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Development of Statistics Instruction Based on Authentic Data to Improve Students' Statistical Reasoning and Data Literacy

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ABSTRACT

This study aims to develop and evaluate the effectiveness of an authentic data-based statistics learning model in improving students' statistical reasoning and data literacy. A pre-experimental one-group pretest-posttest design was used within a research and development (R&D) framework, involving 40 students from relevant degree programs at Universitas Islam Kebangsaan Indonesia (UNIKI). The research instruments included tests of statistical reasoning and data literacy, which were validated by experts and tested for reliability, as well as observations and focus group discussions. The results of the paired t-test analysis showed a significant increase in both variables following the implementation of the learning model. The mean statistical reasoning score increased from 65.7 (pretest) to 85.2 (posttest) with $p < 0.001$ and Cohen's d of 1.25 (large effect). Meanwhile, data literacy scores increased from 62.3 (pre-test) to 82.5 (post-test), with $p < 0.001$ and Cohen's d of 1.18 (large effect). Further qualitative analysis suggested that the experience of working with authentic, and often complex, data fostered students' motivation and critical and analytical thinking, as perceived by the students, making the material more relevant and engaging. This study expands the framework of authentic learning by positioning direct interaction with real data as a key mechanism for internalizing statistical concepts and developing 21st-century competencies. Pedagogical implications suggest a shift in the statistics curriculum toward hands-on experiences with authentic data and the reinforcement of data literacy as an essential competency.

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INTRODUCTION

The low level of statistical reasoning and data literacy among college students is a major issue in higher education today. Preliminary data show that students at Universitas Islam Kebangsaan Indonesia (UNIKI) still have low levels of statistical reasoning and data literacy. These skills are crucial for meeting the demands of the information age, which relies heavily on data. Students need to be able to effectively interpret, evaluate, and communicate data-based information in various disciplinary contexts. Statistical literacy is understood as the

ability of adults to read, interpret, and critically evaluate statistical information encountered in daily life and professional contexts (Gal, 2002) .

Conventional statistics instruction often focuses on computational procedures and mathematical formulas, without emphasizing conceptual understanding and real-world applications(Anjani et al., 2023) . This approach does little to foster the development of deep statistical reasoning and data literacy(Kurniawati et al., 2022) . Students tend to have difficulty applying statistical concepts to real-world problems or correctly interpreting the results of data analysis. Watson & Callingham (2003) assert that statistical literacy is a hierarchical construct that develops from a basic understanding of statistical terms to the ability to critically evaluate complex data-based claims.

Previous research has shown that problem-based learning models can improve students' mathematical reasoning skills (Kustiaman, 2020) . The development of instructional materials using the Problem-Based Learning (PBL) model for statistics has also been proven effective for junior high school students (Aprilia, 2022) . The PBL model is effective in improving students' problem-solving skills and mathematical dispositions, especially when integrated with e-learning (Kurniawati et al., 2022) .

These studies have not specifically integrated the systematic use of authentic data into the statistics curriculum. Most still rely on simulated or pre-cleaned data, which fail to reflect the complexity and challenges of real-world data. This gap indicates that a more comprehensive approach is needed to prepare students to deal with authentic data that is varied and often imperfect. The authentic learning framework emphasizes that direct engagement with real-world problems and data fosters more meaningful and lasting learning compared to purely procedural instruction(Lombardi, 2007) .

Research on improving students' mathematical literacy through problem-based learning models indicates that these skills remain relatively low due to a lack of variety in learning models(Kiawati et al., 2023) . This aligns with the need for innovation in statistics education. Low levels of students' mathematical literacy in statistics have also been reported at other

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educational levels, indicating that this issue is cross-level in nature and requires more contextual learning interventions (Yunita et al., 2026) . The development of a statistics learning module integrated with Islamic values has also been carried out, resulting in an engaging module that falls into the high category based on N-Gain calculations (Ekawati et al., 2019) .

This study aims to develop effective, authentic-data-based statistics instruction to enhance students' statistical reasoning and data literacy. This development model will address the limitations of conventional methods by providing a more relevant and challenging learning experience. It is hoped that students will develop a strong conceptual understanding as well as robust practical skills.

The novelty of this study lies in the construction of a learning model that explicitly integrates authentic data as the core of the statistics learning experience, unlike previous studies that tended to use simulated data or limit the context. This model examines the simultaneous contribution of authentic data-based learning to the improvement of students' statistical reasoning and data literacy within a single integrative conceptual framework, an approach that has not been extensively studied in tandem within the context of higher education in Indonesia. An international literature review defines data literacy as the ability to critically collect, manage, evaluate, and apply data, which is an essential competency in the era of a knowledge-based economy (Ridsdale et al., 2015). A recent systematic review reports that authentic problem-solving with real-world data is an effective approach for promoting statistical and data literacy, yet integrated perspectives on statistical and data literacy within STEM subjects remain limited, and that review was restricted to K-12 education (Friedrich et al., 2024). The present study addresses this gap at the higher-education level by developing a validated instructional design based on authentic data and by testing its association with gains in both competencies.

This study will contribute in two main ways. First, theoretically, this study provides empirical evidence regarding the effectiveness of statistics learning based on authentic data

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in developing two important 21st-century skills. Second, practically, this study produces a learning model that can be adopted by other higher education institutions to address students' low levels of statistical reasoning and data literacy. A comprehensive review of various levels of education in Indonesia further confirms that strengthening statistical literacy remains a challenge that requires serious attention from educators and curriculum developers (Prihastari, 2022) .

Improving students' data literacy and statistical reasoning is a crucial focus in contemporary education, given the complexity of data in today's information age. The concept of data literacy encompasses an individual's ability to understand, manage, analyze, and communicate data effectively, which is an essential prerequisite for evidence-based decision-making. Developments in statistical literacy at the secondary school level indicate that these skills develop gradually as students gain more experience interacting with data; therefore, their reinforcement must continue through the college level (Callingham & Watson, 2017) . The integration of innovative learning models, such as Problem-Based Learning (PBL), has proven effective in addressing these challenges. For example, the implementation of PBL supported by Animaker in statistics classes can significantly improve student engagement and learning outcomes, with teacher engagement reaching 93.3% and student engagement reaching 83.3% in Cycle II (Anjani et al., 2023) .

Research on the effectiveness of teaching methods in statistics often focuses on quantitative parameters such as improvements in learning outcomes or literacy scores. The use of valid and reliable assessment instruments is crucial for ensuring the quality of measurements of students' abilities. In the context of developing instructional materials, the validation process using the 4-D model (Define, Design, Develop, Disseminate) is essential to ensure the suitability of teaching materials (Aprilia, 2022) . This approach ensures that materials, such as syllabi, lesson plans, and worksheets, meet quality standards before being implemented in the teaching and learning process.

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In an effort to improve statistical reasoning, a comparison of learning models is relevant. For example, the Problem-Based Learning (PBL) and Discovery Learning (DL) models demonstrate different levels of effectiveness in influencing mathematical problem-solving skills, with PBL yielding higher average post-test scores than DL. This difference underscores the importance of selecting the appropriate learning model in accordance with the objectives of developing specific skills. The implementation of varied learning methods can address students' low mathematical literacy, which is often caused by the monotony of the "teaching approach .

Another aspect that contributes to improving the quality of learning is the integration of relevant values and contexts. The development of statistics learning modules that integrate Islamic values, for example, shows that these modules are not only engaging but also highly effective in improving learning outcomes, as evidenced by high N-Gain scores (Ekawati et al., 2019) . Authentic data-based learning contexts, which are at the core of this study, align with this approach because they provide relevance and meaning for students. Learning methods such as discussions have also proven effective in improving students' cognitive learning outcomes and motivation, particularly in the topics of statistics and probability. A supportive learning environment, whether through media or interaction, is vital for the development of comprehensive reasoning and data literacy.

RESEARCH METHOD

This study employed a quantitative-dominant mixed-methods approach with a research and development (R&D) design to create a statistics learning model based on authentic data. The 4-D development model (Define, Design, Develop, Disseminate) was used. This approach ensures that the resulting learning materials, such as syllabi, lesson plans, and worksheets, meet the criteria for validity and practicality before implementation (Aprilia, 2022) . A similar development study successfully produced valid, practical, and effective teaching modules in mathematical statistics (Burhanudin et al., 2023).

The research followed the first three stages of the 4-D model (Define, Design, and Develop); the Disseminate stage was not carried out. The effectiveness of the developed instruction was then examined using a pre-experimental one-group pretest–posttest design (O_1 X O_2), in which one group received a pretest, the authentic data-based instruction (X), and a posttest. This design has also been used in JMEA to examine the effect of an instructional approach with paired-sample t-tests (Siregar & Irvan, 2025), and expert validation with a predetermined validity criterion has likewise been applied in JMEA development studies (Hasanah & Irvan, 2025). The intervention was implemented in 8 meetings of 100 minutes each in the Statistics course during the 2025/2026 academic year.

The study population consisted of 40 UNIKI students with low levels of statistical reasoning and data literacy. The relatively small population size prompted the use of a saturated sampling technique (census), so that all 40 members of the population became the research sample. The use of saturated sampling ensures that every element of the population participates, and the collected data comprehensively represents the population. This approach is consistent with development research, which often involves limited groups for product testing (Badrulaini et al., 2020). Although the sample is small, it covers the entire population enrolled in the course, and a paired design with 40 participants has 80% power to detect an effect of about d = 0.45 (α = 0.05, two-tailed; Cohen, 1988), so the observed effects are well within the detectable range.

This study used a statistical reasoning test and a data literacy test as instruments. The statistical reasoning test measures students' understanding of how to interpret and apply statistical concepts to real-world problems. The data literacy test aims to evaluate students' ability to effectively collect, manage, analyze, and communicate data-based information. The validity of the instruments was determined through expert assessment, while their reliability was tested using Cronbach's Alpha; a coefficient above 0.60 indicates adequate internal consistency for the variables among the study's respondents. The development of the statistical reasoning instrument in this study drew upon an approach previously used to

measure students' statistical reasoning abilities in descriptive statistics s (Chan & Ismail, 2014) .

Each test consisted of 15 essay items scored on a 0–100 scale. The statistical reasoning test covered describing data, organizing and reducing data, representing data, and analyzing and interpreting data (Chan & Ismail, 2014; Saidi & Siew, 2022), and the data literacy test covered collecting, managing, evaluating, and applying data (Ridsdale et al., 2015). Content validity was established by three experts in mathematics education and statistics using Aiken's V, with $V \geq 0.80$ as the validity criterion. Reliability was estimated with Cronbach's alpha, yielding $\alpha = 0.82$ for the statistical reasoning test and $\alpha = 0.79$ for the data literacy test. Classroom observations and focus group discussions (FGDs) with 10 students were used to collect qualitative data on students' experiences, motivation, and thinking processes, guided by a structured observation sheet and a semi-structured FGD protocol. Critical and analytical thinking was not measured with a separate test; statements about it are based on students' perceptions expressed in the FGDs and observations.

Product validity was assessed by the same three experts using validation sheets covering the content, construction, and language of the syllabus, lesson plans, student worksheets, and test instruments, while practicality was assessed with response questionnaires completed by the course lecturer and the 40 students after the intervention. Percentage scores of 80% or higher were categorized as valid or practical, applying to both aspects the validity criterion used in a previous development study (Hasanah & Irvan, 2025).

The collected data were analyzed using quantitative descriptive and inferential methods with SPSS software. The descriptive analysis described the characteristics of the data and the students' initial ability profiles. Inferential analysis involved hypothesis testing to determine the effectiveness of authentic data-based statistics instruction in improving students' statistical reasoning and data literacy. Data normality of the pretest and posttest scores was tested with the Shapiro–Wilk test (appropriate for samples below 50), with $p > 0.05$ indicating normality. A paired-sample t-test was then used to compare pretest and posttest scores at a

significance level of $\alpha = 0.05$. The magnitude of the change was expressed as Cohen's d (mean difference divided by the standard deviation of the differences) and interpreted as small (≈ 0.2), medium (≈ 0.5), or large (≥ 0.8) (Cohen, 1988). Had the normality assumption not been met, the Wilcoxon signed-rank test would have been used. Qualitative data from the observations and FGDs were analyzed thematically through data reduction, data display, and conclusion drawing (Miles et al., 2014) and were used to complement the quantitative results.

The 4-D model, simplified into the "define, design, develop" stages, is a strategic approach to producing valid and functional learning products, particularly under constrained conditions (Badrulaini et al., 2020). The "define" stage involves in-depth needs analysis, literature review, and the identification of student characteristics and specific learning objectives for statistics based on authentic data. Formulating indicators of statistical reasoning skills and data literacy, which are to be improved in this phase, ensures that the development focus aligns with the research objectives. The "design" stage focuses on the design of learning components.

This stage involves the development of a syllabus, lesson plans, and student worksheets (LKPD) that integrate authentic data, as well as evaluation instruments (Burhanudin et al., 2023). The integration of authentic data into this design aims to bridge the gap between statistical theory and its real-world applications, encouraging students to think critically and analytically. The "develop" stage involves pilot testing of the initial product, expert validation, and revisions based on the feedback received. Expert validation ensures that the learning tool has high validity in terms of content, construction, and language (Burhanudin et al., 2023). An iterative revision process based on feedback from validators and limited pilot testing enhances the tool's practicality and ensures its feasibility prior to full-scale implementation.

This approach aligns with instructional design principles that emphasize ongoing formative assessment to refine learning products. This R&D model not only produces a

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product but also ensures its quality and effectiveness in achieving the established learning objectives (Utami et al., 2026).

RESULTS AND DISCUSSION

Results

This section presents and discusses the main findings of the study, including respondent characteristics, the results of the instrument's validity and reliability tests, descriptive statistics on students' statistical reasoning skills and data literacy, and the results of hypothesis testing on the effectiveness of the authentic data-based statistics learning model. All analyses were conducted using SPSS software to ensure the accuracy and objectivity of the findings. Most respondents were students from programs of study relevant to data analysis needs, with a sufficiently diverse distribution of age and gender to adequately represent the UNIKI student population. Prior to the intervention, the average scores for statistical reasoning and data literacy (65.7 and 62.3, respectively) were below the course mastery criterion of 75, which is consistent with the initially low level of both competencies and indicates significant room for improvement while also underscoring the need for innovation in statistics education to meet 21st-century competency demands. The research instruments were validated through expert review and their reliability was assessed using Cronbach's Alpha coefficient, which met the criteria for internal consistency, ensuring that the resulting measurements are scientifically sound (Ladayya et al., 2024).

The use of a saturated sampling technique for all 40 students further strengthened the representativeness of the data, as every member of the population with low levels of statistical reasoning and data literacy participated, rather than drawing only a small sample that risked selection bias. This approach is commonly found in development research involving limited target groups and allows researchers to obtain a comprehensive picture of the impact of interventions on the intended population (Badrulaini et al., 2020).

The instruments met the validity and reliability criteria (Aiken's V = 0.86 for the statistical reasoning test and 0.83 for the data literacy test; Cronbach's α = 0.82 and 0.79, respectively). Shapiro–Wilk tests showed that the pretest and posttest scores were normally distributed (statistical reasoning: W = 0.97, p = 0.31; data literacy: W = 0.96, p = 0.18), which justified the use of the paired-sample t-test.

Expert validation showed that the developed learning tools were highly valid, with mean validity scores of 88% for the syllabus, 90% for the lesson plans, 86% for the student worksheets, and 89% for the test instruments (overall mean 88.3%, above the 80% criterion). The practicality questionnaires yielded mean scores of 92% from the lecturer and 87% from the students, indicating that the instruction was practical to implement. These results show that the product met the validity and practicality criteria before its effectiveness was tested.

A hypothesis test using a paired-sample t-test revealed a statistically significant difference between the pre-test and post-test scores for both variables: students' statistical reasoning skills and data literacy. The results of this statistical test are presented in Table 1 below.

Table 1. Paired t-Test Results

Variable	Pre-test Mean	Post-test Mean	p-value	Cohen's d	Effect category
Statistical reasoning	65.7	85.2	<0.001	1.25	Large
Data literacy	62.3	82.5	<0.001	1.18	Large

The data in Table 1 show that both variables experienced a statistically significant increase ($t(39) = 7.91$ for statistical reasoning and $t(39) = 7.46$ for data literacy, both $p < 0.001$). The effect sizes (Cohen's d), 1.25 for statistical reasoning ability and 1.18 for data literacy, are both classified as large, indicating that the observed increases are not only statistically significant but also practically substantial. Students did not merely memorize statistical procedures but were able to apply them to real-world data contexts (Majid & Ernawati, 2025).

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These quantitative findings are supported by qualitative analysis of classroom observations and focus group discussions (FGDs). Students reported that working with authentic data made the statistics material feel more engaging and relevant, encouraging them to be more active in exploring data, identifying patterns, and solving problems, rather than passively absorbing the material as in conventional learning. Interaction with real data also fostered deeper classroom discussions and collaboration among students, as well as cultivating a positive attitude toward statistics and the use of data, not merely cognitive skills (Riani, 2022).

Feedback from the FGD also indicated that students perceived their critical and analytical thinking as having developed through authentic data-based learning and as being beneficial not only in the context of statistics but also transferable to various other disciplines that students pursue. This suggests that the learning model developed not only enhances cognitive abilities in statistics courses but also fosters data-driven thinking competencies that are context-independent and relevant to the demands of the workplace.

From a methodological perspective, the integration of quantitative data (paired t-tests) and qualitative data (observations and focus group discussions) in this study provides triangulation that strengthens the validity of the findings. Quantitative data show the magnitude and significance of the improvement, while qualitative data explain the processes and mechanisms behind these figures, including changes in students' attitudes and motivation that cannot be fully captured by test scores alone. The combination of these two types of data yields a more comprehensive understanding of how and why authentic data-based learning is effective.

In addition to cognitive aspects, the success of this model is also closely tied to motivational factors. The authenticity of the data sparks students' intrinsic motivation because they can see a direct connection between the statistical material they are studying and the phenomena around them. The experience of working with authentic data, which is messy yet meaningful, may foster resilience and problem-solving skills that are essential in

professional contexts, something that is difficult to replicate using clean and neatly organized simulated data (Munir et al., 2025). These imperfections in the data are, in fact, a key pedagogical strength because they require students to develop more advanced skills in data cleaning, transformation, and inference, rather than merely applying formulas mechanically.

Discussion

Improvements in statistical reasoning can be explained through several cognitive mechanisms. Direct interaction with real data encourages students to develop better statistical intuition regarding variability, distributions, and relationships among variables, enabling them to understand what the numbers represent, rather than merely calculating them. Authentic data, which is often far from ideal, also trains students to think critically about the limits of the inferences that can be drawn, moving beyond a mechanistic interpretation of p-values or correlation coefficients. This is the essence of mature statistical reasoning: the ability to reason with and about data, not merely from data (Istianah et al., 2026).

In data literacy, the improvements go beyond mere technical skills and encompass skills, understanding, and attitudes. Students are trained to effectively find, evaluate, manage, and analyze data, including handling missing values, outliers, and various data formats that cannot be replicated with pre-cleaned simulated data. This experience also fosters an understanding of the ethical implications of data use and the ability to communicate findings persuasively, thereby enabling students to become both critical consumers and producers of data (Kiawati et al., 2023).

The design of statistics instruction based on authentic data in this study does not merely involve selecting data sources but also involves designing pedagogical strategies to enable students to engage meaningfully with the data. This approach incorporates elements of Problem-Based Learning (PBL) and Project-Based Learning (PjBL), in which students are presented with real-world problems whose solutions require statistical data analysis (for example, analyzing customer satisfaction survey data or climate data to predict weather

patterns) (Nurjanah & Trimulyono, 2022). The learning stages are designed to follow the statistical inquiry cycle, starting from formulating research questions, collecting or accessing data, exploring data, conducting inferential analysis, and communicating results.

The role of technology (in this case, statistical software such as SPSS) is also important to consider. In this study, the software is not viewed merely as a computational tool, but rather as a means of exploration that allows students to try various analytical approaches, visualize data from different perspectives, and reevaluate the assumptions underlying a statistical method. The use of such technology aligns with the need for data literacy in the workplace, where data is often presented in various formats and requires digital tools to process it efficiently. This finding is consistent with a study of elementary education (PGSD) students that showed that the ability to represent data using software such as Excel and SPSS is an important indicator of students' data literacy (Silalahi & Limbong, 2021).

These findings are consistent with a number of previous studies that demonstrate the effectiveness of active and contextual learning in improving students' reasoning skills. The implementation of Problem-Based Learning (PBL) supported by Animaker, for example, has been shown to enhance student engagement and learning outcomes in statistics(Anjani et al., 2023) , while e-learning-based PBL gradually improved problem-solving skills and mathematical dispositions across each cycle(Kurniawati et al., 2022) , and project-based learning has been shown to enhance students' mathematical reasoning skills(Kustiaman, 2020) . The consistency of these results across various levels and contexts strengthens the argument that active and contextual approaches, when combined with authentic data, have a greater impact than conventional statistics instruction that focuses solely on computational procedures. Unlike those studies, which generally use simulated or pre-cleaned data, this research explicitly places authentic data at the core of the learning experience, so that the complexity and imperfections of the data become an integral part of the learning process itself. This approach expands the problem-based learning framework by suggesting that the authenticity of the data, and not just the structure of the problem, is a key factor in fostering students' motivation and perceived critical thinking (Anfatirul & Waluyo, 2020). Beyond the

studies cited above, international evidence points in the same direction: a systematic review identified authentic problem-solving and real-world data as effective approaches for promoting statistical and data literacy (Friedrich et al., 2024), and real-life activities enriched with gamification elements have been reported to support students' motivation and, in part, their statistical literacy achievement (Cakiroglu & Güler, 2021), although most of this evidence comes from school settings.

Compared to studies highlighting low mathematical literacy resulting from a lack of variation in learning models (Kiawati et al., 2023), this study offers one form of such variation—namely, variation in the sources and characteristics of the data used, rather than solely in the strategies for delivering the material. This type of variation is relevant to implement alongside other learning model variations, such as the integration of contextual values or local wisdom, which have been proven to increase students' interest and learning outcomes in statistics (Ekawati et al., 2019).

The effectiveness of this model is also closely tied to its development process, which involves the definition, design, and development stages (a simplified 4-D model), ensuring that instructional materials such as syllabi, lesson plans, and student worksheets are validated and practical before implementation (Aprilia, 2022; Burhanudin et al., 2023). From a product development perspective, the validity of the "authentic data-based statistics instruction" model is further supported by expert reviews and pilot testing, processes commonly applied in development research with limited target groups (Matondang, 2020). An iterative revision process based on validator feedback ensures that instructional materials possess high validity in terms of content, structure, and language, while also enhancing their practicality before full-scale implementation. A similar experience in developing a statistics module that integrates Islamic values further confirms that relevant and contextual material design, and not just theoretical content, is the key to the success of a learning model.

From a pedagogical perspective, these findings highlight the need for a shift in the statistics curriculum from an emphasis on procedural exercises toward hands-on experience

with authentic data and real-world problems. Authentic data-based case studies need to be a central element of learning, supported by faculty professional development in curating datasets and designing relevant assignments, as well as formative and summative assessments that truly measure the ability to analyze and communicate findings, rather than merely memorizing formulas and procedures.

Practical implementation can take the form of data analysis portfolios, group projects based on real-world case studies, or assessment rubrics that explicitly evaluate the quality of evidence-based interpretation and argumentation, rather than just the accuracy of the final calculations. In this way, assessment serves not only as a measurement tool but also helps shape students' thinking habits when working with data.

The improvements in statistical reasoning and data literacy found in this study are also relevant to the broader 21st-century competency framework, which includes critical thinking, communication, collaboration, and information literacy. Students who are accustomed to working with authentic data tend to be better prepared to tackle academic and professional tasks that require the ability to process complex information and present it convincingly to diverse audiences—a competency that is increasingly in demand across various data-driven fields.

However, implementing this approach is not without challenges, particularly regarding access to authentic data that is relevant and appropriate for students' skill levels, as well as the time and effort required by instructors to curate high-quality datasets. The complexity of authentic data can also pose an initial hurdle for students who are not yet accustomed to it, thus requiring more intensive instructional support in the early stages. Strategies such as using simplified datasets at the introductory level, leveraging open data platforms, and collaborating with industry or research institutions as data sources can serve as practical solutions to address these challenges (Anfatirul & Waluyo, 2020). Flexibility in instructional design and a willingness to adapt materials based on student responses also play a key role in determining the success of implementation in classrooms with varying characteristics. A

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step-by-step approach, moving from more structured data to messier data, can help students build skills progressively without causing excessive cognitive load in the early stages of learning.

In the specific context of UNIKI, these findings offer concrete solutions to the issues of low statistical reasoning and data literacy that form the backdrop of this study. Institutions with similar student populations and resources have the potential to adopt this model, making adjustments to the types of authentic data used to align with their respective academic programs and local contexts. This opens up opportunities for replicating and adapting the model to other academic programs within higher education institutions facing similar challenges.

It should be noted that the single-group pre-experimental design (one-group pretest-posttest) used in this study, while practical for research and development contexts with limited populations, does not include a control group; therefore, the observed improvement cannot be attributed exclusively to the authentic data intervention without considering the possible influence of maturation or the retest effect . Future research could explore the effectiveness of this model over a longer period to determine whether these improvements persist after students complete the course, as well as test its application to other courses that also require data analysis skills, such as research methodology or project-based courses across various academic programs. The sample was also limited to 40 students from a single institution, which restricts the generalizability of the findings; replication with larger and more diverse samples and with a comparison group is therefore needed. In addition, affective factors such as statistics anxiety, which has been found to correlate negatively with statistical reasoning (Saidi & Siew, 2022), were not measured, and the qualitative findings reflect students' perceptions rather than a separate measure of critical thinking.

Overall, the quantitative and qualitative findings in this study reinforce one another and indicate that statistics learning based on authentic data was associated with a significant improvement in students' statistical reasoning and data literacy, while also opening

opportunities for the development of similar models in other higher education contexts that face challenges related to low levels of statistical reasoning and data literacy.

CONCLUSION

This study successfully developed a statistics learning model based on authentic data that was associated with significant gains in students' statistical reasoning and data literacy. The model developed meets the criteria for validity and practicality. Its validity was demonstrated by an expert review of the learning materials (syllabus, lesson plans, and worksheets), which were found to be highly relevant. This model helps address the low levels of statistical reasoning and data literacy among UNIKI students.

The model's potential effectiveness is indicated by the increase in average scores for statistical reasoning and data literacy following its implementation, indicating that the authentic data approach bridges conceptual understanding with real-world applications, in line with the demands of the information age. Its theoretical contribution is to provide empirical evidence on the potential of this approach in enhancing critical competencies in higher education. Its practical implications highlight the importance of pedagogical innovation in preparing students to face the challenges of the data era, as well as the need for wider implementation of similar models.

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