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Ethno-ESD Engineering-Based Learning: Innovative Strategies to Foster Students' Sustainability Attitude and Self-Reported Sustainable Behavior

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Abstract

Ethno-ESD Engineering-Based Learning integrates local wisdom and sustainability to address the limited effectiveness of conventional learning in fostering students' sustainable attitudes and behaviors. This study aims to analyze the effectiveness of the Ethno-ESD Engineering-Based Learning model as an innovative strategy for fostering a sustainable attitude and self-reported sustainable behavior among students. This approach integrates the values of local wisdom (ethno) with the principles of Education for Sustainable Development (ESD) in the context of engineering-based learning. The research method employed a quasi-experimental design with a pretest-posttest control group, involving chemistry education students. The model effectiveness test was analyzed using the T-test and the Effect Size test. The results showed that the application of Ethno-ESD Engineering-Based Learning significantly improved students' sustainability attitude and self-reported sustainable behavior compared to conventional learning ($p < 0.05$). The effect size values of 0.87 and 0.81 showed a high influence on the improvement of attitudes and sustainable behaviors. The research instrument was deemed valid and reliable, as evidenced by Cronbach's Alpha and Composite Reliability values exceeding 0.9 and an AVE above 0.5. These findings demonstrate that integrating local wisdom and ESD principles into engineering learning can foster students' ecological awareness and social responsibility, making this model a valuable alternative for promoting sustainable, eco-friendly lifestyles in higher education.

1. INTRODUCTION

Sustainable development is a developing concept that emerged in the 1980s in response to the growing realization of the need to balance economic and social progress with concern for the environment and natural resource management (Malik, 2018; Angiel & Pokojski, 2019). Sustainable development meets current needs without sacrificing the ability of future generations to meet their own needs (Latchem, 2018; Kioupi & Voulvoulis, 2019). The concept of sustainable development emerged in response to growing concerns about the impact of human activities on the environment. Sustainable development can be achieved through education, because education is a means to change human perceptions, attitudes, and behaviors (Roffe, 2010). UNESCO was appointed as a leader to guide the DESD (Decade of Education for Sustainable Development) and played its key role in developing quality standards in education for sustainable development (Kanapathy et al., 2021).

Environmental education is a crucial means of addressing environmental issues to protect and preserve the environment (Effendi et al., 2020). Environmental education can serve as an intermediary for us to learn ways to overcome environmental problems, prevent further environmental damage, and also learn how to protect and preserve the environment (Heleta & Bagus, 2021). Since then, environmental education has been integrated into the school curriculum. Environmental awareness has long been a topic of teaching in schools, but it has not provided certainty whether environmental education has positive results in Indonesian society (Ardan, 2016). Previous research shows that Indonesian society has a low level of support for environmental conservation. Although various learning models, such as Problem-Based Learning, Project-Based Learning, and Inquiry Learning, have been studied to improve environmental awareness, these approaches still lack the integration of local wisdom and ESD principles, creating a clear research gap addressed by the Ethno-ESD Engineering-Based Learning model (Susilastri & Rustaman, 2015).

Education that focuses on environmental literacy provides an understanding of global issues, but also teaches practical skills that can be applied in daily life to support sustainability (Sasa et al., 2022). Student involvement in practical projects, such as on-campus waste management programs or the development of green areas, can provide hands-on experience and increase students' awareness of their responsibilities towards the surrounding environment (Kuruppuarachchi et al., 2021). In addition, a multidisciplinary approach can prepare students to work in cross-disciplinary teams in the future, creating a more holistic understanding and more effective solutions to global environmental problems (Ariyatun et al., 2025). By recognizing that environmental issues involve a variety of factors and stakeholders, students can develop collaborative skills essential for achieving sustainability at different levels of society (Sudarmin et al., 2024). Based on the identified research gap, you should then formulate the research problem and outline the research objectives. Thus, a multidisciplinary approach not only enhances the quality of learning in environmental chemistry courses but also fosters a deeper and more comprehensive understanding of the complexity of environmental problems.

2. METHOD

This study employs a quasi-experimental method (Hall & Geelan, 2015) with a one-group pretest–posttest and one-shot case study design to assess the effectiveness of the Ethno-ESD Engineering-Based Learning model in enhancing students' attitudes towards sustainability and their self-reported sustainable behavior. The research was conducted in the Chemistry Education Study Program, involving 91 students enrolled in Environmental Chemistry courses during the even semester of the 2024/2025 academic year.

2.1. Research Design and Procedure

The research was conducted through several stages, including instrument validation, limited trials, and testing the effectiveness of the learning model. During the study, the material was delivered within the Environmental Chemistry course, which consisted of eight meetings covering topics such as conservation-based chemistry, as well as water, air, and soil chemistry grounded in local wisdom. The first stage is the validation of the content (expert judgment) carried out by five expert validators in the field of education and the environment using Aiken's V analysis (Ilyana et al., 2025). The results of the validator assessment showed an average Aiken's V value of 0.81 for the Sustainability Attitude construct and 0.79 for the Self-Reported Sustainable Behavior construct, indicating that both have high content validity and are suitable for use. The second stage involved an instrument trial with 26 students who had characteristics similar to those of the main research subject. The test data was analyzed using SmartPLS software to obtain the Corrected Item-Total Correlation and p-value. Statement items with a correlation above 0.3 and a significance of $p < 0.05$

are declared valid. In addition, reliability tests were conducted using Cronbach's Alpha, which yielded values above 0.8, indicating that the instrument is considered reliable.

Furthermore, the construct validity analysis was carried out using SmartPLS 3.0 software through Convergent Validity and Discriminant Validity tests. The Convergent Validity test was evaluated based on the Outer Loading and Average Variance Extracted (AVE) values. In contrast, the Discriminant Validity was tested through the Fornell-Larcker Criterion and Cross Loading. The test results showed that all constructs met the validity criteria, with an AVE value greater than 0.5 and a higher AVE square root compared to the correlation between variables (0.805 and 0.808, respectively, both exceeding 0.717), indicating good discriminant validity.

2.2. Model Reliability and Effectiveness

The construct reliability test was conducted using Composite Reliability and Cronbach's Alpha values. The results of the analysis showed the values of Composite Reliability and Cronbach's Alpha for the Sustainability Attitude variable to be 0.974 and 0.972, respectively. Similarly, for Self-Reported Sustainable Behavior, the values were 0.980 and 0.979, respectively. This value exceeds the minimum limit of 0.6, which indicates that the instrument has excellent internal consistency. The final stage involves testing the effectiveness of the Ethno-ESD Engineering-Based Learning model, which is applied in the engineering project-based lecture process, integrating local wisdom values and the principles of Education for Sustainable Development (ESD). Measurements were conducted through a pretest and posttest to assess the improvement in sustainability attitude and self-reported sustainable behavior of students following the model intervention. The Sustainability Attitude questionnaire consists of 35 items across three indicators: Environmental, Social, and Economic Sustainability, while the Self-Report Sustainable Behavior questionnaire contains 19 items across four indicators: Locus of Control, reflecting personal roles in local and global communities, evaluating and motivating personal actions, and environmental responsibility, providing a comprehensive measure of students' sustainability attitudes and behaviors. The data from the study results were then analyzed quantitatively using the t-test (independent sample t-test) to see the significant difference between the initial and final scores, as well as the calculation of Effect Size (Cohen's d) to determine the degree of influence of the model on changes in students' attitudes and behaviors (Larner, 2014).

3. RESULTS AND DISCUSSION

3.1. Results of Instrument Expert Judgment Validation

This type of validity is the content validity of several items or items of the Sustainability Attitude and Self-Report Sustainability Behavior instruments. The data from the validity sheet, as completed by experts, serves as a reference for conducting data analysis. Validity data were analyzed using Aiken's V validity analysis technique (Aiken, 1985). Five validators carry out the validity of the content. The validator's assessment data is obtained after the validator provides an assessment by filling in the validity instrument that has been provided. The validation results were then analyzed using Aiken's V analysis and presented in Tables 1 and 2.

Table 1. Results of the analysis of the validity of the Sustainability Attitude

Aspect/components	V	Criterion	Interpretation
Sustainability Environmental	0.85	Relevant	Valid
Sustainability Social	0.85	Relevant	Valid
Sustainability Economic	0.75	Quite Relevant	Valid (Revised)
Average	0.81	Relevant	Valid

The results of the validity analysis, using Aiken's V index, showed that the Sustainability Attitude instrument had a good level of validity based on the assessment of five experts. Aiken's V score for the Sustainability, Environmental, and Sustainability Social aspects is 0.85 each, which is included in the relevant category and is declared valid without revision. Meanwhile, the Sustainability Economic aspect obtained a score of 0.75, which is quite relevant; therefore, it is recommended that the editorial content be refined to align more closely with the indicators of the sustainability concept. Overall, the average Aiken's V score of 0.81 indicates that the Sustainability

Attitude instrument has high content validity and is suitable for use in the study to measure students' attitudes towards sustainability.

Table 2. Results of the Self-Report Sustainability Behavior Validity Analysis

Aspects/components	V	Criterion	Interpretation
Locus of control	0.85	Relevant	Valid
Reflecting on one's own role in local communities and (global) communities	0.85	Relevant	Valid
Evaluate and better motivate one's actions in dealing with one's feelings and desires	0.72	Quite Relevant	Valid (Revised)
Responsible for the environment	0.75	Quite Relevant	Valid (Revised)
Average	0.79	Relevant	Valid

The results of the content validity test using Aiken's V analysis of the Self-Report Sustainability Behavior instrument showed that, in general, each aspect had a good level of relevance based on the assessment of five expert validators. The aspects of Locus of Control and Reflection of roles in the local and global communities each obtained a value of 0.85, including the relevant category, and were declared valid without revision. The other two aspects, namely Evaluation and motivation of individual actions, and Responsibility for the environment, obtained values of 0.72 and 0.75, which were categorized as quite relevant, necessitating minor revisions to clarify the meaning of the indicators and the items of the statement. Overall, an average Aiken's V score of 0.79 indicates that the Self-Report Sustainability Behavior instrument has high content validity and can be used to measure students' sustainability behavior with a good level of reliability after minor improvements.

3.2. Limited Trial Analysis Results

In the limited trial stage, a one-shot case study was conducted involving 26 students who were intervened with the Ethno-ESD Engineering-Based Learning model. The results of the limited trial in this study are declared valid if the instrument used meets the validity criteria. An instrument is considered valid if it can accurately measure what it is intended to measure, in accordance with the research purpose. The validity test is carried out through several stages. First, instrument tests were conducted on 26 students enrolled in Environmental Chemistry courses, which shared similar characteristics with the primary research subject. Second, the respondents' scoring results were analyzed using item analysis, where the score of each statement item was correlated with the total score. The analysis process was carried out using SmartPLS software to obtain the Corrected Item-Total Correlation and significance (p-value).

The results of the validity analysis showed that most of the statement items had a correlation value above 0.3, with a significance level of $p < 0.05$, indicating that they are valid and can be used in the study. While some items with correlation values below that limit are considered for revision or elimination to improve the instrument's accuracy. Additionally, JASP is used to analyze the reliability of instruments through Cronbach's Alpha test, with results showing α values of more than 0.8, indicating high reliability. Thus, the instrument tested using SmartPLS is deemed feasible for consistently and accurately measuring students' sustainability attitudes and self-reported sustainable behavior. The initial AVE values are presented in Table 3.

Variabel	Cronbach's Alpha	rho_A	Composite Reliability	Average Variance Extracted (AVE)
Sustainability Attitude	0.964	0.964	0.974	0.657
Self-report Sustainable Behavior	0.989	0.969	0.972	0.586

Based on the results of the construct validity test using the Fornell-Larcker Criterion, both research variables showed an excellent level of validity and reliability. The Sustainability Attitude variable has a Cronbach's Alpha value of 0.964, Composite Reliability of 0.974, and Average Variance Extracted (AVE) of 0.657. These values demonstrate high internal consistency and convergent validity, which are met because the AVE value exceeds 0.5. Meanwhile, the Self-Report Sustainable Behavior variable had Cronbach's Alpha values of 0.989, Composite Reliability of 0.972, and AVE of 0.586, which also showed good convergent reliability and validity. Overall, these results indicate that all indicators in both variables can effectively represent the construct, and the instruments used are feasible for measuring students' sustainability attitudes and sustainable behaviors in the context of Ethno-ESD Engineering-Based Learning.

The validity of the study was assessed through the Discriminant Validity test, which included the Fornell-Larker Criterion and Cross-Loading tests. The Fornell-Larker Criterion test is performed by comparing the AVE value with other latent variables. The concept that must be met is that the correlation value of one AVE with its own variable construct must be greater than that of the other variable construct. This is evident from the diagonal and vertical directions of each variable column in Table 4.

Table 4. Fornell-Larker Criterion processing values

Variabel	Sustainability Attitude	Self-report Sustainable Behavior
Sustainability Attitude	0.805	
Self-report Sustainable Behavior	0.717	0,808

The results of the Fornell-Larcker Criterion analysis show that the square root value of Average Variance Extracted (AVE) in each variable is higher than the correlation value between variables. The diagonal values for the Sustainability Attitude variable and the Self-Report Sustainable Behavior variable were 0.805 and 0.808, respectively, both of which were greater than the correlation value between the variables, which was 0.717. This indicates that each construct has a good discriminator, meaning that each variable can explain its own concept more dominantly than the relationship between variables. Thus, it can be concluded that the measurement model meets the criteria of discriminant validity; therefore, the instrument used is valid for measuring two different but interconnected constructs. A reliable instrument is used repeatedly to measure the same object, producing consistent data (Sugiyono, 2014). The reliability test in this study was conducted using Composite Reliability and Cronbach's Alpha values, which were all above 0.6. The reliability value of the research is presented in Table 5.

Table 5. Composite Reliability Value

	Cronbach's Alpha	Composite Reliability
Sustainability Attitude	0.972	0.974
Self-report Sustainable Behavior	0.979	0.980

The results of the reliability test showed that all variables had Cronbach's Alpha and Composite Reliability values above 0.6, indicating excellent internal consistency (Sugiyono, 2014). The Sustainability Attitude variable yielded values of 0.972 and 0.974, while the Self-Report Sustainable Behavior variable had values of 0.979 and 0.980. Thus, the instrument was declared reliable and consistent in measuring students' attitudes and sustainable behavior.

3.3. Effectiveness of the Ethno-ESD Engineering-Based Learning Model

An analysis of the Sustainability Attitude and self-report sustainable behavior of students was then carried out, including a prerequisite test to assess the normality and homogeneity of the data group before the t-test was conducted. The recapitulation of the results for normality, homogeneity, and the t-test of Sustainability Attitude data and self-report sustainable behavior in the experimental class and the control class is presented in Table 6.

Table 6. Recapitulation of the results of normality, homogeneity, and t-test analysis

Variabel	Class	N	Normality		Homogenites	t
			Mean	Sig.	Sig.	Sig.
Sustainability Attitude	Experiment	36	81.71	0.456	0.073	0.00
	Control	29	74.79	0.831		
Self-report sustainable behavior	Experiment	36	83.76	0.318	0.184	0.00
	Control	29	80.25	0.673		

The results of the analysis in Table 6 indicate that the data on Sustainability Attitude and Self-Report Sustainable Behavior from the experimental and control classes have met the prerequisite test for the analysis. The significance values of the normality tests for all variables were above 0.05, with values of 0.456 and 0.318 for the experimental class and 0.831 and 0.673 for the control class, indicating that the data were normally distributed. The homogeneity test also showed significance values of 0.073 for Sustainability Attitude and 0.184 for Self-Report Sustainable Behavior, indicating that the variance between homogeneous groups was not significant due to $p > 0.05$. The results of the t-test showed a significance value of 0.00 ($p < 0.05$), indicating a significant difference between the experimental and control classes. Thus, the application of the Ethno-ESD Engineering-Based Learning model is efficacious in improving students' sustainability attitudes and sustainable behavior compared to conventional learning. Furthermore, an effect size test was conducted to assess the level of effectiveness of the Ethno-ESD Engineering-Based Learning model on students' Sustainability Attitudes and Self-Reported sustainable behavior. The results of data analysis are presented in Table 7.

Table 7. Effect Size, Sustainability Attitude, and Self-report Sustainable Behavior Test

Variabel	Effect Size	Interpretation
Sustainability Attitude	0.87	high
Self-report sustainable behavior	0.81	currently

The results of the effect size test in Table 7 indicate that the Ethno-ESD Engineering-Based Learning model has a significant influence on improving students' Sustainability Attitudes and Self-Reported Sustainable Behavior. The effect size value of 0.87 for Sustainability Attitude falls into the high category, while the value of 0.81 for Self-Report Sustainable Behavior is categorized as medium to high. These findings demonstrate that the application of a learning model that integrates local wisdom values and Education for Sustainable Development (ESD) principles is practical in fostering students' sustainable attitudes and behaviors. In other words, the Ethno-ESD Engineering-Based Learning model not only has a statistically significant impact but also has a real, practical influence in increasing students' awareness and actions on sustainability issues.

3.4. Discussion

The approach to learning must provide a favorable environment for learners, enabling them to gain more experience in understanding the science process (Bilgin et al., 2015; Maulana et al., 2025), similar to a project-based curriculum that can help students achieve learning outcomes (Harris et al., 2015). The application of teaching methods plays a crucial role in science education (Kizkapan & Bektas, 2017; Zadok, 2020). Therefore, lecturers can contribute by implementing constructivist learning approaches, making learning more meaningful. The Ethno-ESD Engineering-Based Learning model, in its implementation, enables the incorporation of local, cultural, and environmental values into engineering projects. Students not only learn about technology but also understand its relationship with the social context and environment (Yu et al., 2020; Chen et al., 2022). This encourages students to develop a deeper understanding of environmental issues and increase awareness of the impact of technology on sustainability (Mangold & Robinson, 2013).

Further analysis of the evaluation results revealed that the Ethno-ESD Engineering-Based Learning design had a positive impact on two key aspects: attitude sustainability and Self-Reported sustainable behavior of students. Students' understanding of sustainability concepts applied in the context of sustainability projects has increased. This reflects the success of the Ethno-ESD Engineering-Based Learning learning design in transferring sustainability knowledge to students. Changes in sustainability attitudes reflect a shift in students' perspectives on environmental and sustainability issues (Gupta et al., 2024; Misseyanni et al., 2020). The Ethno-ESD Engineering-Based Learning design successfully creates an environment that supports the development of positive attitudes towards sustainability, incorporating ethnographic aspects (the manufacture of biopesticides from black turmeric leaves) to explore local and cultural values that promote sustainability. The increase in self-reported sustainable behavior demonstrates that the learning design of Ethno-ESD Engineering-Based Learning not only provides knowledge and attitude change but also encourages sustainable real-world actions from students (Horvath et al., 2013; Handoyo et al., 2025). The ability of students to report their own sustainable behaviour demonstrates the integration of sustainability values into their daily practices.

The Ethno-ESD Engineering-Based Learning learning model can provide opportunities for students to collaborate with the local community, strengthening community involvement in learning projects (Sahabuddin & Makkasau, 2024; Sudarmin et al., 2025; Zhang et al., 2024). As a result, students can directly experience the impact of the technological innovations they design in the context of sustainability, which can stimulate positive attitudes and actions towards the environment (Winarno et al., 2020). Thus, the Ethno-ESD Engineering-Based Learning learning model not only shapes students' technical expertise, but also encourages the development of deep and sustainable environmental literacy.

The positive impact of the Ethno-ESD Engineering-Based Learning model on students' sustainability attitudes and self-reported sustainable behaviors aligns with constructivist learning theory, which emphasizes learning through active engagement and real-world problem-solving (Devi, 2019). This theoretical perspective supports the finding that students not only gain technical knowledge but also develop meaningful connections between technology, society, and environmental sustainability. Furthermore, the results are consistent with prior studies, which show that project-based and inquiry-based approaches can enhance environmental awareness and promote sustainable behavior in higher education contexts (Sudarmin et al., 2025). Compared to conventional learning methods, which often focus on content mastery without linking it to social and environmental contexts, the Ethno-ESD Engineering-Based Learning model provides a holistic approach that integrates local wisdom, cultural values, and community engagement, thereby addressing gaps identified in previous research. These findings confirm that integrating sustainability principles into engineering-based learning can effectively foster both knowledge and actionable attitudes among students, contributing to the broader goal of achieving sustainable development competencies

4. CONCLUSION

This study demonstrates that the Ethno-ESD Engineering-Based Learning model is efficacious in enhancing students' sustainability attitudes and promoting sustainable behavior. The integration of local wisdom values (ethno) with the principles of Education for Sustainable Development (ESD) in engineering-based learning significantly increased students' ecological awareness and social responsibility ($p < 0.05$; Effect Size 0.87 and 0.81). The research instruments were declared valid and reliable (Cronbach's Alpha and Composite Reliability > 0.9; AVE > 0.5). The implication is that this model can serve as an innovative strategy in higher education to instill sustainable values and support the achievement of the Sustainable Development Goals (SDGs) by transforming students' attitudes and behaviors towards an environmentally friendly lifestyle.

REFERENCES

Aiken, L. R. (1985). Three coefficients for analyzing the reliability and validity of ratings. *Educational and Psychological Measurement*, *45*(1), 131–142.

Angiel, J., & Pokojski, W. (2019). Education for sustainable development-from students' and geography teachers' knowledge to educational activities. *Miscellanea Geographica*, *23*(1), 47–52. https://doi.org/10.2478/mgrsd-2018-0026

Ardan, A. S. (2016). The Development of Biology Teaching Material Based on the Local Wisdom of Timorese to Improve Students' Knowledge and Attitude of Environment In Caring for the Preservation of the Environment. *International Journal of Higher Education*, *5*(3), 190–200. https://doi.org/10.5430/ijhe.v5n3p190

Ariyatun, Sudarmin, Rahmawati, A., Winarto, & Wibowo, T. (2025). Reconstruction of the Engineering Design Project (EDPj) Learning Model based on Ethno-ESD to Actualize Students ' Sustainable Environmental Literacy. *LUMAT: International Journal on Math, Science, and Technology*, *12*(4), 1–28. https://doi.org/https://doi.org/10.31129/LUMAT.12.4.2300

Bilgin, I., Karakuyu, Y., & Ay, Y. (2015). The effects of project based learning on undergraduate students' achievement and self-efficacy beliefs towards science teaching. *Eurasia Journal of Mathematics, Science and Technology Education*, *11*(3), 469–477. https://doi.org/10.12973/eurasia.2014.1015a

Chen, C., An, Q., Zheng, L., & Guan, C. (2022). Sustainability Literacy: Assessment of Knowingness, Attitude, and Behavior Regarding Sustainable Development among Students in China. *Sustainability (Switzerland)*, *14*(9). https://doi.org/10.3390/su14094886

Devi, K. S. (2019). Constructivist Approach to Learning based on the Concepts of Jean Piaget and Lev Vygotsky An Analytical Overview. *Journal of Indian Education*, *44*(4), 5–19.

Effendi, M. R., Setiadi, E., & Ahmad Nasir, M. (2020). The Local Wisdom Based on Religious Values: a Case of Indigenous People in Indonesia. *Humanities & Social Sciences Reviews*, *8*(3), 1395–1404. https://doi.org/10.18510/hssr.2020.83140

Gupta, D. M. S., Samrutwar, A. M., Rahandale, A. M., & Edlabadkar, A. A. (2024). The Influence of Environmental Education on College Students' behavioural Attitudes towards Sustainability. *Journal of Learning and Educational Policy*, *46*, 48–58. https://doi.org/10.55529/jlep.46.48.58

Hall, R., & Geelan, D. (2015). Mixed Methods : In Search of a Paradigm. *The Australian Educational Researcher*, *July*, 0–6. https://doi.org/10.1007/s13384-015-0169-0

Handoyo, E., Ariyatun, A., Syaifuddin, S., Winarto, W., Saputro, S. D., Anwar, E. D., Reffiane, F., & Banu Kenayathulia, H. (2025). Integration of the global attitudes of prospective teachers in encouraging a culture of environmental conservation for sustainable development in higher education. *Multidisciplinary Reviews*, *8*(4). https://doi.org/10.31893/multirev.2025114

Harris, C. J., Penuel, W. R., D'Angelo, C. M., DeBarger, A. H., Gallagher, L. P., Kennedy, C. A., Cheng, B. H., & Krajcik, J. S. (2015). Impact of project-based curriculum materials on student learning in science: Results of a randomized controlled trial. *Journal of Research in Science Teaching*, *52*(10), 1362–1385. https://doi.org/10.1002/tea.21263

Heleta, S., & Bagus, T. (2021). Sustainable development goals and higher education: leaving many behind. *Higher Education*, *81*(1), 163–177. https://doi.org/10.1007/s10734-020-00573-8

Horvath, N., Stewart, M., & Shea, M. (2013). Toward Instruments of Assessing Sustainability Knowledge: Assessment Development, Process, and Results From A Pilot Survey At The University of Maryland. *Journal of Sustainability Education*, *5*(May).

Ilyana, N., Tajuddin, I., Abas, U., Aziz, K. A., Nor, R., Nor, H., & Izni, N. A. (2025). Content Valid ity Assessment Using Aiken ' s V : Knowledge Integration Model for Blockchain in Higher Learning Institutions. *International Journal of Advanced Science and Applications*, *16*(6), 601–608. https://doi.org/10.14569/IJACSA.2025.0160659

Kanapathy, S., Lee, K. E., Mokhtar, M., Syed Zakaria, S. Z., & Sivapalan, S. (2021). A framework for integrating sustainable development concepts into the chemistry curriculum towards achieving education for sustainable development in Malaysia. *International Journal of Sustainability in Higher Education*, *22*(6), 1421–1449. https://doi.org/10.1108/IJSHE-07-2020-0241

Kioupi, V., & Voulvoulis, N. (2019). Education for Sustainable Development : A Systemic Framework for Connecting the SDGs to Educational Outcomes. *Sustainability*, *11*.

Kizkapan, O., & Bektas, O. (2017). The effect of project based learning on seventh grade students' academic achievement. *International Journal of Instruction*, *10*(1), 37–54. https://doi.org/10.12973/iji.2017.1013a

Kuruppuarachchi, J., Sayakkarage, V., & Madurapperuma, B. (2021). Environmental literacy level comparison of undergraduates in the conventional and odls universities in sri lanka. *Sustainability (Switzerland)*, *13*(3), 1–16. https://doi.org/10.3390/su13031056

Larner, A. J. (2014). Effect Size (Cohen ' s d) of Cognitive Screening Instruments Examined in Pragmatic Diagnostic Accuracy Studies. *Dementia and Geriatric Cognitive Disorders Extra*, *4*(2), 236–241. https://doi.org/10.1159/000363735

Latchem, C. (2018). Education for sustainable development. *SpringerBriefs in Open and Distance Education*, *5*, 155–165. https://doi.org/10.1007/978-981-10-6741-9_15

Malik, R. S. (2018). Educational Challenges in 21St Century and Sustainable Development. *Journal of Sustainable Development Education and Research*, *2*(1), 9. https://doi.org/10.17509/jsder.v2i1.12266

Mangold, J., & Robinson, S. (2013). The engineering design process as a problem solving and learning tool in K-12 classrooms. *ASEE Annual Conference and Exposition, Conference Proceedings*. https://doi.org/10.18260/1-2--22581

Maulana, I., Supriyadi, E., Wijanarka, B. S., Ariyatun, & Winarto. (2025). Coding learning innovation: Interactive programming experience with virtual lab platform. *Multidisciplinary Science Journal*, *7*(6). https://doi.org/10.31893/multiscience.2025262

Misseyanni, A., Marouli, C., & Papadopoulou, P. (2020). How teaching affects student attitudes towards the environment and sustainability in higher education: An instructor's perspective. *European Journal of Sustainable Development*, *9*(2), 172–182. https://doi.org/10.14207/ejsd.2020.v9n2p172

Roffe, I. (2010). Sustainability of curriculum development for enterprise education: Observations on cases from Wales. *Education and Training*, *52*(2), 140–164. https://doi.org/10.1108/00400911011027734

Sahabuddin, E. S., & Makkasau, A. (2024). Utilization of virtual reality as a learning tool to increase students' pro-environmental behavior at universities: A maximum likelihood estimation approach. *Eurasia Journal of Mathematics, Science and Technology Education*, *20*(12). https://doi.org/10.29333/ejmste/15654

Sasa, T., Ahmad, W., Bahtiti, N. H., Abujaber, M., Adeyleh, A., & Miri, O. (2022). Assessment Level of Environmental Literacy among Applied Science Private University (ASU) Students. *WSEAS Transactions on Environment and Development*, *18*, 1012–1020. https://doi.org/10.37394/232015.2022.18.97

Sudarmin, Ariyatun, Rahayu, S., Yamtinah, S., Pujiastuti, R. S. E., Munzil, & Winarto. (2025). How to increase student sustainable attitudes: a study effect of the education for sustainable development ethno-pedagogy learning model (EP-ESD). *Multidisciplinary Science Journal*, *7*(5). https://doi.org/https://doi.org/10.31893/multiscience.2025252

Sudarmin, Savitri, E. N., Pujiastuti, R. S. E., Yamtinah, S., Hanim Binti Mohd Zaim, H., & Ariyatun. (2024). Reconstruction of Ethno-Stem Integrated Project Learning Models for Explanation of Scientific Knowledge Regarding Aroma Compounds of Indonesian and World Herbal Teas. *Jurnal Pendidikan IPA Indonesia*, *13*(2), 195–208. https://doi.org/10.15294/wknw8m59

Sudarmin, Sulistyaningsih, T., Savitri, E. N., Pujiastuti, R. S. E., Zain, H. bint M., Winarto, Dewi, R. K., & Ariyatun. (2025). Conservation character learning framework : An ethno-stem integrated inquiry project learning model for community science issue explanation of tea drinking culture and aroma of indonesian tea compound. *Multidisciplinary Science Journal*, 1–12.

Sugiyono. (2014). *Statiska untuk Penelitian*. Alfabeta.

Susilastri, S. D., & Rustaman, N. Y. (2015). Students' Environmental Literacy Profile in School-Based Nature. *Seminar Nasional Konservasi Dan Pemanfaatan Sumber Daya Alam*, 263–269.

Winarno, N., Rusdiana, D., Samsudin, A., Fitria, D., Husaeni, A., Bayu, A., & Nandiyanto, D. (2020). The steps of the Engineering Design Process (EDP) in science education: A systematic literature review. *Journal for the Education of Gifted Young Scientists*. *8*(4), 1345–1360.

Yu, K. C., Wu, P. H., & Fan, S. C. (2020). Structural Relationships among High School Students' Scientific Knowledge, Critical Thinking, Engineering Design Process, and Design Product. *International Journal of Science and Mathematics Education*, *18*(6), 1001–1022. https://doi.org/10.1007/s10763-019-10007-2

Zadok, Y. (2020). Project-based learning in robotics meets junior high school. *Journal of Engineering, Design and Technology*, *18*(5), 941–958. https://doi.org/10.1108/JEDT-01-2019-0023

Zhang, J., Wan Yahaya, W. A. J., & Sanmugam, M. (2024). The Impact of Immersive Technologies on Cultural Heritage: A Bibliometric Study of VR, AR, and MR Applications. *Sustainability (Switzerland)*, *16*(15). https://doi.org/10.3390/su16156446