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STUDENTS' ENVIRONMENTALLY-FRIENDLY BEHAVIOR: THE MEDIATING EFFECT INVESTIGATION

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ABSTRACT

The discovery of problems linked to environmentally-friendly behavior and several antecedent factors motivates this study. This study examines the effect of environmental physics understanding, scientific reasoning, and environmental behavior intentions on environmentally-friendly behavior and investigates the mediating role of scientific reasoning and environmental behavior intentions. This quantitative study used an associative approach. The research population was high schoolers in West Sumatra. The research sample was 407 high schoolers in West Sumatra, obtained through convenience sampling. Data were collected by applying a questionnaire. The research objectives were answered with a structural equation modeling approach. In this study, environmental physics understanding, scientific reasoning, and environmental behavior intentions are significant predictors of environmentally-friendly behavior. The results show that scientific reasoning had a mediating effect on the relationship between environmental physics understanding and environmentally-friendly behavior (β= 0.098, t = 1.794, p-value = 0.006). The environmental behavior intention has no mediating effect on the relationship between scientific reasoning on environmentally-friendly behavior (β= 0.045, t = 1.843, p-value = 0.066) and environmental physics understanding on environmentally-friendly behavior (β = 0.018, t = 1.467, p-value = 0.143). This study has limitations where data are only collected in high schools in West Sumatra, so generalizations are limited. Cross-sectional data add a further limitation to it. Conversely, this research augments the current literature on environmental physics understanding, scientific reasoning, and environmental behavior intentions by focusing on previously unstudied environmentally-friendly behavior. Furthermore, this study offers a novel theoretical explanation for the relationship between realizing the mediating role of scientific reasoning and environmental behavior intentions.

Keywords: environmentally-friendly behavior; environmental physics understanding; scientific reasoning

INTRODUCTION

One way to increase environmentally-friendly behavior is through education ((Jensen, 2002; Meyer, 2015; Yusliza et al., 2020; Soares et al., 2021). Higher education level people are more worried about environmental protection because they are more aware of potential harm (Sun et al., 2018). Individuals who have a greater degree of environmental knowledge engage in environmentally-friendly behavior. The educational system frequently acquires environmental information and specific skills (Ardoin et al., 2020; Litvinenko et al., 2022). Thus, understanding how education contributes to environmentally-friendly behavior becomes essential for policymakers, educators, and other interested parties to improve environmentally-friendly behavior.

Environmental knowledge and skills must be strengthened since one is still in the younger generation group (Thor & Karlsudd, 2020). Currently, many young people are involved in actions on environmental issues in the field. As a result, to find long-term solutions, they must be equip-

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ped with accurate environmental knowledge and skills. Thus, education is vital in encouraging environmentally-friendly behavior to increase the responsibility of competent people with values, skills, and knowledge to contribute to a sustainable environment (Cincera & Krajhanzl, 2013; Ouariachi et al., 2020).

If environmentally-friendly behavior is not instilled early, it will cause more environmental problems (Ginsburg & Audley, 2020), as for the current environmental problems, such as the waste problem. Based on data released by Statistics Indonesia in a report entitled West Sumatra in Figures 2022, it is estimated that the daily waste generation by regencies/cities in West Sumatra will reach 2,077.17 tons in 2021 (BPS Provinsi Sumatera Barat, 2022). This waste, especially plastic, threatens marine life and pollutes the soil and air if burned in the open. In addition, air pollution is caused by vehicle exhausts, dirt, and dust from open construction. If left unchecked, environmental problems will cause physical and psychological disorders. For instance, air pollution (elevated $PM_{10,}$ O_3, and NO_2) can exacerbate depressive symptoms in elders (Gładka et al., 2018; Keshtgar et al., 2021; Duan et al., 2022). Excessive exposure to nitrogen, organic solvents, sulfur oxides, and other environmental pollutants can cause schizophrenia (Attademo et al., 2017; Bernardini et al., 2020). Also, air pollution can cause Alzheimer's, Parkinson's, and stroke (Calderón-Garcidueñas et al., 2021; Murata et al., 2022).

The challenge in education is ensuring that knowledge and skills can be realized in environmentally-friendly behavior. This behavior can be applied through students' qualified scientific reasoning. A good learning process with students' good material absorption will undoubtedly impact their behavior in everyday life. Previous literature has determined that scientific reasoning has a positive and significant relationship with environmentally-friendly behavior (Sahin et al., 2021). As a result, this research proposes a hypothesis that scientific reasoning significantly affects the environmentally-friendly behavior of high schoolers (H1).

Before environmentally-friendly behavior is formed, an individual has an Environmental Behavior Intention. Scientific reasoning also determines whether a person has Environmental Behavior Intentions (Aziz et al., 2021). Scientific reasoning will affect his/her environmental behavior intentions (Ateş, 2020). One's scientific reasoning might reinforce one's desire to protect the environment. Following the previous logic of reasoning supported by the literature review, the researchers propose a hypothesis that scientific reasoning has a significant effect on the environmental behavior intentions of high schoolers (H2)

Individuals with environmental physics understanding may increase their environmentally-friendly behavior. Therefore, scientific knowledge about environmentally-friendly behavior needs significant attention because it has practical uses for a sustainable future (Shafiei & Maleksaeidi, 2020). This knowledge can be obtained from formal education. Individual environmental sensitivity is closely related to environmental knowledge. In addition to knowledge, individuals' values and worldviews influence environmentally-friendly behavior (Zhang et al., 2014; Liobikienė& Posku, 2019; Mainland et al., 2020; Turan & Kiliklar, 2021). The new ecological paradigm is a global perspective on the adverse environmental effects of human activities and a belief in the long-term consequences of environmental problems (Turan & Kiliclar, 2021; Wang et al., 2023). For this reason, the researchers propose a hypothesis that environmental physics understanding significantly affects high schoolers' environmentally-friendly behavior (H3).

Environmental Behavior Intentions can also be caused by environmental physics understanding (Abdullah et al., 2019). The intention to behave in protecting the environment arises from knowledge from school. The understanding gained will encourage a person's intention to environmental behavior (Polonsky et al., 2012). Therefore, the authors hypothesize that environmental physics understanding significantly affects the environmental behavior intentions of high schoolers (H4).

Scientific reasoning reinforces students' mental and physical activities to comprehend environmental physics understanding during the learning process. While studying physics, students are expected to reason and think analytically, logically, creatively, and critically (Palloan & Swandi, 2019; Fitriani & Suhardiman, 2021). Students must be familiar with physics content in the form of concepts, facts, or principles and examine, gather, assert, analyze, and evaluate their understanding of physics (Miharni et al., 2013). Students will find it easier to describe concepts in their language using scientific reasoning if they understand environmental physics (Bao & Koenig, 2019; Brookes et al., 2020; Fitriani & Suhardiman, 2021). For this reason, the researchers propose a hypothesis that environmental physics understanding significantly affects the environmentally-friendly behavior of high schoolers (H5).

Environmental Behavior Intentions are identified as strong internal stimuli and are frequently regarded as the root cause of behavior (Liu et al., 2020). Direct variables increase environmentally-friendly behavior (Untaru et al., 2014; Liu et al., 2020). Environmental behavior intention refers to a person's subjective perception of engaging in either positive or negative environmental behavior with environmentally-friendly behavior (Kaiser & Gutscher, 2003). The EBI of visitors can accurately estimate their environmentally-friendly behavior (Mobley & Kilbourne, 2013; Lee & Jan, 2015; Liu et al., 2020). For this reason, the researchers hypothesize that environmental behavior intention significantly affects the environmentally-friendly behavior of high schoolers (H6).

Students' scientific reasoning can increase environmental behavior intention (Hong et al., 2021), while environmental behavior intention affects environmentally-friendly behavior (Chin et al., 2018). In everyday life, scientific reasoning from the learning process can affect a person's intention to behave, which subsequently becomes environmentally-friendly behavior. Therefore, this research proposes the hypothesis that environmental behavior intention has a mediating effect on the relationship between scientific reasoning and the environmentally-friendly behavior of high schoolers (H7). Students' environmental physics understanding can improve scientific reasoning (Kinslow et al., 2019), and scientific reasoning affects environmentally-friendly behavior (Millet & Weijters, 2023). Environmental physics understanding affects scientific reasoning and, subsequently, environmentally-friendly behavior. Therefore, this study proposes a hypothesis that scientific reasoning has a mediating effect on the relationship between environmental physics understanding and the environmentally-friendly behavior of high schoolers (H8).

Pro-environmental knowledge includes knowledge of practical skills and activities and factual knowledge of environmental themes, terminology, and regulations (Fu et al., 2017). People must first comprehend their requirements and recognize the essential nature and significance of pro-environmental lifestyles before engaging in environmentally-friendly behavior, and it is broadly supported that increasing pro-environmental knowledge results in a stronger intent to involve in environmentally-friendly behavior (Fu et al., 2017; Paço & Lavrador, 2017; Zebardast & Radaei, 2022). Environmental physics understanding can affect a person's intention to behave, and then it becomes environmentally-friendly behavior. Thus, this study hypothesizes that environmental behavior intention mediates the correlation between environmental physics understanding and environmentally-friendly behavior of high schoolers (H9). The conceptual framework of the research is presented in Figure 1

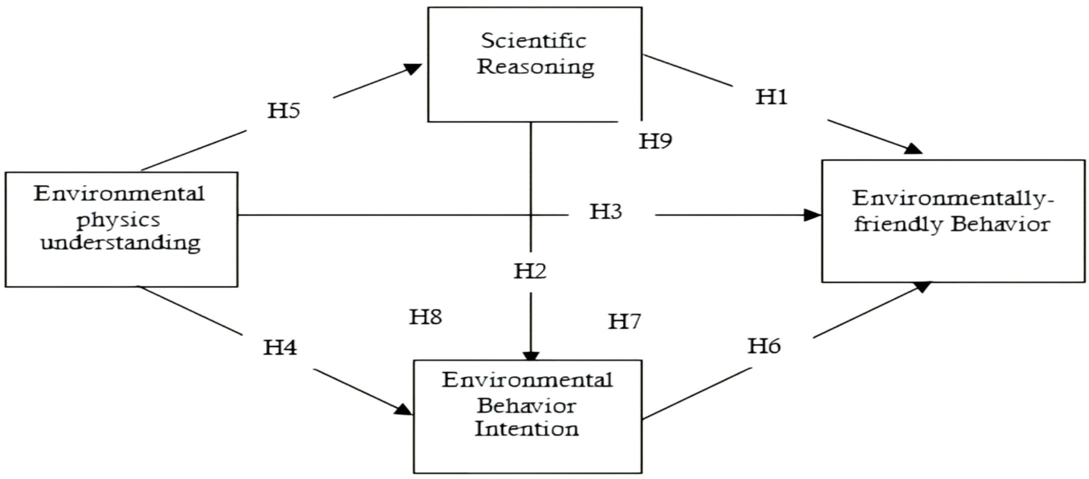

Figure 1. Conceptual Framework

Based on Figure 1, nine hypotheses will be answered through this research. Six out of nine hypotheses look at the direct relationship of the independent variables (environmental physics understanding, scientific reasoning, and environmental behavior intention) with the dependent variable (scientific reasoning, environmental behavior intention, and environmentally-friendly behavior). On the other hand, the other three hypotheses look at the mediating effect of environmental behavior intentions and scientific reasoning on the effect of independent variables on environmentally-friendly behavior.

Although much of the research focuses on students and the environment (Anbarasu & Bhuvaneswari, 2020; Brandisauskiene et al., 2021; García et al., 2022; Kapoor et al., 2021; Rezaly et al., 2021), very few analyze the environmental impact of environmental physics understanding, scientific reasoning, environmental behavior intentions, and environmentally-friendly behavior. The relationship between environmental physics understanding and environmentally-friendly behavior has not yet been studied regarding the mediating role of scientific reasoning and environmental behavior intents. Some studies only focus on identifying environmental awareness (Arshad et al., 2021; El Savada et al., 2021; Orbanic & Kovac, 2021), environmental education (Liao & Li, 2019; Ardoin & Bowers, 2020; Marques & Xavier, 2020), environmental pollution (Ma et al., 2019; Dalu et al., 2020; Nurhayati et al., 2022), and environmental application (Wang & Wang, 2019; Khaleque et al., 2020; Yang et al., 2022). This study examines the effect of environmental physics understanding, scientific reasoning, and environmental behavior intentions on environmentally-friendly behavior based on a theoretical model. Further, the study model, the mediating role of scientific reasoning, and the effect of environmental behavior intentions are statistically investigated and explored.

METHODS

This quantitative study used an associative approach (Cohen, 2018) to evaluate structural models of scientific reasoning, environmental physics understanding, environmental behavior intentions, and environmentally-friendly behavior. The stages were designing research with four variables, designing and testing questionnaires, collecting data, compiling measurement and structural models, and testing the suitability of the SEM model.

The research population was high schoolers in West Sumatra. The research sample was 407 high schoolers in West Sumatra obtained through convenience sampling technique (Table 1). The type of data used was primary data. The research instrument was a questionnaire using Google Forms.

Table 1. Research Sample

Criteria	Option	Frequency	Percentage (%)
Sex	Male	154	38
	Female	253	62
Grade	X	212	52
	XI	152	37
	XII	43	11
Age	15-17	369	91
	18-20	38	9

The research variables were scientific reasoning, environmental physics understanding, environmental behavior intentions, and environmentally-friendly behavior, as shown in Table 2. All research variables were broken down into several items from the questionnaire. Responses from the questionnaire were in the form of choices with a Likert scale from strongly disagree (score 1) to strongly agree (score 4).

Table 2. Research Variable

No	Variable	Number of Items	Source
1	Scientific Reasoning	7	Sun et al. (2022)
2	Environmental physics understanding	10	Kaplowitz and Levine (2005) and Odum (1971)
3	Environmental Behavior Intentions	4	Liu et al. (2020)
4	Environmentally-friendly behavior	6	Liu et al. (2020)

This research variable came from previous research. For scientific reasons, the seven items in this study were adopted from Sun et al. (2022). Environmental physics understanding was evaluated using a scale established by Meng et al. (2022), containing ten items. Environmental behavior intentions consisted of four items adapted from Liu et al. (2020), and environmentally-friendly behavior consisted of six items developed by Liu et al. (2020).

The data was analyzed using the Smart PLS 3 application and Partial Least Squares Structural Equation Modeling (PLS-SEM). The main reason for using PLS-SEM was to predict the main target construction, which was the research objective (Chin, 2010; Ramayah et al., 2016). PLS-SEM is a valuable method for analyzing complex hierarchical models reflecting soft modeling assumptions suitable and favorable for SEM (Papadopoulos et al., 2017). The first step in the PLS-SEM technique is verifying the measurement model shown in Figure 1, then calculating the structural model›s path.

RESULT AND DISCUSSION

The Smart PLS 3 version was applied to a partial least square-structural equation modeling (PLS-SEM) investigation. Procedures for structural assessment and measurement were completed in two stages. The link between unobserved or latent variables (LV) was assessed using a measurement model. A structural model assessment was done to investigate the connection between the underlying exogenous and endogenous factors. Using Composite Reliability (CR) and Average Variance Extracted (AVE), this stage involved evaluating the study model›s internal consistency, reliability, and convergent validity. Tables 3 and 4 give the outcomes of the measuring model. Using Cronbach Alpha and Composite Reliability, all constructs› internal consistency and reflective constructs› reliability were evaluated. Convergence validity was assessed using the Average Variance Extracted (AVE) method. Item loading was examined to ascertain if the index could be relied upon for model measurements.

Table 3. Construct Reliability and Convergent Validity

Latent Variable	Cronbach Alpha	Composite Reliability	AVE
Scientific Reasoning (SR)	0,754	0,844	0,576
Environmental physics understanding (EPU)	0,784	0.852	0,536
Environmental Behavior Intention (EBI)	0,711	0,754	0,506
Environmentally-friendly behavior (EFB)	0,740	0,785	0,549

Based on Table 3, Cronbach's Alpha Reliability and Composite Reliability met the required standards, so the internal consistency reliability was considered acceptable. The Average Variance Extracted (AVE) ranges from 0.506 to 0.576, which also met the requirements. The Heterotrait-Monotrait ratio (HTMT) and the Fornell-Larcker criteria were utilized to evaluate the discriminant validity of this study instrument (Hanafiah, 2020). Table 4 shows the square root relationship with other parameters.

Table 4. The Analysis of Fornell-Larcker Criteria

	Scientific Reasoning	Environmental physics understanding	Environmental Behavior Intention	Environmentally-friendly behavior
Scientific Reasoning	0,759			
Environmental physics understanding	0,495	**0,732**		
Environmental Behavior Intention	0,435	0,331	**0,711**	
Environmentally-friendly behavior	0,404	0,444	0.306	**0,741**

In Table 4, each construct's square root (correlation with other constructs) was more significant than the sum of the squares of each construct, supporting the discriminant validity of the survey instrument.

In Table 5, if the HTMT value is projected to increase by more than 0.9, then the discriminant validity will be less (Cheung et al., 2023). All constructs met the threshold value, meaning our reflective model reached discriminant validity.

Table 5. HTMT Value

	Scientific Reasoning	Environmental physics understanding	Environmental Behavior Intention	Environmentally-friendly behavior
Scientific Reasoning				
Environmental physics understanding	0,635			
Environmental Behavior Intention	0,703	0,517		
Environmentally-friendly behavior	0,603	0,641	0,563	

PLS-SEM includes models for measurement (outer) and structural (inner) analysis. Individual item reliability, internal consistency reliability, convergent validity, and discriminant validity are among the outcomes of the measurement model depicted in Figure 2.

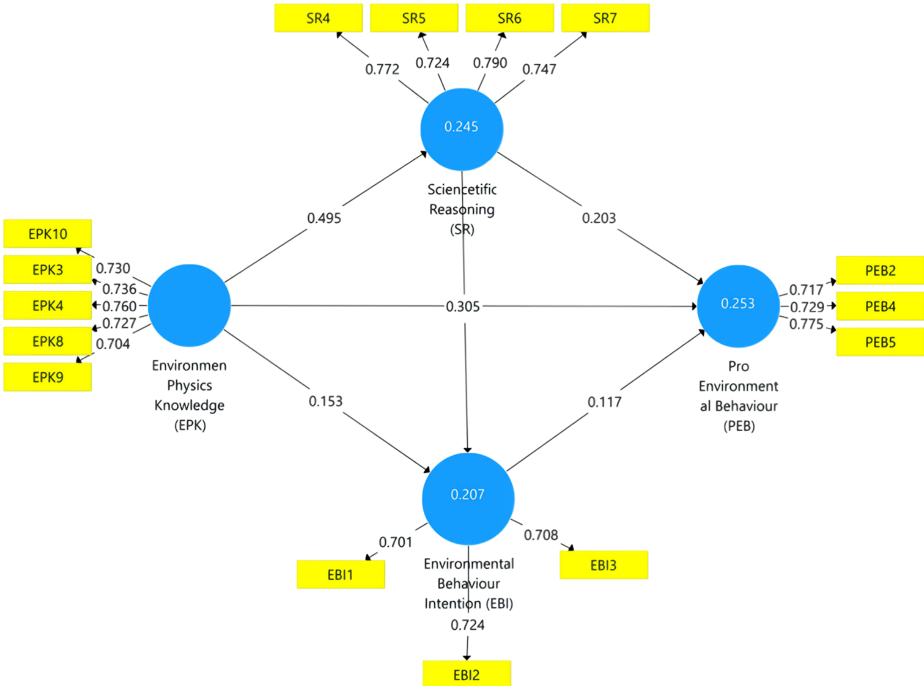

Figure 2. The result of the Measurement Model

Figure 2 shows that all the standard factor loadings are greater or equal to 0.70. The overall model measurements with all observed variable values are valid.

Structural modeling or path analysis is used as the second evaluation in the PLS-SEM analysis to test the suggested hypothesis. The structural model is shown in Table 6, including the findings of the path coefficients, t-statistics, and the significance level of the proposed hypothesis (Bootstrapping results). When a path coefficient's significance is at least 95% confidence level, it is acceptable (Hair & Alamer, 2022). Three hypotheses are rejected, and six are accepted based on the path analysis output in Table 6.

Table 6. Path Coefficient, t-statistics, and Significance Level

	Path Analysis	Path Coefficient B	t-statistics	p-value	Result
H1	SR -> EFB	0.198	2.837	0,005	Accepted
H2	SR -> EBI	0,366	6.145	0,000	Accepted
H3	EPU -> EFB	0.311	4.858	0,000	Accepted
H4	EPU-> EBI	0,151	2.641	0,009	Accepted
H5	EPU -> SR	0,497	9.580	0,000	Accepted
H6	EBI -> EFB	0,123	1.933	0,054	Rejected
H7	SR -> EBI -> EFB	0,045	1,843	0,066	Not Mediated
H8	EPU -> SR -> EFB	0,098	1.794	0,006	Mediated
H9	EPU ->EBI -> EFB	0,018	1.467	0,143	Not Mediated

**p<. 05, **p<.01, ***p<0.001*

Considering the estimated relationship in Table 6, scientific reasoning significantly and positively affected environmentally-friendly behavior (β= 0.198, t = 2.837, p-value = 0.005), indicating that H1 is accepted. Scientific reasoning significantly and positively affects environmental behavior intentions (β= 0.366, t = 6.145, p-value = 0.000), supporting H2. Environmental physics understanding significantly and positively affects environmentally-friendly behavior (β= 0.311, t = 4. 858, p-value = 0.000), indicating that H3 is accepted. Environmental physics understanding also significantly and positively affects environmental behavior intentions (β= 0.151, t = 2.641, p-value = 0.008), indicating that H4 is accepted. The results of H5 are also accepted (β= 0.497, t = 9.580, p-value = 0.000), which states that environmental physics understanding significantly and positively affects scientific reasoning. On the contrary, environmental behavior intention shows an insignificant effect on environmentally-friendly behavior (β= 0.123, t = 1.933, p-value = 0.054), indicating that H6 is not accepted.

From the collected analysis, hypotheses H7 and H9 indicate that environmental behavior intentions do not mediate the relationship between scientific reasoning and environmentally-friendly behavior (β= 0.045, t = 1.843, p-value = 0.066) and the relationship between environmental physics understanding and environmentally-friendly behavior (β= 0.018, t = 1.467, p-value = 0.143). Meanwhile, H8 shows a mediating effect of scientific reasoning on the relationship between environmental physics understanding and environmentally-friendly behavior (β= 0.098, t = 1.794, p-value = 0.006).

This measure also includes an internal structural model for testing the research hypothesis. The hypothesis results are shown in Table 6, and the structural model is shown in Figure 3.

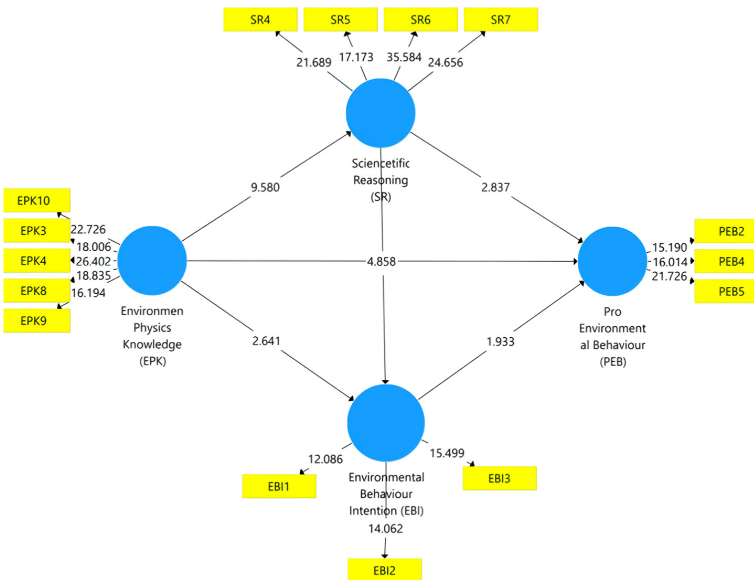

Figure 3. The result of the Structural Model Analysis

Figure 3 explains that the t-statistic of H1, H2, H3, H4, and H5 obtained from the results of the structural model analysis is > 1.96. This indicates that all these hypotheses are accepted. Whereas H6 has a t statistic <1.96, indicating that there is no direct effect that occurs. The conclusion from these results can be referred to in Table 6.

The coefficient of determination (R2) results shows moderate variance (R2 values: 0.253, 0.207, and 0.245) on environmentally-friendly behavior, environmental behavior intentions, and scientific reasoning. Based on Figure 1, scientific reasoning and environmental physics understanding explain 20.7% (R2 = 0.207) of environmental behavior intentions and 25.3% (R2 = 0.253) of environmentally-friendly behavior. Environmental physics understanding explains 24.5% (R2 = 0.245) of scientific reasoning.

The predictive relevance test (Q2) results are in Table 7.

Table 7. Predictive Relevance Test (Q2)

Variable	Q2
Scientific Reasoning	0.136
Environmental Behavior Intention	0,094
Environmentally-friendly behavior	0,126

This study obtains a Q2 value of 0.136 for scientific reasoning, 0.094 for environmental behavior intentions, and 0.126 for environmentally-friendly behavior using an omission distance of 7. The Q2 value indicates scientific reasoning with a small predictive model for all variables. The independent variable proposed in this study is, thus, a determinant of environmentally-friendly behavior.

In general, the results of H1 as the first hypothesis show that scientific reasoning significantly affects the environmentally-friendly behavior of high schoolers. This suggests that scientific reasoning in high schoolers can boost their environmentally-friendly behavior. This finding is similar to Hidayah and Agustin's (2017) research that scientific reasoning can improve the environmentally-friendly behavior of high schoolers.

H2, as the second hypothesis, finds that scientific reasoning significantly affects high schoolers' environmental behavior intentions. This shows that high schoolers' scientific reasoning can increase their environmental behavior intentions. This aligns with the findings of Kirby (2021) and Wu et al. (2021) that scientific reasoning is an indicator of environmental behavior intentions.

The results of H3 generally indicate that environmental physics understanding significantly affects high schoolers' environmentally-friendly behavior. This finding aligns with Shafiei and Maleksaeidi (2020) that understanding environmental physics is critical in shaping students' environmentally-friendly behavior and minimizing individual actions' negative impact on nature. This statement is supported by Turan and Kiliklar (2021), that individuals with environmental knowledge will exhibit voluntary environmentally-friendly behavior.

The finding of H4 with a significant positive beta value in this analysis illustrates that high schoolers' tendency to environmental behavior intentions increases with increasing environmental physics understanding. This finding strongly supports previous research, which states that environmental physics understanding contributes to individual environmental behavior intentions (Fröhlich et al., 2013; Fedi et al., 2021).

Based on the results of H5, it is stated that environmental physics understanding significantly increases students' scientific reasoning. This finding follows Stender et al. (2018) that environmental physics understanding affects students' scientific reasoning.

The H6 result is not accepted. Nonetheless, with positive beta values, high schoolers believe that environmental behavior intentions have less of an impact on their environmentally-friendly behavior. This finding contradicts that environmental behavior intentions can increase environmentally-friendly behavior.

The H7 result illustrates that environmental behavior intentions do not have a mediating effect on the relationship between scientific reasoning and environmentally-friendly behavior. This finding indicates that environmental behavior intention has not yet affected high schoolers' environmentally-friendly behavior. In this case, the high schoolers' environmentally-friendly behavior will not increase or decrease when students believe that scientific reasoning does not contribute to environmental behavior intentions. This result differs from Collado and Evans (2019), who state that environmentally-friendly behavior will be a tangible result of scientific reasoning that increases environmental behavior intentions.

The findings of H8 show that scientific reasoning has a mediating effect on the relationship between environmental physics understanding and environmentally-friendly behavior. These findings suggest that scientific reasoning strengthens the relationship between environmental physics understanding and environmentally-friendly behavior in high schoolers. In this case, environmentally-friendly behavior among high schoolers is heavily reliant on environmental physics understanding, which is influenced by scientific reasoning. This finding follows Geiger et al.'s (2019) study that environmental physics understanding is a core part of environmentally-friendly behavior. However, Ng and Cheung (2022) state that environmentally-friendly behavior will only occur after the individual experiences the influence of environmental physics understanding in his class so that the benefits of scientific reasoning are felt.

The findings of H9 indicate that environmental behavior intentions do not have a mediating effect on the relationship between environmental physics understanding and environmentally-friendly behavior. These results indicate that the environmental behavior intention has not affected high schoolers' environmentally-friendly behavior. In this case, high schoolers' environmentally-friendly behavior will not increase or decrease when they believe that environmental physics understanding does not contribute to environmental behavior intentions. This result differs from Janmaimool and Khajohnmanee (2019) and Tamara et al. (2020), that environmentally-friendly behavior will be a tangible result of environmental physics understanding that increases environmental behavior intentions.

CONCLUSION

This study concludes that environmental physics understanding and environmentally-friendly behavior are substantially correlated, and scientific reasoning plays a critical mediating role in this relationship. However, environmental behavior intentions have no intelligible mediation role in the corellation between scientific reasoning, environmental physics understanding, and environmentally-friendly behavior. However, schools still need to maintain and improve the conditions even though students think that scientific reasoning and environmental physics understanding do not significantly help improve their environmentally-friendly behavior. This finding emphasizes the importance of scientific reasoning in learning environmental physics understanding to enhance students' environmentally-friendly behavior. For this reason, the quantity of learning in schools needs to be increased by involving scientific reasoning through case studies. The results of this study offer important recommendations to academic institutions regarding the elements influencing students' environmentally-friendly behavior.

REFERENCES

Abdullah, S., Samdin, Z., Teng, P., & Heng, B. (2019). The impact of knowledge, attitude, consumption values, and destination image on tourists' responsible environmental behaviour intention. *Management Science Letters*, *9*(9), 1461–1476.

Anbarasu, A., & Bhuvaneswari, M. (2020). Students' Behaviour in the Classroom Environment: A Review. *Innovations and Technologies for Soft Skill Development and Learning*, 61–71.

Ardoin, N. M., & Bowers, A. W. (2020). Early childhood environmental education: A systematic review of the research literature. *Educational Research Review*, *31*, 100353.

Ardoin, N. M., Bowers, A. W., & Gaillard, E. (2020). Environmental education outcomes for conservation: A systematic review. *Biological Conservation*, *241*, 108224.

Arshad, H. M., Saleem, K., Shafi, S., Ahmad, T., & Kanwal, S. (2021). Environmental awareness, concern, attitude and behavior of university students: A comparison across academic disciplines. *Polish Journal of Environmental Studies*, *30*(1), 561–570.

Ateş, H. (2020). Merging theory of planned behavior and value identity personal norm model to explain pro-environmental behaviors. *Sustainable Production and Consumption*, *24*, 169–180.

Attademo, L., Bernardini, F., Garinella, R., & Compton, M. T. (2017). Environmental pollution and risk of psychotic disorders: A review of the science to date. *Schizophrenia Research*, *181*, 55–59.

Aziz, F., Md Rami, A. A., Zaremohzzabieh, Z., & Ahrari, S. (2021). Effects of emotions and ethics on pro-environmental behavior of university employees: a model based on the theory of planned behavior. *Sustainability*, *13*(13), 7062.

Bao, L., & Koenig, K. (2019). Physics education research for 21st-century learning. *Disciplinary and Interdisciplinary Science Education Research*, *1*(1), 1–12.

Bernardini, F., Trezzi, R., Quartesan, R., & Attademo, L. (2020). Air pollutants and daily hospital admissions for psychiatric care: a review. *Psychiatric Services*, *71*(12), 1270–1276.

BPS-Statistics of Sumatera Barat Province. (2022). *West Sumatera in Figure*.

Brandisauskiene, A., Buksnyte-Marmiene, L., Cesnaviciene, J., Daugirdiene, A., Kemeryte-Ivanauskiene, E., & Nedzinskaite-Maciuniene, R. (2021). Sustainable School Environment as a Landscape for Secondary School Students' Engagement in Learning. *Sustainability*, *13*(21), 11714.

Brookes, D. T., Ektina, E., & Planinsic, G. (2020). Implementing an epistemologically authentic approach to student-centered inquiry learning. *Physical Review Physics Education Research*, *16*(2), 20148.

Calderón-Garcidueñas, L., Stommel, E. W., Rajkumar, R. P., Mukherjee, P. S., & Ayala, A. (2021). Particulate air pollution and risk of neuropsychiatric outcomes. What we breathe, swallow, and put on our skin matters. *International Journal of Environmental Research and Public Health*, *18*(21), 11568.

Cheung, G. W., Cooper-Thomas, H. D., Lau, R. S., & Wang, L. C. (2023). Reporting reliability, convergent and discriminant validity with structural equation modeling: A review and best-practice recommendations. *Asia Pacific Journal of Management*, 1–39.

Chin, J., Jiang, B. C., Mufidah, I., Persada, S. F., & Noer, B. A. (2018). The investigation of consumers' behavior intention in using green skincare products: a pro-environmental behavior model approach. *Sustainability*, *10*(11), 3922.

Chin, W. W. (2010). How to write up and report PLS analyses. In *Handbook of partial least squares* (pp. 655–690). Springer.

Cincera, J., & Krajhanzl, J. (2013). Eco-Schools: what factors influence pupils' action competence for pro-environmental behaviour? *Journal of Cleaner Production*, *61*, 117–121.

Cohen, R. I. (2018). Lean methodology in health care. *Chest*, *154*(6), 1448-1454.

Collado, S., & Evans, G. W. (2019). Outcome expectancy: A key factor to understanding childhood exposure to nature and children's pro-environmental behavior. *Journal of Environmental Psychology*, *61*, 30–36.

Dalu, M. T. B., Cuthbert, R. N., Muhali, H., Chari, L. D., Manyani, A., Masunungure, C., & Dalu, T. (2020). Is awareness on plastic pollution being raised in schools? Understanding perceptions of primary and secondary school educators. *Sustainability*, *12*(17), 6775.

Duan, C.-C., Li, C., Xu, J.-J., He, Y.-C., Xu, H.-L., Zhang, D., Yang, J.-Q., Yu, J.-L., Zeng, W.-T., & Wang, Y. (2022). Association between prenatal exposure to ambient air pollutants and postpartum depressive symptoms: a multi-city cohort study. *Environmental Research*, *209*, 112786.

El Savada, N., Suhardi, E., & Istiana, R. (2021). Sequential explanatory analysis of environmental awareness towards responsible environmental behavior (REB) of high school students in Depok City, West Java, Indonesia. *Indonesian Journal of Applied Environmental Studies*, *2*(1), 33–40.

Fedi, A., La Barbera, F., De Jong, A., & Rollero, C. (2021). Intention to adopt pro-environmental behaviors among university students of hard and soft sciences: the case of drinking by reusable bottles. *International Journal of Sustainability in Higher Education*, *22*(4), 766–779.

Fitriani, F., & Suhardiman, S. (2021). Profile of Students' Reasoning Levels Using Ranking Task Exercises in Physics Learning. *Scientiae Educatia: Jurnal Pendidikan Sains*, *10*(2), 107–117.

Fröhlich, G., Sellmann, D., & Bogner, F. X. (2013). The influence of situational emotions on the intention for sustainable consumer behaviour in a student-centred intervention. *Environmental Education Research*, *19*(6), 747–764.

Fu, L., Zhang, Y., & Bai, Y. (2017). Pro-environmental awareness and behaviors on campus: Evidence from Tianjin, China. *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(1), 427–445.

García, B. V., Cabrera, I., Armenta, M. F., & Frías, N. S. C. (2022). Positive school environment, sustainable behaviour and well-being among higher education students. *PsyEcology: Bilingual Journal of Environmental Psychology/Revista Bilingüe de Psicología Ambiental*, *13*(2), 159–200.

Geiger, S. M., Geiger, M., & Wilhelm, O. (2019). Environment-specific vs. general knowledge and their role in pro-environmental behavior. *Frontiers in Psychology*, *10*, 718.

Ginsburg, J. L., & Audley, S. (2020). "You Don't Wanna Teach Little Kids about Climate Change": Beliefs and Barriers to Sustainability Education in Early Childhood. *International Journal of Early Childhood Environmental Education*, *7*(3), 42–61.

Gładka, A., Rymaszewska, J., & Zatoński, T. (2018). Impact of air pollution on depression and suicide. *Int J Occup Med Environ Health*, *31*(6), 711–721.

Hair, J., & Alamer, A. (2022). Partial Least Squares Structural Equation Modeling (PLS-SEM) in second language and education research: Guidelines using an applied example. *Research Methods in Applied Linguistics*, *1*(3), 100027.

Hanafiah, M. H. (2020). Formative vs. reflective measurement model: Guidelines for structural equation modeling research. *International Journal of Analysis and Applications*, *18*(5), 876–889.

Hidayah, N., & Agustin, R. R. (2017). Assessing high school students' pro-environmental behaviour. *Journal of Physics: Conference Series*, *895*(1), 12002.

Hong, W., Liu, R.-D., Ding, Y., Hwang, J., Wang, J., & Yang, Y. (2021). Cross-country differences in stay-at-home behaviors during peaks in the COVID-19 pandemic in China and the United States: the roles of health beliefs and behavioral intention. *International Journal of Environmental Research and Public Health*, *18*(4), 2104.

Janmaimool, P., & Khajohnmanee, S. (2019). Roles of environmental system knowledge in promoting university students' environmental attitudes and pro-environmental behaviors. *Sustainability*, *11*(16), 4270.

Jensen, B. B. (2002). Knowledge, action and pro-environmental behaviour. *Environmental Education Research*, *8*(3), 325–334.

Kaiser, F. G., & Gutscher, H. (2003). The proposition of a general version of the theory of planned behavior: Predicting ecological behavior 1. *Journal of Applied Social Psychology*, *33*(3), 586–603.

Kapoor, N. R., Kumar, A., Alam, T., Kumar, A., Kulkarni, K. S., & Blecich, P. (2021). A review on indoor environment quality of Indian school classrooms. *Sustainability*, *13*(21), 11855.

Keshtgar, L., Shahsavani, S., Maghsoudi, A., Anushiravani, A., Zaravar, F., Shamsedini, N., Rayatpisheh, M., & Dehghani, M. (2021). Investigating the relationship between the long-term exposure to air pollution and the frequency of depression in Shiraz during 2010-2017. *Environmental Health Engineering and Management Journal*, *8*(1), 9–14.

Khaleque, A., Alam, M. M., Hoque, M., Mondal, S., Haider, J. Bin, Xu, B., Johir, M. A. H., Karmakar, A. K., Zhou, J. L., & Ahmed, M. B. (2020). Zeolite synthesis from low-cost materials and environmental applications: A review. *Environmental Advances*, *2*, 100019.

Kinslow, A. T., Sadler, T. D., & Nguyen, H. T. (2019). Socio-scientific reasoning and environmental literacy in a field-based ecology class. *Environmental Education Research*, *25*(3), 388–410.

Kirby, C. K. (2021). Determinants of undergraduates' environmental behavioural intentions and their links to socioscientific issues education. *Interdisciplinary Journal of Environmental and Science Education*, *17*(2), e2231.

Lee, T. H., & Jan, F.-H. (2015). The influence of recreation experience and environmental attitude on the environmentally responsible behavior of community-based tourists in Taiwan. *Journal of Sustainable Tourism*, *23*(7), 1063–1094.

Liao, C., & Li, H. (2019). Environmental education, knowledge, and high school students' intention toward separation of solid waste on campus. *International Journal of Environmental Research and Public Health*, *16*(9), 1659.

Liobikien□, G., & Poškus, M. S. (2019). The importance of environmental knowledge for private and public sphere pro-environmental behavior: modifying the value-belief-norm theory. *Sustainability*, *11*(12), 3324.

Litvinenko, V., Bowbrik, I., Naumov, I., & Zaitseva, Z. (2022). Global guidelines and requirements for professional competencies of natural resource extraction engineers: Implications for ESG principles and sustainable development goals. *Journal of Cleaner Production*, 130530.

Liu, P., Teng, M., & Han, C. (2020). How does environmental knowledge translate into pro-environmental behaviors?: The mediating role of environmental attitudes and behavioral intentions. *Science of the Total Environment*, *728*, 138126.

Ma, X., Chai, Y., Li, P., & Wang, B. (2019). Metal–organic framework films and their potential applications in environmental pollution control. *Accounts of Chemical Research*, *52*(5), 1461–1470.

Mainland, J. D., Barlow, L. A., Munger, S. D., Millar, S. E., Vergara, M. N., Jiang, P., Schwob, J. E., Goldstein, B. J., Boye, S. E., & Martens, J. R. (2020). Identifying treatments for taste and smell disorders: gaps and opportunities. *Chemical Senses*, *45*(7), 493–502.

Marques, R., & Xavier, C. R. (2020). The Challenges and Difficulties of Teachers in the Insertion and Practice of Environmental Education in the School Curriculum. *International Journal on Social and Education Sciences*, *2*(1), 49–56.

Meng, C., Seo, S., Cao, D., Griesemer, S., & Liu, Y. (2022). When physics meets machine learning: A survey of physics-informed machine learning. *ArXiv Preprint ArXiv:2203.16797*.

Meyer, A. (2015). Does education increase pro-environmental behavior? Evidence from Europe. *Ecological Economics*, *116*, 108–121.

Mihardi, S., Harahap, M. B., & Sani, R. A. (2013). The effect of project based learning model with kwl worksheet on student creative thinking process in physics problems. *Journal of Education and Practice*, *4*(25), 188-200.

Miharni, A. (2013). Hubungan kemampuan mendesain kebaya modifikasi dengan hasil jahitan kebaya modifikasi pada siswa kelas XI Jurusan Tata Busana SMK Negeri 8 Medan. *TA 2012/2013* (Doctoral dissertation, UNIMED).

Millet, K., & Weijters, B. (2023). The behavioral intervention positive cueing: Altering self-perception, increasing green awareness, or undermining the signaling value of costly green behavior? *Journal of Environmental Psychology*, 101979.

Mobley, C., & Kilbourne, W. (2013). Gender differences in pro-environmental intentions: A cross-national perspective on the influence of self-enhancement values and views on technology. *Sociological Inquiry*, *83*(2), 310–332.

Murata, H., Barnhill, L. M., & Bronstein, J. M. (2022). Air Pollution and the Risk of Parkinson's Disease: A Review. *Movement Disorders*, *37*(5), 894–904.

Ng, P. M. L., & Cheung, C. T. Y. (2022). Why do young people do things for the environment? The effect of perceived values on pro-environmental behaviour. *Young Consumers*, *23*(4), 539--554.

Nurhayati, N., Agustini, R., & Sudibyo, E. (2022). Analysis of Critical Thinking Skills of Middle School Students on Environmental Pollution Materials. *IJORER: International Journal of Recent Educational Research*, *3*(1), 100–109.

Orbanic, N. D., & Kovac, N. (2021). Environmental Awareness, Attitudes, and Behaviour of Preservice Preschool and Primary School Teachers. *Journal of Baltic Science Education*, *20*(3), 373–388.

Ouariachi, T., Li, C.-Y., & Elving, W. J. L. (2020). Gamification approaches for education and engagement on pro-environmental behaviors: Searching for best practices. *Sustainability*, *12*(11), 4565.

Paço, A., & Lavrador, T. (2017). Environmental knowledge and attitudes and behaviours towards energy consumption. *Journal of Environmental*

Management, *197*, 384–392.

Palloan, P., & Swandi, A. (2019). Development of learning instrument of active learning strategy integrated with computer simulation in physics teaching and learning on makassar state university. *Journal of Physics: Conference Series*, *1157*(3), 32016.

Papadopoulos, T., Gunasekaran, A., Dubey, R., & Fosso Wamba, S. (2017). Big data and analytics in operations and supply chain management: managerial aspects and practical challenges. *Production Planning & Control*, *28*(11–12), 873–876.

Polonsky, M. J., Vocino, A., Grau, S. L., Garma, R., & Ferdous, A. S. (2012). The impact of general and carbon-related environmental knowledge on attitudes and behaviour of US consumers. *Journal of Marketing Management*, *28*(3–4), 238–263.

Ramayah, T., Cheah, J., Chuah, F., Ting, H., & Memon, M. A. (2016). *Partial Least Squares Structural Equation Modeling (PLS-SEM) using SmartPLS 3.0: An Updated and Practical Guide to Statistical Analysis* (1st Edition). Pearson Malaysai Bhd. www.pearson.my

Rezaly, N. F. M., Ahmad, H., & Ghazali, N. H. C. M. (2021). The Influence of Personality and School Environment on Students' Moral: a Review on International School Using Convergence Theory. *Int. J. Educ. Psychol. Couns*, *6*(42), 421–431.

Sahin, E., Alper, U., & Oztekin, C. (2021). Modelling pre-service science teachers' pro-environmental behaviours in relation to psychological and cognitive variables. *Environmental Education Research*, *27*(1), 1–21.

Shafiei, A., & Maleksaeidi, H. (2020). Pro-environmental behavior of university students: Application of protection motivation theory. *Global Ecology and Conservation*, *22*, e00908.

Soares, J., Miguel, I., Venâncio, C., Lopes, I., & Oliveira, M. (2021). Public views on plastic pollution: Knowledge, perceived impacts, and pro-environmental behaviours. *Journal of Hazardous Materials*, *412*, 125227.

Stender, A., Schwichow, M., Zimmerman, C., & Härtig, H. (2018). Making inquiry-based science learning visible: the influence of CVS and cognitive skills on content knowledge learning in guided inquiry. *International Journal of Science Education*, *40*(15), 1812–1831.

Sun, H., Teh, P., & Linton, J. D. (2018). Impact of environmental knowledge and product quality on student attitude toward products with recycled/remanufactured content: Implications for environmental education and green manufacturing. *Business Strategy and the Environment*, *27*(7), 935–945.

Sun, H., Xie, Y., & Lavonen, J. (2022). Exploring the structure of students' scientific higher order thinking in science education. *Thinking Skills and Creativity*, *43*, 100999.

Tamar, M., Wirawan, H., Arfah, T., & Putri, R. P. S. (2020). Predicting pro-environmental behaviours: the role of environmental values, attitudes and knowledge. *Management of Environmental Quality: An International Journal*, *32*(2), 328–343.

Thor, D., & Karlsudd, P. (2020). Teaching and fostering an active environmental awareness design, validation and planning for action-oriented environmental education. *Sustainability*, *12*(8), 3209.

Turan, A. D.-, & Kiliclar, I. E. (2021). The analysis of pro-environmental behaviour based on ecological worldviews, environmental training/knowledge and goal frames. *Journal of Cleaner Production*, *279*, 123518.

Untaru, E. N., Epuran, G. H., & Ispas, A. (2014). A Conceptual Framework Of Consumers'pro-Environmental Attitudes And Behaviours In The Tourism Context. *Bulletin of the Transilvania University of Brasov. Economic Sciences. Series V*, *7*(2), 85.

Wang, J., & Wang, S. (2019). Preparation, modification and environmental application of biochar: a review. *Journal of Cleaner Production*, *227*, 1002–1022.

Wang, Z., Nie, L., Jeronen, E., Xu, L., & Chen, M. (2023). Understanding the Environmentally Sustainable Behavior of Chinese University Students as Tourists: An Integrative Framework. *International Journal of Environmental Research and Public Health*, *20*(4), 3317.

Wu, J. S., Font, X., & Liu, J. (2021). The elusive impact of pro-environmental intention on holiday on pro-environmental behaviour at home. *Tourism Management*, *85*, 104283.

Yang, R., Zhang, Y., Fan, Y., Wang, R., Zhu, R., Tang, Y., Yin, Z., & Zeng, Z. (2022). InVO4-based photocatalysts for energy and environmental applications. *Chemical Engineering Journal*, *428*, 131145.

Yusliza, M. Y., Amirudin, A., Rahadi, R. A., Nik Sarah Athirah, N. A., Ramayah, T., Muhammad, Z., Dal Mas, F., Massaro, M., Saputra, J., & Mokhlis, S. (2020). An investigation of pro-environmental behaviour and sustainable development in Malaysia. *Sustainability*, *12*(17), 7083.

Zebardast, L., & Radaei, M. (2022). The influence of global crises on reshaping pro-environmental behavior, case study: the COVID-19 pandemic. *Science of The Total Environment*, *811*, 151436.

Zhang, Y., Zhang, H.-L., Zhang, J., & Cheng, S. (2014). Predicting residents' pro-environmental behaviors at tourist sites: The role of awareness of disaster's consequences, values, and place attachment. *Journal of Environmental Psychology*, *40*, 131–146.