Design and Evaluation of a Guided Discovery Learning Model to Enhance Junior Secondary Students' Statistical Literacy

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ABSTRACT

Aim. This study develops and evaluates the Guided Discovery Learning (GDL) model to enhance junior high school students' statistical literacy. The model integrates contextual problem-solving tasks to strengthen students' understanding of statistics while fostering statistical literacy.

Methods. A mixed-methods approach with an explanatory sequential design was employed. The GDL model was developed through Educational Design Research (EDR) and subsequently evaluated using a one-group pre-test–post-test design.

Quantitative data were analysed using the Wilcoxon Signed-Rank Test and effect size, while qualitative insights were derived from semi-structured interviews with students and teachers to explore their experiences during implementation.

Results. Expert validation confirmed the strong alignment of the GDL design with the intended outcomes of statistical literacy, emphasising contextual relevance and scaffolding. Statistical analysis indicated significant improvement, with the median score rising from 50.00 to 87.00 ($Z = -5.552$, $p < 0.001$). All students improved, with none declining. The calculated effect size ($r = 0.878$) demonstrated a substantial positive impact of the intervention.

Conclusions. This study addresses theoretical needs by advancing a constructivist-based framework, while meeting practical needs by offering an empirically tested model that enhances statistical literacy. The findings highlight the value of contextually driven, problem-based pedagogy in equipping students with critical, data-informed decision-making skills essential in the big data era.

Originality. This study contributes a structured, inquiry-based GDL framework integrating authentic, real-world problems. It provides a discovery-oriented strategy that develops students' reasoning and decision-making abilities aligned with contemporary educational priorities.

Keywords: statistical literacy, guided discovery learning, mixed-methods, big data era, educational design research

Introduction

The PISA 2022 Assessment and Analytical Framework highlights the importance of statistical literacy in an increasingly data-driven world (OECD, 2023). Statistical literacy refers to the skills required to interpret, analyse critically, and communicate statistical data presented through various media such as tables, graphs, and narrative descriptions (Gal, 2002; Guven et al., 2021; Watson, 2013). This skill is essential not only for researchers but also for the public in making data-informed decisions (François et al., 2020; Sabbati, 2022). However, despite its significance, developing statistical literacy remains a challenge, particularly at the lower secondary level, where abstract and critical thinking skills are still emerging (Garfield et al., 2008; Koga, 2022). Therefore, systematic educational efforts are needed to enhance students' statistical literacy competencies from an early stage.

In the context of mathematics education, statistical literacy has become a global priority, as recommended by the National Council of Teachers of Mathematics (2000), which emphasises the importance of data analysis, probability, and statistical reasoning in school curricula. However, various studies indicate that many students continue to struggle with interpreting data, drawing logical conclusions, and making data-driven decisions (Guven et al., 2021; Oliveira et al., 2016; Zawojewski & Shaughnessy, 2000).

In Indonesia, research highlights that secondary school students possess limited statistical literacy, typically confined to basic understanding and data representation without critical or evaluative thinking skills (Hariyanti, 2020; Prihastari et al., 2022; Takaria & Talakua, 2018). A recent study by Zulqoidi R. Habibie et al. (2024) found that 75% of students scored below 60 on a statistical literacy test, indicating a significant competence gap. This aligns with findings by Achmad Badrun Kurnia et al. (2024), which revealed that 42% of ninth-grade students exhibited a low level of statistical understanding. Furthermore, Heri Retnawati et al. (2019) reported persistent difficulties among Indonesian students in grasping statistical concepts, performing calculations, and using statistical tools. These challenges are exacerbated by inadequate pedagogical resources and insufficient teacher preparedness in fostering statistical literacy (Guven et al., 2021; Koga, 2025; Setiawan, 2019), highlighting the urgent need for more effective pedagogical interventions.

One pedagogical approach that can bridge this gap is Guided Discovery Learning (GDL), which is rooted in constructivist theory and emphasises active student engagement in constructing their understanding (Balım, 2009; Slavin, 2018). GDL allows students to explore information, develop ideas, and build deeper cognitive frameworks through inquiry and data-driven reasoning (Arends, 2012; Kpotosu et al., 2024). Research has shown that GDL improves students' mathematical reasoning, critical thinking, and confidence in understanding statistical concepts (Johnson et al., 2016; Maharani et al., 2024; Manurung & Pappachan, 2025). Although GDL has been widely applied in mathematics education, limited research has specifically explored its role in developing statistical literacy, particularly through problem-solving tasks contextualised with students' real-life experiences (Batanero & Borovcnik, 2016; Garfield et al., 2008).

Addressing this gap, this study aims to design a GDL-based learning model specifically tailored to enhance the statistical literacy of junior secondary school students. The model integrates context-based problem-solving tasks relevant to students' personal, school, and community environments while aligning with the Indonesian curriculum. Accordingly, this research seeks to answer two key questions:

- How is the Guided Discovery Learning model designed to develop students' statistical literacy?
- Does the designed Guided Discovery Learning model enhance students' statistical literacy development?

Literature Review

Statistical Literacy

The definition of statistical literacy is highly complex. Milo Schield (1999) equates statistical literacy with reading, writing, or speaking, encompassing an understanding of basic statistical terminology and the use of simple statistical symbols (Garfield et al., 2012; Ridgway et al., 2011; Schield, 2016; Ziegler & Garfield, 2018). Additionally, it involves the ability to comprehend and communicate statistical information (Guven et al., 2021; Ziegler, 2014). However, Joan Garfield and Deni Ben-Zvi (2005) argue that statistical literacy extends beyond basic skills to include essential competencies for interpreting statistical information and research findings. If the scope of statistical literacy includes understanding research outcomes, then a fundamental definition alone is insufficient.

Statistical literacy extends beyond merely reading and understanding statistical information. It encompasses the ability to interpret data, represent it effectively, and communicate statistical messages in everyday media, including tables, graphs, and diagrams (Ben-Zvi & Garfield, 2004; Chick & Pierce, 2013; Dani & Joan, 2004; Guven et al., 2021; Schield, 2010). This skill set includes organising data, constructing and presenting tables, and working with various forms of data representation (Ben-Zvi & Garfield, 2004). Moreover, statistical literacy is not merely about applying statistical procedures mechanically; it involves the ability to critically analyse, interpret, and evaluate information encountered in daily life (Budgett & Rose, 2017; Gal, 2002; Guven et al., 2021; Koga, 2022). It enables individuals to interpret data accurately, thereby facilitating more informed decision-making in both personal and professional contexts (Diksha Bhola et al., 2024). The foregoing discussion highlights that statistical literacy constitutes a multifaceted construct, requiring not only essential skills such as reading, comprehension, and communication but also advanced cognitive capacities, including interpretation, prediction, and critical reasoning (Koga, 2022; Sharma, 2017).

The determination of statistical literacy indicators was based on a review of expert perspectives on the definition and key aspects of statistical literacy. The researcher synthesised these viewpoints into four core indicators to be integrated into the GDL learning framework as student competency targets. These indicators are supported by expert perspectives as essential components of statistical literacy skills, as discussed earlier. A concise summary is presented in Table 1.

Table 1

Statistical Literacy Indicator Synthesis

Indicator	Code	Experts Cited
Reading and understanding fundamental statistical terminology	SL 1	(Guven et al., 2021; Lehohla, 2002; Ridgway et al., 2011; Rumsey, 2002; Schield, 1999, 2016; Ziegler & Garfield, 2018)
Interpreting and communicating statistical messages	SL 2	(Ben-Zvi & Garfield, 2004; Chick & Pierce, 2013; Gal, 2002; Guven et al., 2021; Schield, 2010)
Concluding or making decisions based on valid statistical data	SL 3	(English & Watson, 2015; Guler et al., 2016; Guven et al., 2021; Watson, 2003)
Critically evaluating statistical information	SL 4	(Ben-Zvi & Garfield, 2004; Budgett & Rose, 2017; Gal, 2002; Guven et al., 2021; Koga, 2022; Ridgway et al., 2011; Wallman, 1993; Watson, 1997)

Source. Own research.

Purpose of Developing Students' Statistical Literacy in Learning

Students often struggle to analyse and synthesise statistical information, partly due to insufficient teacher training and limited instructional resources (Koga, 2025; Retnawati et al., 2019). Moreover, statistical literacy is frequently overlooked as a fundamental skill in the school curriculum and is instead regarded as a supplementary competency (Setiawan, 2019). However, in an information-driven society, statistical literacy is an essential skill expected of all citizens and is increasingly recognised as a critical educational outcome (Garfield et al., 2008). This gap underscores the urgent need for pedagogical innovations that prioritise statistical literacy development in mathematics education.

The integration of statistical literacy into mathematics education has garnered significant attention due to its crucial role in preparing students for an increasingly data-driven world (Gould, 2017; Weiland, 2017). Statistical education begins at the primary and secondary levels, where students acquire fundamental skills such as conducting surveys, collecting data, and presenting information using tables, graphs, and diagrams (Abramovich & Connell, 2021). This foundational stage is essential for fostering data analysis, interpretation, and reasoning skills necessary for various academic disciplines and real-life contexts, enabling students to become informed citizens and critical consumers of information (National Council of Teachers of Mathematics [NCTM], 2000; Papancheva, 2017). Given this, it is imperative that teachers at all levels develop statistical literacy themselves to deliver high-quality learning experiences and effectively equip students with a deeper understanding of statistical concepts through appropriate pedagogical strategies (Metz, 2010). Therefore, this study aims not only to enhance students' statistical literacy skills but also to support junior secondary school teachers by providing an alternative learning framework that serves as a reference for fostering statistical literacy in the classroom.

GDL-Based Instructional Model for Statistical Literacy

Discovery learning fosters an active, student-centred approach in which learners explore concepts, construct meaning, and develop knowledge independently (Arends, 2012; Schunk, 2012). Louis Alfieri et al. (2011) further emphasise that discovery learning enables students to uncover concepts with minimal teacher guidance, often facilitated through simulations, feedback, and example-based problem-solving. In this approach, teachers may provide structured support or encouragement depending on the complexity of the concepts being explored and the learners' level of understanding. Discovery learning is inherently inductive, as students progress from engaging with specific examples to formulating broader generalizations, concepts, and principles (Schunk, 2012).

Table 2
GDL Instructional Phases for Enhancing Students' Statistical Literacy

No	GDL Phase	Activities	Statistical Literacy Outcomes	Form of Guidance
1	Stimulation	Exploring statistical information in real-world contexts or distinguishing examples from non-examples that illustrate concepts.	− Understanding statistical information — Interpreting basic statistical terms and language.	Guided questions to enhance conceptual understanding and relate statistics to students' experiences.
2	Problem Identification	Identifying problems related to real-world contexts.	− Analysing required information to solve statistical problems. − Critically evaluating information.	Guided questions to determine problem-solving steps.
3	Data Collection	− Collecting primary data. − Gathering secondary data from various sources.	Differentiating and selecting appropriate data collection methods.	Guided questions to choose suitable data collection techniques.
4	Data Processing	Processing and analysing data to address the problem, with technology integration such as Excel.	− Interpreting and representing data. − Applying appropriate data analysis methods.	Guided questions to process information and select suitable data presentation techniques.
5	Drawing Conclusions	Summarising key concepts learned using principles from previous stages.	Concluding or making data-driven decisions.	Guided questions to support the conclusion-drawing process.

Source. Own research.

The steps of Guided Discovery Learning (GDL) typically involve presenting students with a problem or question, encouraging exploration and inquiry, facilitating discussions to help them articulate their understanding, and guiding them toward concept discovery through structured activities (Juandika et al., 2024; Mutiah et al., 2024). Syaiful Bahri Djamarah and Aswan Zain (2013) further elaborates on GDL as a six-phase process: Stimulation – Students engage in activities such as reading, listening, or responding to thought-provoking questions. Problem Statement – Students identify and define the problem. Data Collection – Students gather relevant information. Data Processing – Students analyse and interpret the collected data. Verification – Students validate their findings through reasoning and evidence. Generalisation – Based on verification, students derive broader conclusions or conceptual insights.

The characteristics of GDL in this study are adapted from Donal R. Cruickshank et al. (1995), who outlined key instructional principles: (a) establishing conditions for knowledge discovery; (b) encouraging independent exploration and critical thinking; (c) challenging students to construct knowledge through inquiry; (d) promoting high levels of student participation and interaction; and (e) engaging students in higher-order cognitive processes, including analysis, synthesis, and evaluation. To refine the instructional framework, this study integrates the verification and generalisation phases into a single inference stage while preserving the essential learning activities from both phases (Djamarah & Zain, 2013). The specific activities within each GDL phase, along with the corresponding statistical literacy outcomes and instructional guidelines, are presented in Table 2.

Methods

Design

An explanatory sequential mixed-methods design was employed in this study, allowing for the integration of quantitative findings with qualitative insights to provide a more comprehensive understanding of the phenomenon under investigation (Creswell & Clark, 2017). The Guided Discovery Learning (GDL) model was developed based on the principles of Educational Design Research (EDR) (Plomp, 2013), and its effectiveness was evaluated using a one-group pretest–posttest design.

To address the research questions, a two-phase approach was adopted. First, a qualitative educational design research framework was applied to develop the instructional model (RQ1: Model Design). Second, a quantitative one-group pretest–posttest experiment was employed to measure students' statistical literacy before and after the implementation of the model, supplemented by post-implementation qualitative analysis for more profound insights (RQ2: Model Impact Evaluation).

Although the absence of a control group limits the strength of causal inference, the one-group pretest–posttest design is widely regarded in educational research as a valid means of conducting preliminary investigations. Recent studies in culturally responsive pedagogy (Akinsola, 2025), inquiry-based mathematics learning (Teke & Çalışıcı, 2025), and science education (Maison et al., 2025) have all employed this design effectively. In alignment with this scholarly discourse, the present study positions itself as a preliminary yet systematic endeavour to examine the potential effectiveness of the GDL model, offering indicative rather than conclusive evidence that may inform subsequent large-scale or controlled investigations.

Research Stages

The development of the GDL-based instructional model aims to enhance students' statistical literacy. The model was designed using Educational Design Research (EDR), following these stages:

- Needs Analysis, identifying specific needs and challenges in developing statistical literacy within mathematics education through a literature review and teacher surveys.

- Model Development, designing and integrating the GDL instructional model into lesson plans and student worksheets. this paper focuses on student worksheets, detailing student activities within the GDL framework to facilitate statistical literacy.
- Expert Validation, conducted by three experts in mathematics education, statistics education, and a certified senior mathematics teacher. Expert evaluation ensures the model's effectiveness through content validity and significant inter-rater agreement (Buitrago et al., 2023).
- Model Revision, refining the student worksheets based on expert feedback.
- Pilot testing was conducted as a small-scale purposive trial with nine Year 7 students to examine the readability and usability of the worksheets. The pilot aimed solely to identify potential issues of clarity and practicality rather than to yield representative or generalisable findings. During the trial, students worked collaboratively, received instructions on the evaluation process, reviewed the worksheets, and provided descriptive feedback on their clarity and effectiveness.

Implementation and Evaluation of the GDL Model

The experimental design followed a one-group pre-test-post-test approach to assess the effectiveness of the GDL model. The evaluation involved administering a pre-test at the beginning of the intervention and a post-test on statistical literacy at the final session. The pre-test and post-test scores were compared using descriptive and inferential statistical analysis. The GDL-based instruction was implemented over six sessions. Teachers were trained in applying the GDL model, while the researcher acted as an observer to ensure fidelity in classroom implementation. Preparation involved discussions with teachers regarding scheduling, the GDL model, lesson content, and statistical literacy. The researcher also guided teachers through a simulation of GDL steps and facilitated the formation of student groups based on academic ability.

Participants

Participants were selected through purposive sampling to ensure alignment with the study's objectives. The sample consisted of one class of 40 students (22 female, 18 male), aged 12–13 years, from a top-ranked Grade A secondary school in Indonesia. The cohort was heterogeneous in academic ability, with a balanced IQ distribution and varied demographic characteristics, including socioeconomic and geographical diversity. Accordingly, the sample should be regarded as purposive. The GDL model was implemented by a teacher with 15 years' professional experience, holding a government-awarded certification obtained through a rigorous national selection process.

Instrument

A statistical literacy test was employed to assess the impact of the GDL model design. The pre-test and post-test comprised 15 multiple-choice questions, adapted from validated instruments (Çatman Aksoy & Işıksal Bostan, 2021; Watson & Callingham, 2003) and contextualised for Indonesia. The test demonstrated high validity and reliability, with a reliability score of 0.92. Reliability of instrument analysis according to the RASCH model by using the Winstep platform. The detailed results of the reliability test are provided in Appendix (Figure A1).

The test measured four statistical literacy indicators, as outlined in Appendix (Table A1). Additional research instruments included validation sheets and interview guidelines. The validation sheet was designed to evaluate the integration of the GDL model into the Student Activity Sheet (SAS) for fostering statistical literacy. It assessed five key aspects, focusing on alignment with constructivist theory and ease of implementation. The interview guidelines explored students' and teachers' experiences and challenges following the implementation. A semi-structured interview approach was used, allowing for flexible follow-up questions based on participants' responses.

Data Analysis Procedures

This study employed both qualitative and quantitative data analysis techniques. Qualitative analysis was conducted on data obtained from interviews, surveys, classroom observations of GDL implementation, and feedback from students and teachers following the learning process. This qualitative analysis was used to support and enrich the findings from the quantitative analysis, providing a deeper understanding of the impact of the GDL model on students' statistical literacy. Quantitative data analysis was conducted using SPSS 25. The stages of the quantitative analysis in this study are outlined as follows:

- Normality Test: Before performing the significance analysis, it was necessary to ensure that the data satisfied the assumption of normality. The Shapiro-Wilk test was employed for this purpose, as it is appropriate for small sample sizes (Field, 2024). This test was applied to evaluate whether the distribution of the pre-test and post-test data conformed to a normal distribution.
- Significance Test: When the data met the normality assumption, a Paired Samples t-test would typically be applied to compare the mean scores between the pre-test and post-test (Pallant, 2020). Nevertheless, since the data violated this assumption, the analysis was carried out using the Wilcoxon Signed-Rank Test, a non-parametric alternative suitable for non-normally distributed data (Field, 2024).
- Effect Size Analysis: Following the significance analysis, the magnitude of the GDL model's influence on students' statistical literacy was assessed by calculating the effect

size. For non-parametric data, this was computed using the formula $r = Z / \sqrt{N}$. The resulting values were interpreted based on the following benchmarks: an r value below 0.2 indicated a negligible impact, values between 0.2 and 0.5 represented a moderate influence, while values of 0.5 or above signified a substantial effect.

Results

Findings on the Development of the Guided Discovery Learning Model (GDL)

The development of the GDL model began with a needs analysis, focusing on teachers' understanding, the urgency of statistical literacy, and their readiness to facilitate its development among students. The respondents comprised five male and seven female teachers, with teaching experience ranging from 7 to 25 years, ensuring they had substantial instructional expertise. Additionally, the respondents were evenly distributed between six public and six private school teachers, providing diverse perspectives. The processed data from the needs analysis is provided in Appendix (Table A2).

The analysis of the questionnaire data indicates that although the majority of teachers (91.7%) consider statistical literacy important for development, most of them (75%) have limited knowledge and experience in this area. Additionally, the lack of relevant teaching resources presents a further challenge. However, the high willingness of teachers (91.7%) to adopt these resources highlights a significant opportunity for disseminating the GDL-based instructional design for statistical literacy among mathematics teachers. These findings align with classroom observations, which reveal that statistics lessons are predominantly teacher-entered, with direct instruction being the primary mode of teaching. Students tend to be passive during lessons, and many struggle when asked to recall or explain previously taught concepts. This suggests that students do not fully grasp the material during the learning process.

Expert Validation Results

The validation process employed a Likert scale ranging from 1 to 5, reflecting the degree of alignment between the model and the development of students' statistical literacy in statistics learning. The validation results indicate that the GDL model is categorised as 'highly valid,' as presented in Table 3. Revisions were made by the researchers in response to the validators' feedback, with detailed results provided in Appendix (Table A3).

Table 3
Expert Validation Results

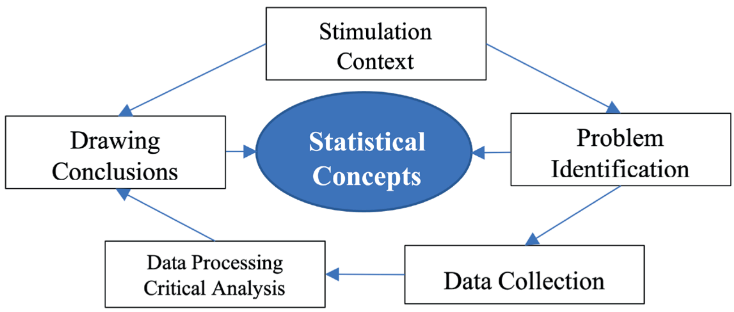
No	Validation Aspect	Average Score (1-5)	Category
1	Alignment with constructivist learning theory	4,6	Highly Valid
2	Integration with statistical literacy indicators	4,5	Highly Valid
3	Clarity of model syntax	4,7	Highly Valid
4	Coherence between activities and learning objectives	4,6	Highly Valid
5	Ease of implementation	4,4	Valid
	Total Average Score	4,56	Highly Valid

Source. Own research.

The results of the limited trial showed that students provided feedback and suggestions on the Student Activity Sheet (SAS) through direct interviews after completing the readability assessment and writing comments on the SAS. Overall, students found the worksheet very interesting, the instructions in the materials were clear enough, and the guided discovery learning approach was fun because of the collaborative group work. However, some students suggested improvements, including increasing the font size, improving the clarity of numerical values in the diagrams, and enhancing the illustrations. The researchers incorporated these suggestions and revised the SAs accordingly before implementation.

GDL Model Design for Enhancing Students' Statistical Literacy

Figure 1
GDL Design Scheme for Developing Students' Statistical Literacy

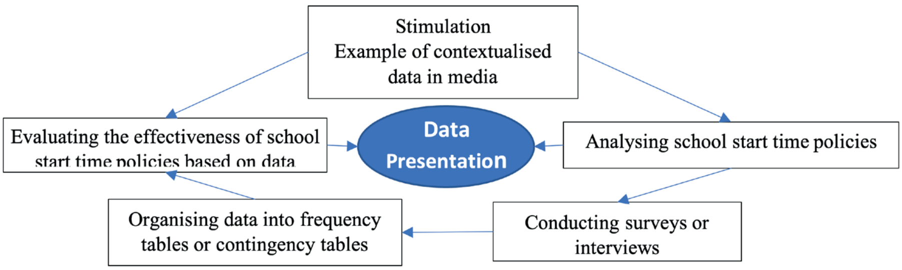


Source. Own research.

The development of the GDL framework (Figure 1) represents a visualisation of the syntax from Table 2, incorporating revisions based on validation results and limited trials. The arrows indicate that the activities are interconnected and sequential. The initial stimulation phase provides context to help students conclude, with problems presented about the statistical concepts being taught. This study incorporated contextual problems designed to foster students' statistical literacy competencies, including the ability to select appropriate data collection methods, accurately present data, evaluate information, draw conclusions, and make decisions based on data analysis. During the concluding phase, students were encouraged to consolidate their understanding and critically reflect on the statistical concepts addressed throughout the learning activities. An example of the instructional design is the development of a Student Activity Sheet (SAS) for the second session on the topic of "Presenting Data Using Tables."

Figure 2

Example of a GDL Design Framework for Understanding Data Presentation Concepts



Source. Own research.

Figure 2 presents an example of a Guided Discovery Learning (GDL) design aimed at providing students with direct experience in understanding data presentation concepts. In the stimulation phase, students are introduced to sample data obtained from media sources, which are relevant to the concept being studied—data presented in tabular form. During the problem identification phase, students encounter a contextual issue related to school start time policies (see Appendix, Figure A2). They are expected to recognise the need to analyse factors such as distance, modes of transportation, and departure times to assist schools in making informed decisions. In the data collection phase, students gather information from their classmates through surveys. Subsequently, in the data processing phase, they organize the collected data into frequency tables or contingency tables to facilitate analysis. At this stage, students are provided with Excel software to assist in data analysis and visualisation in tabular form. Finally, in the conclusion phase, students evaluate whether the 06:45 school start time policy aligns with the collected data and justify their reasoning based on their analysis. This sequence of activities reflects a scientific approach that enables students to develop an applied understanding of statistics while actively enhancing their statistical literacy.

The Impact of the GDL Model on Developing Students' Statistical Literacy

This research assessed the effectiveness of the Guided Discovery Learning (GDL) model by administering a statistical literacy test at the commencement (pre-test) and conclusion (post-test) of the sessions. The descriptive statistical outcomes are shown in Table 4.

Table 4
Descriptive Statistics of Pre-test and Post-test

Variable	Mean	Median	Std. Deviation	Minimum	Maximum
Pre-test	50.18	50.00	5.495	40	60
Post-test	85.28	87.00	5.134	73	93

Source. Own research.

The results of the descriptive analysis indicate a significant improvement in students' statistical literacy following the implementation of the Guided Discovery Learning (GDL) model. The median pre-test score of 50.00 increased to 87.00 in the post-test, reflecting that more than half of the students achieved a higher level of understanding. The mean score also rose from 50.18 to 85.28, with the score range shifting from 40–60 to 73–93, indicating that no students remained in the lower score category after the intervention. Furthermore, the decrease in the standard deviation from 5.495 to 5.134 suggests a more even distribution of scores, signifying that the improvement in understanding was consistent across all participants.

Normality Test

To assess whether the pre-test and post-test data conformed to a normal distribution, the Shapiro-Wilk test was performed using SPSS version 25. This evaluation ensured the suitability of the data for subsequent parametric analyses.

Table 5
Shapiro-Wilk Test Results

Variable	W (Shapiro-Wilk)	p-value	Conclusion
Pre-test	0.874	0.000	Not Normally Distributed
Post-test	0.843	0.000	Not Normally Distributed

Source. Own research.

The results of the normality test yielded p-values below 0.05 for both the pre-test and post-test data, indicating that the assumption of normality was not satisfied. Accordingly, the Wilcoxon Signed-Rank Test, a non-parametric procedure, was performed to determine the significance of the differences in scores.

Statistical Analysis Using the Wilcoxon Signed-Rank Test

This analysis sought to determine whether students' statistical literacy scores differed significantly between the pre-test and post-test following the implementation of the Guided Discovery Learning (GDL) model. The results of the Wilcoxon Signed-Rank Test are shown in Table 6.

Table 6

Wilcoxon Signed-Rank Test Results

Pretest-Postest	Z-score	Asymp. Sig. (2-tailed)	Cohen d (r)
SL 1	-4.801	0.000	0,759
SL 2	-5.118	0.000	0,809
SL 3	-4.836	0.000	0,765
SL 4	-4.492	0.000	0,710
Total	-5.552	0.000	0,878

Source. Own research.

Table 7

Rank-Based Analysis

Rank	N	Mean Rank	Sum of Rank
Negative	0	0,00	0.00
Positive	40	20.50	820
Ties	0	0,00	0.00

Source. Own research.

The Wilcoxon Signed-Rank Test results, as presented in Table 6, revealed a p-value of 0.000 for all statistical literacy (SL) indicators as well as for the overall comparison between pre-test and post-test scores. Given that the p-value falls below the 0.05 significance level, a statistically significant difference was identified between students' scores before and after the intervention. These findings demonstrate that the application of the Guided Discovery Learning (GDL) model leads to a notable improvement in students' statistical literacy. Furthermore, as illustrated in Table 7, every student showed an increase in their score following the GDL-based learning activities. No instances were recorded in which a student's score declined or remained unchanged, suggesting that the model consistently contributes to enhancing students' statistical understanding.

Subsequently, an effect size analysis was conducted to determine the magnitude of the impact of the GDL model (Cohen et al., 2002). Given the non-normal distribution of the data, the effect size (r) was calculated using the formula: ,, where n is the number of participants and z is the test statistic from the Wilcoxon Signed-Rank Test.

The effect size calculations for all statistical literacy indicators showed high values ($r = 0.710 – 0.809$), indicating that the GDL model has a substantial impact across all aspects. Among the SL indicators, SL 2 demonstrated the most significant effect. The total pre-test and post-test score effect size was 0.878, which translates to 77% of the variance in statistical literacy being attributed to the GDL model ($r^2 \times 100\% = 77\%$). These findings further confirm the considerable effectiveness of the GDL model in improving students' statistical literacy.

Students and Teachers' Perceptions of the GDL Model

Interviews were conducted with 10 students to explore their experiences with the Guided Discovery Learning (GDL) method. Qualitative analysis identified four main themes that reflect both the effectiveness and challenges of this model. Representative quotes from student responses are presented in Table 8, as most students provided similar patterns of responses.

Table 8
Student Responses After Implementing the GDL Model

Theme	Excerpt of Student Response
Deeper Conceptual Understanding	*"I now understand how statistics are applied, not just memorising formulas."* (Student 4)
Improved Critical Thinking Skills and Engagement	*"I have become more active, often thinking independently before asking the teacher, which makes me more confident."* (Student 7)
More Interactive and Engaging Learning	*"I enjoy learning statistics more because we can discuss, engage with real-world problems, and discover answers on our own."* (Student 2)
Challenges in the Data Analysis Stage	*"Sometimes I struggle with data analysis, so I need clearer guidance."* (Student 9)

Source. Own research.

Meanwhile, teachers who implemented the GDL model reported that it was highly engaging and systematic, promoting active student participation, encouraging idea generation, and facilitating connections between statistical theory and real-world applications. However, teachers identified time management as a significant challenge, as several stages within the GDL process frequently exceeded the allocated instructional time. Additionally, teachers noted the need to further optimise guidance during data analysis and support students in drawing conclusions or making data-driven decisions. Thus, teachers' responses not only acknowledge the effectiveness of the GDL model in enhancing students' statistical literacy but also highlight the need for continuous refinement of teaching strategies to better accommodate students' learning needs.

Discussion

This study's findings reveal that the implementation of the Guided Discovery Learning (GDL) model contributes positively to the enhancement of students' statistical literacy in lower secondary education. These results align with constructivist theory, which underpins the GDL approach and emphasises active student engagement in constructing their knowledge (Bruner, 1961; Slavin, 2018). The GDL model incorporates more complex statistical activities, such as defining problems, collecting data, and interpreting results, fostering a deeper understanding of statistics through an exploratory learning process (MacGillivray & Pereira-Mendoza, 2011). A significant improvement was observed across all indicators of statistical literacy, including reading and interpreting statistical language, analysing data, drawing conclusions, and critically evaluating statistical information. This underscores the importance of structured learning processes with adequate guidance in overcoming students' limitations in understanding statistical concepts in depth (Garfield et al., 2008; Koga, 2022). Furthermore, Don Kauchak & Paul Eggen (2012) and Richard E. Mayer and Merlic C. Wittrock (2006) emphasise that offering topic-specific examples to support students in problem-solving and promote their conceptual understanding constitutes a fundamental feature of the GDL model, contributing to its effectiveness in statistical instruction.

The findings on SL 1 indicate a significant impact in enhancing students' ability to understand fundamental statistical language, as demonstrated through the Wilcoxon Signed-Rank Test. This supports the findings of Bulent Guven et al. (2021), who emphasise that understanding statistical terminology serves as the foundation for developing more advanced statistical literacy. A real-world context-based approach, such as data exploration from media during the stimulation phase, enables students to connect abstract concepts with everyday experiences, thereby increasing their relevance and comprehension (Batanero & Borovcnik, 2016). Additionally, research by Jane M. Watson (2013) highlights that problem-based statistical learning significantly enhances student engagement and strengthens their grasp of fundamental concepts. SL 2 recorded the most substantial improvement, indicating that students demonstrated enhanced ability in interpreting data and effectively communicating statistical messages. As noted by Thilanka Munasinghe and Amy Svirsky (2021) and Maxine Pfannkuch et al. (2010), strengthening students' ability to interpret data requires providing real-world data applications and linking contextual knowledge with observed data features. The integration of contextual tasks within GDL, such as the analysis of school start-time policies, offers students the opportunity to understand the relevance of data in real-world decision-making processes (Gal, 2002; Watson, 2013).

For indicator SL3, which represents statistical analysis, a significant improvement was observed. This result is consistent with the conclusions drawn by Garfield et al. (2012), who emphasised that discovery-based learning assists students in developing the analytical skills required to comprehend relationships within data. Furthermore, Lyn D. English and Jane M. Watson (2015) highlighted the importance of inquiry-based teaching in enhancing students' statistical decision-making skills. However, despite the observed improvement, some students still require additional support in integrating data from various representations to produce more accurate decisions. Indicator SL4, which measures students' capacity to critically evaluate statistical information, likewise recorded increased scores from the pre-test to the post-test. Although this progress signifies the positive influence of Guided Discovery Learning (GDL) in promoting critical thinking, students still encounter challenges in data analysis, a concern similarly highlighted by teachers. This finding supports the perspectives of Sashi Sharma (2017) and Koga (2022), who argue that critical evaluation is one of the most complex aspects of statistical literacy and necessitates repeated and in-depth problem-based learning. Stephanie Budgett and Drusilla Rose (2017) further reinforced the importance of learning activities that facilitate students' critical evaluation through contextually relevant tasks.

Overall, this study reinforces the significance of structured discovery-based learning in developing students' statistical literacy. The integration of real-world problems, guided inquiry, and collaborative activities within the GDL model allows students to develop a more comprehensive understanding of statistical concepts and utilise them in a range of different contexts. However, further reinforcement is required, particularly in critical analysis activities, to ensure that students develop more comprehensive statistical evaluation skills. These results hold significant implications for the design of curricula and teaching practices in today's data-driven society, preparing students to act as competent, data-informed decision-makers.

Conclusion

This study formulated a Guided Discovery Learning (GDL) model comprising five principal stages: stimulation, problem identification, data collection, information analysis, and conclusion formulation. Each stage is designed to actively engage students in constructing statistical understanding through exploration, critical analysis, and guided inquiry facilitated by structured questioning. The model specifically integrates real-world contexts into every learning activity, which not only enhances student engagement but also strengthens their comprehension of abstract statistical concepts. Expert validation of this design indicates a high level of suitability for supporting the development of students' statistical literacy across four key indicators.

The GDL model significantly enhances students' statistical literacy. The median pre-test score increased from 50.00 to 87.00 in the post-test, indicating that more than half of the students experienced substantial improvement in their understanding. The Wilcoxon Signed-Rank Test results ($Z = -5.552$, $p < 0.001$) demonstrate a substantial increase in scores from the pre-test to the post-test, with every student showing improvement and none experiencing a reduction. The calculated effect size ($r = 0.878$) indicates that the model exerts a strong influence on students' statistical literacy. Overall, this study provides empirical evidence that a systematically designed GDL model, grounded in real-world contexts, is highly effective in improving students' statistical literacy. The proposed GDL model makes a significant contribution to enhancing pedagogical practices by equipping students to meet the demands of the big data era, while also providing a valuable framework for educators to design more effective and contextually appropriate instructional approaches.

Limitations and Recommendations

This study provides evidence of the positive impact of the Guided Discovery Learning (GDL) model on improving students' statistical literacy, though it is not without limitations. Firstly, the absence of a control group restricts the strength of causal inference, as the pre-test–post-test framework alone cannot entirely rule out external influences or random fluctuations in student performance. Nevertheless, as recognised in recent educational studies (Akinsola, 2025; Teke & Çalışıcı, 2025; Maison et al., 2020), the one-group pre-test–post-test design remains a valid and valuable approach for preliminary investigations, providing indicative rather than conclusive evidence. Future research could strengthen causal claims by employing quasi-experimental or randomised controlled designs.

Secondly, as the research was confined to middle school students within a specific region, the generalisability of these findings to wider populations remains limited. However, focusing on this educational level is relevant in an effort to strengthen the foundation of statistical literacy at an early stage. Thirdly, the study primarily examined four cognitive indicators without exploring affective aspects such as student motivation and self-confidence. Nevertheless, this focus offers important insights into students' mastery of essential statistical literacy competencies.

For future research, it is recommended to broaden the scope by involving students from various educational levels to enhance the generalisability of the results. Additionally, incorporating an analysis of affective aspects could provide a more holistic understanding of the model's effectiveness. Furthermore, the development of GDL content that integrates more complex, technology-based statistical tasks could further enhance the model's relevance in the era of big data. Despite these limitations, this study offers an important contribution to the development of statistical literacy and provides a valuable reference for enhancing instructional practices.

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Appendix

Figure A1

RASCH Model Relibility Test Result

SUMMARY OF 15 MEASURED Item

	TOTAL SCORE	COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	47.9	55.0	.00	.73	.96	-.07	1.01	.32
SEM	3.4	.0	.70	.05	.09	.29	.64	.70
P.SD	12.7	.0	2.61	.20	.33	1.10	2.40	2.62
S.SD	13.1	.0	2.71	.21	.35	1.14	2.48	2.71
MAX.	54.0	55.0	9.23	1.06	1.71	2.12	9.90	9.91
MIN.	1.0	55.0	-2.13	.52	.51	-2.00	.10	-1.63

REAL RMSE .79 TRUE SD 2.49 SEPARATION 3.15 Item RELIABILITY .91

MODEL RMSE .75 TRUE SD 2.50 SEPARATION 3.32 Item RELIABILITY .92

S.E. OF Item MEAN = .70

Source. Own research.

Figure A2

Example of Problem Identification Activity in the SAS

2 Identify the problem

6. Take a look and get the key points of the following issues.

Problem illustration

At the beginning of the new academic year, the school will take a new policy regarding school entry hours, which is 06.45 WIB from the previous 07.00 WIB. Therefore, the school wants to know the distance of all students' homes to school, what means of transportation most students use to go to school, and what time students leave home. To get this information, can you help collect information in your class and how can you get this information?

Source. Own research.

Table A1

Blueprint of the Statistical Literacy Assessment Instrument

Indicator	Question Indicator	No
SL 1	Identifying effective methods for data collection	1
	Determining appropriate data presentation techniques	2
	Distinguishing the most suitable data presentation method	3
	Selecting a sample from a population	13
SL 2	Converting data from tables to diagrams	4
	Representing a dataset in table format	5
	Interpreting data from a line graph	10
	Analysing data from a pie chart	11
SL 3	Drawing conclusions from a pie chart	7
	Making decisions based on tabular data	8
	Inferring information from a bar chart	9
	Making decisions using two types of diagrams	12
SL 4	Evaluating accurate statements from a line graph	6
	Assessing the correctness of statistical conclusions	14
	Verifying the accuracy of data presentation in a contextual problem	15

Source. Own research.

Table A2

Summary of the Questionnaire on Statistical Literacy

Aspects Investigated Teacher	Responses		
Familiarity with the term "statistical literacy	Frequently	Occasionally	Never
	8,3%	16,7%	75%
Knowledge of statistical literacy	Good	Adequate	Unfamiliar
	8,3%	16,7%	75%
Importance of developing statistical literacy	Very important	Moderately important	Not important

Aspects Investigated Teacher	Responses		
	91,7%	8,3%	0%
Experience in designing instructional materials for statistical literacy	Frequently	Occasionally	Never
	0%	25%	75%
Availability of instructional materials focused on statistical literacy	Not available	Rarely available	Widely available
	83,3%	16,7%	0%
Willingness to use statistical literacy-oriented instructional materials	Willing	Uncertain	Unwilling
	91,7%	8,3%	0%

Source. Own research.

Table A3

Revisions to Student Activity Sheets Based on Validator Feedback

Validation Aspect	Validator Comments	Revisions and Improvements
Clarity of Model Syntax	The model's syntax is clear, but transitions between stages need to be more structured for easier implementation.	Added a flowchart illustrating stage transitions more systematically.
Ease of implementation	The model is generally applicable in the classroom, but teacher instructions should be simplified for better comprehension by educators.	Developed an implementation guide with simplified language and provided classroom learning scenarios.

Source. Own research.