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Towards Green ELT: An Education for Sustainable Development-Driven Analysis of Environmental Behavior, Technology Integration, and Language Competence

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Abstract

In the context of Education for Sustainable Development (ESD), teaching can be combined with the integration of technology and awareness of the environment. This study aims at exploring the contribution of environmental science integration, value, pro-environmental behavior, and technology integration to English language competence. Guided by UNESCO's ESD principles, this study was conducted to explore the relationships among Environmental System Interaction (ESI), Value and Pro-environmental Behavior (VPB), Technology Integration (TI), and Language Competence (LC). Consequently, the researchers used PLS-SEM with 5,000 bootstrap resamples for the data analysis of 624 senior high school students in South Kalimantan through a questionnaire containing 21 questions with satisfactory reliability and validity. The measurement model showed satisfactory reliability and validity, while the structural model revealed some significant relationships. The findings demonstrated that ESI significantly enhances TI ($\beta = 0.258$, $p < 0.001$), and VPB also significantly enhances TI ($\beta = 0.383$, $p < 0.001$). This supports that environmental interaction and values are important drivers for the willingness of students to use digital technology in learning. At the same time, TI significantly predicts LC ($\beta = 0.440$, $p < 0.001$), showing that technology is a pathway to improving language competence within an ESD-oriented framework. The findings are important for theorizing the integration of ESD and technology-enhanced language acquisition, showing the interplay between environmental engagement and digital activities to support language development. The study also has practical implications for teachers and policymakers on how to integrate environmental themes and digital resources in teaching English to develop sustainability awareness and increase language competency at the same time.

Keywords: *Green ELT, Education for Sustainable Development, Environmental Behavior, Technology Integration, Language Competency*

INTRODUCTION

Education plays a crucial role in the world's sustainable development strategy. The purpose is to develop environmentally conscious citizens and technically skilled people. Sustainable Development is defined by UNESCO as "the acquisition of knowledge, skills, values and attitudes by learners to enable them to address environment-related challenges while promoting global competencies such as languages". In multilingual contexts like Indonesia, there has been an increasing interest in integrating environmental science into English language learning (Jung & Santos, 2022; Nur et al., 2022), thus positioning English not only as a tool for communication but also as a medium for engaging with pressing global environmental issues.

Additionally, there is increasing academic focus on the integration of environmental ideals and pro-environmental conduct into classroom practices that will promote sustainable mindsets (Anggereini & Yelianti, 2023; Maghfiroh et al., 2024; Sholahuddin et al., 2021). One growing approach is Green English Language Teaching (Green ELT) which incorporates environmental themes, sustainability issues and ecological consciousness into English language teaching. Green ELT encourages students to build language abilities while critically engaging with environmental concerns and seeking solutions through meaningful activities in which expressiveness and becoming more responsive to climate change are at the forefront (Raphael & Nandanan, 2024). Thus, students are expected to raise their environmental awareness and develop their language competence. However, there is still limited empirical research into exactly how ESI and VPB interact with LC—particularly within technology-enhanced learning of English.

Technology has become a foundation of ESD-oriented pedagogies, affording authentic, multimodal, and inquiry-based learning opportunities. A number of digital platforms, including Duolingo, Babbel, ELSA Speak, Memrise, FluentU, and Coursera, among others, have been widely recognized as supporting language development (Jiang, 2024; Ostiz-Blanco et al., 2021; Pikhart et al., 2024; Twyman, 2018). However, the degree to which technology in and of itself contributes to language competence, shaped by environmental engagement and linked values, is still underexplored. Most current studies investigate these areas independently, either in terms of the effectiveness of digital language learning or through an environment-based pedagogy, but without consideration of their interlinked impact on learning outcomes.

Recent research suggests that including sustainability issues into the learning of English has enhanced engagement and deepened critical thinking. For instance, Kazazoglu (2025) found that environmental vocabulary and eco-literacy tasks significantly improved students' perceptions and understanding of global sustainability issues. On a related note, other researchers have found that both Content and Language Integrated Learning (CLIL) and project-based approaches can enhance not only language skills but also environmental awareness (Hasrina et al., 2024). In this context, language competency here is defined as learners' ability to understand and utilize English effectively through the integrated development of listening, speaking, reading and writing abilities. It is the learners' ability to communicate meaningfully in a variety of circumstances. Ngo & Le-Khanh (2025) also mentioned that integrating ESD concepts in language instruction promotes linguistic, critical thinking, and sustainability competencies. Technological approaches have been shown to be helpful too. Seraj (2024) described how ideas of green technology are visible in language pedagogy, while Tabasi et al., (2024) found that technology increases student engagement, personalizes learning, and provides access to authentic linguistic and cultural contexts. Taken together, these studies demonstrate that sustainability-oriented and technology-enhanced language learning environments can promote environmental awareness and language competency simultaneously.

However, there are few studies on the interactive effects of environmental participation, environmental values and technological integration on learners' linguistic ability. Understanding these interactions is important since language development in ESD situations is influenced by both environmental and technical elements. It can illuminate more clearly and thoroughly the contribution of sustainability-related attitudes and learning with technology to students' language development by investigating their direct and indirect impact. It depicts a holistic empirical model with interaction among variables in the context of English language acquisition within ESD setting.

Therefore, the present study aims at filling the gap by proposing and empirically testing a structural model that links ESI, VPB, TI, and LC. Examining the structural relationships among the constructs, this study aims to investigate how the interacting influences of environmental and technological factors improve the English language competence of learners. The findings are expected to contribute toward theoretical development within ESD-based language education and provide practical insights for the conduct of environmentally responsive, technology-enhanced English instruction.

Accordingly, this study addresses the following research questions:

1. To what extent does Environmental System Interaction (ESI) influence Technology Integration (TI) in ESD-based English learning?
2. How does Value and Pro-Environmental Behavior (VPB) influence Technology Integration (TI)?
3. Does Technology Integration (TI) significantly predict students' Language Competence (LC)?
4. How do ESI and VPB indirectly influence Language Competence (LC) through Technology Integration (TI)?

Literature Review

Education for Sustainable Development (ESD) in Language Learning

ESD seeks to provide learners with information, values and competencies to deal with environment-related issues globally (Malik et al., 2025; Mestawot & Kopp, 2025; Said et al., 2023). UNESCO states that ESD fosters critical thinking, environmental sensitivity, social responsibility and problem-solving with a future-oriented perspective (Chand et al., 2025). In language education, ESD promotes the use of environmental themes as a means of successfully developing communicative abilities, as students reflect on concerns of sustainability (Kleemann, 2021; Mestawot & Kopp, 2025). It takes language learning beyond grammar and vocabulary and positions English as a tool for engaging with real-world ecological issues.

In the field of ELT, ESD has led to the emergence of the so-called "Green ELT," a pedagogical movement that infuses environmental literacy into classroom activities (Raphael & Nandanan, 2024). It appears from the research that the use of sustainability themes in the classroom encourages students to express ideas on such topics as climate change, biodiversity, pollution, and environmental responsibility, among others, and at the same time develop their linguistic competencies. Other studies, such as (Arslan & Curle 2024), also demonstrate how ESD-based pedagogy can be effectively adapted through CLIL, wherein environmental content is used as the medium for language instruction. Similarly, Ngo & Le-Khanh (2025) discovered that the integration of ESD not only raises student awareness of questions related to sustainability but also reinforces linguistic and critical thinking skills. The aforementioned studies indicate that ESD provides a robust theoretical basis for linking environmental knowledge, technology, and language development in contemporary ELT.

Environmental Interaction and Pro-Environmental Behavior

Environmental System Interaction (ESI) is defined as learners interacting with environmental issues in terms of awareness, understanding, and interaction with ecological systems (Kazazoglu, 2025; Saiful, 2023). Students who interact more with the environmental content tend to develop higher sensitivity towards ecological challenges and are more motivated to work on learning tasks associated with sustainability (Asgher et al., 2021; Saiful, 2020). ESI can augment students' preparedness to learn about environmental themes when introduced through media support, especially within digital platforms that use multimodal forms to represent environmental problems.

In the field of ELT, ESD has led to the emergence of the so-called “Green ELT,” a pedagogical movement that infuses environmental literacy into classroom activities (Anggereini & Yelianti, 2023). VPB is about attitudes, beliefs and behaviors towards trash reduction, energy saving or participating in eco-friendly activities. These beliefs affect students’ willingness to engage in environmental issues and may impact their motivation to use technology in learning. Students with high pro-environmental beliefs had higher positive responses to instructional activities about sustainability (Qi et al., 2025; Shafiei & Maleksaeidi, 2020; Zhao et al., 2024). Moreover, they are more engaged when ecological topics are presented in interactive formats, utilizing digital or multimedia resources (Asmayawati et al., 2024; Seraj, 2024).

Technology Integration in English Language Learning

Technology integration has become an integral feature of current pedagogy and there is no exception in English language teaching. This is the meaningful use of digital technologies such as learning apps, multimedia resources, virtual learning environments and AI-based platforms that can promote language development. Digital tools like Duolingo, ELSA Speak, FluentU, Babbel, and video-based platforms offer students realistic input, practice pronunciation, and immersion in real-life communication scenarios (Pikhart et al., 2024; Susanti et al., 2025). The use of technology encourages multimodal learning with audio-visual and interactive tools that help in acquiring vocabulary, improving listening comprehension, and enhancing speaking fluency (Tang, 2024).

In ESD-oriented teaching, technology enhances the interaction of students with environmental content. For instance, video, simulation, and digital storytelling applications can provide more vivid illustrations of environmental issues than traditional instruction. Technology thus serves as a productive mediator between environmental awareness and language learning. In this respect, Tabasi et al., (2024) report that technology-enhanced learning offers increased motivation, greater engagement, and increased exposure to authentic uses of the target language. Other authors underline how ICT tools can set conditions for collaborative problem-solving by letting students analyze environmental challenges and communicate solutions in English.

With these advantages, technology integration itself becomes the important mediating variable in the relationship between these environmental variables and language competence. Consequently, its functions of facilitating student engagement, content delivery, and shaping learning behavior provide a good rationale for examining TI as a predictor of English language competence within an ESD-informed framework.

METHODS

The approach used in this study is a quantitative research design using Partial Least Squares Structural Equation Modeling. PLS-SEM is appropriate to validate the measurement model and investigate the complex relationships among latent variables in exploratory research (Hair et al., 2021; Mutammimah et al., 2024). In the study, Environmental System Interaction, Value and Pro-Environmental Behavior, and Technology Integration were analyzed to see how they contribute toward students' language competence.

The sample consisted of 624 senior high school students from seven schools in South Kalimantan, Indonesia, selected through a cluster sampling technique. They were mostly female, 58.98%, and 71.95% were 17 years old—the typical age for being most active in technology-based learning. Students were sampled from different academic majors, the highest percentage coming from science programs, 47.28%, and social sciences, 21.47%. This represents a good base for the proposed objective of the study in determining environmental and technology-related constructs across different academic backgrounds.

The level of technology readiness among respondents was very high: 98% of the respondents had a personal smartphone, while 55% regularly accessed the internet through mobile data and 34% had home Wi-Fi. Moreover, social media use was considerable: TikTok (49%) and Instagram (39%) were the most frequently accessed platforms, representing high digital engagement, which validates the technology-related variables in this study. Turning to daily digital behavioral factors, 63% of students were online for more than 4 hours every day, an extensively high level of technology immersion, which is bound to positively predict the technology-infused LC. Most students used local languages at home, amounting to 74.68%, presumably with implications for English language exposure and proficiency—a scenario in which technology-assisted English language learning is all the more necessary. More than 70% planned to pursue further education, which reflects a good academic motivation—an important contextual factor in environmental and language learning programs.

The researchers employed a 21-item questionnaire measured on a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Items represented four constructs of ESI, VPB, TI, and LC based on an adapted PISA 2025 science framework on environmental science competencies. The items were adapted from the PISA 2025 science framework because this framework particularly provides the environmental science competencies domain. Then, the items were modified to suit the context of ESD-based English learning. Three validators took part in expert validation to ensure the content relevance of the items.

Data were collected online using Google Forms and with the assistance of English teachers in six senior high schools in South Kalimantan. Participation was voluntary, and informed consent was granted by the students. Privacy and anonymity were guaranteed, and the respective school authorities approved the study. Data was analyzed by means of SmartPLS 4, first by measurement model assessment in terms of reliability, convergent validity, and discriminant validity, and second by structural model assessment in terms of path coefficients, effect sizes, R^2, and bootstrapping.

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RESULTS AND DISCUSSION
Results
Measurement Model

The researchers applied the PLS algorithm as represented in Figure 1. The initial results indicated three indicators: ESI5, ESI6, VPB6, TI2, and TI7, with less than 0.6 outer loading, which did not meet the necessary validity criteria. Consequently, these indicators were excluded from the model. With their exclusion, all the retained indicators revealed an outer loading of at least 0.6, with most being approximately or higher than the threshold value of 0.7 as recommended by Hair et al., 2021), thus confirming that the retained indicators are suitable representatives of their latent constructs.

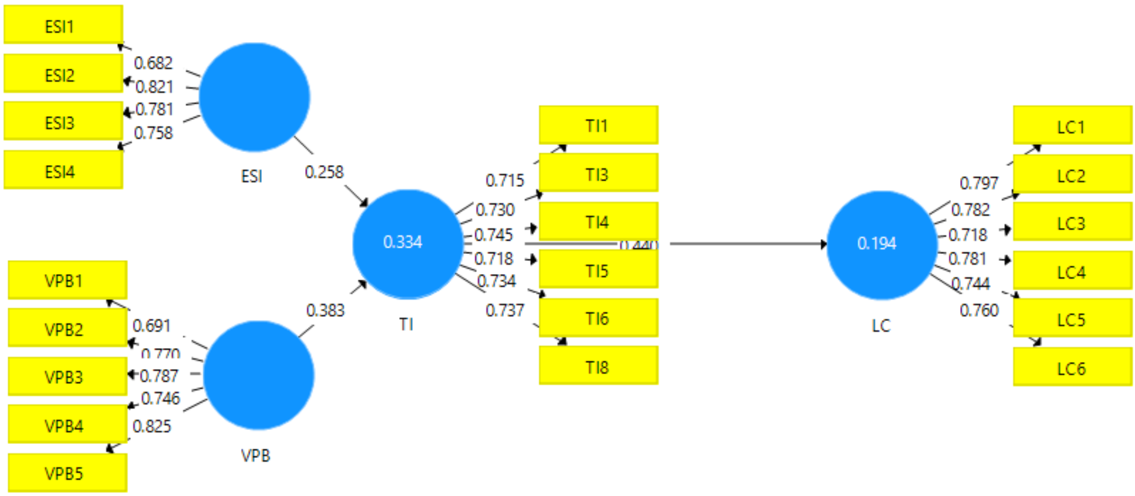

Figure 1. PLS Algorithm result

Furthermore, as shown in Table 1, the results reveal that all constructs reached acceptable reliability because both Cronbach's Alpha (CA) and Composite Reliability (CR) values were above the minimum recommended value of 0.7 (Hair et al., 2021). Also, it offers support to the convergent validity evidence since all Average Variance Extracted (AVE) values are over the minimum threshold of 0.5 (Mohamad et al., 2008).

Table 1. Reliability and Convergent Validity

Factor	Item	Loading	CA	CR	AVE
ESI	ESI1	0.682	0.758	0.847	0.581
	ESI2	0.821			
	ESI3	0.781			
	ESI4	0.758			
VPB	VPB1	0.691	0.822	0.875	0.585
	VPB2	0.770			
	VPB3	0.787			
	VPB4	0.746			
	VPB5	0.825			
TI	TI1	0.715	0.825	0.872	0.533
	TI3	0.730			
	TI4	0.745			
	TI5	0.718			
	TI6	0.734			
	TI8	0.737			
LC	LC1	0.797	0.860	0.894	0.584
	LC2	0.782			

LC3	0.718
LC4	0.781
LC5	0.744
LC6	0760

Discriminant validity checks that the constructs in your model (ESI, VPB, TI, LC) are truly different from one another, meaning that each variable should be measuring something unique. This study employed three approaches towards testing discriminant validity: The Fornell–Larcker criterion, which verifies whether a construct has to share more variance with its own items than with other constructs. As shown in Table 2, each construct of the item in this study is more highly related to its indicators than to the other constructs. Thus, discriminant validity is reached. Second, cross-loading analysis verifies that every item must load highest on its own construct, not on others. In Table 3, the highest number has to be in the column of its construct, which means each item clearly belongs to the correct variable. Thus, it can be established that the constructs are distinct. Finally, the heterotrait–monotrait ratio of correlations: Tables 2 and 3 offer further support that discriminant validity (DV) was satisfactorily established by employing both the Fornell–Larcker criterion and the cross-loading assessment (Sarstedt, 2019).

Table 2. Discriminant Validity

Variable	Fornell- Larcker criterion			
	ESI	LC	TI	VPB
ESI	**0.762**			
LC	0.397	**0.764**		
TI	0.491	0.440	**0.730**	
VPB	0.608	0.277	0.540	**0.765**

Table 3. Cross Loading

Variable	Item	ESI	LC	TI	VPB
ESI	ESI1	**0.682**	0.348	0.333	0.317
	ESI2	**0.821**	0.246	0.409	0.528
	ESI3	**0.781**	0.333	0.379	0.498
	ESI4	**0.758**	0.295	0.373	0.493
LC	LC1	0.396	**0.797**	0.401	0.325
	LC2	0.316	**0.782**	0.302	0.219
	LC3	0.206	**0.718**	0.231	0.147
	LC4	0.227	**0.781**	0.265	0.097
	LC5	0.307	**0.744**	0.429	0.247
	LC6	0.305	**0.760**	0.299	0.154
TI	TI1	0.447	0.357	**0.715**	0.467
	TI3	0.340	0.272	**0.730**	0.370
	TI4	0.383	0.291	**0.745**	0.443
	TI5	0.297	0.382	**0.718**	0.348
	TI6	0.347	0.275	**0.734**	0.379
	TI8	0.311	0.337	**0.737**	0.333
VPB	VPB1	0.496	0.176	0.363	**0.691**
	VPB2	0.482	0.251	0.410	**0.770**
	VPB3	0.431	0.227	0.428	**0.787**

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VPB4	0.460	0.184	0.382	**0.746**
VPB5	0.469	0.217	0.472	**0.825**

Together with the Fornell–Larcker and cross-loading results, HTMT measures how distinct one construct is from another by comparing the correlations between constructs. As seen in Table 4, the constructs in the model are not overlapping, each construct measures a different concept, and discriminant validity is well established (Hair et al., 2021).

Table 4. The Heterotrait–Monotrait (HTMT)

Variable	ESI	LC	TI	VPB
ESI				
LC	**0.4794**			
TI	0.6130	**0.4944**		
VPB	0.7691	0.3066	**0.6455**	

Information:
HTMT < 0.85 : Strict
HTMT < 0.90 : Acceptable

Structural Model

After confirming that the measurement model was valid and reliable, the next step in PLS-SEM is to test the hypotheses and examine how the variables are related**.** This is done through the structural model. The structural model checks how strong the relationship between the variables is, the positive and negative relationships, and the stronger effect. It also checks whether the relationships significantly exist and how much variance the model can explain.

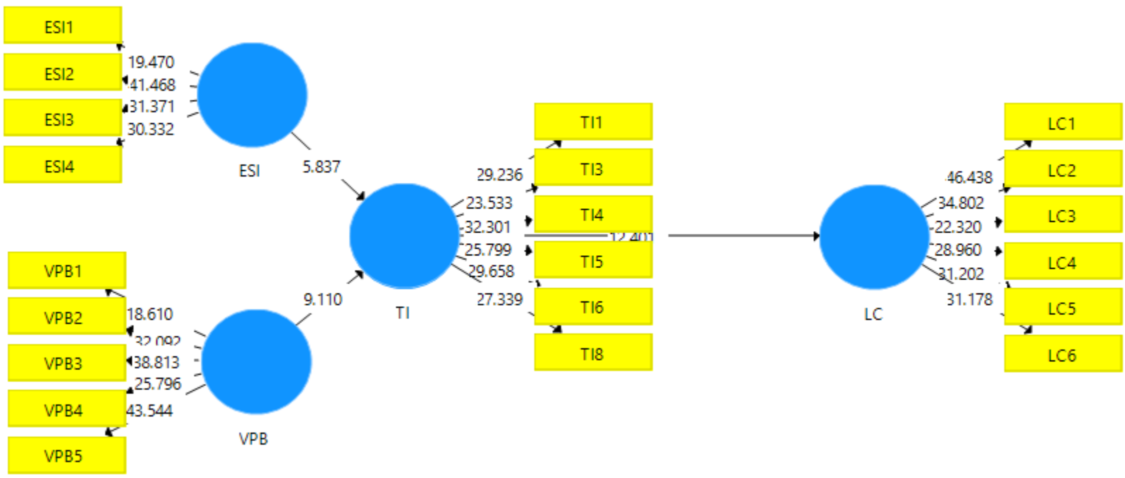

Figure 2. Bootstrapping result with 5,000 subsamples

Figure 2 and Table 5 present the structural phase findings from the SmartPLS computation. The structural model was evaluated by examining the path coefficients (β), t-values, and p-values to test the proposed hypotheses as seen in Table 5.

Table 5. Path Analysis

Path	β	t-value	p-value	Supported?
H1: ESI - > TI	0.258	58.370	0.000	Yes
H2: VPB- > TI	0.383	91.099	0.000	Yes
H3: TI - > LC	0.440	124.011	**0.000**	**Yes**

Notes: The threshold of the t-value is >1.96. The threshold of the p-value is < 0.05 (Al-Hattami, 2023; Hair et al., 2021).

Discussion

These findings established above have implications for understanding how environmental engagement, pro-environmental behavior, and technology use interact in influencing students' competence in the English language within the framework of ESD-oriented learning. The structural model showed that all three hypotheses tested in the study were supported: H1, H2, and H3. H1 tested the influence of ESI on TI. The results showed that this was positive and significant ($\beta = 0.258$, $t = 58.370$, $p = 0.000$). It indicates that students who often interact with environmental systems tend to also use technology in their learning process more actively (Davis, 1989; Gu, 2025; Ou et al., 2021; Seraj, 2024; Suppasetseree et al., 2023). Theoretically, this finding corroborates the hypotheses of Education for Sustainable Development and constructivist approaches to learning—when meaningful interplays with real-world contexts take place, students' motivation to explore learning resources, including digital tools, is enhanced (Roy et al., 2025; Yang, 2024). Students, when confronted with real problems of sustainability, themselves look for more information through multimedia, educational apps, and online resources.

From a pedagogical point of view, this indicates that teachers may facilitate students' technology use by embedding environmental themes into English instruction (Amelia & Chandra, 2021; Arini & Fadilla, 2021; Asgher et al., 2021; Febriyanti & Hidayat, 2023; Listia et al., 2023; Saiful, 2023). Classroom practices, such as analyzing climate change texts, working on eco-projects, or watching sustainability videos, organically support digital engagement. It has particularly important implications for Green ELT, in which environmental content becomes the means for language learning (Nur et al., 2022; Seraj, 2024; Yıldırım & Aytan, 2025). The large effect size of ESI on TI suggests, at the policy level, that schools should make ESD an integral part of the English curriculum. Cross-disciplinary collaboration between English and science educators can further facilitate technology-enhanced environmental learning, encouraging students to use digital tools in a meaningful way.

The path coefficient between VPB and TI was positive, significant, and substantial in magnitude, ($\beta = 0.383$, $t = 91.099$, $p = 0.000$). It implies that students who have a higher level of environmental concern are likely to use technology in learning. In other words, environmental values not only shape students' attitudes toward sustainability but also influence students' willingness to adopt digital tools to support learning and environmental engagement. This result aligns the motivation and value-belief theories in ESD, which stated that students' beliefs and values influence their choices and behavior, including the learning technologies that they use (Bulut & Oksuzoglu, 2025). Students with stronger VPB are highly motivated to learn through searches for digital materials related to sustainability; this, in turn, enhances the role of environmental ethics in the adoption of the technology (Filho et al., 2018; Qi et al., 2025; Zhao et al., 2024). As a result, the significant relationship between VPB and TI highlights the importance of fostering environmental values, as these values can

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indirectly promote more meaningful and purposeful technology use in educational settings.

This observation has substantial consequences for educational practice. Given that positive attitudes toward the environment were important predictors of technology integration, English teachers should actively engage sustainability issues in language learning activities. Reflective writing assignments on environmental issues, conversations about eco-literacy, project-based learning, and problem-solving activities on local environmental challenges, for example, can inspire students to reflect critically on sustainability while enhancing their language abilities (Nur et al., 2022; Raphael & Nandanan, 2024). Such activities enable students to relate environmental principles to real-world actions, which makes the learning more meaningful and increases their drive to use digital technology to seek information, engage with peers, and express opinions.

In English lessons, teachers may further reinforce the VPB and TI through the use of digital tools such as environmental films, interactive maps, virtual field trips, online simulations, and multimedia presentations. These tools provide real-life learning experiences for students. They can research environmental issues on a local and worldwide level while strengthening their reading, listening, speaking, and writing skills. Students who learn about sustainability via technology are more active learners and have more confidence about the use of digital resources for educational reasons.

At the institutional level, schools should develop positive learning environments to encourage environmental responsibility through eco-clubs, recycling drives, school greening, and sustainability projects (Said et al., 2023). Such exercises can reinforce environmental ideas taught in the classroom and result in students using them in their day-to-day lives. Policymakers and education authorities can also promote the creation of “green digital schools," where environmental education and digital literacy are embedded in the curriculum. This approach can serve to equip students to be not just proficient users of technology but also responsible citizens that can contribute to sustainable development in a growing digital society.

Finally, regarding the third hypothesis, it was examined to find out the prediction of technology integration (TI) on language competence (LC). The results showed that there is a substantial and significant effect ($\beta = 0.440$, $t = 124.011$, $p = 0.000$) which means the more students use technology in studying, the greater level of English language proficiency they can acquire. This is consistent with the widely accepted models of TPACK, CALL, and multimodal learning theory that underscore the positive impact of technology on language acquisition (Alsuwaihel, 2024; Ballance, 2023; Suppasetseree et al., 2023).

One possible explanation for this link is that technology provides learners with more access to authentic input in English and opportunities for meaningful language use. Students can develop their listening abilities by watching English-language movies, podcasts, and documentaries available on digital platforms. Pupils can strengthen their reading skills through internet articles, blogs, e-books, and news sites, which expose them to a wide diversity of language and linguistic patterns. Language study applications provide interactive activities and instant feedback to aid with vocabulary and grammar. Likewise, communication tools such as discussion forums, videoconferencing tools, and collaborative writing tools allow students opportunities to practice speaking and writing in real-life circumstances.

Technology is also promoting learner autonomy as children are able to learn outside of school hours and at their own speed. Students can access study material, extra resources, and practice at their own time whenever they choose. The increased exposure and practice may contribute to the development of the vocabulary knowledge, listening comprehension, speaking fluency, reading proficiency, and writing skills that constitute language competence. Therefore, the significant effect of TI on LC suggests that technology is not just a learning tool but also a key means for students to enhance their prospects for language acquisition and communication.

In the context of ESD-based English learning, technology might be increasingly essential in offering access to sustainability-related content. For example, students might watch documentaries about the environment, read articles on climate change, hold online debates about issues of sustainability, or create digital presentations providing solutions to environmental challenges. Such programs allow students to practice their English language abilities while working on real environmental concerns and thereby increase their language skills and their knowledge of sustainability.

CONCLUSION

All in all, the results confirm that using digital tools related to environmental themes while teaching English is both an efficient way to develop students' environmental awareness and their language competencies. It is concluded that environmental interaction improves technology use, environmental values improve technology use even more, and technology use improves language competence. This results of this study indicates that integrating environmental knowledge, pro-environmental values, and culturally grounded content into technology-enhanced instruction can strengthen English language learning. Teachers and policymakers should support ESD-oriented digital pedagogy, expand students' access to technology, and develop culturally relevant materials to promote deeper engagement and improved language competence.

During the implementation of this study, it has several limitations. First, the data were collected from a specific group of students in South Kalimantan, Indonesia, which may limit the applicability of the findings to other educational settings. Second, the study used self-report questionnaire data, which are prone to perception and response biases. Third, the cross-sectional design prevents the establishment of causality between variables. Therefore, future studies are encouraged to use larger and more diverse samples of different kinds of places and educational levels to increase the generalizability of the findings. Longitudinal or experimental designs may be valuable for further examination of causal links between environmental involvement, technology integration, and linguistic proficiency. Future researchers are also recommended to study other relevant variables such as digital literacy, learning motivation, environmental literacy, teacher support, or socio-cultural features to present a more comprehensive picture of ESD-based technology-enhanced language acquisition.

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