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Exploring solid waste management behaviors among undergraduate biology education students

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ABSTRACT

Environmental education is expected to foster responsible waste-management behavior among university students; however, empirical evidence on the stability of solid-waste management beliefs and attitudes across academic levels remains limited. In particular, few studies have examined whether progression in semester level is associated with differences in belief- and attitude-based behavioral tendencies among biology education students. This study aimed to analyze students' solid waste management behavior based on two components of the Theory of Planned Behavior (TPB), namely beliefs and attitudes, and to examine whether these indicators differ across semesters. This research employed a descriptive quantitative design with a cross-sectional survey approach involving undergraduate Biology Education students who had completed the Environmental Knowledge course. Data were collected using a structured questionnaire and analyzed using descriptive statistics and one-way ANOVA after meeting the assumptions of normality. The findings indicate that both belief and attitude indicators are generally categorized as very good across semesters. However, the ANOVA results reveal no statistically significant differences in belief scores across semesters ($p = 0.262$) or in attitude scores ($p = 0.269$), with small effect sizes indicating minimal practical differences. The findings reveal consistently high beliefs and positive attitudes toward solid waste management among Biology Education students, with no significant differences across semester levels, indicating relatively stable environmental orientations throughout academic progression.

INTRODUCTION

Solid waste has become one of the most pressing environmental problems in Indonesia (Iryanthony et al., 2018). As the most dominant type of waste with the largest volume nationwide, solid waste requires serious attention in its management. National data indicate that total waste generation reaches 37,311,750.55 tons per year, with 67.8% of it remaining improperly managed (SIPSN, 2024). This condition shows that a substantial proportion of waste is still disposed of without adequate treatment, potentially causing soil, water, and air pollution and imposing long-term burdens on ecosystems (Erika and Gusmira, 2024). In addition, unmanaged waste increases the risk of ecological and public health problems, including flooding triggered by plastic waste clogging river systems (Mustika et al., 2025).

Since most waste generation originates from daily human activities, efforts to improve solid waste management are highly dependent on individual behavior. Institutions with large populations, such as universities, also contribute significantly to daily waste production through academic and social activities. A cross-cultural study conducted by Trinh and Sakurai (2025) in Vietnam and Japan found that regulatory factors were the most dominant determinants influencing students' e-waste recycling behavior. Therefore, the campus environment can be viewed as a strategic setting for examining waste management practices while fostering more responsible environmental behavior. Research in Vietnam, Bang et al. (2025), also revealed that the availability of waste-sorting facilities plays a strong role in strengthening the relationship between intention and actual behavior. Furthermore, environmental literacy often remains at the cognitive level without being followed by concrete implementation, indicating that the reinforcement of the 3R principles (Reduce, Reuse, Recycle) needs to be continuously promoted to cultivate individual responsibility (Lasmita and Ardeline, 2025). As members of the academic community, students are therefore expected not only to understand environmental concepts but also to translate them into responsible waste management practices in their daily lives.

The campus environment represents a strategic space for instilling awareness of environmental issues (Sudja'i et al, 2026). Students, particularly biology students, have substantial opportunities to practice environmentally friendly behavior (Tampubolon et al., 2024) because they have studied concepts and materials related to environmental management. However, preliminary observations and informal insights suggest that students' waste management practices remain varied. Some students appear to practice storing, recycling, or selling waste, while others may still burn or dispose of it without sorting. Ideally, proper waste management includes sorting waste by type, reducing its volume, reusing materials, recycling, and ensuring final disposal in accordance with environmental procedures (Lasmita and Ardeline, 2025). These variations indicate a potential gap between conceptual understanding and practical implementation in daily campus life.

The gap between understanding and practice can be further examined through a validated behavioural measurement instrument for solid waste management behavior developed by Raghu and Rodrigues, which assesses the underlying factors that influence individuals' solid waste management behaviour (Raghu and Rodrigues, 2021). According to Raghu and Rodrigues (2021), the framework identifies several key behavioral antecedents, including beliefs, attitudes toward behavior, subjective norms, perceived behavioral control, and intention, which ultimately influence actual behavior. This model emphasizes that waste management behavior is not solely determined by an individual's level of knowledge but is also shaped by social support, perceptions of ease or difficulty in performing the behavior, and personal evaluations of its benefits and risks. Therefore, environmental education strategies should not only focus on improving cognitive and affective aspects but also on strengthening factors that encourage the internalization and consistency of environmentally responsible behavior in everyday life.

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Previous studies have identified a recurring pattern among university students, including biology education students, in which environmental knowledge and awareness do not always align with consistent environmental practices. Although biology education students generally demonstrate a good understanding of environmental management, its implementation in daily life remains suboptimal (Imbia & Diartika, 2024). Likewise, students' awareness of environmentally friendly behavior is relatively high; however, its practical application tends to remain at a moderate level (Gabriella and Sugiarto, 2020). Nevertheless, research specifically examining solid waste management beliefs and attitudes among Biology Education students in Islamic higher education institutions remains limited. Biology Education students at IAIN Kerinci operate within a distinctive academic–religious framework in which scientific knowledge of environmental conservation is integrated with moral and religious values that emphasize stewardship and responsibility as khalifah on earth. Investigating solid waste management within this institutional context therefore provides an important contribution to understanding how environmental beliefs, attitudes, and behavioral tendencies are shaped among prospective biology educators.

Based on these considerations, this study analyzes the solid waste management behavior of Biology Education students at IAIN Kerinci by examining differences across semester levels. Semester level is assumed to reflect variations in cognitive maturity, academic exposure, and social responsibility, which may influence students' environmental beliefs and behavioral consistency (Hariyadi et al., 2021). This assumption is supported by previous findings indicating that semester level represents differences in learning experience, academic engagement, and developmental progression among university students (Ningsih and Ferry, 2026). Grounded in the Theory of Planned Behavior, differences in belief structures across semesters may lead to variations in behavioral intentions and actual waste management practices.

METHODS

Research Design

This study employs a quantitative descriptive approach with a cross-sectional survey design, aiming to gain a comprehensive understanding of the population's characteristics through representative sample data (Maidiana, 2021).

Population and Samples

The study population consists of all Biology Education students at IAIN Kerinci who have completed the Environmental Knowledge course, totaling 88 students. A total sampling technique was applied, in which the entire population was included as the study sample.

Procedures

This study was conducted from May to July 2025 at IAIN Kerinci. Data were collected using questionnaires distributed through Google Forms and printed forms, employing a Likert-scale rating system as presented in Table 1. The research instrument was adapted from the solid waste management behavior instrument developed by Raghu and Rodrigues (2021). In this study, the adaptation focused specifically on measuring students' environmental beliefs and attitudes related to solid waste management. Although the original framework is conceptually aligned with the Theory of Planned Behavior, this study only examined the belief and attitude dimensions and did not analyze subjective norms, perceived behavioral control, intention, or actual behavior. Prior to implementation, the instrument underwent content validation through expert judgment and reliability testing to ensure its appropriateness for the research context. The final instrument consisted of two indicators comprising 28 items, as detailed in Table 2.

To provide an initial overview of the respondents' characteristics, this study presents demographic data limited to the semester variable, as semester level is considered relevant in reflecting differences in academic experience and maturity among students. Focusing on semester

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allows for a more specific analysis of variations in waste management behavior across different stages of study. The categorization of respondent scores refers to the scale interpretation guidelines adapted from DeVellis (2016), in which scores are divided into five categories representing the intensity of waste management behavior. The detailed distribution and categorization of scores are presented in Table 3.

Table 1
Conversion of questionnaire answers.

Choice	Answer score
Strongly agree	5
Agree	4
Neutral	3
Disagree	2
Strongly Disagree	1

Table 2
Indicators and number of statements in the solid waste management behavior instrument.

Indicator	Number of items
Solid waste management beliefs	17
Solid waste management attitudes	11

Table 3
Categories of waste management behavior among biology students.

Score (0 – 100)	Category (intensity)
81 – 100	Very good
61- 80	Good
41 – 60	Fair
21 – 40	Bad
0 – 20	Very bad

Data Collection and Analysis
The data were analyzed using descriptive statistics to provide an overview of students' belief and attitude scores on solid waste management. A normality test was conducted using the Kolmogorov–Smirnov test to ensure that the data met the assumptions required for parametric analysis. Furthermore, a one-way ANOVA was applied to examine differences in belief and attitude scores across semester levels, as the semester variable consisted of more than two categories. In addition to statistical significance testing, effect size (η^2) was calculated to determine the magnitude of differences between groups. However, this study was designed as a descriptive comparative investigation; therefore, it did not include regression analysis or structural equation modeling to examine structural relationships among the full constructs of the Theory of Planned Behavior. All statistical analyses were performed using the JASP application.

RESULTS AND DISCUSSION

This section presents the findings of the data analysis regarding solid waste management behavior among Biology Education students at IAIN Kerinci. Descriptive and inferential statistical techniques were employed to provide an overview and examine tendencies in students' reported behavior, in

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line with behavioral waste research emphasizing the importance of empirical analysis in understanding waste management practices (Raghu and Rodrigues, 2020). Furthermore, statistical tests such as normality and ANOVA were conducted to explore potential differences in behavior across semesters (Ngabu et al., 2026), thereby offering indications of how academic progression may relate to environmental action. Interpreting statistical results in this manner is consistent with studies examining university students' waste management behavior, which suggest that cognitive and situational factors contribute to variations in pro-environmental behavior patterns (Wu et al., 2022).

In addition, the interpretation of the findings is directed toward understanding the meaning behind the observed patterns rather than merely reiterating numerical results. Within the framework of the Theory of Planned Behavior, variations in students' solid waste management scores may reflect differences in the strength of attitudes and underlying beliefs that shape behavioral intentions. Previous studies suggest that pro-environmental behavior among university students is not solely determined by knowledge, but by how strongly environmental attitudes are internalized and supported by contextual factors Raghu and Rodrigues (2020). Therefore, the statistical differences identified across semesters can be interpreted as indications of varying levels of psychological readiness and consistency in sustainable waste management practices, rather than as absolute representations of behavioral change.

Descriptive Statistics of Solid Waste Management Behavior Scores

To obtain a general overview of the behavior of Biology Education students in managing solid waste, a descriptive analysis was conducted on the respondents' total scores. This analysis aimed to determine the average value, standard deviation, and minimum and maximum score ranges, thus providing an initial overview before conducting further testing.

Table 4

Descriptive statistical test.

	Valid	Missing	Mean	Standard Deviation	Minimum	Maximum
Total score	83	0	81,08	9,058	60,00	97,00

Based on Table 4, the mean score of 81.08 places students' solid waste management behavior in the "very good" category. In relation to the study's hypothesis, which posits that Biology Education students demonstrate a high level of solid waste management behavior, this finding provides empirical support for the proposed expectation. The overall tendency suggests that students generally hold positive attitudes and behavioral orientations toward responsible waste management within their academic context. However, the standard deviation of 9.058 indicates that variations among students remain evident. This dispersion suggests that although the overall behavioral tendency is strong, the degree of consistency differs across individuals (Marbun et al., 2024). From the perspective of the Theory of Planned Behavior, such variation may reflect differences in the strength of underlying beliefs and attitudes that shape behavioral readiness. Therefore, the findings not only describe the overall category of behavior but also highlight the need to understand how consistently these pro-environmental tendencies are internalized among students.

The range of scores obtained, from 60 to 97, further highlights the differences in behavioral levels among respondents. A minimum score of 60 indicates that some students fall into the "adequate" or "good" categories, while a maximum score of 97 reflects students with very strong waste management behaviors. This pattern aligns with the findings of Gabriella and Sugiarto (2020), who stated that students' environmental awareness tends to be high, but its implementation can vary. Rezeki et al. (2024) also emphasized that good understanding is not always followed by consistent practice among all individuals.

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Student Behavior in Managing Solid Waste Based on Indicators

In addition to the total score, this study specifically analyzed students' solid waste management behavior based on two components of the Theory of Planned Behavior (TPB), namely beliefs and attitudes. It is important to emphasize that the present analysis is limited to these two early cognitive–evaluative components and does not extend to subjective norms, perceived behavioral control, intention, or actual behavior. Therefore, the findings presented in this section should be interpreted as providing an overview of students' foundational psychological dispositions toward solid waste management rather than a comprehensive explanation of the full TPB behavioral pathway. This indicator-based analysis allows for a clearer understanding of how students cognitively perceive and evaluate waste management practices, while acknowledging that the translation of these dispositions into intention and actual behavior requires further empirical examination.

Table 5

Analysis of solid waste management behavior among biology students (based on indicators).

	Solid waste management beliefs	Solid waste management attitudes
Valid	83	83
Missing	0	0
Mean	81,13	81,03
Std. Deviation	9,304	10,16
Minimum	60,00	60,00
Maximum	100,0	100,0

Based on Table 5, the solid waste management beliefs indicator obtained a mean score of 81,13 with a standard deviation of 9,304, which falls into the very good category. This finding descriptively indicates that Biology Education students tend to hold positive beliefs regarding the importance of proper solid waste management and demonstrate awareness of the environmental consequences of improper disposal practices (Debrah et al., 2021). Within the theoretical framework of the Theory of Planned Behavior (TPB), behavioral beliefs are conceptually understood as cognitive considerations that may be associated with the development of attitudes toward a behavior (Raghu and Rodrigues, 2021). In the context of waste management, such beliefs are theoretically linked to value orientations toward reduce, reuse, recycle, and responsible disposal practices. However, this study did not empirically test the structural relationships among beliefs, attitudes, intention, and behavior, so the explanation remains conceptual rather than causal. Furthermore, the variation reflected in the standard deviation suggests that the internalization of these beliefs has not been evenly distributed among all respondents, indicating differences in cognitive strength across individuals. Analysis comparison of solid waste management behavior among biology students (based on indicators) can be seen at Figure 1.

Meanwhile, the solid waste management attitudes indicator yielded a mean score of 81,03 with a standard deviation of 10,16, which is also categorized as very good. This result descriptively indicates that students tend to evaluate solid waste management practices positively and consider them important within their daily academic context. Within the theoretical framework of the Theory of Planned Behavior (TPB), attitude toward behavior is conceptually defined as an individual's positive or negative evaluation of performing a particular action (Raghu and Rodrigues, 2021). Although TPB posits that positive attitudes may be theoretically associated with stronger behavioral intention, the present study did not empirically test the structural relationship between attitudes, intention, and actual behavior. Therefore, the interpretation in this study remains at the level of evaluative tendencies rather than causal influence. Furthermore, the relatively higher standard deviation suggests that affective evaluations are not yet fully consistent across

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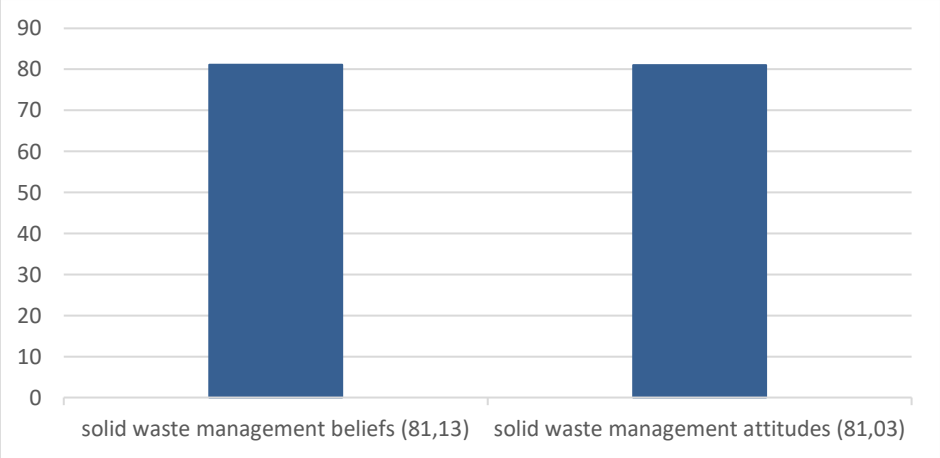
respondents, indicating variability in how strongly students internalize positive attitudes toward solid waste management.

Figure 1

Analysis of solid waste management behavior among biology students (based on indicators).



Students Behavior in Managing Solid Waste based on Beliefs indicator

The descriptive statistical results for the beliefs indicator show relatively close mean scores across semesters, with semester 4 obtaining the highest mean (83,75), followed by semester 6 (82,80), semester 8 (80,00), and semester 2 (78,75) (see Table 6). Referring to DeVellis (2016), scores within this upper range reflect a positive orientation toward the measured construct, indicating that students across all academic levels generally demonstrate strong beliefs regarding solid waste management. However, the relatively small differences between semesters suggest that belief formation may not be strictly associated with academic progression, but rather influenced by shared learning experiences and campus environmental culture that shape students similarly across cohorts (Hariani et al., 2026). Within the TPB framework, behavioral beliefs represent the cognitive basis of attitude formation; yet, in this study, the similarity of mean scores implies that the strength of these beliefs tends to be consistently distributed rather than progressively increasing with semester level. This pattern is in line with Naghavi (2026) who emphasizes that belief structures are often shaped by motivational and contextual factors beyond demographic variables. Therefore, in relation to the research hypothesis concerning semester differences, these descriptive findings preliminarily indicate that variations in belief levels are not substantially pronounced, although further inferential testing is required to confirm whether such differences are statistically significant. It is also important to acknowledge that this analysis remains descriptive-comparative, limiting the extent to which stronger causal or structural inferences within the TPB framework can be drawn.

Table 6

Descriptive statistical test of students' behavior in managing solid waste based on the belief indicator.

Semester	Valid	Missing	Mean	SD	Min	Max
2	30	0	78,75	9,918	61,20	96,50
4	11	0	83,75	7,233	70,60	95,30
6	32	0	82,80	8,971	60,00	100,0
8	10	0	80,00	9,885	60,00	91,80

Note: SD = Standard Deviation

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The SD values for the beliefs indicator range from 7,233 (semester 4) to 9,918 (semester 2), indicating moderate variability within each group. The lower dispersion in semester 4 suggests that students' beliefs are relatively homogeneous, whereas the higher variation in semester 2 implies that early-semester students still demonstrate differing levels of conviction regarding waste management. This variability is theoretically consistent with TPB, where belief strength may differ depending on personal experiences and exposure to environmental learning contexts (Ardoin and Heimlich, 2021). Additionally, the minimum and maximum scores ranging from 60,00 to 100,00 across semesters indicate that although overall tendencies are positive, there remain individuals whose belief levels are comparatively lower. Such variation aligns with the argument that environmental belief development requires continuous contextual reinforcement rather than relying solely on academic instruction (Januardi, 2025).

Although minor variations appear across semesters, these differences should be interpreted cautiously, as the present analysis does not provide direct evidence explaining the underlying causes. It is possible that contextual or situational factors contribute to these slight fluctuations; however, such interpretations remain tentative and require further empirical investigation. In the context of environmental education integration, quantitative comparisons alone are insufficient to explain the dynamics of students' beliefs. A more comprehensive analysis requires consideration of experiential, cultural, and institutional dimensions that shape environmental cognition (Hafiza and Ferry, 2024). Therefore, rather than attributing the pattern to specific academic priorities or cohort characteristics, this study limits its interpretation to the observed statistical tendencies, while acknowledging that deeper explanatory analysis would necessitate additional qualitative or longitudinal data in future research.

The normality test results show that the belief scores meet the assumption of normality, as indicated by a significance value (p = 0,510) greater than 0,05. This result suggests that the data do not exhibit a significant deviation from a normal distribution and are therefore suitable for parametric analysis. Consistent with previous statistical guidelines (Salman & Aleem, 2024), the fulfillment of this assumption allows the data to be further analyzed using ANOVA (Table 7).

Table 7
ANOVA test students behavior in managing solid waste based on beliefs indicator.

Cases	Sum of Squares	Df	Mean Square	F	P
Semester	347,7	3	115,90	1,357	0,262
Residuals	6.750,0	79	85,44		

The ANOVA results indicate that there is no statistically significant difference in students' solid waste management beliefs across semester levels (F(3,79) = 1,357, p = 0,262). The calculated effect size (η^2 = 0,049) falls within the small range, suggesting that semester level accounts for only a minimal proportion of variance in belief scores. This finding indicates that academic progression does not significantly differentiate students' belief orientations regarding solid waste management. Therefore, the results should be interpreted cautiously, as the analysis only demonstrates the absence of mean differences between groups rather than explaining the underlying psychological mechanisms. Within the framework of the Theory of Planned Behavior, these findings suggest that belief formation may be relatively stable across cohorts; however, this study does not test the structural relationships among TPB constructs. Consequently, the interpretation remains limited to group comparison, and further inferential modeling would be required to examine predictive pathways among beliefs and other behavioral determinants.

From the perspective of the Theory of Planned Behavior (TPB), the absence of significant differences across semesters indicates that the constructs underlying behavioral intention may be relatively stable among cohorts. Although students in different semesters experience varying

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academic exposures, this does not guarantee meaningful variation in attitudes or perceived behavioral control toward waste management. Sabtina and Mahariah (2025) further argue that internalized environmental concern and moral obligation play a more decisive role than formal educational level in shaping consistent environmental actions. This supports the interpretation that semester differences may not be a strong predictor of belief-based behavior.

Moreover, referring to DeVellis (2016), the overall mean score falls within the "good" category, indicating that students generally demonstrate positive belief-based tendencies toward solid waste management. However, the lack of significant ANOVA results implies that these positive tendencies are distributed relatively evenly across semesters. This finding reinforces the argument proposed by Akhir et al. (2022) that pro-environmental behavior is more strongly influenced by psychological commitment and normative beliefs than by educational duration. Therefore, strengthening TPB-related components especially attitudes and perceived behavioral control may be more crucial than relying solely on academic progression to enhance sustainable behavior consistency**.**

Table 8

Descriptive statistical test students' behavior in managing solid waste based on attitudes indicator

Semester	Valid	Missing	Mean	SD	Min	Max
2	30	0	79,70	9,917	60.00	92,70
4	11	0	79,50	9,331	65,50	94,50
6	32	0	83,76	10,724	60.00	100.0
8	10	0	78,01	9,253	67.30	96.40

The descriptive statistical results in Table 8 indicate that students' attitudes toward solid waste management generally fall within the positive category across all semesters, with mean scores ranging from 78,01 to 83,76. Such consistently favorable evaluative dispositions suggest that Biology Education students at IAIN Kerinci are cognitively inclined to view sustainable waste practices as important and relevant within their academic and social context. Comparable research has found that university students often demonstrate positive attitudes toward environmental and waste issues, though such attitudes do not always translate directly into consistent behavior without supportive enabling conditions (Nabila and Zulkarnain, 2025). Additionally, studies in higher education contexts have reported that while students may show strong understanding and perceptions of waste management, the translation into action frequently depends on contextual factors such as infrastructure and institutional reinforcement (Hidayah et al., 2021). Therefore, the relatively high attitude scores observed in this study contribute to understanding the psychological foundation of pro-environmental tendencies among biology students, highlighting that favorable attitudes are present but may need further reinforcement through structured educational and campus sustainability initiatives.

The standard deviation values, which are around 9–10 across semesters, indicate moderate variability among students' attitudes. This suggests that although the overall tendency is positive, there are still individual differences in how strongly students internalize pro-environmental beliefs. Within the Theory of Planned Behavior, attitude represents a central determinant of intention, meaning that stronger positive evaluations of waste management are likely to enhance students' intention to act responsibly. The higher mean in semester 6 may reflect greater academic exposure and cognitive engagement with environmental topics, strengthening evaluative beliefs toward sustainable behavior. This pattern is consistent with Masoumidezfouli (2019), who demonstrated that attitude was the strongest predictor of intention (B = 0.58), emphasizing its central role in shaping environmentally responsible behavior. Moreover, Gupta et al. (2024) emphasized that awareness and attitudinal orientation are foundational elements in encouraging participatory waste management practices among students.

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Interestingly, although semester 6 shows the highest mean, the overall pattern does not demonstrate a strictly linear increase across academic levels, as semester 8 records a slightly lower mean despite being in the final stage of study. Within the broader TPB framework, attitude is theoretically positioned as one determinant of intention; however, it is important to emphasize that this study did not directly measure intention or actual behavior, and therefore no causal or structural relationships among TPB components can be concluded from the present data. It is possible that contextual or situational factors may play a role in shaping how attitudes are expressed across semesters, yet such factors were not empirically examined in this research. As highlighted by Jerath (2021), awareness and positive attitudes require continuous reinforcement to support sustainable practices, while Masoumidezfouli (2019) notes that structural constraints, such as limited recycling facilities, may hinder the practical manifestation of pro-environmental orientations. Therefore, the findings of this study are limited to describing variations in attitude levels across semesters, and further research is required to investigate how these attitudes may relate to intention and actual waste management behavior within a comprehensive TPB model.

The normality test results show that the attitude scores meet the assumption of normality, as indicated by a significance value (p = 0,476) greater than 0,05. This result suggests that the data do not exhibit a significant deviation from a normal distribution and are therefore suitable for parametric analysis. Consistent with previous statistical guidelines to Çimen (2024) the fulfillment of this assumption allows the data to be further analyzed using ANOVA (Table 9).

Table 9

ANOVA test students' behavior in managing solid waste based on attitudes indicator based on semester.

Cases	Sum of Squares	Df	Mean Square	F	P
Semester	408,7	3	136,2	1,335	0,269
Residuals	8.058,9	79	102,0		

The ANOVA results indicate that there is no statistically significant difference in students' attitudes toward solid waste management across semesters, as reflected by a significance value (p = 0,269) greater than 0.05, F(3,79) = 1,335. The calculated effect size (η^2 = 0,048) indicates a small magnitude of effect, suggesting that semester level explains only approximately 4.8% of the variance in attitude scores. Although slight variations in mean scores are observed among semester groups, these differences are not statistically meaningful and therefore do not warrant post-hoc analysis. These findings suggest that students' attitudes toward solid waste management remain relatively stable across academic progression, and the observed variations are more likely attributable to random distribution rather than systematic differences between semester cohorts (Leo and Sardanelli, 2020). This pattern is consistent with previous findings indicating that university students often demonstrate relatively homogeneous environmental attitudes across academic levels, particularly when exposed to similar institutional learning environments and sustainability programs (Ferry and Ramadani, 2021).

Within the framework of the Theory of Planned Behavior (TPB), attitudes represent one of the primary determinants of behavioral intention. The absence of significant differences across semesters implies that students may have developed relatively stable evaluative beliefs about waste management early in their academic journey, and these beliefs remain consistent over time. TPB posits that behavior is shaped not merely by educational exposure but by the strength of attitudes, subjective norms, and perceived behavioral control (Imari et al., 2021). Therefore, even if academic experience increases, attitudes may not significantly differ unless reinforced by strong normative and contextual influences.

Furthermore, the insignificant ANOVA findings highlight that academic progress alone does not automatically strengthen pro-environmental attitudes. According to the TPB, sustainable

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behaviour change requires continuous reinforcement of internal motivation and perceived control, not just an increase in knowledge or study duration (Cao et al., 2023). In this context, the relatively homogeneous attitude scores across semesters may indicate that institutional culture, shared learning experiences, and similar environmental exposure contribute more substantially to shaping students' attitudes than the semester level itself. This interpretation is consistent with findings that indicate pro-environmental attitudes among students are more influenced by collective academic experiences and environmental awareness programs than by demographic differences or academic levels (Ningsih and Ferry, 2026). Thus, strengthening subjective norms and facilitating practical engagement may be more important strategies than merely relying on academic progress to improve attitudes towards solid waste management.

CONCLUSION

This study aimed to analyze students' beliefs and attitudes toward solid waste management and to examine whether differences exist across semester levels. The findings indicate that Biology Education students generally demonstrate high levels of environmental beliefs and positive attitudes toward solid waste management. These results suggest that cognitively and evaluatively, students possess a strong foundation regarding the importance of responsible waste practices. However, the ANOVA results reveal no statistically significant differences in belief and attitude scores across semesters. The effect sizes obtained were small, indicating that semester level contributes minimally to variations in students' beliefs and attitudes. This finding suggests that academic progression alone does not substantially differentiate students' environmental orientations, and that such orientations may remain relatively stable throughout their study period. Within the scope of this study, the results are limited to the measurement of beliefs and attitudes as components conceptually related to the Theory of Planned Behavior. Since intention and actual behavior were not directly measured, the conclusions cannot extend to behavioral outcomes. Nevertheless, the consistently positive scores across semesters imply that environmental values have been relatively well internalized among Biology Education students. For future research, it is recommended to include additional TPB components, particularly behavioral intention and perceived behavioral control, in order to obtain a more comprehensive understanding of solid waste management behavior. Further studies may also employ longitudinal designs or structural equation modeling to examine the relationships among beliefs, attitudes, and behavior more rigorously. Additionally, qualitative approaches could be incorporated to explore contextual and institutional factors that may influence the translation of environmental attitudes into consistent waste management practices.

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