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Meaningful learning to enhance conceptual understanding, engagement, and mathematical reasoning in elementary statistics education

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Abstract

Background: Elementary school statistics education faces challenges due to students' low conceptual understanding, often resulting from abstract and procedural teaching methods.
Aims: This study aimed to examine the implementation of meaningful learning in elementary statistics, assess its effects on students' conceptual understanding and engagement, and identify supporting and inhibiting factors.
Method: A mixed-method explanatory sequential design was employed. Quantitative data were collected through perception questionnaires from 60 fifth-grade students, while qualitative data were obtained via participatory observations, semi-structured interviews, and classroom documentation involving one teacher and 15 students in a purposively selected class. Quantitative data were analyzed descriptively, and qualitative data were analyzed using the Miles and Huberman model.
Results: Meaningful learning positively influenced statistics education. Mean scores were 3.42 for conceptual understanding (SD=0.51), 3.67 for material relevance (SD=0.48), 3.38 for motivation (SD=0.55), 3.25 for engagement (SD=0.62), and 3.35 for satisfaction (SD=0.58). All students (100%) agreed that the material was relevant to real-life contexts. Mini-project activities, such as the "Our Body Statistics" project, enhanced active participation. Supporting factors included teacher creativity, student enthusiasm, and a supportive learning environment; inhibiting factors included time constraints, varied student readiness, and limited contextual resources.
Conclusion: Implementing meaningful learning improves conceptual understanding and engagement in elementary statistics. Contextual, experience-based approaches should be expanded with adequate teacher training and time allocation to optimize learning outcomes.

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INTRODUCTION

Statistics education at the elementary level is essential for developing students' foundational data literacy and analytical thinking skills. Students are introduced to statistical concepts progressively from grades four to six, including data collection, organization, and basic measures such as mean, median, and mode. These skills equip students to interpret and manage information in both academic and everyday contexts. However, many students experience difficulties understanding these concepts due to the abstract and procedural nature of traditional instruction. Instruction often emphasizes memorization of formulas and computation without connecting the

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knowledge to real-life applications (A. Alam & Mohanty, 2024; Nilimaa, 2023). As a result, students perceive statistics as challenging and irrelevant, which negatively affects their motivation and engagement in learning activities. Classroom observations indicate that learning remains largely teacher-centered, and opportunities for active participation are limited (M. Alam, 2023; Hsiao et al., 2022; Kranzfelder et al., 2020; Treve, 2024; Woods & Copur-Gencturk, 2024; Zhang et al., 2021). Students often struggle to internalize statistical concepts and to apply them in problem-solving contexts. Such challenges highlight the need for instructional strategies that promote deeper understanding and meaningful application of statistical knowledge. Without targeted interventions, the gap between students' procedural skills and conceptual understanding continues to widen.

Elementary statistics education also serves as a foundation for higher-order reasoning and evidence-based decision-making skills. Developing conceptual understanding at an early stage fosters long-term statistical literacy, enabling students to make informed interpretations of data (Katnic et al., 2024; Kong et al., 2022; Prediger et al., 2023; Raffaghelli & Stewart, 2020). Engaging students through contextualized activities can enhance both cognitive and affective aspects of learning. Active learning strategies, such as hands-on projects, promote collaboration, discussion, and critical thinking in meaningful ways (Malik & Zhu, 2023; Patiño et al., 2023; Vale & Barbosa, 2023; Williamson, 2023; Yannier et al., 2021). These approaches allow students to apply abstract concepts to authentic tasks, thereby increasing comprehension and retention. Challenges remain, however, including limited resources, varying levels of student readiness, and time constraints within school schedules. Teacher preparation is critical to implementing effective learning strategies that support understanding and engagement. Educators must be equipped to design and facilitate activities that bridge theory and practice. Effective implementation requires careful planning to ensure that learning objectives are met while students remain actively involved. Addressing these challenges is essential to improve the quality and relevance of elementary statistics education.

Furthermore, integrating meaningful learning approaches with project-based activities provides opportunities for students to construct knowledge actively. Project-based methods encourage students to engage in problem-solving and apply statistical concepts in real-world scenarios (Chang et al., 2024; Cujba & Pifarré, 2024; Karan & Brown, 2022; Williamson, 2023). Despite evidence of their effectiveness in older students and adult learners, research at the elementary level remains limited. Few studies have explored how active, contextually relevant projects impact young learners' conceptual understanding, engagement, and reasoning skills. Additionally, the combination of quantitative and qualitative research methods in elementary settings has been underutilized. Investigating both learning outcomes and classroom processes offers a more comprehensive understanding of instructional effectiveness (Elfeky et al., 2020; Huang et al., 2020; Shi et al., 2020; Wei, 2023). Rural and under-resourced schools, in particular, present unique challenges that may influence the success of meaningful learning approaches. There is a need to examine how project-based, contextualized learning strategies can be adapted to younger learners. Insights from such research can inform curriculum design and teacher professional development. Ultimately, understanding these dynamics is crucial to improving student outcomes in elementary statistics education.

Despite extensive research on meaningful learning and project-based learning (Chang et al., 2024) and its positive effects on student engagement in higher education and adult learning contexts (Bowden et al., 2021; Lo et al., 2024; Nkomo et al., 2021), there is limited empirical evidence on the implementation of meaningful learning specifically in elementary school statistics, where abstract concepts often hinder conceptual understanding (Polman et al., 2021). Existing studies primarily focus on older students, teacher preparation, or technology-mediated learning, while few investigate how active, contextualized, project-based activities influence elementary students' conceptual understanding, engagement, and reasoning skills. Moreover, research rarely integrates quantitative

assessments of learning outcomes with qualitative exploration of classroom processes, including factors supporting or inhibiting effective learning, particularly in under-resourced or rural elementary school settings (Hernáiz-Pérez et al., 2021; Wilson, 2021). This gap underscores the need for mixed-methods research examining both learning outcomes and implementation processes of meaningful learning in authentic, elementary statistics classrooms.

This study aims to examine the implementation of meaningful learning in elementary statistics education and its effects on students' conceptual understanding, engagement, and reasoning skills. Specifically, it seeks to explore how active, project-based learning activities facilitate students' comprehension of statistical concepts. The study also investigates factors that support or hinder the effective application of meaningful learning in classrooms. By employing a mixed-methods approach, it integrates both quantitative assessment and qualitative observation to provide a holistic understanding of the learning process. Another objective is to analyze how contextualized projects influence students' motivation and participation in class. The research further examines the role of teacher facilitation and classroom environment in enhancing learning outcomes. It also considers variations in student readiness and engagement across different classroom contexts. Insights from this study are intended to inform instructional strategies and curriculum development in elementary statistics education. The study aims to provide evidence-based recommendations for teachers to optimize learning experiences. Ultimately, the research contributes to bridging the gap between theoretical understanding and practical application of meaningful learning in elementary classrooms.

LITERATURE REVIEW

Meaningful learning is widely recognized as a pedagogical approach that enhances students' understanding by connecting new knowledge with existing cognitive structures. It emphasizes the integration of conceptual knowledge, contextual relevance, and active student participation in the learning process. In elementary mathematics education, meaningful learning has been associated with improved comprehension, retention, and problem-solving abilities (Kikas et al., 2020; Koskinen & Pitkäniemi, 2022; Lein et al., 2020; Polman et al., 2021). Studies in thematic and mathematics contexts indicate that linking lessons to students' experiences fosters motivation and engagement. Project-based learning has emerged as a complementary method to meaningful learning, enabling students to apply concepts to real-world tasks (Chang et al., 2024; Silma et al., 2024; Williamson, 2023). Evidence suggests that active participation through projects can enhance both cognitive and affective learning outcomes. The implementation of meaningful learning requires careful instructional design, teacher facilitation, and alignment with curriculum standards. Challenges often arise due to varying student readiness, limited resources, and abstract content. Addressing these challenges is critical to ensure that the learning experiences are authentic and impactful. The synergy between meaningful and project-based learning provides a strong foundation for fostering statistical literacy in young learners.

Research on student engagement highlights its critical role in learning effectiveness, particularly in mathematics and statistics education. Engagement encompasses behavioral, cognitive, and emotional dimensions that collectively influence achievement. Empirical studies show that students who actively participate in learning activities demonstrate higher levels of understanding and retention. Digital technologies, interactive activities, and collaborative learning strategies have been linked to enhanced engagement in classrooms (Gopinathan et al., 2022; Md Sabri et al., 2024; Ullah & Anwar, 2020; Zitha et al., 2023). However, much of the literature focuses on secondary or tertiary education, leaving gaps in elementary education research. Engagement in younger learners requires careful adaptation of instructional strategies to suit developmental levels.

Providing meaningful, contextually relevant tasks is essential to sustain attention and motivation. The integration of hands-on activities and real-life data contributes to experiential learning. Moreover, teacher guidance and scaffolding play a pivotal role in mediating engagement. Without such support, even well-designed tasks may fail to produce meaningful learning outcomes.

Statistical literacy in elementary students has received increasing attention in recent years, reflecting the importance of data-driven reasoning in modern society. Understanding concepts such as mean, median, and mode, along with the ability to interpret data, is foundational for future quantitative literacy (Frisby, 2024; Kotronoulas et al., 2023). Research indicates that students often struggle with abstract representations of data when instruction is procedural rather than conceptual. Contextual learning, in which students analyze real-world data, has been shown to improve comprehension and relevance. Mini-projects and classroom experiments allow students to construct knowledge actively and internalize statistical concepts. Nevertheless, evidence of systematic application of meaningful learning in elementary statistics remains limited. Many studies focus on general mathematics, with less attention given to the unique challenges of teaching statistics (Bakker et al., 2021; Bromage et al., 2022; Strohmaier et al., 2020). Effective interventions require both cognitive and affective considerations. Incorporating meaningful learning in statistics may also enhance students' critical thinking and reasoning abilities. A well-structured framework that integrates project-based and contextually relevant activities is therefore essential.

The implementation of meaningful learning in classroom settings is influenced by teacher practices, instructional materials, and learning environment. Teachers act as facilitators who guide students in linking prior knowledge with new concepts. Professional development and training in instructional strategies are necessary to maximize the benefits of meaningful learning (Darling-Hammond et al., 2020; Didion et al., 2020; Fernández-Batanero et al., 2022). Limited resources, large class sizes, and heterogeneous student abilities can constrain effective implementation. Research highlights the importance of designing tasks that are authentic, challenging, and collaborative (Cabbeke et al., 2025; Hussein, 2021). Peer interaction and group work provide opportunities for social constructivist learning. Assessment methods should also reflect conceptual understanding rather than solely procedural skills. Classroom observations suggest that students respond positively when they perceive tasks as meaningful and relevant. Providing timely feedback and opportunities for reflection strengthens knowledge construction. Overall, effective implementation depends on a combination of curriculum alignment, teacher competence, and supportive learning environments.

Finally, the literature underscores the potential of integrating meaningful learning with active, experiential, and project-based approaches in elementary education. Evidence suggests that such integration can enhance understanding, engagement, and reasoning across multiple subjects. Statistical education, in particular, benefits from contextualized projects where students collect, analyze, and interpret data. These practices help bridge the gap between abstract concepts and real-life application. Despite promising results, gaps remain in exploring mixed-methods approaches that combine quantitative and qualitative evaluation of learning outcomes. Few studies have examined how meaningful learning affects both conceptual understanding and classroom engagement simultaneously. Research in under-resourced and rural contexts is particularly scarce. Understanding these dynamics is critical to inform curriculum development and teacher training. Addressing these gaps can provide evidence-based strategies for improving elementary statistics education. Ultimately, a systematic approach integrating meaningful learning and project-based activities offers a pathway to more effective and engaging statistical learning for young learners.

METHOD

Research Design

This study employed a mixed-methods approach with an explanatory sequential design. Initially, quantitative data were collected through a student perception questionnaire to obtain an overview of students' responses to the implementation of meaningful learning in elementary statistics. The qualitative phase followed, involving participatory classroom observations, semi-structured interviews, and document analysis to deepen the understanding of quantitative results and explore contextual dynamics. The design was chosen to allow comprehensive insights into both outcomes and processes of meaningful learning implementation. The sequential approach enabled the integration of numerical data and in-depth qualitative perspectives. Quantitative analysis provided descriptive insights into student perceptions. Qualitative data allowed exploration of teaching strategies, student engagement, and contextual challenges. The approach is particularly suitable for understanding complex interventions in authentic classroom settings. Overall, this design facilitated a holistic examination of meaningful learning in elementary statistics.

Participants

Participants included 60 fifth-grade students from four elementary schools in Karangpandan sub-district who completed the perception questionnaire. Additionally, a purposive sample consisting of one class of 15 students and one teacher was selected for in-depth case study activities, including observation, interviews, and document collection. Inclusion criteria for the teacher included prior experience teaching statistics using meaningful learning approaches. The selected school, SD N 03 Dayu, was located in a peripheral area to provide a context differing from urban schools. Students' ages ranged from 10 to 12 years. Gender distribution in the questionnaire sample was balanced. Data collection occurred during the second semester of the 2024/2025 academic year. The purposive selection ensured that the class represented authentic application of meaningful learning. The sample provided sufficient diversity to explore variations in engagement and conceptual understanding. Ethical approval and informed consent were obtained from all participants.

Instruments

The instruments comprised a structured observation sheet for teacher strategies and student activities, a semi-structured interview guide for both teacher and students, document analysis including lesson plans and student work, and a student perception questionnaire using a 4-point Likert scale. The questionnaire included 15 items across five indicators: conceptual understanding, relevance of material, motivation, active participation, and satisfaction. Sample statements included tasks such as explaining mean, median, and mode in one's own words, connecting statistical concepts to daily life, and participating actively in mini-projects. Content validity was established through consultation with two mathematics education experts and one evaluation expert, achieving a CVI greater than 0.80. Reliability testing on 30 students outside the sample showed a Cronbach's alpha of 0.85. Data collection spanned February to July 2025. Questionnaires were administered after four instructional sessions. Observations were documented in field notes and structured templates. Interviews explored experiences, instructional strategies, and challenges during the learning process. Document analysis focused on instructional planning and student outputs.

Data Analysis

Quantitative data from the student questionnaire were analyzed using descriptive statistics, including percentage distributions of "Agree" and "Strongly Agree" responses for each indicator. Qualitative data were analyzed using thematic analysis following the Miles and Huberman model, including data reduction, data display, and conclusion drawing. Coding was applied to interview

transcripts and observation notes to identify key themes. Triangulation of multiple sources ensured data credibility. Member checking, thick description, audit trail, and confirmability were employed to enhance trustworthiness. Integration of quantitative and qualitative findings provided a holistic perspective on both outcomes and process. Patterns in student engagement, motivation, and conceptual understanding were examined. Qualitative insights complemented quantitative trends, highlighting contextual factors influencing meaningful learning implementation.

Procedure

The data collection procedure involved four steps. First, participatory classroom observations documented teaching strategies and student engagement during statistics lessons. Second, semi-structured interviews were conducted with the teacher regarding planning, implementation, and challenges, and with students regarding learning experiences and conceptual understanding. Third, document collection included lesson plans and student work for analysis. Fourth, the student perception questionnaire was distributed to 60 students after four sessions of meaningful learning activities. The study took place from February to July 2025. Ethical approval was obtained from the school principal, and informed consent was obtained from all participants. Data confidentiality was maintained, and findings were used solely for academic purposes. Researchers ensured minimal disruption to regular classroom activities. The procedure enabled triangulation of outcomes, processes, and contextual insights for a comprehensive understanding of meaningful learning implementation.

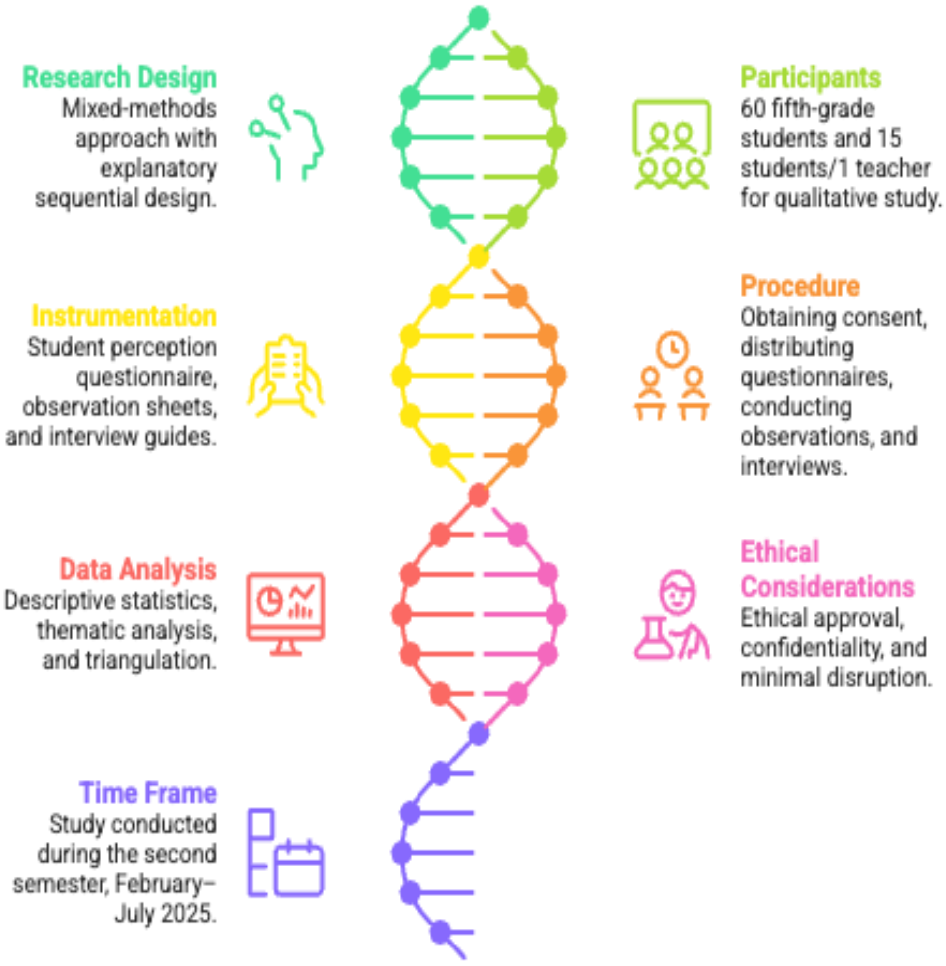

Figure 1. Research method flow

RESULTS AND DISCUSSION

Results

The case study conducted in elementary schools in Karangpandan sub-district produced findings from both qualitative and quantitative data sources, including classroom observations, interviews, document collection, and student questionnaires. The classroom teacher implemented meaningful learning by connecting statistical content with real-life contexts and mini-projects.

Implementation dynamics of meaningful learning in elementary statistics

In-depth observation was carried out in one fifth-grade class consisting of 15 students. Observational data revealed that the teacher applied meaningful learning principles through contextual and project-based strategies. A representative activity, the "Our Body Statistics" mini-project, required students to measure their peers' heights, record the data in tables, represent it in simple bar charts, calculate the mean, median, and mode, and present the results. Before initiating the mini-project, the teacher posed contextual questions to stimulate students' thinking and emphasize the relevance of statistical concepts in daily life. Students were grouped to facilitate discussion and collaboration. Group members coordinated roles and responsibilities to complete the worksheets and prepare reports. The classroom atmosphere was active and lively, with previously passive students demonstrating engagement in measuring, recording, and discussing data. Teacher facilitation included guiding questions such as "If the average height of your group is 130 cm, what does it mean?" and "Why are the medians different between groups A and B?" These activities demonstrated a shift from teacher-centered to student-centered learning, where students actively constructed their own knowledge.

Figure 2. The teacher poses contextual prompting questions about statistics.

Figure 3. Students confirm the mini-project tasks with the teacher.

Figure 4. Students carry out the mini-project activities.

Teacher and student responses

Interviews with the teacher indicated positive perceptions. The teacher reported that using students' own data helped them understand statistical concepts more concretely and reduced abstraction. Additionally, the teacher noted that teaching became more flexible, requiring fewer resources, which is particularly relevant in peripheral areas with limited facilities. Students expressed excitement and reduced anxiety during the activities. One student stated, "It's fun, like playing a guessing game but using mathematics. I realized calculating the average helps us understand the overall group condition." Another student added, "I was confused about the median at first, but sorting our heights helped me understand it by myself." These responses indicate that students internalized statistical concepts and developed a deeper understanding. During data collection and analysis activities, students worked in small groups to gather real data from their environment, such as measuring heights and counting books. They then applied these data to create frequency tables, bar charts, and calculate mean, median, and mode. This experiential approach made abstract statistical concepts concrete. Observational notes highlighted high levels of enthusiasm and active participation, with students discussing data, sharing tasks, and presenting their analyses. The teacher reported increased focus and participation, including students who were normally shy. Almost all students interviewed preferred learning by doing and found the approach enjoyable and meaningful.

Supporting and inhibiting factors

Key supporting factors included teacher creativity and commitment, which transformed abstract content into meaningful activities, and principal support providing autonomy in classroom instruction. Student enthusiasm and characteristics facilitated active interaction and guidance. The classroom environment was supportive, promoting a growth mindset and peer collaboration.

Inhibiting factors included time and resource limitations, as preparing worksheets and materials required extra effort and administrative time. Student readiness varied, with some requiring additional scaffolding. Limited access to statistical tools and media sometimes constrained activity complexity. Time allocation for lessons posed challenges, as explorations and discussions often exceeded scheduled periods, placing pressure on the teacher to cover content.

Quantitative Findings

Student perception questionnaires (N=60) indicated a highly positive response to meaningful learning implementation, as summarized in Table 1 below. The mean scores ranged from 3.25 to 3.67, and standard deviations indicated consistent responses. Notably, 100% of students recognized the relevance of statistical content to real life, reflecting effective

internalization of concepts. High percentages in conceptual understanding (93.3%) and motivation (93.3%) further confirmed that the approach not only enhanced interest but also improved conceptual comprehension.

Table 1. Summary of Student Perception Questionnaire on Meaningful Learning in Statistics (N=60)

Aspect Measured	Mean	SD	Percentage (%)
Increased conceptual understanding	3.42	0.51	93.3
Material relevance to real life	3.67	0.48	100
Increased motivation and interest	3.38	0.55	93.3
Student active participation	3.25	0.62	86.7
Satisfaction with meaningful learning	3.35	0.58	91.7

These results illustrate a strong impact of the meaningful learning approach on students' engagement and conceptual comprehension, supporting the educational principles of linking new knowledge to students' prior cognitive structures.

Discussion

The implementation of meaningful learning through the "Our Body Statistics" mini-project demonstrated a significant paradigm shift from teacher-centered to student-centered learning in elementary statistics education. Students actively engaged in measuring, recording, analyzing, and presenting data, which facilitated the construction of their own knowledge rather than passive reception of information. This approach aligns with theoretical perspectives on experiential learning, where connecting theoretical concepts to authentic activities enhances conceptual understanding. The mini-project enabled students to link abstract statistical ideas with tangible experiences, bridging the gap between theory and practice. Observational data revealed that students previously considered passive were now actively collaborating and debating to determine median and mode values (Choi & Hur, 2023; Hsiao et al., 2022). Teacher facilitation through guiding questions helped scaffold understanding and encouraged reflective thinking. The classroom environment became more dynamic, with students demonstrating curiosity, initiative, and accountability in group tasks (Bhardwaj et al., 2025; Peterson, 2020; Zitha et al., 2023). The use of simple tools, such as measuring tapes and millimeter graph paper, contributed to the concreteness of abstract concepts. Overall, these results indicate that meaningful learning can transform statistical learning into an active and relevant experience for students.

Quantitative and qualitative evidence collectively confirmed the effectiveness of meaningful learning in improving conceptual understanding and motivation. Student questionnaires reflected high levels of perceived relevance, understanding, and engagement, while interviews highlighted students' enjoyment and deeper comprehension of statistical concepts. The process enabled students to explain statistical ideas in their own words, demonstrating internalization of knowledge. These findings are consistent with prior studies on experiential and contextual learning, emphasizing that authentic, hands-on tasks enhance learning outcomes (Moser & Lewalter, 2024; Yao, 2023). Students' enthusiasm for data collection and analysis suggests that learning by doing can reduce anxiety and foster positive attitudes toward mathematics. The teacher's role evolved from information provider to facilitator, enabling personalized guidance and collaborative problem-solving. This approach reflects best practices in modern mathematics pedagogy, where active participation and meaningful contexts are prioritized. Students reported that connecting content to their own experiences increased motivation and understanding. The combination of observational, interview, and questionnaire data provided robust triangulation for assessing learning impact. These results underscore the critical role of interactive and contextually grounded strategies in elementary statistics.

Supporting factors such as teacher creativity, commitment, and effective instructional design were pivotal in the successful implementation of meaningful learning. The teacher designed activities

that transformed abstract statistical content into authentic tasks that were relevant to students' everyday lives. A supportive classroom culture, including a growth mindset and collaborative norms, further enhanced student participation and engagement. Students' intrinsic enthusiasm and active characteristics complemented the teacher's strategies, facilitating a mutually reinforcing learning environment. Principal support and institutional autonomy allowed the teacher to adapt instructional methods flexibly. Observational data indicated that even in resource-limited settings, students could engage meaningfully when tasks were well-designed and contextualized. Project-based activities promoted peer interaction, discussion, and problem-solving, fostering higher-order thinking skills (Bhaumik et al., 2024; Loyens et al., 2023). These elements collectively contributed to the construction of conceptual understanding and the internalization of statistical principles. Classroom discourse demonstrated natural development of mathematical reasoning through collaborative analysis and argumentation. The findings highlight the interplay between teacher capacity, student characteristics, and environmental support in effective learning implementation.

Despite the positive outcomes, several challenges limited optimal implementation, including time constraints, diverse student readiness, and limited instructional resources. Teachers had to invest additional time to prepare worksheets, set up mini-projects, and manage classroom logistics, which occasionally conflicted with administrative demands. Students unfamiliar with active or inquiry-based learning required scaffolding and additional support to participate effectively. Variations in students' prior knowledge necessitated differentiated guidance during activities. Limited access to technological tools and statistical manipulatives constrained the complexity and scale of projects. The fixed schedule of instructional periods often restricted time available for extended exploration and discussion. Nevertheless, these obstacles were mitigated through careful planning, the use of locally available materials, and fostering a culture of collaborative learning. The teacher strategically leveraged students' everyday experiences to provide accessible and meaningful contexts. This adaptive approach ensured that students remained engaged and achieved conceptual gains despite logistical challenges. These findings indicate that meaningful learning can be resilient and effective even in under-resourced educational environments.

The integration of authentic data collection and project-based activities significantly enhanced students' conceptual understanding and engagement. By measuring heights, compiling data, and performing statistical calculations, students experienced firsthand the relevance and application of abstract concepts. This method transformed statistical learning into a concrete and meaningful activity, facilitating the development of critical reasoning and problem-solving skills. Students' positive perceptions and active participation demonstrate the value of connecting academic content to their lived experiences. The approach aligns with contemporary perspectives on equitable mathematics education, emphasizing inclusivity, responsiveness, and the creation of accessible learning opportunities. Teacher observations indicated improved focus, increased confidence, and the willingness of students to express ideas and collaborate. Even with minimal technological support, the project provided a rich environment for meaning-making and skill development. These findings support the use of contextualized, project-based strategies in elementary mathematics curricula. Overall, the study highlights the potential of meaningful learning to transform abstract statistical concepts into engaging, relevant, and comprehensible experiences for students.

Implications

The findings of this study suggest that implementing meaningful learning through project-based activities in elementary statistics can significantly enhance both students' conceptual understanding and engagement. By integrating real-life data collection and analysis into classroom activities, students are able to construct knowledge actively and internalize statistical concepts more

effectively. The shift from teacher-centered to student-centered learning creates opportunities for deeper cognitive processing, critical thinking, and collaborative problem-solving. Teachers are encouraged to adopt contextualized instructional strategies that connect abstract mathematical concepts to students' daily experiences, thereby increasing relevance and motivation. Additionally, even in resource-limited or peripheral school settings, meaningful learning can be implemented successfully with simple materials and well-designed tasks. The study highlights the importance of teacher creativity, commitment, and scaffolding in facilitating student learning and maintaining equitable access to learning opportunities. School administrators and policymakers should recognize the value of allocating time and institutional support to enable extended exploration and active engagement in the classroom. Furthermore, formative assessments and reflection activities can be incorporated to monitor progress and reinforce conceptual understanding. The approach also promotes growth mindset practices, encouraging students to view mistakes as learning opportunities and fostering resilience. Students' positive responses indicate that meaningful learning can transform their attitudes toward mathematics, making it more enjoyable and personally relevant. These results imply that curriculum designers should consider integrating project-based, experiential learning into standard elementary statistics curricula. Overall, this study underscores the potential of meaningful learning to enhance educational outcomes and support the development of critical life-long statistical literacy skills.

Limitations and Suggestions for Future Research

This study has several limitations that should be acknowledged when interpreting the findings. First, the research was conducted in a single elementary school with a purposive sample, which may limit the generalizability of the results to other schools or regions. Second, the sample size for qualitative observations was relatively small, focusing on one class of 15 students and one teacher, which may not capture the full diversity of student experiences. Third, the study primarily relied on self-reported data through questionnaires and interviews, which may introduce bias in students' and teachers' perceptions. Fourth, the data collection period was limited to a single semester, restricting the observation of long-term effects of meaningful learning on students' statistical literacy. Fifth, technological limitations and resource constraints may have influenced the scope and complexity of the mini-projects. Sixth, variations in students' prior knowledge and readiness were not controlled, which could affect the consistency of engagement and outcomes. Seventh, teacher facilitation played a significant role, and differences in teacher expertise may yield different results in other contexts. Eighth, external factors such as classroom environment and administrative support were not systematically measured. Ninth, the study did not include a control group for comparative analysis with traditional teaching methods. Tenth, the focus was on statistical concepts, so findings may not fully apply to other mathematics topics. Eleventh, cultural and local contextual factors may limit the applicability of results to other educational settings. Therefore, future research should expand to multiple schools, include larger and more diverse samples, consider longitudinal designs, incorporate control groups, and examine the influence of teacher training, resources, and cultural context on the effectiveness of meaningful learning in elementary statistics.

CONCLUSION

The findings of this study indicate that the implementation of meaningful learning through project-based activities in elementary statistics significantly enhances students' conceptual understanding and engagement. Students actively participating in data collection, analysis, and presentation were able to internalize statistical concepts more effectively than through traditional teacher-centered approaches. The "Our Body Statistics" mini-project facilitated a shift from procedural learning to conceptual understanding by connecting abstract statistical principles to

authentic, real-life experiences. Quantitative and qualitative data consistently demonstrated improvements in motivation, participation, and comprehension among students. The approach also fostered collaborative learning, critical thinking, and problem-solving skills through peer interaction and group-based tasks. Teacher facilitation played a crucial role in scaffolding students' learning, guiding discussions, and supporting individualized understanding. The study also highlighted that meaningful learning can be successfully implemented even in resource-limited or peripheral schools using simple tools and contextualized tasks. Supporting factors included teacher creativity, student enthusiasm, and a supportive classroom environment, whereas challenges involved time constraints, student readiness variability, and limited instructional media. These findings suggest that meaningful learning is not dependent on advanced technology but rather on thoughtful instructional design and engagement with students' experiences. Furthermore, project-based and experiential approaches provide opportunities for equitable learning by making abstract concepts accessible and relevant to all students. Overall, meaningful learning in elementary statistics promotes both cognitive and affective development, creating a foundation for long-term statistical literacy. The study emphasizes the potential of contextualized, student-centered instruction to transform classroom practice and improve educational outcomes in mathematics.

AUTHOR CONTRIBUTIONS STATEMENT

Ema Butsi Prihastari was responsible for the research conceptualization, data collection, implementation of meaningful learning activities in elementary classrooms, statistical data analysis, and drafting of the manuscript. Wardono contributed to the research supervision, methodological validation, instructional evaluation, interpretation of the research findings, and critical revision of the manuscript. Scolastika Mariani assisted in data collection, classroom observation, and document analysis, providing support in ensuring data quality and consistency. Masrukan contributed to the development of research instruments, validation of questionnaires, and review of instructional design implementation. All authors participated in the development of the theoretical framework, analysis and triangulation of qualitative and quantitative data, and final manuscript review. All authors discussed the findings, approved the final version of the manuscript, and agreed to be accountable for all aspects of the research.

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