstly, the questionnaire was demonstrated to show good reliability through validation based on previous studies. In addition, the behavioral performance of the questionnaire participants was observed through ChopMelon Net real-world problem-solving scenarios and independently rated by the students' class guide to ensure the objectivity of the evaluation. The correlation between learners' questionnaires and teachers' ratings was 0.76, indicating that the questionnaires reflect learners' real abilities better. Concepts such as "learning satisfaction" and "behavioral intention" were directly analyzed as a result of the quantitative data from the questionnaire.

Appendix B

Questionnaire for users of ChopMelon Net ①
Basic information
1. Your age range: ✧ Up to 18 years old ✧ 18–24 years old ✧ 25–34 years old ✧ 35–44 years old ✧ 45+ years old
2. Your gender: ✧ Male ✧ Female ✧ Other ✧ Don't want to disclose
3. Your occupation: ✧ Student ✧ Educator ✧ Professional ✧ Freelance ✧ Other (please specify) _____
4. What is your educational background? ✧ High school and below ✧ Specialized/undergraduate ✧ Master and above
Frequency with ChopMelon Net
5. How often do you use ChopMelon Net? ✧ Daily ✧ Weekly ✧ Monthly ✧ Occasionally
Critical thinking and problem-solving skills
6. How would you rate your critical thinking skills before using ChopMelon Net? ✧ Very low ✧ Low ✧ Moderate ✧ High ✧ Very high
7. How would you rate your critical thinking skills after using ChopMelon Net? ✧ Very low ✧ Low ✧ Moderate ✧ High ✧ Very high
8. How would you rate your problem-solving skills before using ChopMelon Net? ✧ Very low ✧ Low ✧ Moderate ✧ High ✧ Very high

9. How would you rate your problem-solving skills after using ChopMelon Net?
- ✧ Very low
- ✧ Low
- ✧ Moderate
- ✧ High
- ✧ Very high

Overall evaluation (scoring)

10. How effective do you think ChopMelon Net is in helping you understand and solve real social problems? Please rate:
- ✧ 20–40 points
- ✧ 40–60 points
- ✧ 60–80 points
- ✧ 80–100 points

11. What improvement suggestions do you have for ChopMelon Net?

Questionnaire for users of ChopMelon Net ②

Based on the TAM: User satisfaction and technology acceptance

1. I think that using ChopMelon Net will improve my learning/productivity.
- ✧ Strongly agree
- ✧ Agree
- ✧ Neutral
- ✧ Disagree
- ✧ Strongly disagree

2. I found ChopMelon Net easy to get started using.
- ✧ Strongly agree
- ✧ Agree
- ✧ Neutral
- ✧ Disagree
- ✧ Strongly disagree

Based on the TPB: Behavior Change

3. I intend to continue to use ChopMelon Net to support my studies/work.
- ✧ Strongly agree
- ✧ Agree
- ✧ Neutral
- ✧ Disagree
- ✧ Strongly disagree

4. My social circle (e.g., friends, colleagues) find my use of ChopMelon Net useful.
- ✧ Strongly agree
- ✧ Agree
- ✧ Neutral
- ✧ Disagree
- ✧ Strongly disagree

Based on the KBGT: Knowledge Enhancement

5. I have improved my knowledge in my profession by using ChopMelon Net.
- ✧ Strongly agree
- ✧ Agree
- ✧ Neutral
- ✧ Disagree
- ✧ Strongly disagree

6. I was able to apply what I learnt through ChopMelon Net to real life.
   - ✧ Strongly agree
   - ✧ Agree
   - ✧ Neutral
   - ✧ Disagree
   - ✧ Strongly disagree

7. What challenges or difficulties have you encountered in using ChopMelon Net?

References

1. Agbedahin, A.V. Sustainable development, Education for Sustainable Development, and the 2030Agenda for Sustainable Development: Emergence, efficacy, eminence, and future. *Sustain. Dev.* **2019**, *27*, 669–680. [CrossRef]
2. Baig, M.I.; Yadegaridehkordi, E. Flipped classroom in higher education: A systematic literature review and research challenges. *Int. J. Educ. Technol. High. Educ.* **2023**, *20*, 61. [CrossRef]
3. Shin, J.C.; Harman, G. New challenges for higher education: Global and Asia-Pacific perspectives. *Asia Pac. Educ. Rev.* **2009**, *10*, 1–13. [CrossRef]
4. Van Damme, D.; Zahner, D.; Cortellini, O.; Dawber, T.; Rotholz, K. Assessing and developing critical-thinking skills in higher education. *Eur. J. Educ.* **2023**, *58*, 369–386. [CrossRef]
5. Zoller, U. Science Education for Global Sustainability: What Is Necessary for Teaching, Learning, and Assessment Strategies? *J. Chem. Educ.* **2012**, *89*, 297–300. [CrossRef]
6. Jansen, R.S.; van Leeuwen, A.; Janssen, J.; Kester, L.; Kalz, M. Validation of the self-regulated online learning questionnaire. *J. Comput. High. Educ.* **2016**, *29*, 6–27. [CrossRef]
7. Berchin, I.I.; Dutra, A.R.d.A.; Guerra, J.B.S.O.d.A. How do higher education institutions promote sustainable development? A literature review. *Sustain. Dev.* **2021**, *29*, 1204–1222. [CrossRef]
8. Shulla, K.; Filho, W.L.; Lardjane, S.; Sommer, J.H.; Borgemeister, C. Sustainable development education in the context of the 2030 Agenda for sustainable development. *Int. J. Sustain. Dev. World Ecol.* **2020**, *27*, 458–468. [CrossRef]
9. Oezdemir, O. A New environmental education perspective: Education for Sustainable Development. *Egit. Bilim-Educ. Sci.* **2007**, *32*, 23–38.
10. Springett, D. Education and the Problems of Sustainable Development. *Probl. Ekorozwoju* **2016**, *11*, 7–14. [CrossRef]
11. Kopnina, H.; Meijers, F. Education for sustainable development (ESD) Exploring theoretical andpractical challenges. *Int. J. Sustain. High. Educ.* **2014**, *15*, 188–207. [CrossRef]
12. Borys, T. Decade of Education for Sustainable Development—Polish Challenges. *Probl. Ekorozwoju* **2010**, *5*, 59–70.
13. Stare, J.; Klun, M. Problem-oriented practice for students of the bologna. *Didact. Slov.-Pedagos. Obz.* **2008**, *23*, 146–158.
14. Kohler, B. Mastering problem serving tasks and acquiring skills: Studying with problem-oriented text models. *Z. Entwicklungspsychol. Padagog. Psychol.* **2000**, *32*, 34–43.
15. Hu, Y.H.; Xing, J.; Tu, L.P. The Effect of a Problem-oriented Teaching Method on University Mathematics Learning. *Eurasia J. Math. Sci. Technol. Educ.* **2018**, *14*, 1695–1703.
16. Budde, J. Problem-Oriented Perspectives on Heterogeneity as an Ambivalent Topic in Research on Teaching and Schools. *Z. Padagog.* **2012**, *58*, 522–540.
17. Chung, J.C.C.; Chow, S.M.K. Promoting student learning through a student-centred problem-based learning subject curriculum. *Innov. Educ. Teach. Int.* **2004**, *41*, 157–168. [CrossRef]
18. Özyurt, Ö. Examining the Critical Thinking Dispositions and the Problem Solving Skills of Computer Engineering Students. *Eurasia J. Math. Sci. Technol. Educ.* **2015**, *11*, 353–361. [CrossRef]
19. Szabo, Z.K.; Körtesi, P.; Guncaga, J.; Szabo, D.; Neag, R. Examples of Problem-Solving Strategies in Mathematics Education Supporting the Sustainability of 21st-Century Skills. *Sustainability* **2020**, *12*, 10113. [CrossRef]
20. Steward, K.C.; Gosselin, D.; Chandler, M.; Forbes, C.T. Student Outcomes of Teaching About Socio-scientific Issues in Secondary Science Classrooms: Applications of EzGCM. *J. Sci. Educ. Technol.* **2023**, *33*, 195–207. [CrossRef]
21. Brown, M.C.; McNeil, N.M.; Glenberg, A.M. Using Concreteness in Education: Real Problems, Potential Solutions. *Child Dev. Perspect.* **2009**, *3*, 160–164. [CrossRef]
22. Kopnina, H. Education for the future? Critical evaluation of education for sustainable development goals. *J. Environ. Educ.* **2020**, *51*, 280–291. [CrossRef]
23. Persky, A.M.; Medina, M.S.; Castleberry, A.N. Developing Critical Thinking Skills in Pharmacy Students. *Am. J. Pharm. Educ.* **2019**, *83*, 161–170. [CrossRef] [PubMed]
24. Škėrienė, S.; Jucevičienė, P. Problem solving through values: A challenge for thinking and capability development. *Think. Ski. Creat.* **2020**, *37*, 100694. [CrossRef] [PubMed]
25. Tasgin, A.; Dilek, C. The mediating role of critical thinking dispositions between secondary school student's self-efficacy and problem-solving skills. *Think. Ski. Creat.* **2023**, *50*, 101400. [CrossRef]
26. Tümkaya, S.; Aybek, B.; Aldag, H. An Investigation of University Students' Critical Thinking Disposition and Perceived Problem Solving Skills. *Eurasian J. Educ. Res.* **2009**, *9*, 57–74.

27. Ahmady, S.; Shahbazi, S. Impact of social problem-solving training on critical thinking and decision making of nursing students. *BMC Nurs.* **2020**, *19*, 94. [CrossRef]
28. Ma, H.; Zhao, M.; Wang, H.; Wan, X.; Cavanaugh, T.W.; Liu, J. Promoting pupils' computational thinking skills and self-efficacy: A problem-solving instructional approach. *Educ. Technol. Res. Dev.* **2021**, *69*, 1599–1616. [CrossRef]
29. Bolmsten, J.; Manuel, M.E. Sustainable participatory processes of education technology development. *Educ. Technol. Res. Dev.* **2020**, *68*, 2705–2728. [CrossRef]
30. Orakci, S. Structural relationship among academic motivation, academic self-efficacy, problem solving skills, creative thinking skills, and critical thinking skills. *Psychol. Sch.* **2023**, *60*, 2173–2194. [CrossRef]
31. Tsai, C.-A.; Song, M.-Y.W.; Lo, Y.-F.; Lo, C.-C. Design thinking with constructivist learning increases the learning motivation and wicked problem-solving capability—An empirical research in Taiwan. *Think. Ski. Creat.* **2023**, *50*, 101385. [CrossRef]
32. Liu, Y.; Wen, W.; Gao, Y.; Zhang, X.; Qu, T.; Yin, D.; Peng, X.; Shi, Y. Online Homework Intelligent Platform Based on Self-Regulated Learning (SRL): Essential for Sustainable Development of Online Higher Education. *Sustainability* **2022**, *14*, 16904. [CrossRef]
33. Sridharan, S.; Bondy, M.; Nakaima, A.; Heller, R.F. The potential of an online educational platform to contribute to achieving sustainable development goals: A mixed-methods evaluation of the Peoples-uni online platform. *Health Res. Policy Syst.* **2018**, *16*, 106. [CrossRef]
34. Liu, S.; Guo, D.; Sun, J.; Yu, J.; Zhou, D. MapOnLearn: The Use of Maps in Online Learning Systems for Education Sustainability. *Sustainability* **2020**, *12*, 7018. [CrossRef]
35. Sun, C.; Liu, J.; Razmerita, L.; Xu, Y.; Qi, J. Higher Education to Support Sustainable Development: The Influence of Information Literacy and Online Learning Process on Chinese Postgraduates' Innovation Performance. *Sustainability* **2022**, *14*, 7789. [CrossRef]
36. Huang, Y.; Pan, L.; Wang, Y.; Yan, Z.; Chen, Y.; Hao, X.; Xia, T. Exploring the User Acceptance of Online Interactive Mechanisms for Live-Streamed Teaching in Higher Education Institutions. *Sustainability* **2023**, *15*, 13529. [CrossRef]
37. Li, C.; Zhou, H. Enhancing the Efficiency of Massive Online Learning by Integrating Intelligent Analysis into MOOCs with an Application to Education of Sustainability. *Sustainability* **2018**, *10*, 468. [CrossRef]
38. Cheung, R.; Vogel, D. Predicting user acceptance of collaborative technologies: An extension of the technology acceptance model for e-learning. *Comput. Educ.* **2013**, *63*, 160–175. [CrossRef]
39. Sussman, R.; Gifford, R. Causality in the Theory of Planned Behavior. *Personal. Soc. Psychol. Bull.* **2019**, *45*, 920–933. [CrossRef]
40. Swart, J.; Powell, J. An analytical theory of knowledge behaviour in networks. *Eur. J. Oper. Res.* **2012**, *223*, 807–817. [CrossRef]
41. Butler, H.A. Predicting Everyday Critical Thinking: A Review of Critical Thinking Assessments. *J. Intell.* **2024**, *12*, 16. [CrossRef] [PubMed]
42. Mulnix, J.W. Thinking Critically about Critical Thinking. *Educ. Philos. Theory* **2012**, *44*, 464–479. [CrossRef]
43. Yanchar, S.C.; Slife, B.D.; Warne, R. Critical Thinking as Disciplinary Practice. *Rev. Gen. Psychol.* **2008**, *12*, 265–281. [CrossRef]
44. Fischer, A.; Greiff, S.; Wüstenberg, S.; Fleischer, J.; Buchwald, F.; Funke, J. Assessing analytic and interactive aspects of problem solving competency. *Learn. Individ. Differ.* **2015**, *39*, 172–179. [CrossRef]
45. Van Merriënboer, J.J.G. Perspectives on problem solving and instruction. *Comput. Educ.* **2013**, *64*, 153–160. [CrossRef]
46. Qi, D.; Zhang, M.; Zhang, Y. Influence of Participation and Value Co-creation on Learner Satisfaction of MOOCs Learning: Learner Experience Perspective. *Asia-Pac. Educ. Res.* **2020**, *31*, 61–70. [CrossRef]
47. Harlim, J.; Belski, I. Long-term Innovative Problem Solving Skills: Redefining Problem Solving. *Int. J. Eng. Educ.* **2014**, *29*, 280–290.
48. Harms, C.; Jackel, L.; Montag, C. Reliability and completion speed in online questionnaires under consideration of personality. *Pers. Individ. Differ.* **2017**, *111*, 281–290. [CrossRef]
49. Tsai, C.-L.; Cho, M.-H.; Marra, R.; Shen, D. The Self-Efficacy Questionnaire for Online Learning (SeQoL). *Distance Educ.* **2020**, *41*, 472–489. [CrossRef]
50. Hai, L.; Sang, G.; Wang, H.; Li, W.; Bao, X. An Empirical Investigation of University Students' Behavioural Intention to Adopt Online Learning: Evidence from China. *Behav. Sci.* **2022**, *12*, 403. [CrossRef]
51. Kassab, S.E.; El-Baz, A.; Hassan, N.; Hamdy, H.; Mamede, S.; Schmidt, H.G. Construct validity of a questionnaire for measuring student engagement in problem-based learning tutorials. *BMC Med. Educ.* **2023**, *23*, 844. [CrossRef] [PubMed]
52. van de Pol, J.; de Vries, N.; Poorthuis, A.M.G.; Astrid, M.G.; Mainhard, T. The Questionnaire on Teacher Support Adaptivity (QTSA): Reliability and Validity of Student Perceptions. *J. Exp. Educ.* **2023**, *91*, 765–797. [CrossRef]
53. Tan, A.J.Y.; Davies, J.L.; Nicolson, R.I.; Karaminis, T. Learning critical thinking skills online: Can precision teaching help? *Educ. Technol. Res. Dev.* **2023**, *71*, 1275–1296. [CrossRef]
54. Goodsett, M. Best practices for teaching and assessing critical thinking in information literacy online learning objects. *J. Acad. Librariansh.* **2020**, *46*, 102163. [CrossRef]
55. Ali, K.; Barhom, N.; Duggal, M.S. Online assessment platforms: What is on offer? *Eur. J. Dent. Educ.* **2022**, *27*, 320–324. [CrossRef]
56. Araos, A.; Damsa, C.; Gasevic, D. Browsing to learn: How computer and software engineering students use online platforms in learning activities. *J. Comput. Assist. Learn.* **2022**, *39*, 676–693. [CrossRef]
57. Rodríguez-Loinaz, G.; Ametzaga-Arregi, I.; Palacios-Agundez, I. ICT tools and citizen science: A pathway to promote science learning and Education for Sustainable Development in schools. *J. Biol. Educ.* **2022**, *6*, 1–17. [CrossRef]
58. Rodríguez, P.; Nussbaum, M.; Dombrovskaia, L. ICT for education: A conceptual frameworkfor the sustainable adoption of technology-enhanced learning environments in schools. *Technol. Pedagog. Educ.* **2012**, *21*, 291–315. [CrossRef]

59. Joshi, K.; Kumar, R.; Bharany, S.; Saini, D.K.J.B.; Kumar, R.; Ibrahim, A.O.; Abdelmaboud, A.; Nagmeldin, W.; Medani, M.A. Exploring the Connectivity Between Education 4.0 and Classroom 4.0: Technologies, Student Perspectives, and Engagement in the Digital Era. *IEEE Access* **2024**, *12*, 24179–24204. [CrossRef]
60. Svenningsson, J.; Hultén, M.; Hallström, J. Understanding attitude measurement: Exploring meaning and use of the PATT short questionnaire. *Int. J. Technol. Des. Educ.* **2016**, *28*, 67–83. [CrossRef]
61. Elshof, L. Toward sustainable practices in technology education. *Int. J. Technol. Des. Educ.* **2009**, *19*, 133–147. [CrossRef]