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From Data Reading to Statistical Literacy: Examining Grade-Level and Gender Differences in Indonesian Elementary Students' Data-Description Skills

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Abstract: This study aims to examine Indonesian elementary students' data-description skills as a foundational dimension of statistical literacy and to investigate differences across grade levels and gender. A quantitative cross-sectional design was employed with 2,106 students from Grades 2, 4, and 6 across 16 urban and rural schools. Four open-response tasks assessed students' abilities to identify information in tables, recognize visual codes, explain data, and make predictions or draw conclusions. Confirmatory Factor Analysis (CFA) and multi-group CFA were used to examine the measurement structure, while Welch's t-test, Welch's ANOVA with Games–Howell post hoc comparisons, and Cohen's d were used to assess group differences and effect sizes. All four indicators significantly contributed to the data-description construct, with drawing conclusions showing the strongest association. Most students (78.3%) were classified at the Idiosyncratic level, indicating predominantly literal or surface-level interpretations of data. Mean scores increased from Grade 2 (M = 1.15) to Grade 4 (M = 1.33) and Grade 6 (M = 1.92), with significant differences across all grade-level pairs ($p < .001$; d = 0.47–1.39). Female students scored slightly higher than male students, although the effect size was small (d = 0.27). Instruction should therefore move beyond literal data reading by engaging students more explicitly and consistently in comparing data, explaining relationships, and justifying predictions or conclusions using evidence from tables and graphs.

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Introduction

The ability to understand, interpret, and critically reason about data encountered in everyday life is widely recognized as a central component of statistical literacy (Gal, 2002; OECD, 2019). In an era increasingly shaped by data-driven communication, statistical literacy has become a core competency for informed decision-making and responsible citizenship in the 21st century (Gould, 2017; OECD, 2019). For young learners, the development of statistical literacy does not primarily involve performing complex calculations or applying sophisticated formulas; rather, it begins with building statistical intuition—the capacity to recognize patterns, interpret visual information, and make sense of data representations in meaningful ways (Jones et al., 2000; Watson & Callingham, 2002). Developing this capability from an early age is essential for preparing students to participate effectively in a society where data plays a central role in communication, policy, and daily decision-making (Gould, 2017; OECD, 2019).

In primary school settings, the development of statistical literacy often begins with students' ability to read and describe data presented in pictograms, graphs, and tables (Franklin et al., 2005; Mendikbudristek, 2022). These early skills include identifying information from visual displays, recognizing symbols or visual codes, explaining the meaning of data, and making simple predictions based on observed patterns (Jones et al., 2000; Watson & Callingham, 2002). Such competencies represent foundational forms of data description and interpretation that support the later development of statistical reasoning and statistical thinking (Garfield & Ben-Zhi, 2008). Consequently, the ability to read and describe data is not merely a basic technical skill but a critical step in building students' capacity to engage meaningfully with data throughout their educational trajectory (Franklin et al., 2005; Mendikbudristek, 2022; OECD, 2019).

For elementary students, interpreting graphs and tables involves more than locating individual values. Students must attend to relevant visual features, coordinate information across categories or quantities, recognize relationships and patterns, and use these relationships to construct meaningful interpretations (Jones et al., 2000; Watson & Callingham, 2002). As students progress, these cognitive demands shift from literal data reading toward increasingly relational and evidence-based reasoning. Thus, examining data-description skills provides an important window into how young learners develop the cognitive processes underlying statistical literacy.

Despite the recognized importance of data-description skills, empirical evidence on how these skills develop during primary education remains limited, particularly in Indonesia (Hasanah et al., 2024; Prihastari et al., 2022). The Indonesian context is particularly relevant because students are expected to engage with increasingly complex forms of data representation and interpretation as they progress through primary education. However, limited evidence is available regarding whether these curricular expectations are reflected in students' actual progression from basic data reading toward more quantitative and analytical reasoning. Examining students across different grade levels therefore provides an important opportunity to identify how foundational data-description skills develop within the Indonesian primary-school context and where potential gaps in students' statistical understanding may remain.

In addition to understanding developmental progression, examining variation in statistical literacy across student characteristics remains an important area of inquiry. Several studies have suggested that students' statistical literacy tends to improve as grade level increases. For instance, Jones et al. (2000) and Mooney (2002) reported that students in lower grades are generally able to read simple data representations, whereas students in higher grades demonstrate greater capacity to interpret data and engage in more complex statistical reasoning. These findings suggest a developmental progression in statistical understanding as students advance through school (Callingham & Watson, 2017; Watson & Callingham, 2002). However, other studies have reported inconsistent results, indicating no significant differences in statistical literacy across grade levels (Watson & Moritz, 2000; Yolcu, 2014). Such mixed evidence highlights the need for further investigation into how statistical literacy develops across different stages of primary education.

Gender differences in statistical literacy have also received considerable attention in the literature. Some studies suggest that female students tend to perform slightly better in reading and analyzing data, which has been attributed to differences in learning motivation or engagement in statistics-related activities (Carmichael, 2009; Chiesi & Primi, 2015; Yolcu, 2014). In contrast, other research has found no meaningful differences in statistical literacy between male and female students, suggesting that gender-related variations may be minimal or shaped by contextual factors such as instructional practices and learning environments (Kurnia et al., 2023). These contrasting findings indicate that the role of gender in the development of statistical literacy remains inconclusive and warrants further empirical

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examination.

Therefore, this study aims to characterize Indonesian elementary school students' data-description skills and to examine how these skills differ across grade levels and gender. Specifically, the study investigates students' performance across four components of data description—identifying information, recognizing visual codes, explaining data, and drawing conclusions—and examines their distribution across developmental levels of statistical literacy. The study contributes empirical evidence on the structure and developmental pattern of data-description skills across Grades 2, 4, and 6 in the Indonesian primary-school context, while also providing evidence on the extent to which these skills vary by gender.

Research Method

The assessment framework was grounded in the statistical literacy framework of Jones et al. (2000). Data-description skills were operationalized through four indicators: identifying specific information in graphs or tables (DD1), recognizing symbols or visual codes (DD2), explaining information presented in data representations (DD3), and making predictions or drawing conclusions based on patterns in the data (DD4). Students' responses were further classified into four developmental levels—Idiosyncratic, Transitional, Quantitative, and Analytical—representing increasing sophistication from literal or surface-level data reading to quantitative and evidence-based interpretation (see **Table 1** for more details).

Table 1. Development of Statistical Literacy Level for Data Description

Level	Level Description	Characteristics
Level 1: Idiosyncratic	Students read data literally, but their descriptions are unfocused, include irrelevant information, and show limited understanding of graph conventions.	Do not understand titles, axes, or labels; reasoning is subjective; do not recognize that two displays can represent the same data; evaluation is based on irrelevant aspects.
Level 2: Transitional	Students begin to show awareness of graph conventions, but their descriptions remain tentative and incomplete.	Start recognizing elements of graphs; realize that two displays can represent the same data; explanations are still based on surface features (e.g., shape or color) and focus on only one aspect.
Level 3: Quantitative	Students are able to provide more confident and complete descriptions and begin to connect elements of data within the display.	Understand graph conventions; identify relationships among data; use more than one aspect in evaluation; begin to apply quantitative reasoning.
Level 4: Analytical	Students are able to explain data comprehensively and use appropriate numerical relationships to evaluate data displays.	Complete and accurate descriptions; use appropriate numerical relationships; logical and coherent explanations; evidence-based evaluation.

This study involved 2,106 elementary school students from 16 schools located in Mataram City, West Lombok, Central Lombok, and East Lombok, Indonesia, including 678 Grade 2 students, 686 Grade 4 students, and 742 Grade 6 students. The schools were purposively selected to represent both urban and rural settings, while Grades 2, 4, and 6 were included to represent different stages of primary education. Participation was voluntary, informed consent was obtained from the schools prior to data collection, and students' identities were anonymized in accordance with ethical research standards. Stratified purposive sampling was used to ensure proportional representation across grade levels and to

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support meaningful developmental comparisons. Participation was voluntary, informed consent was obtained from schools prior to data collection, and students' identities were anonymized in accordance with ethical research standards.

Data were collected using four open-response tasks aligned with the four data-description indicators (Table 2). Each task required students to provide an answer and a written explanation, allowing both the accuracy of the response and the reasoning used to interpret the data representation to be examined. The tasks represented progressively more complex demands, ranging from identifying information in tabular data and interpreting visual codes to comparing data across groups, recognizing patterns, and making data-based predictions or conclusions.

Table 2. Operationalization of Data-Description Assessment Tasks

Item	Data Representation	Task Demand	Skill Assessed
DD1	Tabular data on students' extracurricular participation	Locate relevant values and combine them to answer a question about a specified category.	Identifying specific information in tabular data.
DD2	Categorical graph of ice-cream sales	Identify the highest value for a specified day and explain the answer using information from the display.	Recognizing and interpreting visual codes in data representations.
DD3	Comparative graph of male and female visitors across several days	Compare two groups across the week and determine which group is greater overall.	Explaining and comparing information across data groups.
DD4	Time-based representation of weekly tree growth	Identify a growth pattern and extrapolate it to predict a future value.	Making predictions or drawing conclusions based on data patterns.

Prior to the main data collection, the instrument was reviewed by four experts with expertise in literacy, elementary mathematics, mathematics education, and statistical literacy. The experts evaluated the alignment of the items with the intended data-description indicators, the clarity of wording and visual representations, and their appropriateness for elementary school students. The instrument was revised based on their feedback and subsequently pilot-tested with 100 students before being administered on a larger scale to 2,106 students.

Confirmatory Factor Analysis (CFA) was used to evaluate the construct validity of the four-indicator data-description model, with model fit evaluated using CFI, RMSEA, and TLI (Brown & Haris, 2013; Hair et al., 2013). Multi-group CFA was subsequently used to examine variation in measurement parameters across gender and grade levels (Kline, 2016; Nurhayati et al., 2023). Observed-score differences between male and female students were examined using Welch's independent-samples t-test, while grade-level differences were examined using Welch's ANOVA followed by Games–Howell post-hoc comparisons. Cohen's d was used to quantify the magnitude of group differences.

Table 3. Illustrative Coding of Student Responses to Item DD2

Illustrative Response	Developmental Level	Classification Rationale
"Chocolate ice cream sold the most because its color is the most attractive and the picture is the biggest."	Level 1: Idiosyncratic	The response relies on subjective visual features rather than the represented data.
"Chocolate ice cream sold the most because its bar is higher than the others."	Level 2: Transitional	The student recognizes a relevant graphical feature but provides only a simple, non-quantitative

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		explanation.
"Chocolate ice cream sold the most because it is about 25, while vanilla is about 18 and strawberry about 20."	Level 3: Quantitative	The student uses numerical values and compares multiple data points to justify the answer.
"Chocolate ice cream sold the most at about 25 units, compared with strawberry at about 20 and vanilla at about 18; therefore, chocolate had the highest sales."	Level 4: Analytical	The student integrates numerical comparisons into a logical, evidence-based conclusion.

Students' written responses were coded into four developmental levels of statistical literacy: Idiosyncratic, Transitional, Quantitative, and Analytical. Two independent raters coded the responses, achieving 85% agreement, indicating acceptable inter-rater reliability (Cohen, 1960; McHugh, 2012). To illustrate the coding procedure, Table 3 presents representative responses to DD2, in which students were asked to identify the ice-cream flavor with the highest sales on Wednesday from a categorical graph and explain their reasoning.

Results and Discussion

Validation of measurement model and group comparison in data description skills

Confirmatory Factor Analysis (CFA) was conducted to evaluate the construct validity of the data-description dimension of statistical literacy, comprising four indicators: identifying information in graphs or tables (DD1), recognizing symbols or color codes (DD2), explaining data information (DD3), and making predictions or drawing conclusions (DD4). Using the Maximum Likelihood method with 2,106 elementary school students, all indicators showed statistically significant factor loadings: 0.562 (DD1), 0.559 (DD2), 0.472 (DD3), and 0.633 (DD4). DD4 showed the strongest association with the latent construct, whereas DD3 showed the lowest. Model fit evaluation indicated acceptable adequacy, with $\chi^2 = 97.7$ (df = 2, $p < .001$) and CFI = 0.961, suggesting that the hypothesized construct was generally consistent with the empirical data.

Multi-group CFA indicated that some measurement parameters varied across gender groups, with the overall constraint score test reaching statistical significance, $\chi^2(7) = 60.35$, $p < .001$. Accordingly, differences in the measurement structure across gender groups were interpreted cautiously. As a complementary analysis addressing differences in observed data-description scores, male and female students were compared using Welch's independent-samples t-test, with Cohen's d used to quantify the magnitude of the difference (see Table **4**).

Table 4. Group Differences in Data Description Skills by Gender and Grade Level

Comparison	Group Statistics, M (SD)	Statistical Test	p	Effect Size
Gender	Male: 1.404 (0.589); Female: 1.571 (0.664)	Welch's t(1938.10) = 6.05	< .001	d = 0.267
Grade level	G2: 1.148 (0.273); G4: 1.330 (0.479); G6: 1.923 (0.726)	Welch's F(2, 1255.43) = 373.31	< .001	—
Grade 2 vs Grade 4	ΔM = 0.182	Games–Howell	< .001	d = 0.466
Grade 2 vs Grade 6	ΔM = 0.775	Games–Howell	< .001	d = 1.390
Grade 4 vs Grade 6	ΔM = 0.593	Games–Howell	< .001	d = 0.957

Female students obtained slightly higher overall data-description scores than male students. Welch's t-test showed that the difference was statistically significant, $t(1938.10) = 6.05$, $p < .001$; however, the magnitude of the difference was small (Cohen's d = 0.27). Thus, although gender differences were statistically detectable, their practical magnitude was limited.

Multi-group CFA also indicated variation in measurement parameters across grade levels; therefore, differences in the measurement structure were interpreted cautiously. As a complementary observed-score analysis, grade-level differences were examined using Welch's ANOVA followed by Games–Howell post-hoc comparisons. As shown in

Table 4, mean data-description scores increased progressively from Grade 2 to Grade 4 and Grade 6. The overall grade-level difference was statistically significant, $F(2, 1255.43) = 373.31$, $p < .001$, and all pairwise comparisons were significant ($p < .001$). The magnitude of the differences increased from $d = 0.47$ between Grades 2 and 4 to $d = 0.96$ between Grades 4 and 6 and $d = 1.39$ between Grades 2 and 6. These results provide strong evidence of progressive differences in data-description skills across grade levels.

Development of Data Description Skills among Elementary School Students

The findings of this study indicate that Indonesian elementary school students possess four key data description skills: identifying information in graphs or tables (DD1), recognizing symbols or visual codes (DD2), explaining data information (DD3), and making predictions or drawing conclusions based on data (DD4). The significant factor loadings observed across all four indicators suggest that these skills collectively form a coherent and valid construct of statistical literacy in the data description dimension. This result confirms that data description skills represent an essential component of students' early statistical understanding.

The distribution of students across the four developmental levels of statistical literacy further illustrates the progression of these skills among elementary school students (**Table 5**). Most students were classified at Level 1 (Idiosyncratic), accounting for 78.3% of the total sample, indicating that many students were still at an early stage of understanding data representations. At this level, students tended to read data literally and showed limited ability to explain or interpret information beyond surface features. A smaller proportion of students reached Level 2 (Transitional) (13.9%), where they began to recognize graph conventions and provide simple explanations based on visual information. Only 6.4% of students reached Level 3 (Quantitative) and 1.2% reached Level 4 (Analytical), suggesting that relatively few students were able to interpret relationships among data, apply quantitative reasoning, or provide evidence-based explanations.

Table 5. Student description data skills among grades

Level	**Number of Students in Each Grade**			**Total across level**
	2	**4**	**6**	
1 (Idiosyncratic)	655 (39.7%)	606 (36.7%)	388 (23.5%)	1649 (78.3%)
2 (Transitional)	23 (7.8%)	59 (20.1%)	212 (72.1%)	294 (13.9%)
3 (Quantitative)	0 (0.0%)	17 (12.5%)	119 (87.5%)	136 (6.4%)
4 (Analytical)	0 (0.0%)	4 (14.8%)	23 (85.2%)	27 (1.2%)
Total across grade	678 (32.2%)	686 (32.6%)	742 (35.2%)	2106 (100.0%)

The predominance of students at the Idiosyncratic level is a particularly important finding. It suggests that, for many students, engagement with data representations remains largely focused on literal or surface-level features rather than on coordinating numerical information, relationships, and evidence to construct an interpretation. One plausible explanation is that students may have had greater experience with tasks requiring them to locate or report information from tables and graphs than with tasks requiring them to explain, justify, compare, or draw conclusions from data. Such experiences could support basic data reading without necessarily promoting the transition toward quantitative and analytical reasoning. This interpretation is consistent with developmental perspectives on statistical

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literacy, which emphasize that progression beyond literal data reading requires opportunities to reason about relationships and justify interpretations using evidence (Jones et al., 2000; Watson & Callingham, 2002; Shaughnessy, 2007). However, because the present study did not directly examine classroom instruction, textbook characteristics, or students' prior learning experiences, these factors should be regarded as plausible explanations rather than causal conclusions.

The grade-level distribution also demonstrates a clear developmental progression in students' data description skills. Students in Grade 2 were predominantly concentrated at Level 1, whereas students in Grade 6 showed substantially higher representation in Levels 2, 3, and 4. In particular, Grade 6 students accounted for 72.1% of students at the Transitional level, 87.5% at the Quantitative level, and 85.2% at the Analytical level. This pattern suggests that students' ability to interpret and reason with data develops progressively as they advance through primary education.

Conceptually, these findings are consistent with statistical literacy frameworks proposed by Jones et al. (2000) and Watson and Callingham (2002), which position the ability to read and describe data as a foundational stage in the development of statistical literacy. Among the four indicators, the ability to make predictions or draw conclusions (DD4) demonstrated the strongest contribution to the construct, indicating that students have begun to develop data-based inference skills. This result reinforces the view that drawing conclusions from data represents a higher level of statistical thinking that emerges as students gain experience in interpreting patterns and relationships in data (Franklin et al., 2005; Garfield & Ben-Zhi, 2008).

However, the indicator related to explaining information from graphs or tables (DD3) showed a relatively lower contribution, suggesting that articulating the meaning of data remains challenging for some students. This finding is consistent with previous studies showing that students often experience difficulties in interpreting data logically and communicating their reasoning (Shaughnessy, 2007; Watson, 2006). Overall, these results suggest that while students demonstrate foundational data-reading and inference skills, the ability to provide clear and logical explanations of data requires further instructional support.

Differences in Data Description Skills between Male and Female Students

The results of the multi-group Confirmatory Factor Analysis indicate that the structure of the data description construct is generally comparable between male and female students. This finding suggests that the measurement model is capable of assessing data description skills consistently across gender groups, indicating that the underlying competencies are fundamentally similar for both male and female students.

Although minor variations were observed in the contribution of certain indicators—particularly in recognizing visual conventions in graphs (DD2)—these differences did not represent substantial disparities in overall ability. Instead, they likely reflect variations in students' learning experiences or cognitive strategies rather than inherent gender-based differences. This interpretation is consistent with previous research showing that gender differences in statistical literacy at the primary education level are typically small and more strongly influenced by environmental and instructional factors than by biological characteristics (Carmichael, 2009; Shibley, 2005).

Furthermore, the indicator related to making predictions or drawing conclusions (DD4) demonstrated relatively strong contributions across both gender groups, indicating that data-based inference skills develop similarly among male and female students. Taken together, these findings suggest that gender does not play a dominant role in shaping students' data description skills, and that instructional opportunities and learning experiences

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are likely more influential factors in supporting statistical literacy development.

Differences in Data Description Skills across Grade Levels

Compared with the small gender effect, substantially stronger differences were observed across grade levels. Students' mean data-description scores increased progressively from Grade 2 to Grade 4 and Grade 6, with significant differences between all grade pairs. The magnitude of these differences also increased across grades, ranging from a moderate difference between Grades 2 and 4 ($d = 0.47$) to a large difference between Grades 4 and 6 ($d=0.96$) and a very large difference between Grades 2 and 6 ($d = 1.39$). Because the study compared different cohorts rather than following the same students longitudinally, these findings should be interpreted as a cross-sectional pattern consistent with developmental progression. Nevertheless, the systematic increase across grade levels suggests that students' ability to understand and reason with data becomes increasingly sophisticated across primary education.

The pattern of factor loadings provides complementary insight into how different components of data description are associated with the underlying statistical-literacy construct across grade levels. In particular, the relatively strong contribution of DD4, especially at the higher grade level, indicates that performance on tasks requiring students to identify patterns, make predictions, and draw data-based conclusions is closely associated with their broader data-description competence. This should not be interpreted as evidence that DD4 was the easiest skill or the skill most successfully mastered by students. Rather, inference-oriented tasks require students to coordinate multiple elements of a data representation, recognize relationships among values, and integrate this information into a justified conclusion. Such tasks may therefore be particularly informative in differentiating students with different levels of statistical understanding.

In contrast, DD1 primarily requires students to identify information explicitly represented in a graph or table. This involves a more localized form of processing in which students retrieve specific information rather than coordinate multiple relationships within a representation. Its relatively lower contribution at earlier grade levels may therefore reflect the foundational nature of direct data-reading tasks, which may be less sensitive to differences in students' broader statistical reasoning. Taken together, the observed grade-level differences and the factor-loading pattern suggest an increasing integration of basic data reading, interpretation, and inference as students progress through primary education. From a cognitive perspective, this pattern is consistent with a shift from attending mainly to isolated features of data displays toward coordinating quantities, relationships, and patterns to construct evidence-based interpretations, in line with developmental perspectives on statistical literacy (Jones et al., 2000; Shaughnessy, 2007; Watson & Callingham, 2002).

Conclusion

This study provides empirical evidence that elementary students' data-description skills can be represented through four related components: identifying information, recognizing visual codes, explaining data, and making predictions or drawing conclusions. Among these components, drawing conclusions showed the strongest association with the underlying data-description construct.

The findings also reveal a distinctive developmental profile. Most students remained at the Idiosyncratic level, indicating that their responses were predominantly characterized by literal or surface-level interpretations of data. At the same time, progressively higher data-description scores were observed from Grade 2 to Grade 4 and Grade 6, with substantial differences across grade levels. Because the study was cross-sectional, this pattern should be interpreted as consistent with developmental progression rather than as evidence of individual growth over time. Gender differences were statistically significant but small in magnitude.

The main contribution of this study is therefore to provide a large-sample empirical profile of how foundational data-description skills are structured and distributed across different stages of Indonesian primary education. The findings highlight that the major instructional challenge is not simply enabling students to retrieve information from data representations, but supporting their transition from literal data reading toward relational, quantitative, and evidence-based reasoning.

Recommendation

Based on the findings, statistics instruction in elementary school should provide structured opportunities for students to move from literal data reading toward quantitative and evidence-based reasoning. For tasks involving data explanation, teachers can use sentence stems or a simple claim–evidence–reasoning structure, prompting students to state what the data show, identify the numerical or visual evidence supporting their statement, and explain how the evidence justifies their interpretation. For example, prompts such as "The data show that …," "I know this because …," and "Therefore, I conclude that …" can help students connect their explanations explicitly to the information represented in tables or graphs.

Short data-discussion routines can also be used to address the predominance of Idiosyncratic responses. Students may first be asked what they notice in a data display, then to compare quantities or identify patterns, and finally to justify their observations using specific values from the representation. As students become more proficient, these activities can progress toward predicting trends and drawing conclusions from multiple pieces of evidence. Such instructional progression directly targets the transition from surface-level descriptions toward quantitative and analytical reasoning identified in this study.

Future research should examine whether such structured instructional approaches improve students' progression across levels of statistical literacy. Longitudinal studies are also needed to investigate changes in data-description skills over time and to determine how instructional experiences, digital tools, and different learning contexts contribute to students' statistical-literacy development.

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