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Enhancing Students' Understanding of Statistical Concepts through the Implementation of Lesson Study in Android-Assisted Learning

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Abstract: The integration of interactive digital media in mathematics learning has been widely recognized as an effective approach to enhancing students' conceptual understanding, particularly in statistics, a subject that demands both procedural fluency and meaningful data interpretation. Interactive media-assisted learning enables students to engage with abstract statistical concepts through visualization, simulation, and hands-on data manipulation, thereby fostering deeper comprehension and sustained motivation. Building on this premise, this study develops and implements a lesson study framework integrated with an Android-based application to improve junior high school students' understanding of statistical concepts. The lesson study method involved three cyclical stages: Plan, Do, and See. During the planning stage, the research team and collaborating mathematics teachers conducted a needs analysis, identified students' learning difficulties, developed discovery-learning-based instructional modules, and designed an Android application with data input, visualization, and statistical simulation capabilities. The implementation stage involved classroom instruction supported by the application, with systematic observation using a researcher-developed structured classroom observation protocol that covered student engagement, instructional alignment, and the quality of technology integration. The instrument was reviewed and validated by two experts in mathematics education before implementation. The reflection stage focused on collaborative evaluation of the learning process to iteratively refine instructional design and application functionality. Quantitative classroom observation data showed increased student participation and task completion across the implementation cycles. In addition, qualitative findings from classroom observations and reflective notes indicated improvements in students' conceptual understanding and classroom engagement. The integration of technology into the lesson study model fosters a more contextualized, interactive, and reflective learning environment, thereby enhancing the quality of statistics instruction at the junior high school level.

Keywords: lesson study, Android application, statistics learning, student understanding, junior high school.

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INTRODUCTION

Mathematics education, particularly in the domain of statistics, occupies a central role in preparing students to navigate an increasingly data-driven world (Shimizu & Kang, 2022; Watson & Smith, 2022). At the junior high school level, statistics serves as a foundational subject that bridges abstract mathematical reasoning with real-world decision-making (Hariyanti et al., 2025; Kurnia et al., 2024; Muniz et al., 2022). However, numerous studies have consistently documented that students encounter substantial difficulties in mastering statistical concepts, ranging from data representation and interpretation to measures of central tendency (Jamil & Sulaiman, 2020; Miller & Finkelstein, 2018). These difficulties are frequently attributed to the predominance of conventional, lecture-based pedagogical approaches that prioritize procedural memorization over conceptual understanding, resulting in passive learning experiences that fail to engage students meaningfully with statistical reasoning (Anderson et al., 2019).

An increasing amount of research shows that integrating interactive digital media into mathematics learning is a powerful lever for improving student engagement, motivation, and understanding of concepts. Bright et al. (2024) found that technology-mediated instruction exerts a significant positive effect on students' mathematics performance, with students' interest serving as a key mediating variable. Similarly, Mayer (2009) established through extensive empirical work that multimedia learning combining visual representations with interactive manipulation substantially enhances the construction of mental models for abstract concepts. In the context of statistics education specifically, interactive tools that allow students to input real data, generate visualizations, and observe the immediate consequences of parametric changes have been shown to bridge the gap between symbolic notation and meaningful interpretation (Mulyadi & Setiawan, 2021).

The proliferation of Android-based mobile applications has opened new pedagogical possibilities for delivering such interactive learning experiences. Mobile applications offer accessibility, portability, and adaptability, enabling students to engage with learning materials beyond the constraints of the classroom (Yilmaz, 2020; Becker, 2020; Darlin et al., 2026). Features such as real-time graph generation, statistical simulations, and data entry interfaces make Android applications particularly well-suited to support the exploratory and discovery-oriented approaches that statistics learning demands (Abdullah et al., 2024; Weiland & Engledowl, 2022). Despite this potential, existing literature indicates a notable scarcity of educational applications specifically designed to support statistics learning at the secondary school level. Most available applications are either generic mathematics tools with limited contextual relevance or platforms intended for higher-education learners, whose complexity may exceed the digital literacy level of junior high school students (Kumar & Raza, 2019). The selection of Android as the delivery platform was informed by considerations of accessibility and portability (Yilmaz, 2020; Becker, 2020; Reychav et al., 2015), as Android devices constitute the majority of smartphones used by junior high school students in Indonesia.

Furthermore, the effectiveness of educational technology is strongly influenced by its perceived ease of use. Applications with complex interfaces may divert students' attention from learning activities toward operational difficulties, thereby reducing their pedagogical value (Davis, 1989).

Beyond the question of appropriate tools, effective statistics learning also requires a robust pedagogical framework that supports teacher reflection, collaborative instructional design, and continuous improvement (Schreiter et al., 2024). Lesson study, a Japanese model of professional development in which teachers collaboratively plan, observe, and reflect on instruction in iterative cycles, has emerged as one of the most evidence-based approaches to achieving these goals (Lewis, 2002; Fernandez, 2002; Baumfield et al., 2022; Richit et al., 2024). Buchholz and Keisler (2021) demonstrated the efficacy of lesson study in statistics instruction, showing that the iterative Plan-Do-See cycle enables teachers to identify and systematically address students' conceptual misconceptions. Dudley (2014) further argues that the reflective dimension of lesson study is particularly valuable in technology-integrated classrooms, as it provides a structured mechanism for evaluating whether digital tools genuinely advance learning objectives or merely introduce novelty. In Indonesia, Nurdiana (2022) found that implementing lesson study in secondary-level mathematics classrooms significantly improved both teachers' pedagogical competence and student learning outcomes, underscoring its applicability in the national educational context.

Despite these parallel advances, the integration of lesson study with Android-based digital applications in the specific domain of statistics education remains largely unexplored. Existing studies tend to examine either the use of mobile applications as standalone instructional tools, without embedding them within a reflective pedagogical framework, or lesson study as a teacher development strategy without the support of integrated digital media (Darling-Hammond et al., 2021). This bifurcation represents a meaningful gap in the literature, as it leaves unanswered the question of whether the combined model can produce learning improvements that neither component can achieve independently. Addressing this gap is particularly urgent given the Indonesian national curriculum's increasing emphasis on data literacy and statistical reasoning at the junior high school level, set against a backdrop of persistent underperformance in these competencies (Jamil & Sulaiman, 2020; Herlambang et al., 2025; Nusantara et al., 2026).

This study is informed by three complementary theoretical perspectives. Mayer's (2009) multimedia learning theory suggests that learning is enhanced when information is presented through both visual and verbal channels, with interactive features enabling active processing. Davis's (1989) Technology Acceptance Model proposes that users' acceptance of technology is determined by perceived usefulness and perceived ease of use, both of which are design considerations in the Android application. Bruner's (1961) discovery learning framework further suggests that students construct a deeper understanding when they actively explore concepts rather than passively receive information. The integration of these perspectives, multimedia design, technology acceptance, and discovery learning guided the instructional design and application development in this study.

Research Questions

The present study therefore aims to develop and implement a lesson study framework integrated with a purpose-built Android application, and to examine its effect on junior high school students' understanding of statistical concepts. In pursuing this aim, the study addresses the following research questions:

1. How is a lesson study-based learning model integrated with an Android application developed and implemented in junior high school statistics instruction?
2. To what extent does the implementation of Android-assisted lesson study improve students' understanding of statistical concepts across iterative learning cycles?
3. What pedagogical and technical factors influence the effectiveness of Android-assisted lesson study in the context of junior high school statistics learning?

METHOD

Research Design

The study followed an explanatory sequential mixed-methods design. Quantitative data were first collected to describe changes in student engagement and task completion across lesson study cycles. Qualitative evidence obtained through observations, reflection sessions, and student work was subsequently used to explain the observed quantitative trends and to provide deeper insight into the effectiveness of the Android-assisted lesson study implementation.

This study adopted lesson study as the primary research methodology. Lesson study is a collaborative, practice-based approach to instructional inquiry in which a team of educators engages in cyclical processes of joint planning, classroom implementation, and structured reflection with the explicit purpose of improving the quality of learning experiences (Lewis, 2002; Fernandez, 2002). As a research methodology, lesson study is distinguished from other forms of educational inquiry by its focus on the learning process itself, examining how instructional design, classroom interactions, and pedagogical decisions collectively shape the quality of student learning, rather than rendering evaluative judgments about individual teacher performance or student ability. This orientation made lesson study particularly appropriate for the present study, which sought to understand how integrating an Android-based application into a collaboratively designed learning environment could enhance the quality of statistics instruction at the junior high school level.

This study employed a mixed-methods approach with an explanatory sequential design embedded within the lesson study framework. Quantitative data were collected through structured classroom observations and learning assessments to identify changes in student participation and learning performance across cycles. These findings were subsequently interpreted and elaborated through qualitative data derived from observation notes, teacher reflections, student worksheets, and reflective discussions conducted during the See phase.

The study was conducted at SMP Negeri 9 Malang, a public junior high school in East Java, Indonesia. The lesson study team consisted of four members: one lead researcher and three collaborating mathematics teachers from SMP Negeri 9 Malang. The lead researcher coordinated the overall research process, facilitated collaboration among lesson study team members, conducted observer training, and supervised data collection and analysis throughout the study. The three collaborating teachers are certified mathematics educators actively teaching at SMP Negeri 9 Malang, each contributing practical classroom expertise and contextual knowledge of the learning environment. The lesson study was implemented across two cycles. Cycle 1 was conducted in Class VIII B and Cycle 2 in Class VIII C, with one mathematics teacher designated as the model teacher in each cycle and the remaining team members serving as structured observers.

The selection of Class VIII B and Class VIII C employed purposive sampling. These classes were chosen in consultation with the school because they were taught by the same mathematics teacher and exhibited comparable academic characteristics, as indicated by school records and prior mathematics performance. Such selection ensured consistency in implementing the lesson study cycles.

Data were collected through four instruments developed collaboratively by the lesson study team during the planning stage: structured classroom observation sheets, semi-structured teacher reflection sheets, student learning worksheets, and a structured conceptual assessment instrument. The conceptual assessment was administered as a pre-test and post-test to evaluate students' understanding of statistical concepts, including data representation, measures of central tendency, and data interpretation.

The conceptual assessment instrument consisted of open-ended and short-response items designed to measure students' ability to (1) select appropriate forms of data representation, (2) calculate and interpret measures of central tendency, and (3) draw evidence-based conclusions from statistical data. The instrument was reviewed by two mathematics education experts for content validity. A scoring rubric was developed collaboratively by the lesson study team to ensure consistent evaluation of student responses. The instrument was administered only in Cycle 2; Cycle 1 was dedicated to application orientation and foundational data collection, while Cycle 2 enabled full implementation, including both pre- and post-assessments.

The structured observation sheets also enabled observers to record the frequency of predefined student behaviors, including voluntary questions, task completion, and participation in group discussions. These quantitative indicators were used to monitor changes in student engagement across lesson study cycles and to complement the qualitative findings obtained from observations and reflective discussions. The observation sheets contained behavioral indicators organized into three domains (student engagement, instructional alignment, and technology integration quality), ensuring that observational focus remained on the learning process rather than on individual performance. Prior to implementation, all observers participated in a calibration session to align their understanding of each indicator and resolve interpretive discrepancies through discussion of sample classroom scenarios. This process was intended to enhance consistency in data collection across observers. However, formal inter-rater reliability statistics such as Cohen's Kappa or Fleiss' Kappa were not calculated in the present study.

Data were analyzed using a combination of quantitative and qualitative procedures. Quantitative data obtained from classroom observations were analyzed descriptively using frequencies, percentages, means, and comparisons across lesson study cycles. Qualitative data from observation notes, reflection sheets, interviews, student worksheets, and conceptual assessment responses were analyzed to identify recurring patterns related to student engagement, conceptual understanding, and technology integration.

The observation protocol combined qualitative field notes with structured behavioral recording. Observable student behaviors, including voluntary questioning, task completion, and participation in group discussions, were documented using a frequency-based tally system. Observers recorded the occurrence of predefined behaviors throughout each lesson, and the resulting frequencies were summarized descriptively to identify changes across lesson study cycles. In addition, qualitative notes were used to capture contextual information regarding classroom interactions and learning processes. The lesson study activities were carried out through three main stages: Planning (Plan), Implementation (Do), and Reflection (See).

Task completion was defined operationally as the successful completion of all worksheet components in accordance with the lesson objectives. A worksheet was categorized as "completed" when students (1) finished the required data representation tasks, (2) correctly performed the requested statistical calculations, (3) provided written interpretations of the results, and (4) formulated a conclusion supported by the analyzed data. Observer judgments were based on the presence and conceptual appropriateness of these four components rather than on task submission alone.

Planning Stage (Plan)

At this stage, the lesson study team convened to collaboratively design the statistics learning plan and the Android application that would support its implementation. The planning process was grounded in a systematic problem-identification procedure conducted using two complementary approaches. First, a document analysis of the national mathematics curriculum (Kurikulum Merdeka) was undertaken to identify the scope, sequence, and core competencies of statistics learning at the Grade VIII level. Second, semi-structured interviews were conducted with the three collaborating mathematics teachers to gather their professional insights regarding the specific aspects of statistics learning that students most frequently find challenging, the instructional strategies previously employed, and the perceived adequacy of available learning materials. The convergence of findings from these two procedures formed the empirical basis for selecting priority learning topics and designing the instructional modules and Android application features. (1) Identifying key topics and core competencies in statistics based on curriculum document analysis and teacher interviews; (2) Developing discovery learning-based teaching modules integrated with the Android application; (3) Developing student worksheets, structured observation instruments, and application user guidelines; (4) Designing the open class implementation scenario and assigning roles lesson study team members; (5) Establishing learning achievement indicators as the basis for evaluating the quality of the learning process.

The observation instruments were designed with specific behavioral indicators across three domains: (1) student engagement, operationalized as the frequency of on-task behavior, active participation in group discussions, and voluntary questioning; (2) instructional alignment, referring to the correspondence between planned and enacted learning activities; and (3) technology integration quality, assessed through student independence in operating the application and the frequency of technical difficulties encountered. Prior to implementation, all observers participated in a calibration session to ensure consistent interpretation and application of these indicators across the observation team.

Implementation Stage (Do)

This stage was conducted as an open class, with one member of the lesson study team serving as the model teacher. In contrast, the lead researcher and the two remaining collaborating teachers served as structured observers. The model teacher facilitated the instructional module and guided students in applying the Android application to engage with statistical concepts, including data collection, data presentation, and the interpretation of statistical measures.

Throughout the implementation, the observer team systematically documented the learning process using the structured observation sheets developed during the planning stage. Observational focus was directed toward the quality of student learning interactions, the degree of alignment between instructional plans and enacted activities, the appropriateness of application use at each stage of the lesson, and the emergence of any contextual factors that influenced the learning process. The use of pre-agreed observation instruments ensured that data collection remained consistent, focused, and comparable across observers.

Reflection Stage (See)

Immediately after the open class, the full lesson study team conducted a structured reflection session. Drawing on the completed observation sheets and field notes gathered during implementation, the team engaged in systematic discussion to evaluate the quality of the learning process, identify aspects of the instructional design that functioned effectively, and surface areas warranting refinement. Reflective discussion was grounded in observational evidence rather than subjective impression, ensuring that insights generated were both specific and actionable.

The outcomes of each reflection session were directly applied to revise the teaching modules, refine application features, and formulate instructional decisions for the subsequent cycle. This evidence-driven iterative process ensured that lesson study functioned not merely as a sequence of activities but as a genuine mechanism for continuous improvement of the learning experience, consistent with the foundational principles articulated by Lewis (2002), Dudley (2014), and Selamat et al. (2025).

RESULT AND DISCUSSION

Cycle 1

Planning stage (plan)

Throughout the planning process, several key activities were carried out, resulting in a preliminary product guided by a statistics learning design for an Android application. Intensive discussions were held among the lead researcher and three mathematics teachers at SMP Negeri 9 Malang, who served as collaborators. The main outcomes of the Plan phase are as follows:

1. Identification of priority topics

Based on curriculum document analysis and semi-structured teacher interviews conducted during the problem identification stage, the priority topics selected for this lesson study were: data collection, data presentation in the form of tables and diagrams, data processing (mean, median, and mode), and drawing simple conclusions from data.

The teacher interviews revealed that students' difficulties in these topics are not merely procedural but are rooted in specific conceptual challenges. Observer field notes documented several instances in which students used the terms *"mean" and "median"* interchangeably during group discussions. For example, one group explained that the *median* was obtained by summing all data values and dividing by the number of observations, reflecting a misunderstanding of the distinction between the two measures of central tendency. Students also demonstrated persistent difficulty with reading and constructing data visualizations, specifically, interpreting the vertical axis of bar charts and understanding what proportional segments in pie charts represent relative to the whole dataset. Furthermore, students showed limited ability to move between representations, that is, to recognize that a table, a bar chart, and a pie chart constructed from the same dataset convey equivalent information in different forms. These specific conceptual gaps, identified through teacher interviews and corroborated by curriculum competency mapping, informed the design of both the instructional modules and the interactive features of the Android application.

2. Development of teaching modules

The collaborative team developed teaching modules for two instructional sessions, integrating the Discovery Learning model with the Android application. The modules were designed with consideration of: integration of digital literacy activities, application usage procedures (login flow, data input, graph visualization), group work schemes and student discussions, and emphasis on critical thinking skills and data interpretation.

3. Development of learning media

At this stage, an initial prototype of the Android application was tested by the collaborating teachers on a limited basis to ensure basic functionality, including numeric data input, data presentation, and statistics problem simulations. Following this trial, the collaborating teachers provided structured feedback on the application's user interface (UI) design. Specifically, teachers noted that the data input screen displayed an excessive number of numeric fields simultaneously, which they anticipated would overwhelm students with limited prior experience with digital tools. Additionally, the graph visualization output was initially rendered at a fixed, small scale, making it difficult to read the axis labels clearly on standard smartphone screens. Based on this feedback, two concrete revisions were made to the prototype prior to classroom implementation: the data input screen was restructured into a stepwise entry format that presents one variable at a time, and the graph display was updated to support pinch-to-zoom functionality to enhance readability on varied screen sizes. These interface adjustments were made with explicit reference to Davis's (1989)

Technology Acceptance Model, which identifies perceived ease of use as a primary determinant of the effectiveness of technology adoption in learning contexts.

4. Development of observation and reflection instruments

The team developed structured classroom observation instruments and reflection sheets for use during the open class. As detailed in the Method section, the observation instruments contained behavioral indicators across three domains: student engagement, instructional alignment, and technology integration quality. A calibration session was also conducted prior to implementation to ensure inter-observer consistency in applying these indicators. The reflection sheets were designed to document post-open class discussion outcomes in a structured manner, capturing identified strengths, areas for improvement, and specific recommendations for the subsequent cycle.

5. Mapping of the open class scenario

It was also the planning meeting at which it was decided that the first open class would be held in Class VIII B at SMP Negeri 9 Malang, comprising 32 students. Teacher A (a pseudonym used to preserve participant confidentiality) would serve as the model teacher, with the other two teachers and the researcher as observers.

Findings from the Plan phase suggest that the lesson study methodology can guide teachers in facilitating the development of more innovative, context-specific learning in statistics through digital technology. This observation is in line with the findings of Lewis (2002), who highlights that lesson study is an effective method for teacher professional improvement through collaborative planning, observation, and reflection.

The teachers at SMP Negeri 9 Malang worked collaboratively to develop the teaching modules, allowing them to exchange ideas openly and identify practical strategies to support students experiencing learning difficulties. This aligns with Fernandez (2002), who found that lesson study allows teachers to learn from one another and build personal knowledge of instruction.

An Android app is expected to help students better understand abstract statistical concepts by enabling them to see and interact with data in a different way. Mayer (2009) argues that visual media and interactive technology can help students understand complex concepts by providing meaningful and practical representations. Furthermore, teachers' feedback on the interface design underscores the importance of implementing user-friendly guidelines to ensure that digital media effectively supports students' active engagement. This is in line with Davis (1989) in the Technology Acceptance Model (TAM), which states that perceived ease of use influences users' interest and the effectiveness of technology adoption in learning.

The observation instruments and reflection sheets developed serve as essential tools to ensure that lesson study implementation is measurable, evaluable, and continuously improved. This supports the principle of continuous improvement, which is central to lesson study, as emphasized by Dudley (2014), who describes it as an ongoing process of instructional enhancement grounded in reflection on actual classroom practices.

This Plan phase also demonstrates an increase in teachers' capacity to design learning across formats, transitioning from conventional teaching modules to interactive digital learning. Teachers are not only implementers but also designers and evaluators of instructional innovation, in line with the demands of teacher professionalism in the digital era (OECD, 2019). Therefore, the Plan phase serves as a crucial foundation to ensure that the Do and See phases are well-directed and have a meaningful impact on improving students' understanding of statistics at SMP Negeri 9 Malang.

Implementation stage (do)

In the Do phase, the learning process was implemented in Class VIII B at SMP Negeri 9 Malang, comprising 32 students. A mathematics teacher from SMP Negeri 9 Malang acted as the model teacher, while the other two teachers, together with the lead researcher, served as structured observers. The learning activities were conducted over two sessions, each lasting 2 × 40 minutes. The first session was designed to achieve two specific learning objectives: (1) students are able to collect, organize, and present data in the form of tables, bar charts, and pie charts using the Android application; and (2) students are able to explain the differences between data representation forms and identify which representation is most appropriate for a given dataset. The second session targeted three objectives: (1) students are able to calculate the mean, median, and mode of a dataset using both manual methods and the application's automatic calculation features; (2) students are able to interpret the meaning of each measure of central tendency in relation to the context of the data; and (3) students are able to draw simple, evidence-based conclusions from the results of their data analysis.

The teacher began the lesson by relating statistical concepts to students' daily lives, using data on height, weight, and agricultural yields in their surroundings. After that, the students were directed to access the Android application to process and display data in tables and diagrams. Some students still needed assistance with the login process and navigating the application's basic features during the initial phase of the session. Figure 1 illustrates the implementation of the Android-assisted statistics learning activities during Cycle 1.

Figure 1. Example of implementation in cycle 1 (android-based statistics learning application interface used during data entry activities)

The teacher then assigned the students discovery-based tasks, having them gather simple data in the classroom. The application generated pie and bar charts of the students' recorded heights within each group. The students demonstrated visible enthusiasm as they observed real-time data visualizations on their own devices. The teacher facilitated small group discussions to guide students in making sense of the data. The observer team documented student engagement levels, inter-student interactions, and responses to the digital application. Observations indicated that collaborative dynamics within groups were productive. However, some students who were more accustomed to conventional lecture-based approaches required additional time to orient themselves to the discovery-based task structure.

In the main activity, the teacher guided students in examining the results of the mean, median, and mode calculations produced by the application's automatic features. Students explored the differences among the values obtained and attempted to articulate their meaning in relation to their classmates' height data. Discussions were lively, and several students began to demonstrate nascent critical thinking by constructing logical arguments about the implications of the calculation results. The teacher supported conceptual bridging by explicitly connecting the application outputs to manual calculations demonstrated on the board, helping students understand that both methods yield equivalent results through different processes.

At the close of the lesson, a brief reflection session was conducted jointly by the teacher and students. Student responses were collected through an open-ended written exit slip administered at the end of the second session, in which students were asked to describe their experience of application-based learning, identify one concept they found clearer as a result of using the application, and note any difficulties they encountered. This instrument provided structured, documentable feedback that could be systematically analyzed alongside the observational data. Based on the exit slips collected at the end of Cycle 1, 27 of the 32 students (84.4%) indicated that the learning process was more engaging and that the ability to observe data analysis results visually facilitated their understanding. The observer team and the lead researcher also held an initial discussion to evaluate the application's effectiveness, the teacher's strategies for facilitating discussions, and technical aspects that require improvement for the next cycle.

Regarding the technical difficulties encountered during this session, the primary obstacle was the instability of the school's Wi-Fi network, which caused intermittent disruptions when students attempted to access the application's cloud-based graph rendering feature. This connectivity dependency was an architectural limitation of the Cycle 1 application prototype, which required a stable internet connection to generate and display visualizations. This issue was distinct from students' device capability, as all participating students possessed compatible smartphones; the constraint was therefore infrastructural rather than individual. This diagnosis informed the specific technical remediation undertaken in the planning stage of Cycle 2, namely the development of an offline mode that removed the application's dependency on continuous network connectivity.

Overall, the implementation of the Do phase in Cycle 1 proceeded constructively and provided meaningful first experiences for both teachers and students in utilizing digital technology as a tool for learning statistics at the junior high school level.

Reflection stage (see)

The See phase was conducted immediately following the completion of Cycle 1's learning implementation and classroom observation. The reflection session involved the mathematics teacher from SMP Negeri 9 Malang, the lead researcher, and two observer teachers, who engaged in a structured discussion grounded in the field notes and observation sheets collected during the open class. The model teacher opened the discussion by presenting a narrative account of the classroom experience, including students' responses to the application and the technical constraints encountered during the session.

Figure 2 summarizes the findings from the Cycle 1 reflection and the corresponding instructional and technical revisions implemented in Cycle 2. The identified challenges included

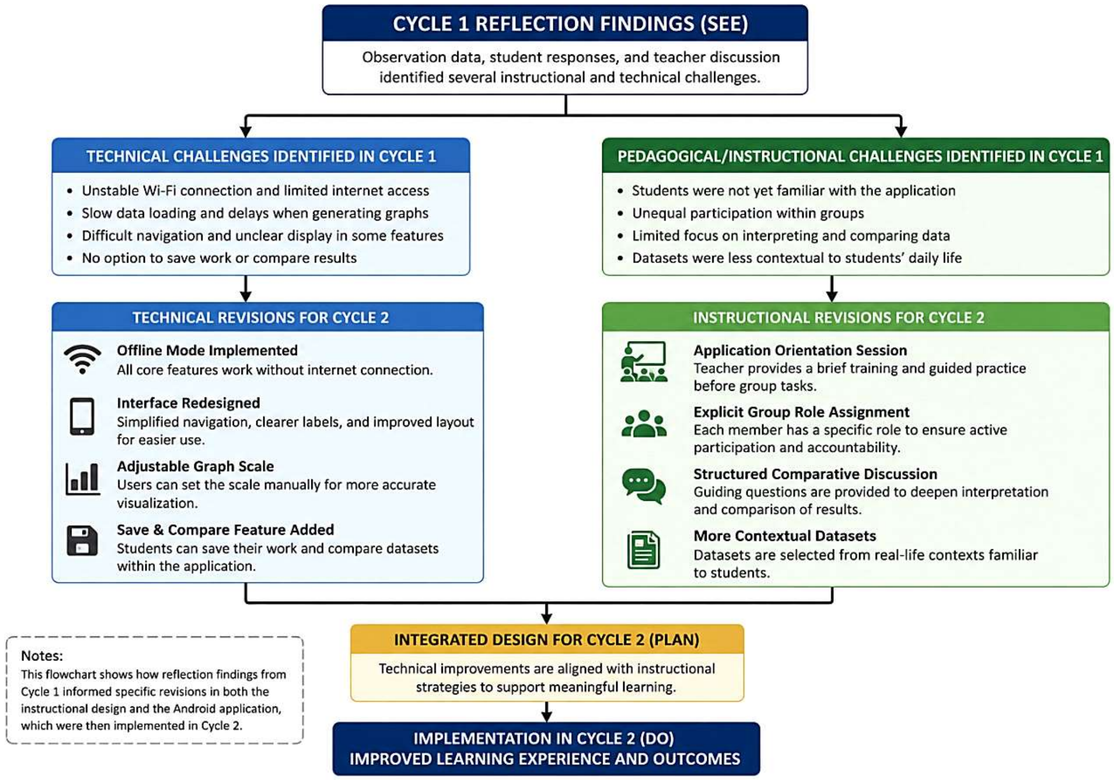

Figure 2. Instructional and technical revisions derived from cycle 1 reflection and implemented in cycle 2

unstable Wi-Fi connectivity, students' unfamiliarity with the application, and unequal participation during group activities. These findings informed the development of an offline mode, application orientation sessions, interface improvements, and more structured collaborative learning activities.

The reflection session identified several strengths in the Cycle 1 implementation. Student engagement was notably high during application-based activities; the discovery-oriented task structure generated sustained collaborative interaction and active participation that extended beyond what the observer team typically documented in conventional lecture-based lessons at the same school. The immediate visual feedback provided by the application, particularly the real-time rendering of bar and pie charts, appeared to support students' transition from symbolic data to graphical representations, facilitating comprehension of concepts typically presented in static, textbook-bound formats. The model teacher also noted that the application's capacity to display calculation outputs instantaneously enabled more fluid explanations of measures of central tendency during the guided discussion phase.

Alongside these strengths, the reflection session also identified several areas requiring improvement. A subset of students did not possess personal devices, necessitating device-sharing arrangements that limited individual interaction with the application. The school's Wi-Fi infrastructure proved insufficiently stable to support simultaneous access to applications by 32 students, resulting in repeated disruptions during the graph visualization activity. Additionally, several students demonstrated limited prior experience with data-oriented digital tools, which required additional facilitation time during the application's initial navigation phase and temporarily reduced the time available for conceptual discussion.

A critical reflection emerging from Cycle 1 concerns the inadequacy of the initial needs analysis conducted during the planning stage. Although the lesson study team systematically analyzed curriculum requirements, identified students' learning difficulties, and reviewed instructional needs, no formal audit of the school's technological infrastructure was undertaken prior to implementation. Consequently, the stability of the Wi-Fi network and its capacity to support simultaneous access by an entire class were assumed rather than empirically verified. The connectivity disruptions encountered during Cycle 1 therefore revealed a limitation not only of the application prototype but also of the planning process itself. This oversight highlights the importance of including infrastructure readiness assessments such as network capacity testing, device compatibility checks, and contingency planning as an integral component of technology-enhanced lesson study. The lesson study team acknowledges this omission as a methodological weakness in the initial planning stage and addresses it in Cycle 2 by developing an offline mode and conducting a more systematic evaluation of technical readiness.

Based on these reflective findings, the lesson study team reached consensus on three specific improvements to be implemented in Cycle 2. First, a structured application orientation session would be conducted at the outset of each learning meeting, covering login procedures, data entry, and graph navigation to reduce navigational demands during the core learning activity. Second, the application development team would integrate an offline mode into the Cycle 2 prototype, eliminating the dependency on network connectivity that had disrupted Cycle 1 implementation. Third, group discussion activities would be restructured to assign explicit roles to each group member including data entry, graph interpretation, and reporting to ensure equitable participation and prevent passive engagement.

The reflection exercise further reinforced the value of sustained collaboration between the lead researcher and the classroom teachers in the iterative refinement of instructional design. Each team member contributed a distinct observational perspective, and the convergence of these perspectives produced a more comprehensive diagnosis of the learning process than any single observer could have achieved independently. This finding is consistent with Dudley's (2014) characterization of the See phase as a mechanism for reconstructing professional understanding through the collective analysis of real classroom evidence. Consequently, the reflective process in Cycle 1 served not only to identify technical and pedagogical shortcomings but also to strengthen the collaborative professional culture that is foundational to effective lesson study implementation.

Cycle 2

Planning stage (plan)

Planning activities in the second cycle were conducted as a direct response to the reflective findings of Cycle 1, which identified the need for improvement in both the technical and pedagogical dimensions of Android-assisted statistics learning. Three planning meetings were held involving the lead researcher and three collaborating mathematics teachers of SMP Negeri 9 Malang. These meetings focused on three principal areas of refinement: improving students' technical readiness prior to the core learning activity, optimizing the application's functionality to remove infrastructural barriers to engagement, and deepening the quality of students' conceptual engagement with statistical data in contextually meaningful settings.

The conceptual assessment instrument described in the Method section was administered in Cycle 2 to provide additional evidence of students' conceptual understanding. This instrument consisted of a written conceptual assessment containing items designed to evaluate students' ability to: (1) identify appropriate data representation forms for given datasets; (2) calculate and interpret measures of central tendency; and (3) draw evidence-based conclusions from visual data representations. The pre-session assessment was administered at the beginning of the first meeting of Cycle 2 to establish a baseline understanding. In contrast, the post-session assessment was administered at the close of the final meeting to document learning progression. Student responses were qualitatively examined to identify patterns of conceptual understanding, common misconceptions, and persistent learning difficulties. The assessment was used as a diagnostic tool to complement classroom observations, reflection notes, and student worksheets rather than as a standardized quantitative measure of learning gains.

Based on the discussion results, the following improvements to the learning process were agreed upon. First, a dedicated application orientation session would be conducted at the outset of each meeting, covering login procedures, data entry, and navigation of the updated features. Second, the development team revised the application to incorporate an offline mode, enabling full functionality without dependency on network connectivity. Third, the user interface was redesigned in response to the specific feedback gathered in Cycle 1. The data input screen, which teachers had identified as visually overwhelming, was restructured into a stepwise entry format. The graph display was updated to support adjustable scaling. Additionally, a new "save and compare" feature was introduced, enabling students to store multiple datasets and generate side-by-side visual comparisons a functionality directly motivated by the Cycle 1 finding that students struggled to connect data from different groups during discussion activities. These interface revisions were guided by the principle that perceived ease of use is a foundational determinant of effective technology adoption in learning environments (Davis, 1989).

The instructional modules were also revised and extended into three sessions, with a stronger emphasis on pattern recognition and the interpretation of data analysis outputs. The Discovery Learning model was retained but supplemented with structured comparative discussion activities, in which students were asked to relate data visualizations to real-life contexts, including trends in examination scores, library visitor frequency, and school environmental cleanliness data. These contextual anchors were selected based on teacher interview findings from the problem identification stage, which indicated that students demonstrate deeper engagement when statistical tasks are connected to phenomena within their immediate school environment.

The observation instruments and reflection sheets were also refined for Cycle 2. The observation form was expanded to include indicators of cognitive engagement, specifically students' ability to generate data-based interpretations and pose questions that reflect deeper analytical thinking. The open class for Cycle 2 was planned to be held in Class VIII C at SMP Negeri 9 Malang, comprising 31 students, with the same model teacher as in Cycle 1.

Implementation stage (do)

In Cycle 2, the Do phase was implemented in Class VIII C at SMP Negeri 9 Malang, comprising 31 students, with a school mathematics teacher serving as the model teacher. The learning activities were conducted over three meetings, each lasting 2 × 40 minutes. As a preliminary activity before the core learning tasks, the teacher delivered a structured orientation session covering login procedures, data entry, and navigation in offline mode a direct remediation of the connectivity barriers encountered in Cycle 1. This orientation ensured that students could engage independently with the application from the outset of each session without diverting instructional time to technical troubleshooting.

Figure 3. Example of implementation in cycle 2

Figure 3 illustrates students' engagement in comparative data analysis activities using the "save and compare" feature. Through this activity, students compared datasets generated by different groups and formulated evidence-based interpretations regarding observed variations.

Each meeting was structured around specific learning objectives. The first meeting focused on students' ability to collect observational data from their immediate school environment and represent it accurately in tabular and graphical forms using the application. The second meeting focused on the calculation and contextual interpretation of mean, median, and mode, with students required to articulate, in writing on their worksheets, the meaning of each measure in relation to the specific dataset they had generated. The third meeting introduced comparative data analysis, in which students used the application's "save and compare" feature to juxtapose datasets collected by different groups and identify patterns of variation across the class. These progressive objectives were designed to move students from procedural data handling in the first session to interpretive and comparative reasoning by the third session, consistent with the cognitive progression emphasized in discovery learning frameworks (Bruner, 1961).

Following this, the teacher facilitated activities in which students compared datasets from different groups using the "save and compare" tool in the application software. This was made possible by the tool, which helped learners identify differences in data distribution among the various groups. This process sparked curiosity among learners, who asked questions such as what causes differences in outcomes and why there is variation in diagrams. The teacher then helped learners focus on presenting valid statistical information.

Quantitative indicators recorded through the structured observation protocol revealed measurable improvements in student engagement during Cycle 2. The frequency of voluntary student questioning, one of the behavioral indicators on the observation sheet, increased from an average of 3.2 questions per group in Cycle 1 to 6.7 in Cycle 2. Observer field notes also recorded a marked reduction in off-task behavior during the application navigation phase, consistent with the elimination of the connectivity barriers that had disrupted Cycle 1. The proportion of groups that completed all worksheet tasks within the allotted time increased from approximately 60% in Cycle 1 to 87% in Cycle 2, reflecting improved instructional efficiency, attributable in part to the structured orientation session and in part to the removal of technical interruptions in the offline mode. Task completion was determined using the worksheet completion criteria described in the Method section, which required students to complete data representation, calculation, interpretation, and conclusion-drawing activities. Task completion was operationally defined as the successful completion of all worksheet components, including data representation, calculation, interpretation, and conclusion-drawing, in accordance with the lesson objectives. These observational indicators collectively suggest that the Cycle 2 implementation produced a more sustained and equitable learning engagement than was achieved in the preceding cycle.

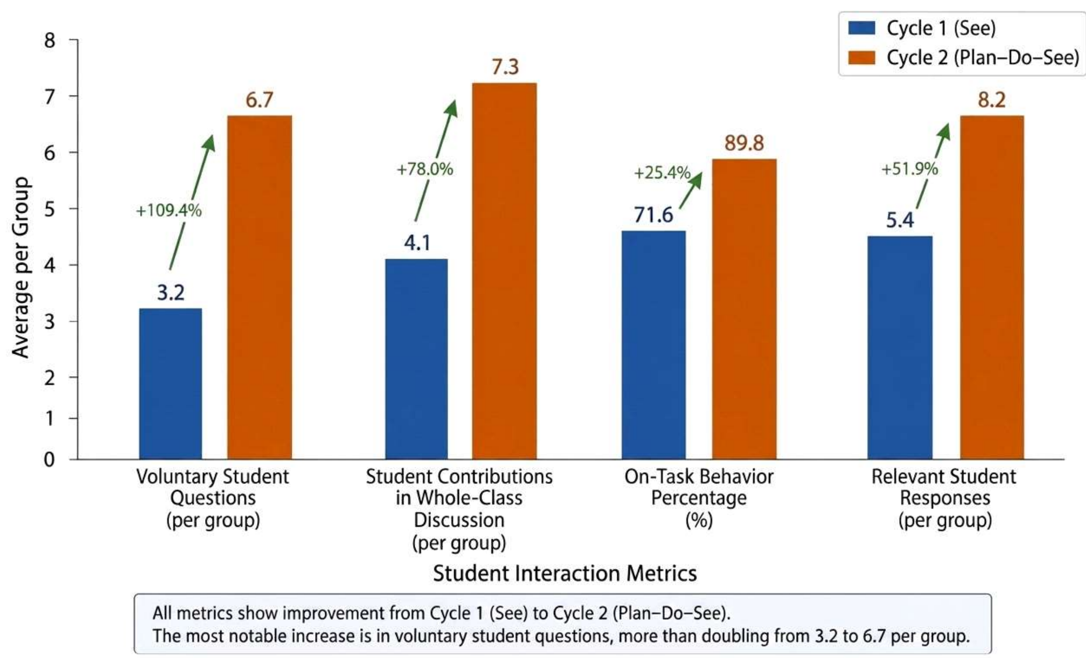

Figure 4. Changes in student interaction indicators across lesson study cycles

Figure 4 presents a visual comparison of student interaction indicators observed across the two lesson study cycles. The most notable improvement was in voluntary student questioning, which increased from an average of 3.2 questions per group in Cycle 1 to 6.7 in Cycle 2. In addition, the proportion of groups completing all worksheet tasks increased from approximately 60% to 87%, indicating greater student engagement and instructional efficiency following the revisions implemented after Cycle 1.

Following the group activities, the teacher facilitated a whole-class discussion in which representatives from each group presented their comparative findings. The use of the "save and compare" feature prompted substantive inter-group dialogue, with students raising questions about the sources of variation in their respective datasets and proposing contextual explanations for the differences observed. The teacher guided students toward statistically grounded explanations, reinforcing the connection between visual data representations and their underlying mathematical meanings.

Reflection stage (see)

The See phase in Cycle 2 was conducted after the final learning session and involved the mathematics teacher, the lead researcher, and two collaborating teachers. Reflective processes in Cycle 2 took the form of a thorough discussion to assess how well the learning process was implemented, students' responses, and the improvements applied in response to reflections from Cycle 1. Overall, learning implementation in Cycle 2 was smoother than in the previous cycle. Students demonstrated higher levels of observable engagement during learning activities and were able to use the application more independently compared with Cycle 1. Moreover, the teacher showed better competence in managing time and conducting classroom discussions. In addition, the learning process was characterized by greater student participation, more active group discussions, and fewer technical interruptions compared with Cycle 1. Figure 4 illustrates reflective processes in Cycle 2.

Figure 5. Collaborative reflection session used to identify instructional and technical revisions for cycle 2

The reflection session shown in Figure 5 served as the basis for identifying instructional and technical improvements, including the introduction of an offline mode, structured application orientation, and explicit group role assignments.

From the findings, it can be concluded that the students became more engaged in the learning process and were able to use the application independently, without encountering any technical problems, while performing operations such as entering data, creating diagrams, and explaining the results of calculations. It was observed that teachers who collaborated in the process noticed increased interaction among students when working in groups. Students participated more actively in classroom discussions and provided data-based explanations more frequently during group activities.

Apart from increasing student engagement, another achievement noted in the reflection was an improvement in students' understanding of statistical ideas. The students started to see how the representation of the data was connected with its meanings. According to the model teacher, most students had made some inferences about the data-processing outcomes and the results presented by the application. The use of digital media helped students understand how numbers and graphs, such as bar and pie charts, were connected.

The reflection session also highlighted the effectiveness of the specific improvements implemented between cycles. The offline mode was unanimously identified by the observer team as the single most consequential technical improvement, as it removed the infrastructural barrier that had been the primary source of disruption in Cycle 1 and allowed the model teacher to maintain instructional momentum throughout all three sessions. The structured application orientation, conducted at the outset of each meeting, reduced the amount of time required for technical assistance and enabled students to engage more independently with the application. Observer notes indicated fewer navigation-related interruptions during Cycle 2, allowing greater continuity in the learning process and more time for statistical discussions.

The collaborative dynamics of the lesson study team were also evaluated during the reflection. Each observer contributed distinct analytical perspectives grounded in their respective areas of expertise: the lead researcher focused on the alignment between instructional design principles and enacted activities, while the classroom teachers drew on their knowledge of students' prior learning histories to interpret behavioral patterns observed during the sessions. This division of observational focus ensured comprehensive coverage of the learning process and yielded a richer collective analysis than a single-observer approach would have. Darling-Hammond et al. (2021) similarly found that the collaborative structure of lesson study generates professional learning that is more sustained and contextually grounded than individual reflection practices.

The reflection further revealed two areas for potential future development. First, while the three-session structure of Cycle 2 provided greater depth than the two-session structure of Cycle 1, several groups indicated on their worksheets that they would have benefited from additional time for the comparative analysis activity in the third session. Second, the range of real-world data contexts, while expanded relative to Cycle 1, could be further enriched in future implementations by incorporating datasets sourced from students' own environments such as household energy consumption or local weather patterns to maximize the personal relevance of statistical inquiry. These observations do not diminish the achievements of Cycle 2 but rather point to productive directions for the continued development of the lesson study model beyond the scope of the present study, consistent with the principle that lesson study is, by nature, an ongoing rather than a terminal process (Lewis, 2002).

Overall, the See phase of Cycle 2 confirms that the systematic, evidence-driven improvements implemented between cycles produced a measurably higher quality learning process. The integration of an offline-capable Android application within a collaboratively designed and reflectively refined lesson study framework demonstrates that technology-enhanced statistics learning can be made both accessible and intellectually substantive at the junior high school level, provided that pedagogical design and technological development proceed in genuine dialogue with one another (Mishra & Koehler, 2006; Ruthven, 2012).

CONCLUSION

This study demonstrates that the development and implementation of Android-assisted lesson study contribute significantly to improving the quality of statistics learning at the junior high school level. The combination of collaborative lesson study and digital learning media provides an interactive, reflective, and learner-focused learning process. The findings suggest that integrating lesson study with the Android application supported students' engagement with statistical concepts and facilitated meaningful learning activities related to data representation, interpretation, and discussion.

The unique aspect of this study is the integration of lesson study with an Android application, which enables an efficient balance among technology, pedagogy, and content. This integration leads to a new method for learning mathematics that adapts to new technologies without compromising its core principles.

Regarding implications, the study has provided a guide for teachers to develop technology-based lesson studies in mathematical learning, specifically in statistics. For future work, it is recommended that further technical improvements be made to the application regarding access and usability. Future work could include applying the tool to other subjects and educational levels.

One limitation of this study is that inter-rater reliability statistics were not formally calculated. Although observer calibration sessions were conducted to promote consistency in interpreting observation indicators, future studies should incorporate statistical measures of observer agreement, such as Cohen's Kappa or Fleiss' Kappa, to strengthen methodological rigor. Because the study did not employ a standardized quantitative learning assessment with inferential statistical analysis, conclusions regarding learning improvement should be interpreted as being based on observational and qualitative evidence rather than on statistically verified achievement gains.

For future work, three directions are recommended: (1) technical improvements to the application to enhance accessibility and usability; (2) application of the tool to other mathematical topics and educational levels; and (3) incorporation of student voice through systematic interviews or focus groups to capture their perspectives on the learning experience. These directions build on the foundation established in this study and align with the principle that lesson study is by nature an ongoing rather than a terminal process (Lewis, 2002).

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DECLARATION OF GENERATIVE AI USAGE IN THE WRITING PROCESS

During the preparation of this manuscript, the authors used ChatGPT (OpenAI) to assist with language editing, grammar improvement, text refinement, and enhancement of academic writing clarity. All outputs generated by the AI tool were critically reviewed, revised, and validated by the authors. The authors assume full responsibility for the final content of the manuscript, including its accuracy, originality, and scientific integrity.

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