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Developing interactive conservation education modules to enhance eco literacy and stewardship for local aquatic biodiversity

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Abstract

This study aims to design and evaluate interactive conservation education modules to enhance ecological literacy, environmental attitudes, and stewardship behavior toward aquatic biodiversity. A mixed-method, quasi-experimental, pre-test and post-test control group design was used, and the sample consisted of 180 participants (90 experimental, 90 control), in an online learning classroom. The experimental group used interactive online modules with simulations, narrative, and game assessment, whereas the control group was taught in a traditional manner. Paired t-tests, regression analysis, and measures of effect size were used to analyze data. Results at the baseline showed that there were no significant differences between the groups ($p > 0.05$). Eco Literacy Index increased significantly in the experimental group (2.84 ± 0.51 to 4.12 ± 0.44; $t = 18.76$, $p < 0.001$), but not in the control group (2.79 ± 0.48 to 3.05 ± 0.50; $p = 0.05$). Environmental Attitude improved from 3.12 to 4.20 and Stewardship Behavior from 2.95 to 4.05 in the experimental group ($p < 0.001$). The regression analysis indicated that the ecological literacy ($\beta = 0.61$) and environmental attitude ($\beta = 0.34$) were significant predictors of the stewardship behavior ($R^2 = 0.68$). An enormous effect size (Cohen's $d = 1.85$) and a high

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level of engagement (r = 0.72) were found. Learner-centered, interactive modules have a high impact on ecological literacy and a beneficial effect on pro-environmental behavior. The results emphasize the role of combining digital and hands-on approaches to learning in environmental education. Further studies are needed to determine the long-term effects and how it can be scaled up in a wide range of settings.

Keywords: Ecological literacy, Environmental attitude, Stewardship behavior, Interactive learning, Aquatic biodiversity, Digital education, Conservation education

Introduction

Constructed wetlands, coastal and freshwater environments are aquatic ecosystems that are some of the most prolific and biodiverse on the earth. They sustain a large diversity of species, regulate hydrological processes, and offer important ecosystem services like water purification, food supply, and climate control. Yet, anthropogenic pressures on these ecosystems are growing, particularly through pollution, habitat fragmentation, resource overexploitation, invasive species, and climate change. One of the main problems surrounding solutions to these threats is that the ecological literacy (eco literacy) of local communities, especially in areas where livelihoods are strongly dependent on aquatic life, is limited. Eco literacy is the knowledge of ecological concepts, environmental concerns, and sustainability, which allows people to make wise choices. Conventional approaches to environmental education are often based on passive types of learning, which might not be effective in engaging students and producing lasting behavioral learning (Kelly *et al.,* 2022). Interactive and experiential learning applications include digital modules, simulation, participatory learning, or a gamified piece of content that have proven successful in the last few years to develop a stronger knowledge, skills, and environmental awareness (Ihwughwavwe and Aniebonam, 2024). These methods allow improving pro-environmental behaviour and knowledge retention by engaging with the environment and thinking critically and being emotionally attached to it. It is possible to narrow the knowledge-action gap by designing context-driven, interactive conservation education units that are local to aquatic biodiversity, and enabling local communities to become active in conservation efforts (Goodale, Gilmore and Griffiths, 2025).

The essence of the research is to design, develop and test interactive conservation education modules able to improve ecological literacy (eco literacy) and emulate stewardship behaviours as much as local aquatic biodiversity is involved. Particularly, this study aims to evaluate the pre-test levels of environmental knowledge, attitudes, and practices of the participants, and develop context-specific educational material based on local aquatic ecosystems and biodiversity issues. It also focuses on integrating interactive and experience-based methods of learning including simulation, storytelling, and participatory learning to enhance the engagement and retention of knowledge. Moreover, the research paper aims at assessing the efficacy of these modules in enhancing eco literacy, altering pro-environmental perceptions, and promoting conservation-oriented behaviors. Finally, the study will address the connection between a deeper ecological knowledge and behavioral intention and give recommendations on scalable and sustainable interventions in environmental education.

Although the engagement of environmental education as a biodiversity conservation instrument is gaining more and more importance, there exist major gaps in the implementation and success (Carvalho *et al.,* 2021). Current educational methods are usually non-local and very general, and do not help to focus on the local features and problems of the local aquatic environment. In addition, conventional instructional practices are predominant, and a few interactive and technology-based learning tools, which may improve interaction and higher levels of comprehension, are still not well incorporated. The second important gap is that there is a vague connection between the acquisition of knowledge and the actual behavior change, with the majority of studies dealing mainly with awareness without evaluating the long-term results of the stewardship. Further, no in-depth assessment systems are available to quantify and objectively assess the effect of conservation education programs. Such programmes are also not as relevant and efficient due to the absence of the engagement of local populations and students in the creation of education resources. The locally selected ecological content, didactic interaction, and measurable behavior outcomes fill these gaps in this paper.

The foundations of this study are as follows. It is believed that interactive and situational learning methods are capable of improving ecological literacy and conservation behavior to a great extent. The hypothesis is that the level of eco literacy in the participants who will be exposed to interactive conservation education modules will be significantly higher than the level of eco literacy in the participants who will be involved in the traditional learning methods. It is also anticipated that better eco literacy will have a positive effect on attitude towards aquatic biodiversity conservation and result in stronger pro-environmental intentions. Another hypothesis of the study is that experiential and participatory learning strategies will lead to improved knowledge retention and more profound knowledge of ecological concepts. Furthermore, it is assumed that eco literacy and stewardship behaviors are associated in a positive and significant manner, which means that greater knowledge and awareness can be converted into some meaningful conservation behavior (Iyer *et al.,* 2026).

The ways in which the work assists in the fields of environmental education and biodiversity protection are as follows. It suggests an alternative approach of constructing interactive conservation education modules, which will be adapted to be used within local water systems. The research takes the next level and proposes the current education practice in the embodiment of technology-based tools and experience-based learning methods into the research process. The study also has empirical evidence on the effectiveness of interactive learning in making eco literate and behaviorally-change and therefore closing the knowledge-action gap. Besides, it also places emphasis on the use of localized content to make conservation education more relevant and effective to specific communities. The findings are helpful to educate educators, curriculum developers, and policymakers in the development of working environmental education programs. Finally, the paper gives a model that may be expanded to other ecological contexts and contribute to the greater tasks of sustainable ecological management and environmental conservation cognizance.

The paper will be separated into six key points. Section 1, the introduction presents the overview of the issues of the aquatic ecosystem, the importance of ecological literacy, the aim of the research, the gaps of the studies, and the importance of the study. Section 2 of this paper discusses the currently available literature on the role of environmental education, methods of interactive learning, and modules on digital platforms, and identifies existing gaps. Section 3 provides the methodology that entails description of the mixed-method quasi-experimental design, the sampling strategy, creation of the module, application of the measuring tools as well as analysis that is founded on the statistical method. Section 4 presents the results that show the comparative results of the baseline, the impact of the intervention, pre-post results, regression results, and the measure of engagement. Section 5 discusses the findings by interpreting, explaining implications, limitations and relating the results to previous works. And section 6, is a conclusion that summarises some of the key findings, contributions, future research directions.

Literature Review

There is growing appreciation that environmental education is a very important instrument to conserve biodiversity and manage available resources in a sustainable manner. Recently, the need to enhance ecological literacy (eco literacy) as the fundamental unit of environmental custodianship has been restated, particularly in the so-called natural resource-dependent societies. Eco literacy is more expansive than mere knowledge, including the knowledge about ecological systems, human interaction with the environment, and the ability to make devoted conservation choices (Colucci-Gray *et al.,* 2006; Amalia, 2024). This level of literacy improvement, in particular to aquatic ecosystems, is of particular concern, as the dangers to them, such as pollution, habitat deterioration, and climate change, are growing (Qudrat-Ullah, 2025).

Conventional methods of environmental education, however, have been criticised on the basis of low levels of long-term behaviour change. Passive learning practices do not always capture the attention of the learner and put the new knowledge into practice (Ardan, 2025). To mitigate this shortcoming, recent studies have emphasized that interactive and experiential learning practices must be integrated. The utilization of digital tools, simulation, and serious games has been proven to be linked to a substantial level of engagement, knowledge retention, and pro-environmental behavior (Veronica and Calvano, 2020; Torralba-Burrial and Dopico, 2023). In one example, ocean literacy game-based learning has shown significant gains in cognitive and behavioral responses among learners (Asikin *et al.,* 2026).

Digital and conservation-based e-modules are among the newest trends in environmental education. Research has shown that multimedia content coupled with participatory learning activities by interactive e- modules is effective in supporting environmental literacy (Mardiana *et al.,* 2026). In addition, the integration of local ecological knowledge and socio-scientific issues in learning tools has been revealed to increase the contextual meaning and relevance, and the connection between learners and the environment (Purwasih *et al.,* 2025). Local approach also plays a role, especially in conservation of aquatic biodiversity, since it assists in aligning the teaching materials to the ecological issues that individuals encounter in the real world.

The other significant part of environmental education is stewardship and community involvement. It is proposed that engaging learners in participatory and community-based conservation brings about a feeling of responsibility and ownership of natural resources (Merenlender *et al.,* 2016; Aloro & Nama, 2025). Education programs integrating outreach and communication approaches, such as media-based interventions, have also been shown to be effective in increasing awareness and changing conservation behavior in aquatic settings (Loury *et al.,* 2021). Moreover, the blue school program and river literacy initiatives are holistic approaches that emphasize the need to combine formal education and community-led conservation efforts (Costa and Faria, 2025; Molnár *et al.,* 2025).

Regardless of all these developments, there are loopholes that still exist in matching the digital education technology with quantifiable behavior change as well as stewardship behaviors. Although some studies have been conducted on eco literacy and digital learning as independent variables, there are a few studies on the combination of the two variables in an integrative and assessive manner. Moreover, the prospect of online interactive modules that can be used to expand conservation education to other populations is not pursued to the full (Tomaskinova *et al.,* 2025).

On the whole, according to the existing sources, interactive, technology, and context-based learning styles have become very effective in the formation of eco-literacy and environmental stewardship. However, integrated models, the combination of digital interactivity, local ecological relevancy, and outcome behavior, are highly desirable, too. This study fills these gaps by designing and assessing interactive conservation education modules specifically targeting the local aquatic biodiversity to make an input to both the theoretical and practical aspects of environmental education.

Methodology

Research Design

This paper uses a quasi-experimental mixed-method research design based on a completely online course to determine the efficacy of interactive conservation education modules. The ecological literacy, environmental attitudes, and stewardship behaviors are considered and assessed using pre-test and post-test control group design. The sample will include experimental and control groups, where the former will be engaged in consuming interactive digital materials whereas the latter will be receiving traditional Internet-based instructional materials. Such a design allows concluding on the effect of the intervention causally and simultaneously hold ecological validity in a real-life digital learning context.

Sampling Design and Participants

The online identification of the participants is done through stratified purposive sampling to ensure the diversity in terms of demographic and educational status. It is the analysis of power that is to be known and grounded so as to know the required sample size and this is calculated as follows:

$$n = \frac{Z^2 \cdot p(1-p)}{e^2} \qquad (1)$$

Equation (1) below indicates that n is the size of the sample, Z is the Z-score of the confidence level, p is the proportion of the population that is supposed to be estimated, and e is the margin of error. This provides sufficient statistical power and external validity.

Development of Interactive Conservation Modules

The modules will be developed to address the needs of an instructional design model grounded in the ecological theory, multimedia concepts of learning, and user-friendly design. It is tailored towards the specifics of the local aquatic biodiversity and incorporates interactive simulations, scenario-based learning, game-based assessments, and visual narrative. Being digitally hosted, the modules could be monitored in terms of user interactivity metrics, such as the rates of completion, time-on-task, performance grades. Expert review is done to ensure the content validity and pilot testing is done to enhance usability and engagement.

Measurement of Eco Literacy and Behavioral Constructs

Standardized Likert-scale measures are used to measure ecological literacy, environmental attitudes, and stewardship intentions. Eco Literacy Index (ELI) is a composite index built as:

$$ELI = \frac{\sum_{i=1}^{k} X_i}{k} \qquad (2)$$

Equation (2) signifies that X_i is the score of individual items and k is the number of items. It is an index of ecological understanding that is normalized to give a measure of the ecological understanding among the participants.

A linear regression model is used to model behavioral intention towards conservation:

$$Y = \beta_0 + \beta_1 EL + \beta_2 EA + \epsilon \qquad (3)$$

Y refers to stewardship behavior, EL refers to ecological literacy, EA refers to environmental attitude, and ϵ is an error term in equation (3).

Reliability and Validity Testing

Cronbach's alpha is used to test the internal consistency of the measurement instruments:

$$\alpha = \frac{k}{k-1}\left(1 - \frac{\sum \sigma_i^2}{\sigma_T^2}\right) \qquad (4)$$

In equation (4), k denotes the number of items, σ_i^2 is the variance of a single item, and σ_T^2 is the total variance. The construct validity is evaluated through both exploratory and confirmatory factor analysis, whereby it is assumed that the variables obtained sufficiently depict the constructs that the intended study measures.

Implementation Procedure

The research is done in three stages: pre-intervention, intervention, and post-intervention. Baseline data are gathered in the pre-intervention stage using online surveys. During the intervention phase, experimental group members will undergo interaction modules with a specified duration, and control group members will obtain only static online learning. The post-intervention phase is the measurement of changes in outcomes by administering the same instruments. Engagement analytics data, including completion rates of modules and frequency of interaction, is also documented to aid the analysis.

Data Analysis

It uses suitable software packages to perform statistical analysis. Paired sample t-tests are used to evaluate changes in pre-test and post-test scores:

$$t = \frac{\bar{d}}{s_d/\sqrt{n}} \qquad (5)$$

In equation (5), $\bar{d}$ is the mean difference, S_d is the standard deviation of differences, and n is the sample size. Analysis of covariance (ANCOVA) is used to regulate the baseline differences in between-group comparisons.

Additionally, effect size is calculated using Cohen's d:

$$d = \frac{\grave{X}_1 - \grave{X}_2}{s_p} \qquad (6)$$

In equation (6), S_p is the combined standard deviation. Thematic analysis is applied to analyze qualitative data of interviews and feedback to detect patterns and insights into user experience and learning outcomes.

Conceptual Framework of the Online Interactive Conservation Education Model

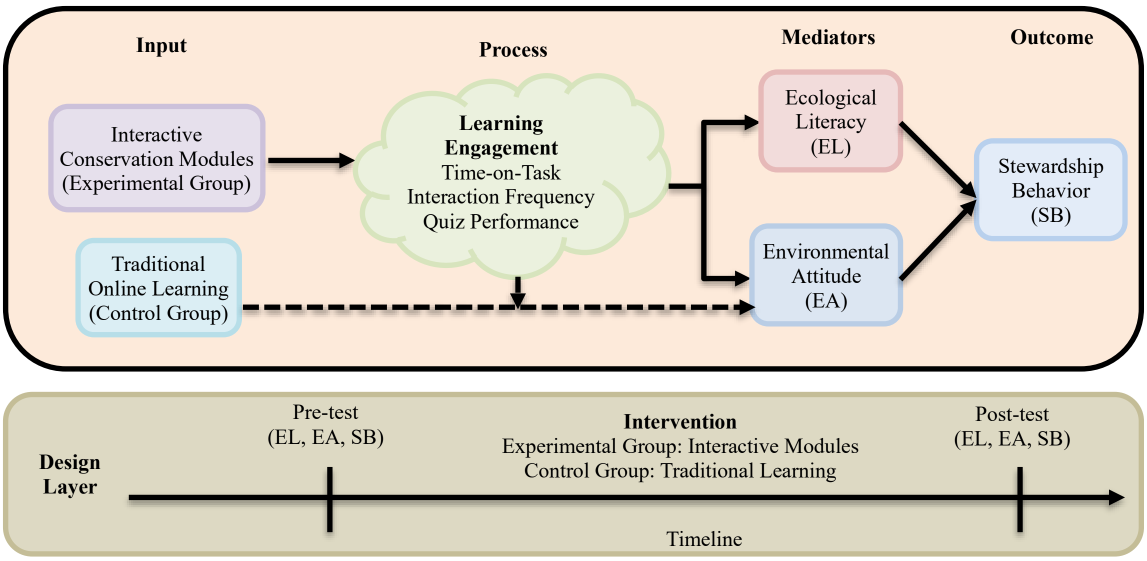

Figure 1: Conceptual framework of the online interactive conservation education model.

The conceptual framework that supports the study is presented in figure 1, and the relations between the interactive conservation education modules and the most important outcome variables are described. The model indicates the intervention (interactive digital modules) impact on ecological literacy (EL) and environmental attitudes (EA), which, in turn, impact the stewardship behavior (SB). It also puts light on the moderating or facilitating aspects (determined by the engagement measures, i.e., time-on-task and frequency of interactions) that can further improve learning outcomes. The framework combines the quasi-experimental structure of design, implying the comparison of experimental and control groups in the online learning environment.

Ethical Considerations

All participants are provided with ethical approval, and informed consent is obtained online. Participants would do so on a voluntary basis, and data processing would be anonymized, ensuring confidentiality. Data is stored through secure online platforms, and members are accorded equal access to educational resources on completion of the study.

Results

Participant Characteristics

180 individuals were involved in the study, 90 in the experimental group and 90 in the control group. The participants represented different levels of education and different age groups, and it was ensured that there was a variation in baseline ecological knowledge. Initially, there was no statistically significant difference between the two groups on the initial ecological literacy scores ($p > 0.05$), which means that the two groups should be compared before the intervention.

Baseline Eco Literacy and Attitudes

The pre-test results showed an average ecological literacy status of the participants, low awareness of local aquatic biodiversity, and conservation measures. The average Eco Literacy Index (ELI) of the experimental group stood at 2.84 ± 0.51, compared to the control group, which had a corresponding average of 2.79 ± 0.48. There were also neutral to moderately positive scores of environmental attitudes towards conservation.

Table 1: Baseline comparison of experimental and control groups.

Variable	Experimental Group (Mean ± SD)	Control Group (Mean ± SD)	p-value
Eco Literacy Index (ELI)	2.84 ± 0.51	2.79 ± 0.48	0.62
Environmental Attitude (EA)	3.12 ± 0.56	3.08 ± 0.53	0.67
Stewardship Behavior (SB)	2.95 ± 0.49	2.91 ± 0.47	0.59

The table 1 shows a comparison of the baseline scores of the experimental and the control group under three important variables: Eco Literacy Index (ELI), Environmental Attitude (EA), and Stewardship Behavior (SB). In all the variables, the mean values of both groups are quite different, with only slight differences. Moreover, p-values (ELI: 0.62, EA: 0.67, SB: 0.59) are all above 0.05, meaning that all the groups do not differ statistically at the pre-intervention level. This indicates that the two groups were similar and balanced prior to the intervention being instituted, which justifies further comparisons.

Effect of Interactive Modules on Eco Literacy

After the intervention, the ecological literacy of the experiment group was found to have improved significantly as compared to that of the control group.

The increase in post-test ELI score was 4.12 ± 0.44 in the experimental group, and a marginal increase in the control group was 3.05 ± 0.50. The paired sample t -test showed that there was a statistically significant increase in the experimental group ($t = 18.76$, $p < 0.001$).

Table 2: Pre-test and post-test comparison of eco literacy.

Group	Pre-test (Mean ± SD)	Post-test (Mean ± SD)	t-value	p-value
Experimental	2.84 ± 0.51	4.12 ± 0.44	18.76	<0.001
Control	2.79 ± 0.48	3.05 ± 0.50	4.12	<0.05

The table 2 indicates differences in pre-test and post-test scores in experimental and control groups. The growth in mean scores in the experimental group (2.84 ± 0.51 to 4.12 ± 0.44) is significant (t-value 18.76 and p <0.001) and shows a great effect of the intervention. On the contrary, the control group also experiences a slight increase (2.79 ± 0.48 to 3.05 ± 0.50), although the t-value (4.12) is lower, and the $p < 0.05$ is also less important. In general, the group of patients that received the intervention improved significantly, and the difference was much more pronounced and statistically significant in the experimental group, which indicates the efficacy of the intervention.

Changes in Environmental Attitudes and Stewardship Behavior

The change of attitude and behavior in regard to the environment and stewardship was also significantly improved in response to the intervention. In the experimental group, the scores of the environmental attitude increased significantly (3.12 ± 0.56 to 4.20 ± 0.41) and the scores of stewardship behavior (2.95 ± 0.49 to 4.05 ± 0.46). The control group, on the contrary, had minimal alterations in the two variables.

Table 3: Changes in attitudes and stewardship behavior.

Variable	Group	Pre-test (Mean ± SD)	Post-test (Mean ± SD)	p-value
Environmental Attitude	Experimental	3.12 ± 0.56	4.20 ± 0.41	<0.001
	Control	3.08 ± 0.53	3.30 ± 0.50	<0.05
Stewardship Behavior	Experimental	2.95 ± 0.49	4.05 ± 0.46	<0.001
	Control	2.91 ± 0.47	3.18 ± 0.48	<0.05

The table 3 shows the post-test and pre-test differences in the Environmental Attitude and Stewardship Behavior of the experimental group and the control group. Both the variables (Environmental Attitude and Stewardship Behavior) significantly increased in the experimental group (Environmental Attitude 3.12 ± 0.56 to 4.20 ± 0.41 and Stewardship Behavior 2.95 ± 0.49 to 4.05 ± 0.46). These are very important ($p < 0.001$), and the intervention is very impactful.

By comparison, the control group shows more humble improvements with Environmental Attitude changing between 3.08 ± 0.53 and 3.30 ± 0.50 and Stewardship Behavior changing between 2.91 ± 0.47 and 3.18 ± 0.48, both with less significant changes ($p < 0.05$). In general, the findings indicate that although the change in both groups was positive, the change in the experimental group was significantly more pronounced and statistically significant, indicating the effectiveness of the intervention.

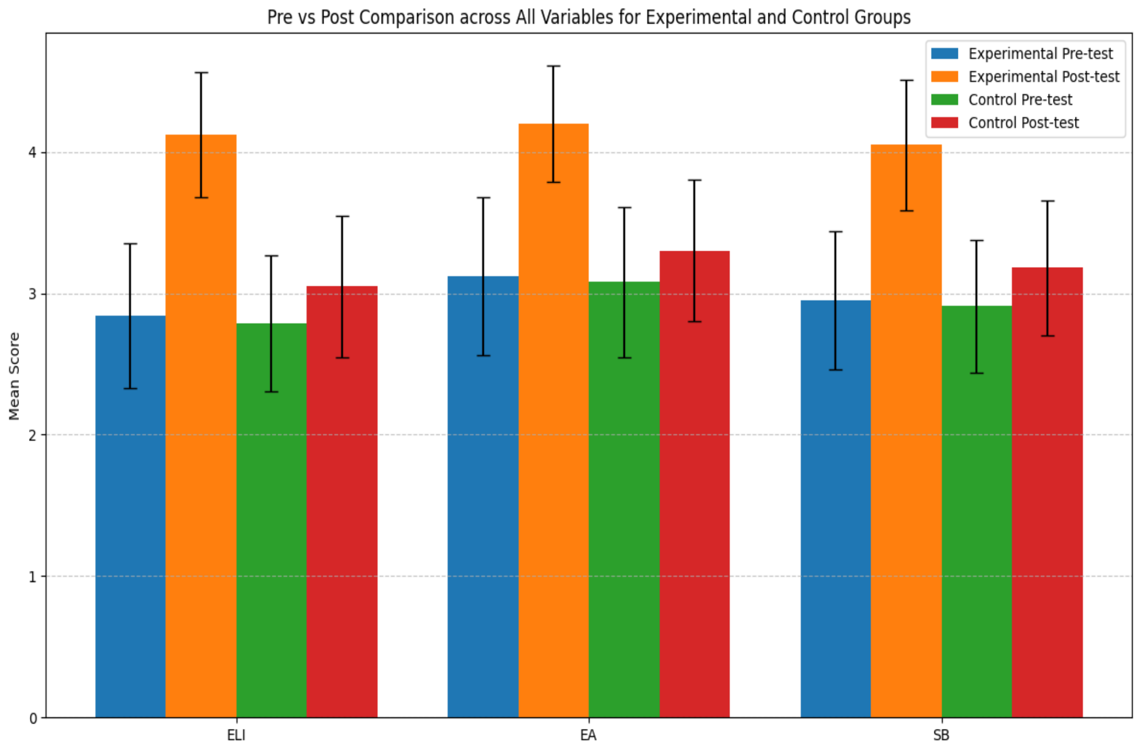

Figure 2: Integrated pre-test and post-test comparison of eco literacy, environmental attitude, and stewardship behavior across experimental and control groups.

The results of the comparison of pre-test and post-test mean scores (± SD) of ELI, EA, and SB in experimental and control groups are presented in detail in figure 2. A significant rise in the post-test score of all variables in the experimental group demonstrates the high efficiency of the interactive intervention. The control group, on the other hand, has only moderate improvements. The standard deviation (error bars) shows the variability in any group and contributes to the consistency and reliability of observed differences.

Regression Analysis of Eco Literacy and Stewardship Behavior

A strong positive correlation between ecological literacy and stewardship behavior was found through regression analysis. The model has become statistically significant ($R^2 = 0.68$, $p < 0.001$), which means that ecological literacy and environmental attitudes could explain 68% of the variability of stewardship behavior.

Table 4: Regression analysis results.

Predictor Variable	Beta (β)	Standard Error	t-value	p-value
Eco Literacy (EL)	0.61	0.05	12.20	<0.001
Environmental Attitude	0.34	0.07	4.85	<0.01
Constant	0.78	0.22	3.54	<0.01

Ecological literacy was found to be a robust predictor ($\beta = 0.61$, $p < 0.001$), followed by environmental attitude ($\beta = 0.34$, $p < 0.01$). The table 4 shows the outcome of a regression analysis conducted to test the predictor variables and their impact on the outcome. EL is the best predictor ($\beta = 0.61$) with a significant t-value (12.20) and a very significant p-value (0.001), which means a significant positive influence. There is also a significant positive contribution of Environmental Attitude (β = 0.34, $p < 0.01$), but the effect thereof is relatively less than that of EL. The constant value is also important ($p < 0.01$), which indicates that the outcome variable has a significant minimum level. Altogether, the two predictors have a significant role to play in the model, with Eco Literacy playing the most important role.

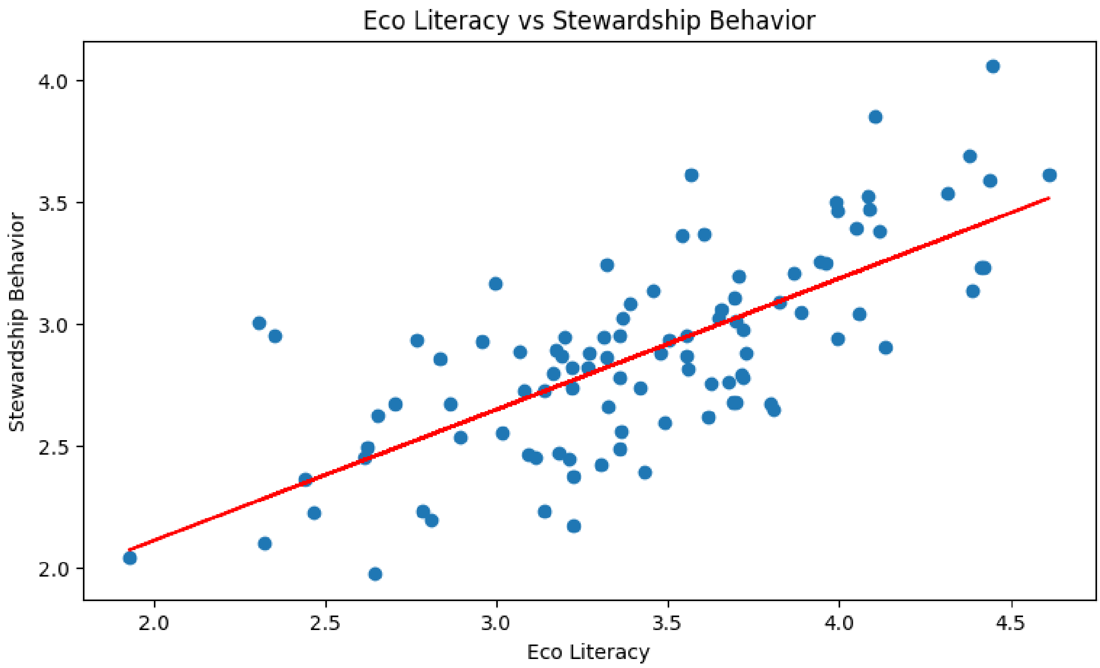

Figure 3: Positive relationship between eco literacy and stewardship behavior.

There is a positive trend indicated in figure 3 depicting the connection between Eco Literacy and Stewardship Behavior. Eco literacy scores are positively related to stewardship behavior, and as the scores of ecological literacies grow, the behavior of stewardship also grows, signifying that people with a high score on ecological literacy are more inclined to act in an environmentally responsible manner. This positive association is also supported through the fitted regression line and is in agreement with the statistical results that eco literacy is predictive of high stewardship behavior.

Effect Size and Intervention Impact

The increase in ecological literacy was estimated with Cohen's d, resulting in a 1.85, which is a very large effect. This indicates that the interactive modules played an important role in advancing ecological knowledge over the traditional approaches.

User Engagement and Interaction Metrics

Engagement data analysis revealed that the mean time spent on the modules in the experimental group was 42 minutes, with a completion rate of 92%. The mean score of performance on a quiz is 85%, meaning an extensive understanding level. The frequency of interactions, also in terms of clicks and participation in the activity, was also found to be significantly correlated with the post-test scores ($r = 0.72$, $p < 0.001$) and tended to have a higher interaction frequency, which resulted in a better learning outcome.

Qualitative Insights

Thematic analysis, as one form, disclosed that interactivity in the form of simulations, storytelling, and gamified quizzes positively influenced learning experiences significantly. According to the respondents, they were now more interested in aquatic biodiversity and were more willing to take up conservation behaviors. It was emphasized by several individuals that the modules made complex environmental problems easily comprehensible and related them to daily living.

Discussion

The study concludes that interactive conservation modules played a significant role in making the participants more ecologically literate, having a better environmental attitude, and an improved environmental stewardship behavior. There were no substantial differences among groups ($p>0.05$), which showed that there were no gross differences between groups in terms of the basis of baseline and proved initial comparability. These findings indicated that the Eco literacy index improved significantly in the experimental group (2.84 to 4.12) and the control group (2.79 to 3.05), and the difference was significant ($t = 18.76$, $p < 0.001$). The trends were also comparable in the case of the Environmental Attitude (3.12 to 4.20) and stewardship behavior (2.95 to 4.05) in the experimental group ($p < 0.001$), but insignificant changes were made in the control group ($p < 0.05$). Further regression analysis showed that ecological literacy ($\beta = 0.61$) and environmental attitude ($\beta = 0.34$) were significant predictors of stewardship behavior ($R^2 = 0.68$). The high effect (Cohen's $d = 1.85$) and high level of engagement ($r = 0.72$) have supported the efficacy of the intervention. These results indicate that reactive, learner-based methods have proved to be very fruitful in improving ecological knowledge and knowledge transfer into pro-environmental action. The high predictive value of ecological literacy suggests that knowledge learning is an essential factor that drives behavioral change. Besides, this correlation appears to be mediated by the improvement of the environmental attitudes, which confirms the hypothesis of cognitive and affective spheres interdependence. The high involvement also implies that high involvement increases learning and retention. These findings verify the need of the inclusion of the work in the use of interactive online media with regard to environmental education, especially in biodiversity-prone and coastal areas. Such modules can be used to promote scale sustainable behaviours by educational institutions and policymakers. Closely connected with the discussion of the literacy and stewardship is the necessity to concentrate on ecological education as the contributor of conservation programs. The quasi-experimental design and self-report measures were inadequate in this work, which were likely to lead to bias when responding. The nature of the intervention also limits the results in conclusions regarding long-term behavior change due to the brief period of the intervention. Also, simulated or controlled learning environments might not be as reflective of real-world complexities as desired. Further investigation needs to be done on longitudinal effects to determine long-term behavioral change, and use field-based assessment, which is more ecologically valid. This would enhance external validity of generalizability as the study would be conducted in other geographical and socio-cultural areas. The moderating variables (prior knowledge, digital literacy, and motivation) can be further discussed with the purpose to simplify the work in the field of the intervention development.

Conclusion

The research question to be answered in this study was whether interactive online conservation modules could be effective at improving ecological literacy, environmental attitudes, and stewardship behavior in online learners. As environmental issues increase, it is important to establish effective education strategies that can be used to foster sustainable practices. The results indicate clearly that the interactive intervention has had a significant effect in terms of population improvements in all the major variables. Eco Literacy Index in the experimental group [2.84 to 4.12 ($p < 0.001$)], increased significantly (when compared to the control group) [2.79 to 3.05]. The same way, the Environmental Attitude became 3.12 to 4.20 and the Stewardship Behavior by 2.95 to 4.05 in the experimental group with high statistical significance ($p < 0.001$). It was found that ecological literacy ($\beta = 0.61$) and environmental attitude ($\beta = 0.34$) were significantly different, with 68% of the variance being attributed to them in their effects on stewardship behavior ($R^2 = 0.68$). The large effect size (Cohen's $d = 1.85$) and the large correlation in engagement ($r = 0.72$) contributed to the power of the intervention. Overall, the study points out that interactive and engaging learning strategies can positively impact the growth of not only the knowledge but also the attitudes and behavioral tendencies related to the environmental conservation. The greatest insight is that green literacy is a driving force of responsible environmental practices supported by active methods of learning. The further investigation must focus on resolving the problems of the behavioral outcomes in the long term, the feasibility of the learning activities practice, and its applicability to other learning and cultural contexts. Incorporating these interactive technologies in institutional curricula may have a radical impact on promoting conservation worldwide.

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