JURNAL EDUSCIENCE (JES)
p-ISSN : 2303 - 355X | e-ISSN : 2685 - 2217
PUBLISHED BY : LPPM of UNIVERSITAS LABUHANBATU

Integration of Product-Based Learning and Upcycled Materials in Mathematics Learning in Elementary Schools

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ARTICLE INFO

Keywords:
product-based learning;
upcycled materials;
learning outcomes;
elementary school

ABSTRACT

Purpose – This study aims to examine the effectiveness of product-based learning with upcycled materials in improving elementary school students' mathematics learning outcomes on bar chart material.

Methodology – The study employed a classroom-based, iterative research design implemented across several learning phases to optimize the learning process and outcomes. The participants were 37 fourth-grade students with heterogeneous academic abilities. We collected data through learning outcome tests, observations, and documentation, and analyzed them using quantitative and qualitative approaches.

Findings – The results showed a significant increase in student learning outcomes. The average score increased from 63.8 in the initial phase to 72.4, then to 84.1 in the final phase. The percentage of learning completion also increased from 37.8% to 62.2%, then to 89.2%, exceeding the established learning effectiveness criteria. The findings indicate that integrating product-based learning with upcycled materials improves learning outcomes and strengthens students' conceptual understanding through active, contextual, and meaningful learning activities. Students' active involvement supported by concrete media enabled deeper knowledge construction and reinforced the constructivist learning approach.

Contribution – This study contributes to the development of innovative mathematics learning by integrating product-based learning with environmentally based learning media, providing an alternative contextual learning approach that supports student engagement, creativity, and environmental awareness in elementary education.

Received 24 Maret 2026; Received in revised form 08 April 2026; Accepted 06 June 2026
Journal Eduscience (JES) Volume 13 No. 3 (2026)
Available online 30 June 2026

INTRODUCTION

Mathematics learning in elementary schools plays an essential role in developing students' numeracy literacy as a foundation for logical, analytical, and systematic thinking. One important topic in elementary mathematics is data representation, particularly bar charts, which require students to collect, organize, present, and interpret data visually. Learning activities involving data representation also support the development of students' mathematical communication, statistical reasoning, and ability to interpret quantitative information in meaningful contexts (Clements & Sarama, 2011; Ponte et al., 2023). However, previous studies indicate that elementary school students still struggle to understand bar chart concepts. Teacher-centered instruction and the limited use of concrete learning media largely influence this condition, which restricts students' active engagement in meaningful learning (Amaliah et al., 2022; Karina & Sujarwo, 2023; Rofi'ah et al., 2024).

Research on data representation learning shows that students often struggle to connect numerical data with its visual representation due to insufficient concrete and contextual learning experiences (Husna et al., 2022). Recent studies also emphasize that students' numeracy literacy improves when learning activities are linked to real-life contexts and supported by hands-on or manipulative media, particularly through problem-solving and equitable instructional design (Seshaiyer & Suh, 2022; Rahmadhani et al., 2022; Fauzi & Usamah, 2023). In addition, contextual and student-centered learning approaches are considered essential for strengthening conceptual understanding and learning engagement in elementary mathematics, including through blended and technology-supported instruction (Attard & Holmes, 2020; Polly & Martin, 2024). Recent studies also indicate that innovative teaching materials and problem-solving-oriented mathematics activities contribute positively to students' numeracy literacy, mathematical reasoning, classroom participation, and creative thinking in STEM-integrated learning environments (Ahdhianto et al., 2020; Lestari et al., 2023; Zaini et al., 2023; English & King, 2023; Juliantara et al., 2024).

In response to these challenges, current curriculum reforms emphasize student-centered, contextual, and meaningful learning that encourages active knowledge construction (Kemendikbudristek, 2022). One relevant approach is product-based learning, which involves students in planning, creating, and presenting tangible products that represent their conceptual understanding. This approach has been shown to enhance students' engagement, creativity, and mathematics achievement in elementary education (Fitriani et al., 2021; Santoso et al., 2022; Ramadhan & Susanti, 2024). Such learning activities also enhance students' collaboration, problem-solving, and creativity, as well as their active participation in mathematics instruction (Fitriani et al., 2021; Santoso et al., 2022). From a theoretical perspective, elementary school students are at the concrete operational stage, where learning is more effective when supported by direct interaction with concrete objects (Piaget, 1972). This view is consistent with Bruner's theory of representation, which explains that learners progress through enactive, iconic, and symbolic stages from concrete experiences toward abstract understanding (Bruner, 1966). These theoretical perspectives strongly support the use of concrete learning media in mathematics instruction.

Furthermore, using upcycled materials in material-based learning and concrete teaching aids increases student engagement, creativity, and environmental awareness (Drosos & Symeonaki, 2023; Wahyudi et al., 2024; Rozy et al., 2024; Nurhasanah & Putri, 2023). Their integration into classroom learning also promotes sustainability values by fostering students' ecological awareness and responsibility through meaningful learning experiences. In mathematics learning, the use of upcycled materials allows students to connect mathematical concepts with everyday environmental issues while encouraging responsible behavior and sustainable thinking (Santi et al., 2022; Wali, 2023). The use of upcycled materials in classroom-based product creation also provides opportunities for students to develop creativity while strengthening environmental responsibility through hands-on learning activities (Çakıroğlu & Yıldız, 2024; Yılmaz & Kartal, 2024). However, most previous studies still examine instructional models and learning media separately, without integrating upcycled materials as an integral component of instructional design.

Although extensive research has examined product-based learning and concrete learning media in elementary mathematics, several gaps remain in the literature. First, there is limited research on systematically integrating instructional models and upcycled materials within a single instructional framework. Second, studies focusing specifically on data representation learning in elementary mathematics remain limited compared to other mathematics topics. Third, the integration of sustainability-oriented materials, such as upcycled resources, into mathematics instruction—particularly as part of students' product creation processes—has not been widely explored. These gaps indicate that the systematic integration of pedagogical approaches, concrete media, and sustainability-oriented learning in elementary mathematics instruction remains underdeveloped.

Therefore, this study proposes a systematic instructional framework that integrates product-based learning with upcycled materials, embedding them as an inseparable component of the student product-creation process rather than treating them as supplementary media. This integration aims to strengthen students' conceptual understanding, engagement, collaboration, and numeracy literacy through meaningful and contextual learning experiences. Accordingly, this study aims to investigate the effectiveness of this integrated approach on elementary school students' learning outcomes in bar chart concepts, with specific emphasis on achievement, conceptual understanding, engagement, and numeracy literacy.

METHODOLOGY

Research Design and Procedure

This study employed a classroom-based iterative research design to systematically examine the effectiveness of the implemented learning approach in improving students' mathematics learning outcomes. The iterative design enabled continuous refinement of the learning process and provided comprehensive insights into the intervention's effectiveness. The researchers structured the study into four systematic stages: learning design, implementation, observation, and reflective evaluation, all carried out systematically to optimize learning effectiveness. This design was selected to ensure a systematic evaluation of the learning intervention and to capture progressive improvements in students' learning outcomes across phases.

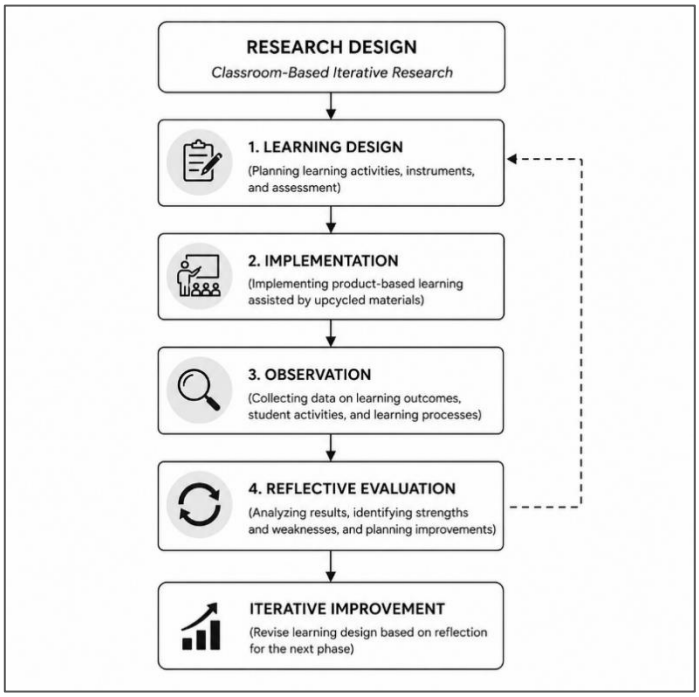

Figure 1. Flowchart of Classroom-Based Iterative Research Design

To ensure data validity, this study employs a highly structured and systematic procedure. In the learning design stage, learning materials were systematically prepared, including lesson plans, teaching materials, student worksheets, and learning media in the form of products made from upcycled materials. The learning design was based on product-based learning principles, emphasizing active student involvement in producing products as representations of conceptual understanding (Nurhayati, 2022; Ramadhan & Susanti, 2024). The use of upcycled materials aimed to create concrete, contextual, and environmentally oriented learning experiences (Wali, 2023; Rizko et al., 2023).

During the implementation stage, students actively planned, collected, processed, and presented their learning outcomes through product-based activities. These collaborative tasks fostered discussion, critical thinking, and creativity, aligning with 21st-century learning principles (Yuliani & Putra, 2021; Asmiyunda, 2023). The researchers observed the entire learning process to examine student activities and the implementation of the learning approach. A reflective evaluation analyzed learning outcomes, identified challenges, and formulated improvements for subsequent learning phases (Putri et al., 2023).

Research Subject

The subjects of this study were 37 fourth-grade students from SD Negeri Napis II, selected purposively. The school selected is because it represents an elementary school environment that still faces challenges in mathematics learning outcomes, particularly in bar chart material, and supports the implementation of contextual and environmentally based learning. The selected participants had heterogeneous academic abilities, consisting of students with high, moderate, and low learning achievement levels. In addition, the students showed varying levels of participation in learning and conceptual understanding, making them suitable subjects for examining the effectiveness of product-based learning with upcycled materials.

Data Collecting

Learning outcome tests, observations, and documentation were the primary methods of data collection. The researchers administered learning outcome tests to fourth-grade students to measure their understanding of bar chart material after implementing product-based learning with upcycled materials. The tests focused on assessing students' abilities to interpret data, organize information, construct bar charts, and conclude data presentations. Observations throughout the learning process targeted student engagement, participation, collaboration, creativity, and the teacher's implementation of the learning approach. The observational data provided clear insights into students' learning activities and the overall effectiveness of the instructional process during the intervention. The research documentation comprised photographs, student learning products, lesson plans, field notes, and classroom activity records. These documents supported and strengthened the research findings by providing visual and descriptive evidence of the learning process and student participation.

Instrument

The instruments used in this study included observation sheets for student and teacher activities, learning outcome tests in the form of descriptive questions, product assessment rubrics, and documentation such as photos and field notes. All instruments were systematically developed and validated by experts. The validation results confirmed that the instruments are valid and suitable for the research. In addition, the reliability testing showed that the instruments had acceptable reliability for consistently measuring students' learning outcomes and learning activities.

Data Analysis

Learning outcome data were analyzed using descriptive quantitative methods, including calculating mean scores and the percentage of students who completed learning. Observational data were analyzed using descriptive qualitative analysis through data reduction, data display, and conclusion drawing. A minimum success criterion required at least 80% of students to attain the minimum mastery criterion (MMC) of 75 to

determine the learning approach's effectiveness. To enhance the validity and reliability of the findings, data triangulation was conducted by comparing results from tests, observations, and documentation.

FINDINGS

Results of Analysis in Cycle I

Planning

In the planning stage, a product-based learning approach integrated with differentiated instruction guided the design of learning activities to foster active student participation. The differentiated instruction framework categorized students into visual, auditory, and kinesthetic learning styles, with each group receiving specific project tasks focused on bar chart presentations. Learning instruments, project schedules, and activity procedures were systematically prepared to support collaborative learning activities and the implementation of contextual learning using upcycled materials. The planning stage resulted in the readiness of instructional materials, learning media, and project designs needed to support the learning process effectively.

Implementation

During the implementation stage, collaborative and context-based learning activities facilitated product-based learning using upcycled materials. Students actively participated in collecting, organizing, and presenting data related to bar chart material. Differentiated group assignments structured the learning activities for the visual, auditory, and kinesthetic profiles. Each group completed project tasks according to their learning characteristics while remaining focused on developing a conceptual understanding of bar charts.

During the initial implementation activities, students collected data through direct observation and simple interviews based on their assigned tasks. These activities encouraged students to engage directly with real-life contexts and develop their understanding of data collection processes. Students actively participated and collaborated during data collection.

Figure 2. Observation and Bar Chart Construction Using Upcycled Materials

After collecting the data, students worked collaboratively in groups to organize it into tables and transform it into bar charts using upcycled materials. Students actively discussed the project design, selected suitable materials, and created three-dimensional bar chart products. The implementation process encouraged students to develop creativity, communication skills, and collaborative learning experiences while constructing conceptual understanding through direct practice.

At the end of the implementation stage, each group presented its project results to the class. Students explained the data presentation process and interpreted the information displayed in their bar chart products. The presentation activities promoted students' confidence, communication skills, and a deeper understanding

of data presentation concepts. In addition, peer feedback and teacher guidance helped students improve their understanding through interactive learning experiences.

Figure 3. Students' presentation of 3D bar chart products

The implementation results showed that students were actively engaged throughout the learning activities and demonstrated increased collaboration, creativity, and conceptual understanding in developing and presenting bar chart products made from upcycled materials.

Observation

The observation stage in cycle I showed improvements in both the learning process and student learning outcomes following the implementation of product-based learning with upcycled materials. Based on classroom observations, students demonstrated active participation during learning activities. Students were actively involved in collecting data, organizing information, discussing project tasks, and presenting the results of their collaborative group work. The use of upcycled materials also encouraged students to participate more enthusiastically and confidently during the learning process.

In addition, students showed improved collaboration and communication skills throughout the implementation of project-based activities. Group discussions and hands-on learning experiences enabled students to construct conceptual understanding through direct involvement in the learning process. Students were also able to connect mathematical concepts with real-life contexts through activities involving data collection and bar chart construction.

The results of the learning outcome test conducted at the end of cycle I indicated an improvement compared to the initial condition. Of the 37 students, 23 students achieved scores equal to or above the minimum mastery criterion (MMC = 75), while 14 students had not yet reached the expected level of mastery. The average student score increased to 72.4, with a learning completion rate of 62.2%. Although the results demonstrated improvement, the percentage of learning completion had not yet achieved the predetermined criteria of learning effectiveness, which required at least 80% of students to achieve the MMC. These reflective findings prompted further modifications to the instructional execution in the next cycle. Table 1 summarizes the student learning outcomes in Cycle I.

Table 1. Student Learning Outcomes in Cycle I

Indicator	Result
Number of Students	37
Students Achieving MMC (75)	23
Students Not Yet Achieving MMC	14
Average Score	72.4
Learning Completion Rate	62.2%

The data presented in Table 1 show that student learning outcomes in cycle I improved compared to the initial condition. Of the 37 students, 23 met the minimum mastery criterion (MMC), while 14 had not yet achieved mastery learning. The average student learning outcome score reached 72.4, with a learning completion rate of 62.2%. These findings indicate that implementing product-based learning with upcycled materials improved students' understanding of bar chart material. However, the percentage of learning completion had not yet met the predetermined criteria for learning effectiveness, indicating the need for further improvement in the subsequent cycle.

Reflection

The reflection stage in cycle I was conducted based on the results of observations and student learning outcomes obtained during implementation. Although student learning outcomes improved compared to the initial condition, the percentage of learning completion had not yet met the predetermined criteria for learning effectiveness, which require at least 80% of students to achieve the minimum mastery criterion (MMC). The implementation of learning activities revealed several challenges. Some students still had difficulty interpreting data and constructing bar charts correctly. In addition, several students were not yet fully confident in presenting the results of their group discussions and required further guidance during collaborative activities.

The reflection results guided the formulation of several instructional improvements for Cycle II. The teacher provided clearer instructions on project procedures, strengthened guidance during group discussions, and optimized the use of upcycled materials to better support students' conceptual understanding. In addition, the modified strategy prioritized active participation among all group members to foster better collaboration and communication during learning activities. These improvements aimed to enhance the effectiveness of the learning process and optimize student learning outcomes in the subsequent cycle.

Results of Analysis in Cycle II

Planning

The researchers formulated the planning stage in Cycle II based on reflections from Cycle I—several systematically designed improvements aimed at optimizing the learning process and elevating student learning outcomes. The teacher refined the learning design by providing clearer instructions regarding project implementation, strengthening guidance during group discussions, and improving classroom management to ensure more active student participation during learning activities.

In addition, revised learning materials, worksheets, and project procedures facilitated a clearer understanding of how to collect, organize, and present data in bar charts. The researchers also optimized the use of upcycled materials by selecting materials that were easier to work with and better suited for constructing three-dimensional bar chart products. These improvements aim to support students in developing conceptual understanding more effectively through active and contextual learning experiences. The planning stage in Cycle II resulted in improved instructional readiness, more structured project activities, and better learning strategies to support the implementation of product-based learning with upcycled materials in the subsequent cycle.

Implementation

The implementation stage in Cycle II was carried out by applying several improvements based on reflections from Cycle I. Learning activities continued to use a product-based learning approach, assisted by upcycled materials, through collaborative, contextual learning. Students participated more actively and confidently throughout the learning process, following clearer instructions and improved teacher guidance during project activities. At the beginning of the implementation activities, students collected data through direct observations and simple interviews as part of their group assignments. Compared to Cycle I, students

showed greater participation and understanding during data collection. Students were better able to identify, organize, and interpret data related to bar charts.

During the project, students worked collaboratively in groups to organize data into tables and to construct three-dimensional bar charts using upcycled materials. Students demonstrated improved collaboration, creativity, and communication skills during group discussions and product development activities. The improved learning guidance in Cycle II enabled students to complete project tasks more systematically and effectively. Furthermore, students presented the results of their projects to the class and explained the process of data presentation using the bar charts they had created. Compared to Cycle I, students appeared more confident and were able to explain mathematical concepts more clearly and systematically. The implementation activities in Cycle II indicated improvements in student participation, conceptual understanding, and collaborative learning experiences during the learning process.

Figure 4. Students' bar chart product and presentation in Cycle II

Figure 4 shows students presenting their bar chart projects made with upcycled materials to the class. Students demonstrated increased confidence and active participation during the presentation activities. The learning activities also reflected improved collaboration and conceptual understanding in presenting and interpreting data through concrete learning media. Figure 4 also illustrates student presentation activities in Cycle II. Students explained the results of their bar chart projects and demonstrated improved confidence, communication skills, and conceptual understanding during the learning process.

Observation

The observation stage in Cycle II showed significant improvements in both the learning process and student learning outcomes following the refinement of product-based learning with upcycled materials. Based on classroom observations, students demonstrated higher levels of participation, collaboration, and confidence during learning activities. Students were more actively involved in group discussions, data processing, product construction, and presentation activities compared to Cycle I. The implementation of contextual and collaborative learning activities enabled students to understand bar chart concepts more effectively through direct learning experiences. Students also showed improved communication skills and creativity during project completion activities. Teacher guidance and learning management in Cycle II contributed to creating a more interactive and effective learning environment. The results of the learning outcome test conducted at the end of Cycle II demonstrated a substantial improvement compared to the previous cycle. Of the 37 students, 33 students achieved scores equal to or above the minimum mastery criterion (MMC = 75), while only 4 students had not yet reached the expected level of mastery. The average student learning outcome score increased to 84.1, with a learning completion rate of 89.2%. These results indicate that the learning implementation successfully achieved the predetermined criteria for effectiveness. Table 2 summarizes the student learning outcomes in Cycle II.

Table 2. Student Learning Outcomes in Cycle II

Indicator	Result
Number of Students	37
Students Achieving MMC (75)	33
Students Not Yet Achieving MMC	4
Average Score	84.1
Learning Completion Rate	89.2%

The data presented in Table 2 indicate a significant improvement in student learning outcomes in Cycle II compared to Cycle I. The number of students achieving the minimum mastery criterion (MMC = 75) increased substantially, while the number of students who had not yet achieved mastery decreased. In addition, the average student score and learning completion rate showed a marked improvement following the refinement of learning activities in Cycle II. These results demonstrate that implementing product-based learning with upcycled materials effectively enhanced students' understanding of bar chart material, as reflected in improved conceptual understanding and overall learning achievement.

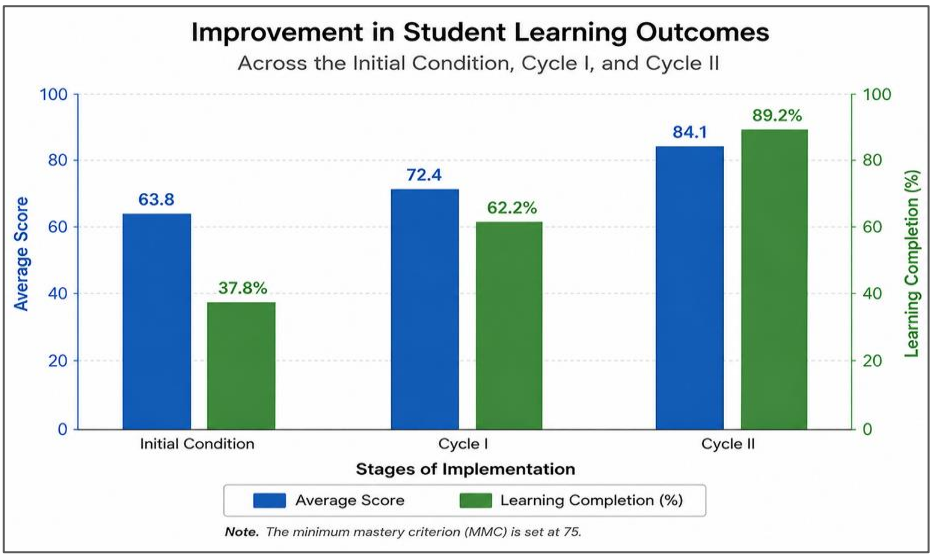

Figure 5. Improvement in student learning outcomes across cycles

Figure 5 shows a consistent improvement in student learning outcomes from the initial condition to Cycle II. The increase in average scores and completion rates indicates that product-based learning with upcycled materials positively affected students' conceptual understanding and learning achievement in mathematics.

Reflection

The reflection stage in Cycle II indicated that the improvements implemented based on Cycle I results significantly enhanced the effectiveness of the learning process. The refinement of learning design, clearer instructional guidance, improved classroom management, and optimized use of upcycled materials successfully created a more structured, interactive, and student-centered learning environment. These improvements enabled better organization of learning activities, particularly in guiding students through the stages of data collection, data organization, and data presentation using bar charts.

In terms of learning implementation and student learning outcomes, students demonstrated higher levels of participation, confidence, and collaboration compared to Cycle I. Using product-based learning with upcycled materials provided more meaningful, concrete learning experiences, enabling students to construct mathematical concepts more effectively. In addition, students showed improvement in communication skills during group discussions and presentations, as they were able to explain the process of creating bar charts more systematically. The learning outcomes also showed substantial improvement: 33 out of 37 students

achieved the minimum mastery criterion (MMC), with an average score of 84.1 and a learning completion rate of 89.2%, indicating that the learning intervention was effective.

Despite the significant improvement, a small number of students (4 students) had not yet achieved mastery, indicating that additional individualized support is still required, particularly for students who experience difficulties in understanding abstract representations of data. Overall, the results of Cycle II confirm that implementing product-based learning with upcycled materials is effective in improving both learning outcomes and student engagement in mathematics, especially in bar chart material. The iterative improvements between Cycle I and Cycle II also demonstrate that continuous Reflection and instructional refinement play an important role in optimizing learning effectiveness in elementary school contexts.

DISCUSSION

The findings of this study indicate that implementing product-based learning supported by upcycled materials improved students' mathematics learning outcomes in bar chart material. The increase in student achievement across cycles suggests that active participation in planning, creating, and presenting products helped students better understand data representation. Students became more involved in the learning process because they were not only receiving information but also directly organizing data and transforming it into visual representations. This finding supports previous studies showing that active, student-centered learning positively contributes to students' mathematical understanding and participation (Hidayat et al., 2022; Rahman & Sari, 2023).

Students also demonstrated a better understanding through hands-on activities such as collecting data, organizing information, and constructing bar charts with reusable materials. These activities helped students connect mathematical concepts with concrete learning experiences, making abstract ideas easier to understand. Group collaboration during the learning process also encouraged communication, interaction, and student participation, thereby improving classroom engagement and achievement. This finding aligns with previous studies reporting that hands-on and contextual learning approaches can strengthen students' understanding in elementary mathematics (Rahmadhani et al., 2022; Rofi'ah et al., 2024).

The improvement from Cycle I to Cycle II also highlights the importance of reflective teaching practice in classroom learning. Revisions made after Cycle I—including clearer instructions, better classroom management, and more effective teacher guidance—supported more active student participation and improved learning outcomes in Cycle II. It shows that learning success is influenced not only by the learning model itself but also by its effective classroom implementation.

Overall, this study demonstrates that integrating product-based learning with upcycled materials can support students' understanding of bar chart concepts and improve mathematics learning outcomes in elementary school. These findings are consistent with previous studies reporting that project-based and problem-based learning contribute to students' engagement, conceptual understanding, and mathematics achievement in elementary classrooms (Nurjanah et al., 2024; Wiastrini et al., 2024). However, this study was conducted in a single classroom and focused solely on bar chart material. Therefore, the researchers recommend further research to explore the application of this approach in different grade levels, broader mathematics topics, and wider learning contexts.

CONCLUSION

Based on the research findings, the researchers can conclude that integrating product-based learning with upcycled materials effectively improves elementary school students' mathematics learning outcomes, particularly in bar chart material. These improvements elevated not only students' academic achievement but also their active participation, collaboration, communication, and conceptual understanding during the learning process. The use of upcycled materials enabled students to engage in concrete and contextual learning experiences, making mathematical concepts more meaningful and easier to understand.

The novelty of this study lies in integrating product-based learning and upcycled materials within a single instructional framework for elementary school mathematics instruction. Unlike previous studies that tended to examine learning models and media separately, this study demonstrates that combining instructional strategies with concrete environmental learning media can support more engaging mathematics learning experiences. The findings also contribute to the theoretical literature on constructivist and active learning perspectives by showing that students develop conceptual understanding more effectively through direct involvement and contextual learning experiences.

However, this study was limited to a single elementary school context and focused only on bar chart material involving fourth-grade students. Consequently, these specific characteristics restrict the generalizability of the findings to broader educational settings or different mathematics topics. The researchers recommend future research to examine the implementation of this approach across different grade levels, mathematical topics, and broader learning environments, and to investigate its long-term impact on students' mathematical reasoning, creativity, and environmental awareness.

ACKNOWLEDGMENT

First and foremost, we express our utmost gratitude to Allah SWT for His blessing and guidance, which steered this research to its proper completion. The authors would like to sincerely thank the thesis supervisor and the lecturer of the Independent Study course on article writing for their guidance and constructive feedback throughout the research process. We highly appreciate the principal, teachers, and Grade V students of SD Negeri Napis Dua for their valuable cooperation and participation during the implementation of this study. The authors also express sincere gratitude to her beloved parents, husband, and children for their prayers, love, and continuous support during the completion of this research.

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