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Food Waste
How to Educate Students for Sustainability Literacy through an Interactive E-Book in Vocational High Schools

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Abstract

Food waste is an increasingly critical environmental issue that requires attention from the education sector to strengthen students' sustainability literacy. This study aimed to develop and examine the feasibility and effectiveness of an interactive food-waste e-book for vocational high school students in Indonesia. The research employed a development model using ADDIE (Analysis, Design, Development, Implementation, and Evaluation). Product feasibility was assessed through expert validation (content and media) and teacher appraisal, while effectiveness was tested using a pre–post design involving 36 students. Instruments included a sustainability-literacy questionnaire covering Knowle dge, relevant values (awareness), and skills, as well as expert feasibility rating sheets. The results showed that the e-book was rated highly feasible in terms of substance, pedagogy, and technical quality. Students' sustainability literacy improved significantly after the intervention. The average knowledge score increased from 64.63 to 83.15 (N-gain = 0.5148; moderate–good), values/awareness increased from 64.07 to 82.73 (N-gain = 0.5374; moderate–good), and post-test skills reached 82.67 (very good). The overall sustainability-literacy score achieved 82.85 (very good). These findings indicate that the interactive e-book is both feasible and effective in enhancing vocational students' sustainability literacy related to food-waste management and prevention.

1. INTRODUCTION

Food waste is a pervasive challenge with environmental, social, and economic consequences, and it is recognized across countries as a shared concern (OECD, 2023). In Indonesia, food residues constitute the largest share of municipal solid waste 39.71% of the total exacerbating greenhouse gas emissions and resource inefficiency (Kehutanan et al., 2024). Limited sustainability literacy is one of the underlying factors: without the knowledge, values, and skills needed to act, communities struggle to make sustainable decisions (Manzoor et al., 2024). Schools therefore hold a strategic mandate to cultivate sustainability competencies and prudent food management in the younger generation (Miterianifa & Mawarni, 2024).

In vocational high schools, translating *Education for Sustainable Developmen*t (ESD) into concrete, practice-oriented learning remains a challenge. Preliminary observations in Bogor indicate students' understanding of food waste is still low (average knowledge score 58; low category), and sustainability attitudes are not yet reflected in sustained behaviors at school (Saldiana et al., 2025). This gap underscores the need for instructional designs that integrate cognitive understanding, affective commitment, and actionable skills precisely the dimensions emphasized in sustainability literacy (Rosliana et al., 2023).

Interactive digital media offer a promising pathway. Prior initiatives in Indonesia show that e-books and illustrated digital content can effectively communicate food waste issues and motivate youth engagement, from interactive illustration books for 18–24-year-olds (Putri et al., 2023) to academic/applied e-books on food waste management (Handayani et al., 2022) and youth-oriented zero-waste advocacy (Asiah et al., 2022). Beyond public awareness, educational research also indicates that electronic books can improve sustainability literacy to a moderate level (Warliyah et al., 2023). Visual elements support comprehension by clarifying complex information (Witabora, 2012). Yet, formal integration of e-books into school instruction aligned to curriculum, tailored to learner needs, and meeting didactic-pedagogical standards remains limited (Sumarmi et al., 2021).

This article positions an interactive e-book on food waste as a pedagogical solution for vocational high schools, explicitly designed to strengthen sustainability literacy through context-rich, action-oriented learning. Building on the ADDIE development model, the e-book integrates multimodal content (videos, comics, quizzes, reflective prompts) to connect day-to-day decisions planning purchases, storage, processing, and handling leftovers with sustainability concepts and values (Bhira et al., 2024). The study aims to: (i) develop a vocationally relevant interactive e-book aligned with ESD; (ii) establish its feasibility through expert (content and media) and teacher validation; (iii) evaluate its effectiveness in improving students' sustainability literacy across knowledge, values/awareness, and skills; and (iv) document student responses as end users.

By aligning instructional media with vocational practice and ESD goals, this work contributes a scalable approach to educating students for sustainability literacy in vocational high schools addressing an urgent need to reduce food waste through informed, value-driven, and skillful action (Malefors et al., 2024; Martin-rios et al., 2025).

2. METHOD

The study followed the ADDIE model (Analysis, Design, Development, Implementation, Evaluation) to produce an interactive e-book focused on food waste. Analysis identified curricular alignment with vocational competencies and ESD aims. The Design stage specified learning objectives, content structure, interaction flow, assessments, and media elements (comics, videos, quizzes, external links, and reflective prompts). Development produced a prototype with modern interface, accessible navigation, and multimodal content for classroom and online use.

Feasibility was examined via expert validation (content and media) and teacher appraisal using structured rating sheets covering substance (curricular fit, topicality, conceptual depth), pedagogy (clarity of objectives, scaffolding, assessment), and technical aspects (visual design, accessibility, interactivity). Effectiveness was tested in a pre–post implementation with 36 vocational high school students.

The instrument used consisting of:

1. Sustainability literacy questionnaire: three domains knowledge, relevant values (awareness), and skills. Scores were computed for pretest and posttest; normalized gain (N-gain) was estimated where applicable.

2. Expert/teacher feasibility sheets: Likert based ratings aggregated by domain.

3. Student responses: brief perception survey capturing relevance, clarity, engagement, and perceived behavioral reflection.

We compared prepost means for literacy domains and computed N-gain for knowledge and values. Post-only skills and overall means were summarized and categorized against established interpretation bands (e.g., very good). Feasibility ratings were summarized per domain. Descriptive emphasis was used given the development focus and sample size; where relevant, results are interpreted against practical significance and adoption criteria.

3. RESULTS

3.1 Product profile

E-book integrates cognitive, affective, and psychomotor content in a context close to students' daily lives (planning purchases, storage, processing, and handling leftovers). Features include a modern interface, simple navigation, interactive quizzes, short educational videos, comics, external links, and reflective activities designed to promote transfer from concepts to action. The media functions in face-to-face and online modalities.

Table 1. Profile e-book

Cover		Interactive media	Comic 
Color			Quiz 
Typo graf	Muli **Muli** ABCDEFGHIJKLMNOPQRSTUVWXYZ abcdefghijklmnopqrstuvwxyz 0123456789		Video 

The interactive e-book *Awas Food Waste* was developed using the ADDIE model to align vocational learning with *Education for Sustainable Development* (ESD) in a concrete, practice-oriented way (Purwanto et al., 2023). The content is organized along everyday food-management decisions planning purchases, storing ingredients, processing, and handling leftovers so concepts are immediately relatable to vocational learners. Each module integrates cognitive targets, affective targets, and psychomotor targets.

Design choices emphasize accessibility and engagement. The interface employs modern visuals, clean typography, and simple navigation to support both classroom and online use. Interactivity is embedded through formative quizzes, short videos, comics for narrative framing, external links to credible resources, and reflective prompts that nudge students to connect material to their own routines at school and home. Assessment is woven throughout: low-stakes checks for understanding within modules, reflective questions anchoring values and intentions, and a post-learning skills task encouraging concrete actions (e.g., leftover repurposing).

Pedagogical alignment is explicit. Learning objectives, media, and assessments are constructively aligned to sustainability literacy dimensions. For example, a storage module pairs a short explainer video (knowledge), a mini-scenario comic on labeling and rotation (values/awareness), and a quick-action checklist for proper storage (skills). This coherence—validated by experts and teachers ensures the e-book operates as more than a reading resource; it functions as a guided learning experience that builds understanding, strengthens pro-sustainability dispositions, and supports transfer to real practices.

Table 2
Indicator Domain Sustainability Knowledge, Sustainability Relevant Values, Sustainability Skills

No	Domain	Indicator
1	Sustainability knowledge	1. Understanding basic ecological principles
		2. Approaching problems and situations from a systems perspective
		3. Assessing the impact of technology use and human actions
2	Sustainability relevant values	1. Appreciate and evaluate other people's work from various perspectives based on different backgrounds, motivations, and intentions.
		2. Committed to fairness and inclusivity, towards achieving sustainability
		3. Have respect or appreciation for nature and all living things
3	Sustainability skills	1. Using tools, objects, and work procedures based on sustainability

3.2 Effectiveness Findings

Effectiveness was examined using a pre–post design with 36 vocational high school students. Results show meaningful learning gains consistent with the e-book's intended outcomes. Knowledge increased from 64.63 to 83.15 (N-gain 0.5148; moderate–good), and values/awareness increased from 64.07 to 82.73 (N-gain 0.5374; moderate-good). Post-intervention skills reached 82.67 (very good), and the overall sustainability literacy average was 82.85 (very good). These shifts indicate that the e-book not only improved conceptual understanding but also strengthened value orientations and self-reported skills related to preventing and managing food waste key indicators of sustainability literacy development in vocational contexts.

Table 3
Total Student Sustainability Literacy Score

Domain of Sustainability Literacy	Pre	Post	N-Gain	Post-test Results
Knowledge	64.63	83.15	0.5148	Very Good
Relevant Value	64.07	82.73	0.5374	Very Good
Skill	-	82.67	-	Very Good
Average Sustainability Literacy		82.85		

These findings complement preliminary observations in Bogor that initially indicated low understanding (average knowledge 58; low category) and limited translation of sustainability attitudes into actions at school (Saldiana et al., 2025), and they address calls to strengthen formal curriculum integration of sustainability literacy and food-waste management in schools. To provide a more comprehensive visual overview of the distribution of scores and the pattern of change in students' knowledge, the pretest and posttest data were visualized in a scatter plot, as shown in the following Fig. 1.

Based on the pretest and posttest score graph, the majority of respondents showed a meaningful increase in scores, with the average score rising overall. The visualization of individual changes per respondent confirms this pattern, as most lines move upward from pretest to posttest. Only six respondents showed no change (difference = 0): Respondent_14, Respondent_18, Respondent_24, Respondent_28, Respondent_31, and Respondent_32. Interviews with these six students revealed various factors contributing to their score stagnation.

Respondent_14 reported feeling tense during the posttest and struggled with time management, which prevented them from reviewing their answers. Respondent_18 experienced fatigue due to lack of sleep and felt uncertain when faced with varied question contexts, leading them not to revise their initial answers. Respondent_24 missed two core topics because of being absent, so they chose to answer only what they were sure of and skipped items that they actually could have attempted. Respondent_28 reduced practice frequency after feeling "good enough" following the pretest, which resulted in difficulties with reasoning-based items. Respondent_31 often misinterpreted the intent of questions and did not fully utilize example explanations, causing their answers to be close to correct but not enough to gain additional points. Meanwhile, Respondent_32 felt overly confident and lost points on detailed steps or justifications required in higher-order questions.

Overall, the quantitative and qualitative findings consistently indicate that the intervention was effective for the majority of participants; however, the improvement was not evenly distributed due to a combination of factors including emotional readiness, gaps in content mastery, test-taking strategies, and motivation. Recommended follow-up actions include targeted remedial sessions on missed or poorly understood topics, context- and reasoning-based practice with rapid feedback, strengthening of test-taking strategies, and refinement of argumentation and step-by-step explanations for high-achieving students to help them move beyond performance plateaus.

Next, prerequisite tests for statistical analysis were conducted to ensure the appropriateness of the selected statistical methods. The prerequisite test performed was the normality test. The Shapiro–Wilk test showed that the pretest scores were not normally distributed ($W = 0.880$; $p < 0.001$) and that

the posttest scores were also not normally distributed (W = 0.899; p = 0.003). For a paired design, the normality of the difference scores (post–pre) is more relevant. When the normality assumption for the difference scores is not met, inferential analysis is continued using the Wilcoxon signed-rank test. The results indicated a statistically significant increase from pretest to posttest ($p < 0.001$), demonstrating a highly significant difference between students' initial and final knowledge. This finding is further supported by the N-gain analysis, which yielded an average value of 0.5148 (moderate category). This result shows that students succeeded in utilizing more than half of their potential knowledge gain. Although classified as moderate, this achievement is very encouraging given the complexity of the food waste topic, which includes understanding basic ecological principles, systems thinking, and the relationship between storage technologies and environmental pollution—areas that were entirely new to most students.

The successful improvement in knowledge can be attributed to the characteristics of the interactive e-book, which combines factual content, engaging visualizations (graphs, comics, illustrations), interactive features (barcodes linking to educational videos, online quizzes, emission calculators), and a contextual approach that connects global issues to students' everyday lives. The integration of SDG-related values in the material also helped students understand the relevance of food waste within the broader context of sustainability. Based on the series of analyses conducted on the knowledge domain related to food waste and sustainability issues, it can be concluded that the use of the e-book was proven effective in significantly improving students' sustainability knowledge.

Sustainability awareness is the second domain in the analysis of sustainability literacy and serves as a bridge between knowledge and action; it reinforces values, attitudes, and concern that drive pro-environmental and pro-social behavior. The interactive e-book intervention, which integrates comics, educational videos, and reflective quizzes, was designed to activate this affective domain. In general, the results show a meaningful increase in students' awareness scores, reflected in a moderate average N-gain and a significant pre–post difference according to nonparametric testing. This confirms that interactive media-based learning not only enriches knowledge but also effectively supports the internalization of sustainability values.

Quantitatively, the improvement is reflected in an average N-gain of approximately 0.5374, indicating that students, on average, closed about half of the possible gap between their initial condition and the maximum score. This represents a practically meaningful effect, consistent with the aim of the affective domain to shift value preferences and readiness to act. The normality test indicated that the pretest scores were not normally distributed, while the posttest scores were normally distributed; therefore, the Wilcoxon signed-rank test was chosen as a conservative approach for the difference analysis. The result was significant ($p < 0.001$) with a large effect size, which substantively means that the post-intervention gains were not only consistent for most students but also strong in practical terms. The comparison of pretest and posttest scores is presented in Fig. 2.

The graph shows a general shift from pretest to posttest scores for almost all students. The average posttest score consistently lies above the initial pretest score, indicating a broadly distributed improvement. Visually, this upward movement appears stable across the entire sequence of students, from those who started at a moderate level to those who already had high scores at the outset. This provides strong evidence that the intervention worked consistently across the whole class, not just for a small subgroup.

There are two main possible reasons for this pattern of improvement. First, the narrative and visual elements in the interactive e-book make the issue of food-waste sustainability feel close and relevant easy to remember, easy to understand, and easy to connect with everyday experiences. Second, the reflective quizzes and interactive videos encourage students to examine their own attitudes. This combination shifts the focus from merely "knowing the concept" to "understanding why and how to take a stance," so the change is not only cognitive but also affective (Vilmala et al., 2022). The impact is especially visible among students who started with low scores: their doubt decreased, their thinking became more structured, and their value preferences more firmly established. Meanwhile, students who already had high scores at the beginning still showed gains, even though their room for improvement was narrower; these gains typically occurred because they became more careful in reading instructions, distinguishing between similar options, and ensuring that their reasoning was accurate.

Variation in responses across students is also quite informative. For some students, the increase is very steep, suggesting that short but consistent learning sessions, combined with simple reflection, were effective in improving how they interpret items and weigh answer choices. For others, especially those already close to a performance ceiling, the gains are smaller but still meaningful in terms of quality: they refined details, organized how they explained their reasoning, and avoided minor errors that previously reduced their scores. There is also a group with moderate gains who have clearly improved but still need support with items that use unfamiliar contexts and with making fine distinctions between similar options. The following summarizes interview results from several students whose scores showed sharp increases.

Res_33 represents a substantial jump. This respondent rewatched sample explanations, noted the key steps, and then gradually increased the difficulty level of the practice items. These small habits made them more confident when reading items and more aware of the underlying reasoning flow, leading to more accurate answer choices. Res_21, who already started with a high score, continued to improve by sharpening attention to detail. This student regularly wrote brief reasons for each option, checked for minor details that are often overlooked, and chose more challenging practice items to avoid boredom. Their improvement came not from the quantity of practice alone, but from the quality of the process: clear reasoning and consistency in distinguishing between similar options. Res_5 recorded moderate gains after learning to break questions into smaller steps. This student first wrote down the given information, then determined the next steps one by one. Practice with varied but structurally similar items helped them feel more prepared when encountering question contexts that did not exactly match classroom examples, so they were less likely to stop midway through the process.

These visual findings suggest that the intervention plays a dual role: it raises the overall average level while also consolidating foundational skills. To sustain the gains of students who showed sharp improvement, brief reflective routines and short, regular practice sessions need to be maintained so that the change does not become temporary. For students nearing the performance ceiling, enrichment activities based on real-world scenarios—such as short case studies, data-based argumentation tasks, or mini-projects—will help deepen their reasoning and commitment, rather than merely increasing scores. Meanwhile, for students with moderate gains, the focus should be on working with items in new contexts and strengthening their ability to differentiate between similar answer options.

4. DISCUSSION

The findings demonstrate that an ADDIE-designed interactive e-book can be both feasible and educationally impactful for advancing sustainability literacy in vocational high schools. Strong expert and teacher validations across substance, pedagogy, and technical quality indicate institutional readiness for classroom adoption and blended implementation, addressing calls for formal curricular integration of sustainability content (Pengestuti et al., 2024). This approach moves beyond awareness-raising toward habitual practice, responding to critiques that conventional textbooks often privilege cognitive mastery while neglecting affective and behavioral dimensions of sustainability learning. Moreover, this finding complements recent evidence that digital communication strategies based on behavioral models such as AISAS (Attention–Interest–Search–Action–Share) are effective in strengthening youth engagement and knowledge sharing on food-waste issues in Indonesia (Putri et al., 2023)

The moderate–good N-gain values for knowledge and values/awareness, together with very good post-intervention skills and overall literacy, point to the value of multimodal resources and reflective scaffolds for translating ESD principles into concrete, context-specific actions. This aligns with evidence that visuals and structured electronic books reduce cognitive load, deepen processing of complex topics, and support intention formation. Positive learner responses relevance, clarity, engagement likely functioned as mechanisms of impact, helping students connect content to everyday food-handling decisions, which addresses the low baseline understanding observed in Bogor.

Positioning the intervention within vocational routines matters. Food waste is a cross-cutting environmental and social issue recognized globally, and it is particularly salient in Indonesia where food residues constitute the largest share of municipal waste (Yu et al., 2023). By mapping modules to authentic tasks. E-book operationalizes sustainability literacy as knowing, valuing, doing, moving beyond awareness to practice. This responds to limitations of conventional textbooks that often emphasize cognitive mastery at the expense of affective and behavioral dimensions and builds on Indonesian digital initiatives that have thus far focused more on public awareness than on classroom-embedded learning.

Practically, schools can adopt the e-book as a blended learning resource: slot modules alongside relevant vocational competencies; use in-module quizzes for formative checks; and treat reflective prompts as micro-projects (Sjöberg, 2025). For future work, larger and more diverse samples, comparison groups, and behavioral indicators (e.g., plate-waste tracking, storage-labeling adherence) would strengthen causal claims and clarify which features produce the largest gains. Lightweight learning analytics (time-on-task, item-level patterns) could personalize learning and guide iterative improvements. Overall, the study contributes a scalable, curriculum-aligned approach to educating vocational students for sustainability literacy advancing the urgent agenda of food-waste reduction through informed, value-driven, and skillful action.

5. CONCLUSION

This study demonstrates that an interactive e-book on food waste, developed with the ADDIE framework and aligned to vocational routines, is both feasible for classroom integration and effective in strengthening students' sustainability literacy. Expert, media, and teacher validations rated the product highly across substance, pedagogy, and technical quality, indicating strong readiness for blended implementation and curricular alignment.

Measured with a pre–post design in 36 vocational high school students, the e-book produced meaningful gains: knowledge improved from 64.63 to 83.15 (N-gain 0.5148), values/awareness increased from 64.07 to 82.73 (N-gain 0.5374), post-intervention skills reached 82.67 (very good), and the overall literacy average was 82.85 (very good). Positive learner responses—highlighting relevance, clarity, interactivity, and reflective prompts—suggest that multimodal content and guided reflection effectively translate ESD principles into concrete, context-specific actions.

By mapping modules to authentic tasks planning purchases, storage, processing, and handling leftovers the e-book operationalizes sustainability literacy as knowing valuing doing, addressing the limitations of conventional textbooks that overemphasize cognitive mastery. Practically, the product offers a scalable, curriculum-aligned pathway for vocational schools to cultivate responsible consumption and food-waste reduction behaviors.

Future work should broaden samples and contexts, include comparison groups, and incorporate behavioral indicators (e.g., plate-waste tracking, storage-labeling adherence) and simple learning analytics to refine personalization. Even so, the present findings provide clear evidence that an interactive e-book can meaningfully enhance sustainability literacy in vocational high schools and support the urgent agenda of reducing food waste through informed, value-driven, and skillful action.

Declarations

Author Contributions

Conceptualization, A.P.; Methodology, I.R.; Formal analysis, A.P; Investigation, N.S.; Data curation, N.S.; Visualization, N.S.; Resources, T.M.; Supervision, A.P. and I.R.; Project administration, I.R.; Funding acquisition, T.M.; Writing original draft, A.P.; Writing review and editing, A.P., I.R., N.S., and T.M. All authors have read and agreed to the published version of the manuscript.

ETHICS DECLARATION

The authors declare that there are no conflicts of interest regarding the publication of this paper. This study has obtained ethical approval from the Research Ethics Committee of Universitas Pakuan. The ethical clearance was issued under approval letter number No. 371/LPPM/UP/XI/2025. All research procedures were conducted in accordance with ethical standards involving human participants, and informed consent was obtained from all participants prior to data collection.

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Figures

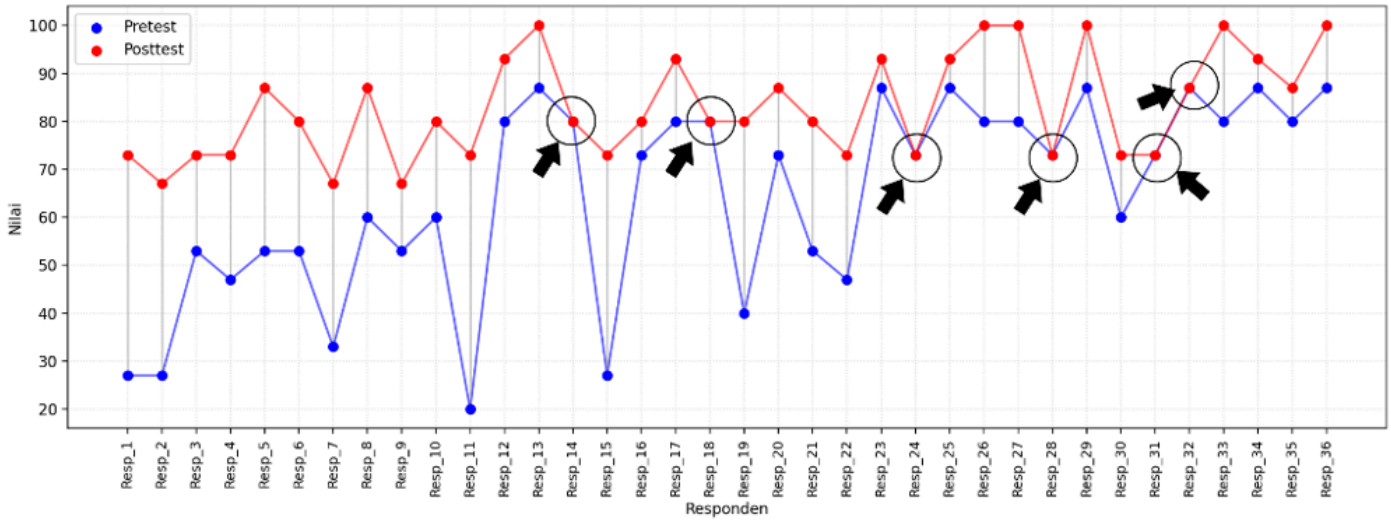


Figure 1

*Comparison of Pretest vs Posttest Scores (*Knowledge)

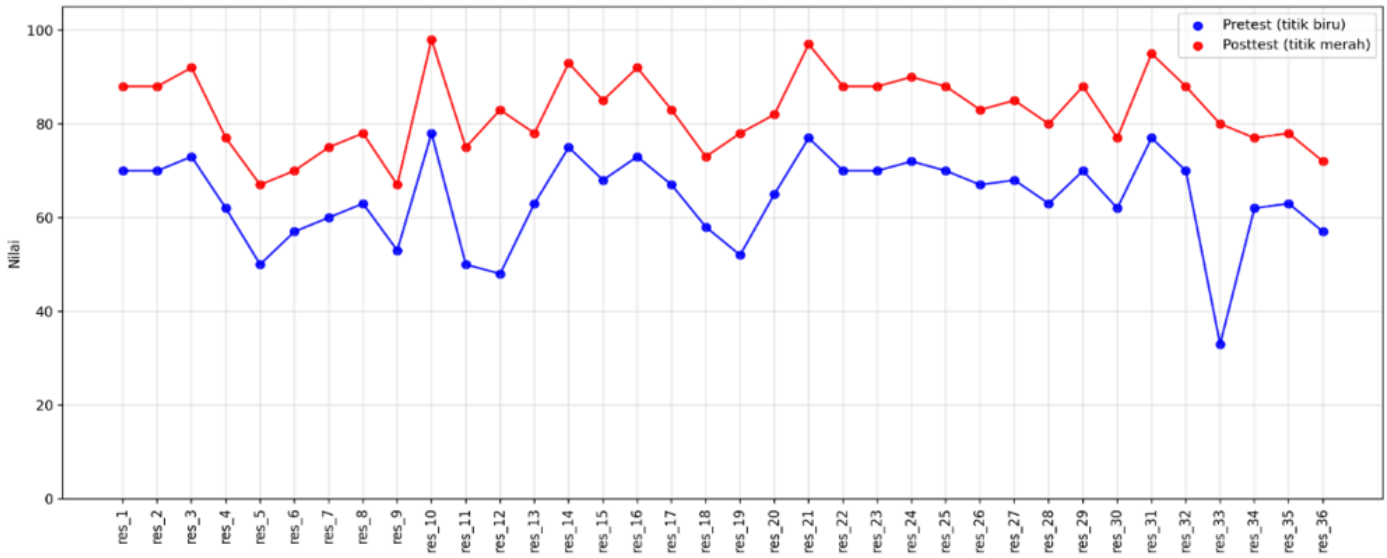


Figure 2

Comparison of Pretest vs Posttest Scores (Awareness)