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The Gap in Employing and Interpreting Skills in Junior High School Students' Mathematical Literacy on Systems of Linear Equations: A Cognitive Style Perspective

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ABSTRACT

Mathematical literacy, the ability to formulate, employ, and interpret mathematics in real-life contexts, is a critical competency for junior high school students, yet these three components rarely develop evenly, particularly in contextual topics such as systems of linear equations with two variables. Many students can formulate problems into mathematical models but struggle to employ and interpret the solutions meaningfully, a gap believed to be influenced by cognitive style. This study describes the gap between employing and interpreting skills in junior high school students' mathematical literacy on this topic, viewed through the lenses of field-dependent (FD) and field-independent (FI) cognitive styles. This qualitative case study involved 24 eighth-grade students in Bandung. The Group Embedded Figures Test classified students into FD and FI categories, followed by a contextual mathematical literacy test and semi-structured interviews with selected participants. Both groups showed a decline across all three indicators, but the sharpest decline occurred in different areas. FD students (17 of 24) scored 49% on "formulating," dropping to 25% on "employing" and 16% on "interpreting," so that the step from formulating to employing was their primary obstacle. FI students (7 of 24) scored consistently higher (62%, 52%, and 33%) but, in the group totals, dropped most sharply between "employing" and "interpreting," although individual patterns were mixed. Analysis of written responses and interviews revealed qualitatively different error patterns: FD students' errors stemmed from conceptual understanding and reliance on peers, whereas FI students' errors were technical in nature. Instruction should therefore target the stage that poses the real challenge for each cognitive style group.

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■ INTRODUCTION

Mathematical literacy is the capacity to use mathematics in real-life situations: to formulate situations mathematically, to employ mathematical concepts and procedures, and to interpret the outcomes in the original context (OECD, 2026a; Suhardiyani et al., 2026). The notion of mathematical literacy in PISA is intricately linked to the mathematical representation of real-world scenarios and to mathematics as a foundation for life after education (Stacey & Turner, 2015). Modeling is in turn treated as one of the core mathematical competencies (Maaß, 2006; Niss & Højgaard, 2019).

Indonesia's performance on this competence remains a concern. In PISA 2025, Indonesian 15-year-olds scored 364 in mathematics against an OECD average of 463, essentially unchanged from 2022, and only 17% reached at least Level 2 compared with 65% across the OECD (OECD, 2026b). Earlier work suggests that the difficulties begin early in the solution process. In an error analysis of released PISA tasks, Wijaya et al. (2014) found that Indonesian students in the ninth and tenth grades predominantly struggled with contextual comprehension (38%) and translating it into mathematical problems (42%). In contrast, mathematical processing and encoding accounted for 17% and 13%, respectively. A scholarly examination revealed that merely 10% of the assignments in three Indonesian textbooks were grounded in context (Wijaya et al., 2015), which suggests limited opportunity to practice such tasks; a later study in Indonesia examined how such opportunities relate to students' performance on context-based tasks (Wijaya et al., 2018).

Systems of Linear Equations with Two Variables (SPLDV) are a suitable context for examining these processes, because one

contextual problem requires students to express a verbal situation as two equations, solve them, and interpret the solution in the situation. Algebraic understanding matters here: Knuth et al. (2005) demonstrated that middle school students' comprehension of equivalence and variables influences how successfully they solve problems, which strategies they use, and how they justify their solutions. Studies of SPLDV problems among Indonesian junior high school students report errors in understanding the problem, in transforming it into a model, and in process skills, the latter partly attributed to carelessness and haste (Santoso et al., 2019). Difficulties in initial algebra among Indonesian students (Jupri et al., 2014), and more generally in turning word problems into algebraic expressions (Jupri & Drijvers, 2016; MacGregor & Stacey, 1993), point to the same early transitions. Viewed through the modeling cycle, such errors can be seen as blockages at the transitions between phases of modeling (Borromeo Ferri, 2006; Galbraith & Stillman, 2006), and the empirical literature on teaching and learning mathematical modeling has long attended to such difficulties (Schukajlow et al., 2018), yet where the blockage occurs may differ between students.

Cognitive style is one learner characteristic that may explain such differences. Cognitive styles are understood as mental shortcuts that people employ to interpret information regarding their surroundings (Kozhevnikov, 2007). A well-known dimension is field dependence–independence (Witkin et al., 1977b): field-independent (FI) learners are inclined to focus on specifics, analyze information methodically, and depend on intrinsic signals, whereas field-dependent (FD) learners depend more on external cues and the overall context (Witkin et al., 1977b; Xie et al., 2025). A recent meta-analysis encompassing 42 studies indicated a moderate positive link between field independence and academic success in elementary and secondary students (r = .308), influenced by the assessment tool, subject domain, and kind of achievement (Xie et al., 2025). Findings are not uniform across studies and instruments (Tinajero & Páramo, 1997; Xie et al., 2025), and a correlation with overall achievement does not show where, within a multi-step task, the differences emerge.

Field dependence–independence offers a theoretical reason to expect that these blockages are not located at the same transition for both groups. Formulating a contextual SPLDV problem requires separating the relevant quantities from the surrounding narrative and restructuring them into two equations, an operation that draws on the analytic, disembedding processing associated with field independence (Witkin et al., 1977b). FD students, who rely more on overall context and external cues, may therefore be more likely to struggle from the outset and carry an incomplete model into the employing phase, where elimination or substitution must be carried out on symbols detached from the story. FI students, in contrast, may be better equipped for the symbolic work of employing. However, their reliance on internal cues and their attention to detail could make them more prone to treating the numerical solution as a finished product, so that reconnecting it to the situation (interpreting) is where they are most likely to falter (Verschaffel et al., 1994). These expectations are tentative working propositions rather than hypotheses to be tested. They are drawn from the theory of cognitive style and from the modeling cycle (Galbraith & Stillman, 2006), and the present study examines whether, and in what form, they appear in students' written work and interviews. Figure 1 illustrates the resultant conceptual framework that connects the three literacy indicators with the two processing orientations.

In Indonesia, research on mathematical literacy and cognitive style has received steady attention. However, a systematic review of 11 such studies published between 2018 and September 2022 found that most were conducted at the senior high school level and focused on Java (Rum & Juandi, 2023), suggesting that junior high school students are comparatively underrepresented. A qualitative study of junior high school students found that FI students showed competence in all three components of numeracy; in contrast, FD students primarily achieved only the comprehension and application aspects (Son et al., 2026). This is the closest study to ours, but as its abstract indicates, it examined numeracy in general rather than a specific topic such as SPLDV, and it did not focus on the nature of the errors behind each group's difficulties. It therefore remains unclear where, across formulating, employing, and interpreting, each group's largest drop occurs on SPLDV problems, and whether the errors at that point are conceptual or technical.

This study therefore aims to describe where, across the formulating, employing, and interpreting indicators, the most significant decline in mathematical literacy among junior high school students regarding SPLDV is observed in both field-dependent and field-independent learners, along with the sorts of errors that contribute to this decline. Guided by the framework in Figure 1, this study addresses three research questions: (1) How do field-dependent students perform across the formulating, employing, and interpreting indicators? (2) How do field-independent students perform across the same indicators? (3)

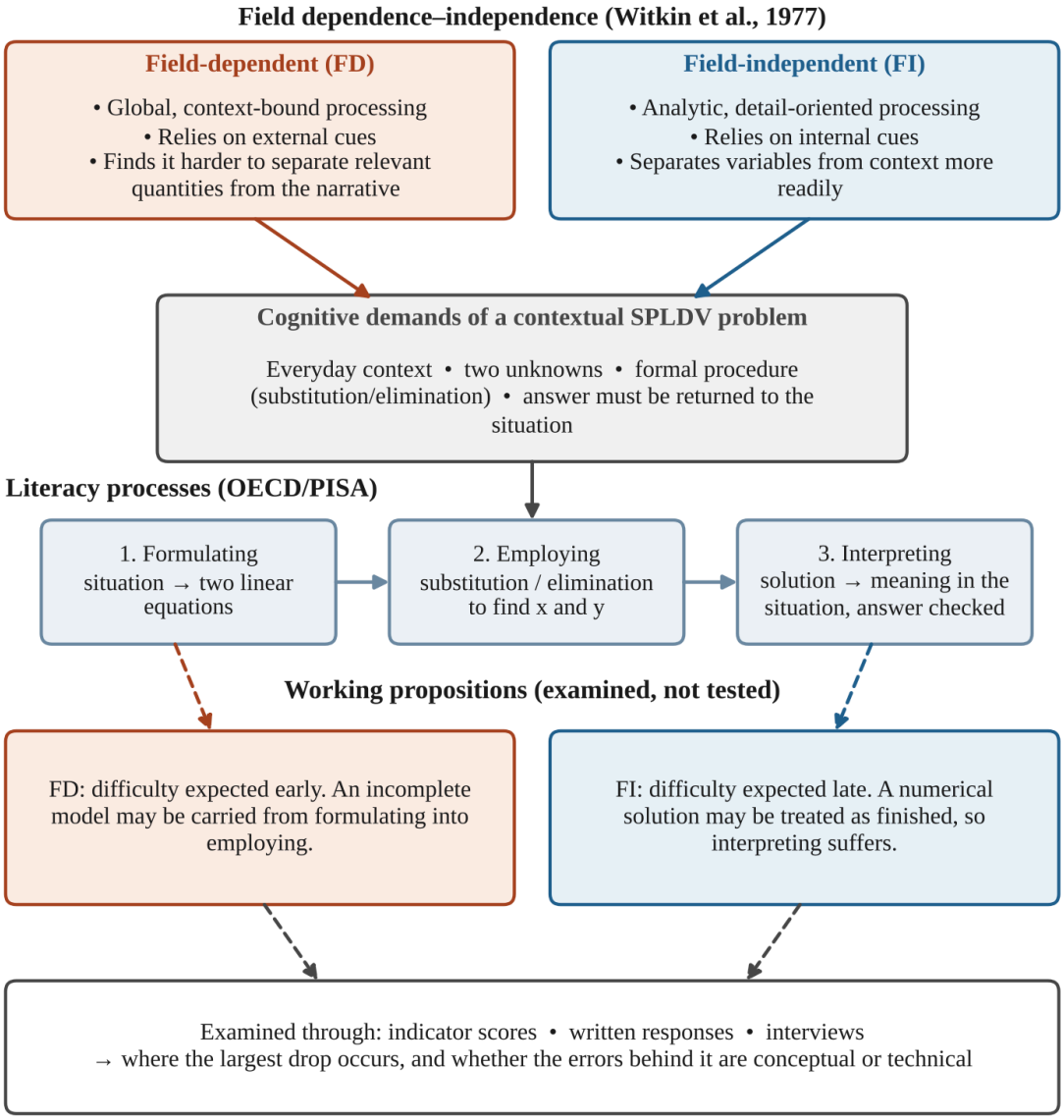


Figure 1. Conceptual framework linking field Dependence–Independence, the demands of contextual SPLDV problems, and the three mathematical literacy processes

At which stage does the largest drop occur in each group, and what types of errors underlie it?

METHOD

Research Design

This study used a qualitative case study design to describe where, across the formulating, employing, and interpreting indicators, the largest drop in students' mathematical literacy on SPLDV occurs for field-dependent (FD) and field-independent (FI) students, and which types of errors underlie it. A case study allows a complex phenomenon to be examined within its context using several sources of data (Baxter & Jack, 2008; Yazan, 2015). The case was one eighth-grade class at a public junior high school in Bandung. The study had three stages: (1) the GEFT was administered to classify cognitive style; (2) all students completed the written mathematical literacy test on SPLDV at the school on the same day; and (3) two days later, the selected students were interviewed individually about their written work. Interviews were recorded on a mobile device and transcribed word for word.

Research Subjects and Sampling Technique

The target group was eighth-grade students who had studied SPLDV. All 24 students of one class took part; no selection was made

within the class. The Group Embedded Figures Test (GEFT) identified 17 students as field-dependent (FD) and 7 as field-independent (FI). Four students (two from FD and two from FI) were questioned. They were purposively selected based on cognitive style, score variation, mathematical literacy attainment category, and characteristics of their written answers that needed further exploration. They are reported with codes (FD7, FD10, FI2, FI6).

Instruments and Data Collection

Data were collected at the school in March 2025. The cognitive style test and the mathematical literacy test were administered on 17 March, and the interviews were conducted on 19 March. Three types of data were collected: GEFT scores (for classification), written test responses (scores and solution steps), and interview accounts (students' explanations). The test and the interview guide were validated by one junior high school mathematics teacher and two mathematics education lecturers.

Cognitive style

The GEFT (Witkin et al., 1971) has 25 items in three sections: 7 practice items and two scored sections of 9 items each, giving scores of 0–18. Scores of 0–9 were classified as FD and 10–18 as FI (Kepner & Neimark, 1984).

Mathematical literacy

The test had three contextual essay problems on SPLDV, each requiring students to formulate, employ, and interpret in sequence. Each indicator was scored separately using a rubric, with maximum scores of 3, 4, and 3 per problem for formulating, employing, and interpreting, respectively, for a total of 30 (Table 1). Employing was given a higher maximum because it covers more complex procedures: choosing a method, carrying out algebraic operations, and obtaining an accurate result. This weighting was a design decision. Because results are reported as percentages of each indicator's ideal score, the indicators remain comparable.

A semi-structured guide was developed from the three indicators of mathematical literacy (formulating, employing, and interpreting). Example prompts, translated from Indonesian, were: “Do you understand the problem given? Explain the meaning of this problem in your own words” (formulating the problem into a mathematical model); “What steps must be taken to solve the problem?” and “Did you experience any difficulty during the calculation?” (employing mathematical procedures); and “Do you think the result you obtained has answered the question in the problem?” (interpreting the solution in the context of the problem). The guide contained 15 questions (six on formulating, five on employing, and four on interpreting). It was used flexibly: not every question was asked of every student, and follow-up questions were added to probe specific parts of each student’s written answer. Where an explanation revealed a misconception, the interviewer clarified the correct procedure after eliciting the student’s reasoning.

Table 1. Mathematical literacy indicators and maximum scores

Indicator	What students do in each problem	Maximum score (three problems)
Formulating	Express the situation as two linear equations	9
Employing	Solve the system by substitution or elimination	12
Interpreting	Relate the solution to the situation and answer the question	9

Data Analysis and Interpretation

Test results were transformed into percentages of the optimal score: the sum of the scores obtained by a group divided by the sum of its ideal scores, computed for each cognitive style group and for the class as a whole (Table 3). For each student, the score on each indicator was converted to a percentage of its maximum (9, 12, and 9 points over the three problems), and the drop between consecutive indicators was computed in percentage points. Because the groups are small and unequal (17 FD and 7 FI students), the distribution of individual scores, and not only the group totals, is shown in boxplots with every student’s score overlaid (Figure 6). The largest drop within each group was taken from the group totals (Table 3) as the location of its gap (RQ1–RQ3), and the number of students whose own largest drop fell at each transition was counted to check whether the group pattern holds for individual students. No inferential test was applied; with seven FI

students, the comparison is descriptive. Errors in written work were classified as conceptual or technical. Conceptual errors show a lack of understanding of a mathematical concept or relationship, for example, forming equations that do not match the information given or using a procedure without understanding its meaning. Technical errors are slips in writing, calculation, or reading information when the underlying concept is understood, for example, writing 15 for 15,000. The type was decided by comparing the written answer with the student's own explanation in the interview. Interview transcripts were analyzed thematically (Nowell et al., 2017), and the themes were used to explain the errors found in the written work. Finally, the themes and error types of the four interviewed students were compared across the FD and FI groups and arranged in a thematic map linking the characteristics of each cognitive style, the location of the largest drop, and the type of error (Figure 7).

Trustworthiness

Credibility was supported through data triangulation (Carter et al., 2014; Shenton, 2004). GEFT scores, written responses, and interview accounts were compared: the GEFT determined the cognitive style group, the written test showed the performance pattern, and the interviews explained the reasons behind errors. The researcher scored and coded the data; the results were discussed with and approved by the supervisors. Independent double coding and member checking were not used.

Ethical Considerations

The school gave verbal permission before data collection and later issued a written reply dated 11 April 2025, after the data had been collected. Students agreed to participate, and parents' written consent, signed electronically, was obtained on 17 March 2025, the day of the cognitive style and written tests and two days before the interviews. Participation was voluntary and did not affect grades. Data were anonymized, and excerpts use participant codes.

■ RESULT AND DISCUSSION

The results are presented in the order of the research questions. The cognitive style profile of the class is reported first, followed by overall achievement on the three literacy indicators, the performance and error patterns of FD students (RQ1) and of FI students (RQ2), and finally a comparison of where the largest drop occurs in each group and what types of errors lie behind it (RQ3).

Profile of Students' Cognitive Styles

The GEFT results for 24 eighth-grade students showed scores ranging from 0 to 17, with an average of 6.83. Based on the criteria of Kepner and Neimark (1984), students with scores of 0 to 9 were categorized as FD, and those with scores of 10 to 18 were categorized as FI. The grouping results are presented in Table 2.

Table 2. Grouping of students' cognitive styles

Cognitive Style	Number of Students	Percentage	Average Score
Field-Dependent (FD)	17	70.8%	4.88
Field-Independent (FI)	7	29.2%	11.57

Of the 24 students, 17 (70.8%) were classified as FD and 7 (29.2%) as FI. The mean GEFT score of the FD group (4.88) lay well below the cut-off, whereas that of the FI group (11.57) lay just above it. Because only seven students belong to the FI group, the figures reported for this group below describe this class and should not be read as stable estimates.

Students' Overall Mathematical Literacy Achievement

Students' total mathematical literacy scores ranged from 13 to 100, with an average of 35.6, which is considered low. Table 3 presents performance on each indicator for the class as a whole and for the two cognitive style groups.

At the class level, performance declined steadily from formulating to interpreting, which is consistent with the view that returning from a mathematical result to the situation is a demanding step that students often neglect (Galbraith & Stillman, 2006; Verschaffel et al., 1994). The pattern differs from the early concentration of errors that Wijaya et al. (2014) reported for released PISA tasks. However, that study classified error types rather than scoring each indicator against a rubric, so the two are not directly comparable. The class-level

pattern, however, conceals a difference between the two groups. FI students scored higher than FD students on every indicator. However, the distance between the groups was widest on employing (27 percentage points, compared with 13 on formulating and 17 on interpreting), and the point at which each group's performance fell most steeply was different. The next two sections examine what lies behind these patterns; as the cases show, performance also varies within each group.

Table 3. Mathematical literacy performance by indicator for the whole class and for each cognitive style group

Indicator	FD (n = 17)		FI (n = 7)		All (n = 24)	
	Score/ideal	%	Score/ideal	%	Score/ideal	%
Formulating	75 / 153	49	39 / 63	62	114 / 216	53
Employing	52 / 204	25	44 / 84	52	96 / 288	33
Interpreting	25 / 153	16	21 / 63	33	46 / 216	21
Total	**152 / 510**	**30**	**104 / 210**	**50**	**256 / 720**	**36**

Note. Score/ideal = total score obtained by the group divided by its ideal score (number of students × the maximum scores in Table 1 over the three problems: 9, 12, and 9). The class-level values are computed from the two group totals. Percentages are rounded to the nearest whole number.

Achievement Patterns Among Field-Dependent Students

Table 3 shows that FD students' performance fell most steeply immediately after formulating. The interviews suggest that this fall reflects how FD students handled the model rather than an inability to begin. Formulating a contextual SPLDV problem requires students to pull the relevant quantities out of the narrative and impose the structure of two equations on them. Witkin et al. (1977b) associate field dependence with a stronger reliance on the given context and on externally provided structure, so FD students may be expected to reach the employing stage with a model that is incomplete or not their own, a possibility raised in the framework (Figure 1). The two interviewed FD students show two ways in which this can happen. In one, the model is sound, but the procedure that follows is carried out intuitively, without a formal justification the student can articulate (FD7). In the other, the model itself is borrowed, so that a procedure carried out correctly still produces a wrong result (FD10). Neither case can account for the size of the decline by itself, and two interviews cannot show how many of the 17 FD students followed each pattern; they indicate the mechanisms through which scores are lost after formulating. The cases are presented below. To understand this pattern more concretely, here are two contrasting cases from the FD group.

Subject FD7 (relatively high total score within their group, 14 of 30)

Figure 2 shows the subject's answer sheet for question number 1. On the answer sheet, the subject wrote down two correct equations based on the problem's information, then solved them using the elimination method to obtain $x = 12,000$ and $y = 15,000$. Although the final result was correct, the subject did not explicitly write the multiplication sign when multiplying the two equations and jumped directly to the elimination result without showing the complete steps of subtracting one equation from the other. When asked to clarify, the student explained the steps intuitively: "For y, it's $10y = 150,000$; I just moved it to the other side, so I divided it." This explanation indicates that the student understands the final result of a procedure but is not yet able to articulate the formal reasoning behind it. On the answer sheet, the subject also stopped immediately after writing "so $x = 12,000$ and $y = 15,000$," without continuing to calculate the total price, which was actually what the question asked for. When asked if that answered the question, the subject realized, "Oh, right, not yet, ma'am. I should have multiplied $12,000$ by 2 and $15,000$ by 3, then added them together." On this problem, the gap in the subject's work is specific: it is not an inability to interpret the problem conceptually, but a tendency to stop writing before finishing, even though they verbally knew the steps that should have been taken. The picture is less favorable on question 2, where the subject wrote only the given data ("60," "54," and "4 years") without defining variables or writing any equation, and said, "I think I should use equations, but I'm confused about where to start" and "I should have first let x and y stand for them and then made equations, like when it was explained in class, but I forgot." FD7 could therefore carry out a familiar

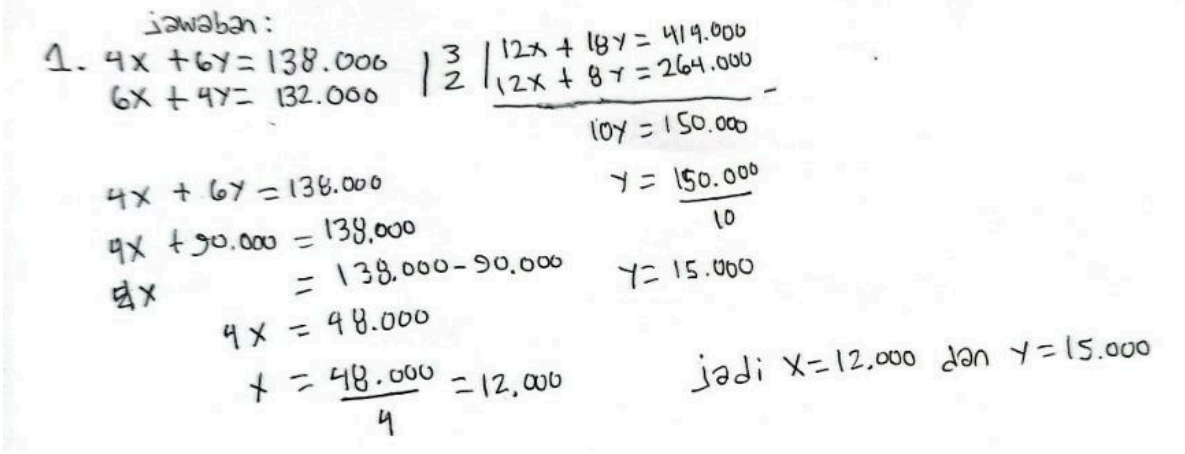


Figure 2. Student FD7's response to question number 1

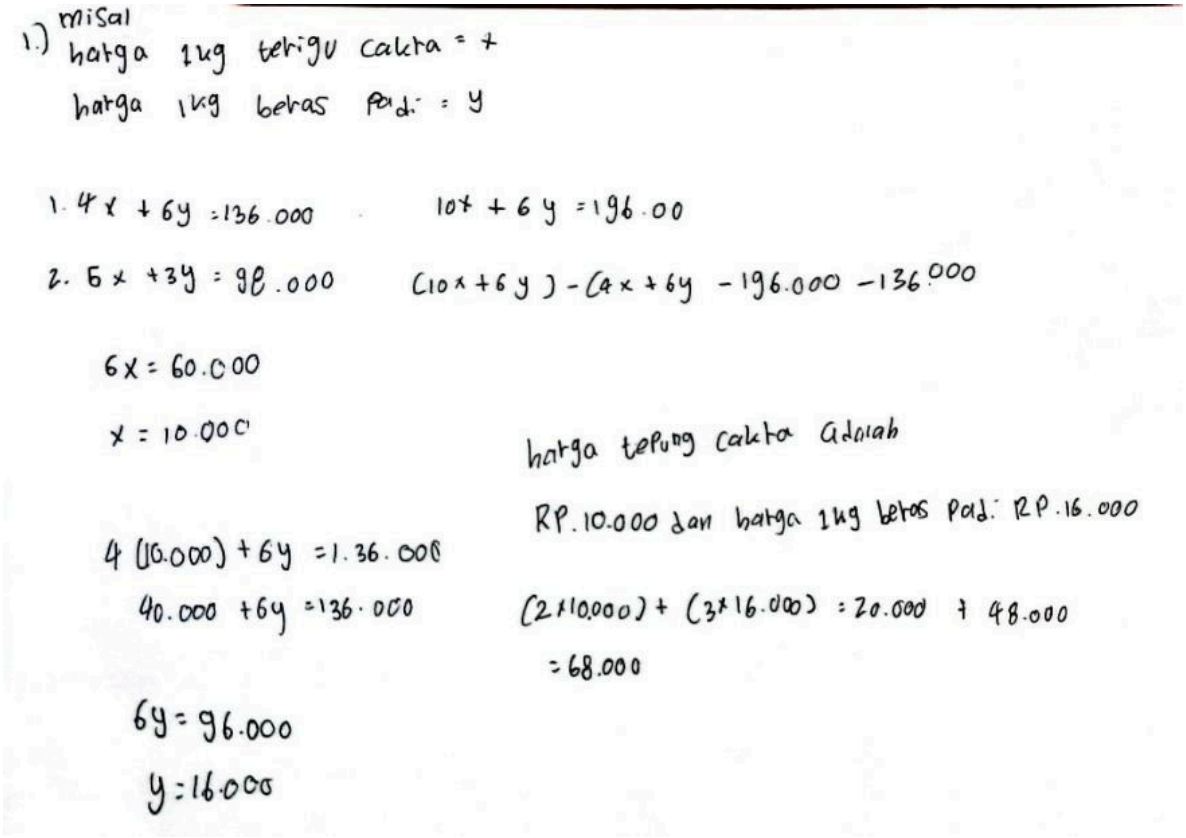


Figure 3. Student FD10's response to question number 1

procedure on an already structured problem, but could not build the model when the problem required it.

Subject FD10 (highest total score in their group, 18 of 30)

Figure 3 shows the subject's answer sheet for the same problem. In the second row, it is clear that the subject wrote the equation "$5x + 3y = 98,000$," whereas according to the problem, it should have been "$6x + 4y = 132,000$." Because the initial model was already incorrect, the entire subsequent elimination process (which, in terms of the sequence of steps, was actually correct) also resulted in an incorrect answer: "the price of Cakra flour is $Rp10,000$, and the price of 1 kg of Padi rice is $Rp16,000$," with a final total of $Rp68,000$. When asked about the second equation, the subject admitted, "No, ma'am, I think it's wrong. I just copied my friend's work, so I'm not sure if it's right." This case reveals a

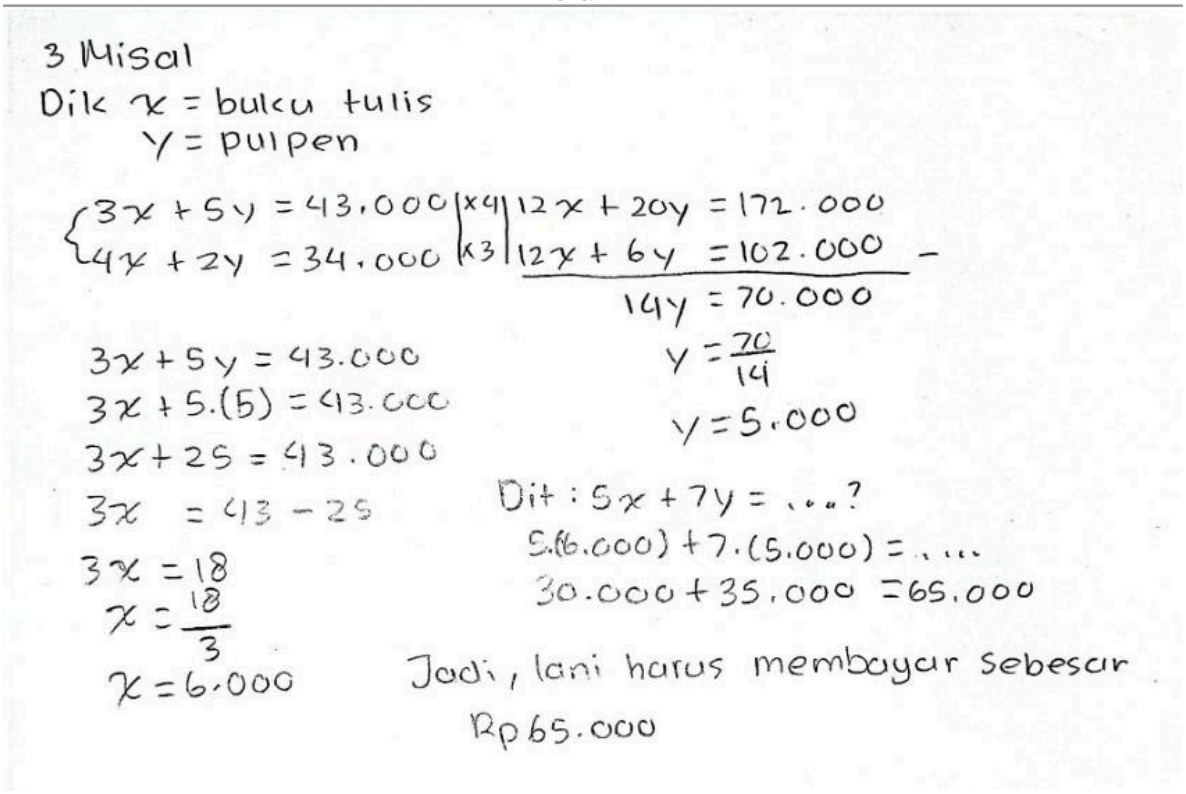


Figure 4. Student FI6's response to question number 3

different type of gap compared to FD7: it is not a matter of stopping before completion, but rather making a mistake as early as the formulation stage due to copying a classmate's work, causing the employing and interpreting stages to fail as well, even though the elimination procedure itself was carried out correctly. Because FD10 had the highest total score in the FD group, the case also shows that a borrowed model on one item can coexist with stronger work elsewhere; it illustrates a mechanism rather than a typical FD student.

These two cases show that the decline among FD students does not stem from a single difficulty. FD7 knew the steps intuitively but could not yet articulate the formal reasoning behind them, which is procedural knowledge not yet supported by conceptual understanding (Rittle-Johnson et al., 2001); this resembles Son et al. (2026), where FD students primarily achieved comprehension and application but consistently struggled to advance to reasoning. FD10 shows the opposite sequence: the procedure was sound, but the model was not the student's own. Difficulties in turning a verbal situation into equations are well documented (Jupri & Drijvers, 2016; MacGregor & Stacey, 1993), and a model written without being understood cannot be repaired by the stages that follow, so the correct elimination in FD10's answer could not rescue the employing and interpreting stages.

FD10's reliance on a classmate's work can also be read through the cognitive style literature. Field-dependent learners are described as more attuned to the social environment, more inclined to treat other people as a frame of reference, and more susceptible to others' influence (Pithers, 2002; Witkin & Goodenough, 1977a). They also tend to depend on externally supplied structure when the material is not already organized for them (Pithers, 2002; Witkin et al., 1977b). Formulating a contextual SPLDV problem is precisely a step in which the student has to build the structure, and FD10's remark, "I just copied my friend's work," is consistent with a turn to an external source at that point. This reading should be treated with caution. It rests on a single interview, and copying during a test may also reflect low confidence in one's own model or time pressure, which cognitive style alone does not explain; the interview does not show whether FD10 could have formulated the equations without help.

Achievement Patterns Among Field-Independent Students

Table 3 shows that FI students scored higher than FD students on every indicator and that, in

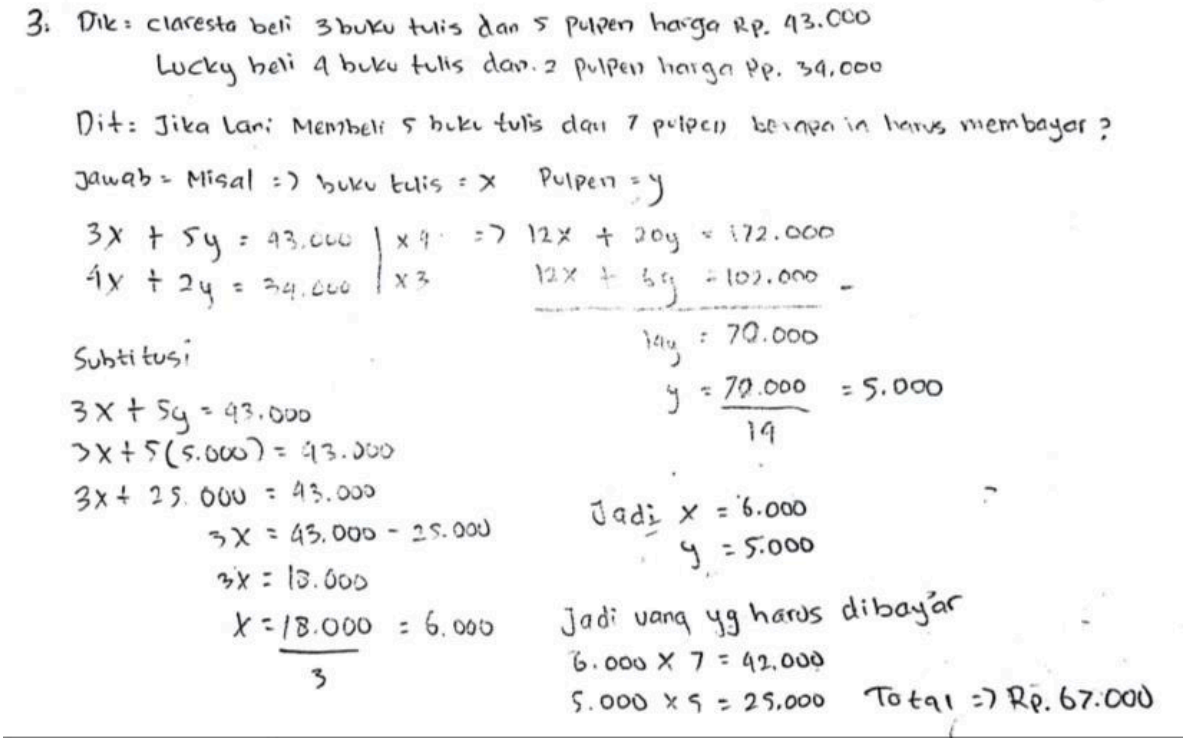


Figure 5. Student FI2's response to question number 3

the group totals, their performance held up through employing and fell most steeply at interpreting; Figure 6 shows that this is a tendency and not a uniform pattern, since the largest drop of individual FI students was split between the two transitions. This is compatible with the working proposition in Figure 1 for learners who rely on internal cues and attend to detail: the analytic work of separating the quantities, writing the equations, and carrying out the algebra was largely secure, while the step of returning to the situation was where performance fell (Witkin et al., 1977b). The two interviewed FI students suggest that what went wrong at the end of the solution was not understanding of the procedure but slips of notation and of reading the question, which both students attributed to hurrying ("I was just rushing to finish quickly"; "maybe because I was in a hurry at the time"). As with the FD group, two interviews cannot show how common these slips were among the seven FI students. Here are two contrasting cases from the FI group.

Subject FI6

Figure 4 shows the subject's answer sheet for question number 3. Subject FI6 wrote "$y = 5,000$" in full in the division result row (70/14). However, in the next substitution row, they wrote "$3x + 5.(5) = 43,000$," using the number 5 without the thousands placeholder, and then in the final row wrote the results out in full again: "so $x = 6,000$" and "$y = 5,000$," with the final conclusion "Lani must pay $Rp65,000$." This pattern indicates that the subject used a calculation strategy involving simplifying numbers, then restoring the original scale in the final answer; a practical calculation habit, not a conceptual error. The subject herself confirmed this habit when asked for clarification: "I was just rushing to finish quickly at that moment."

Subject FI2

Figure 5 shows the subject's answer sheet for the same question. The entire process of deriving and applying the formula on this sheet is written neatly and systematically, using complete notation, resulting in the correct values of $x = 6,000$ and $y = 5,000$. However, in the last row, the student mistakenly associated the variables with the number of items asked for: writing "$6,000 \times 7 = 42,000$" and "$5,000 \times 5 = 25,000$," resulting in a total of $Rp67,000$, even though the question asked for 5 notebooks and 7 pens (it should have been $6,000 \times 5$ and $5,000 \times 7$, resulting in $Rp65,000$). When the mistake was pointed out, the student immediately realized her error: "Oh, right, Ms. Teacher, Lani was supposed to buy 5 notebooks and 7 pens, not the other way around. I got them mixed up, maybe because I was in a hurry at the time." This error was purely due to a lack of careful review of the question, not a failure to understand the concept or procedure.

Compared to FI6, who answered completely correctly and relied solely on simple

mental arithmetic, the FI2 case shows variation within the FI group as well. However, it differs from the variation in the FD group: FI2's error on question 3 was a careless mistake in the last line, not a conceptual error from the start as in FD10.

Comparison of Gap Patterns and Error Types Between Field-Dependent and Field-Independent Students

Figure 6 shows the distribution of individual scores behind Table 3. Panel (a) shows each student's score on the three indicators and panel (b) the drop between consecutive stages for each student; the group means (white markers) equal the percentages in Table 3. Among FD students, scores fall steadily, and the spread narrows: the median drops from 44% on formulating to 17% on employing and 11% on interpreting, and no FD student exceeded 44% on interpreting. Among FI students, the median stays at 67% from formulating to employing and falls to 11% on interpreting. However, the spread is wide at every stage: interpreting scores range from 0% to 100%, and one student (SI6) obtained full marks on all three indicators.

At the individual student level, the FD pattern is clearer. The largest drop fell between formulating and employing for 11 of the 17 FD students and between employing and interpreting for 5, with one tie. The FI group is divided: the largest drop fell between employing and interpreting for 3 of the 7 students, between formulating and employing for 3, and one student showed equal drops. The group-level contrast in Table 3 is therefore a tendency, strongest for FD students and weaker for FI students, and not a pattern shared by every student. In addition, 9 of the 17 FD students and 4 of the 7 FI students scored zero on every indicator of at least one problem, and the scores do not distinguish a problem left blank from one attempted and answered wrongly; part of the decline at the later stages may therefore reflect problems that were not reached. Given the group sizes, these descriptive figures should not be read as evidence of a tested difference between the groups.

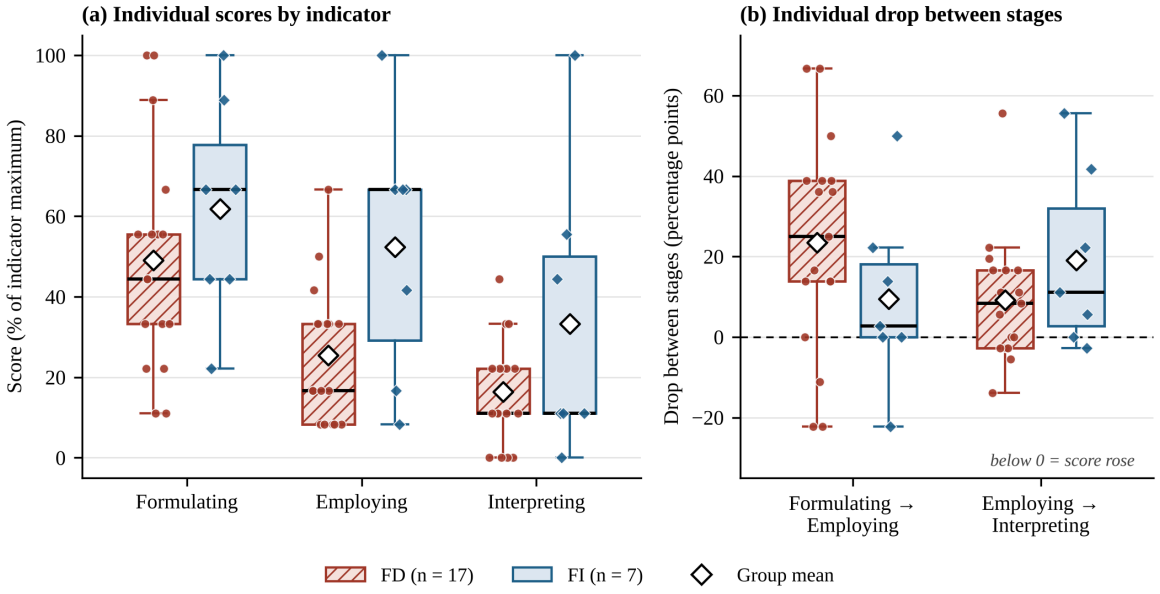


Figure 6. Distribution of individual scores by indicator \(a) and drop between consecutive stages \(b) for FD \(n \= 17) and FI \(n \= 7) students. each marker is one student; boxes show the median and interquartile range, whiskers extend to the most extreme score within 1.5 times the interquartile range \(markers beyond the whiskers are outliers), and white diamonds show group means \(equal to the percentages in table 3). in panel \(b), values below zero indicate that the score rose between stages.

The four cases above clarify the pattern in Figure 6. For FD students, points are lost in two ways: through an intuitively carried-out solution that is left unfinished (FD7), and through a model taken from a classmate at the formulation stage, which causes later stages to fail even when the procedure is correct (FD10). For FI students, formulating and employing were relatively well mastered, and the errors that appeared at the end of the solution were technical: a habit of simplifying numbers that made the working hard to follow (FI6) and carelessness in rereading the question (FI2), rather than conceptual failures.

Figure 7 brings the cases together as a thematic map linking the characteristics of each cognitive style to the location of the largest drop

and to the type of error. Two features stand out. First, the two groups differ not only in where the drop occurs but in what lies behind it. For FD students, the themes concern whose model it is and whether the procedure is understood well enough to be explained and completed, which are matters of conceptual understanding. For FI students, the themes concern notation and attention to the question at the end of the solution, which are technical matters. Second, the map is consistent with the working propositions in Figure 1: FD students' difficulty appears early and carries into later stages, whereas FI students' difficulty appears late in the group totals (individual FI patterns were mixed; Figure 6). Because the map is built from four interviewed students, it is offered as an account of these cases and not as a general model of FD and FI students.

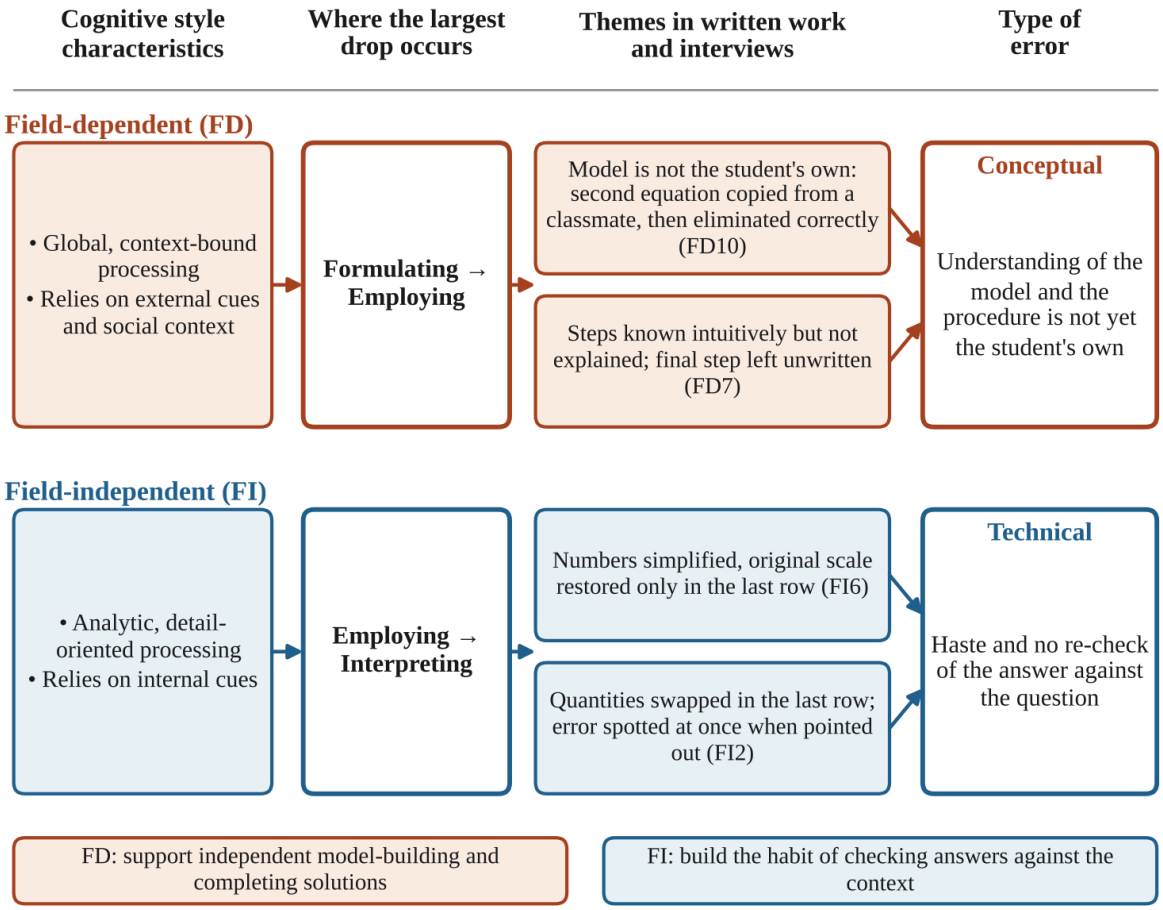


Figure 7. Thematic map linking cognitive style characteristics, the location of the largest drop, and error types in solving SPLDV problems

This difference adds an important nuance to the general conclusions of previous studies stating that FI students are superior overall compared to FD students (Tinajero & Páramo, 1997; Xie et al., 2025). This study shows that FI students' superiority is relative: they still have weaknesses, but the nature of their errors differs qualitatively from that of FD students; specifically, they are more technical in nature and can be corrected through the cultivation of carefulness, whereas FD students' errors are more deeply rooted in conceptual understanding and the ability to formulate problems independently.

This pattern is compatible with Son et al. (2026), who found in a different content area (numeracy) that FI students generally showed competence across the three components. In contrast, FD students tended to reach only the understanding and application components, so that each group showed its own profile. This study extends that line of work to mathematical literacy on SPLDV, while also adding a new layer of findings. What distinguishes the two groups is not only where their weaknesses lie across the indicators but also the nature of the accompanying errors: conceptual for FD students and technical for FI students. This difference in

error types makes a one-size-fits-all intervention less effective.

Pedagogical Implications

For FD students, interventions should focus on strengthening their ability to formulate problems independently so they do not rely on copying their peers' work, and on cultivating the habit of completing written solutions through to the final stage. For FI students, a more appropriate intervention involves developing the habit of double-checking final answers against the context of the problem, in line with the attention that research on modeling gives to monitoring and checking one's own solution (Stillman & Galbraith, 1998), and ensuring consistency in numerical notation, given that most of the FI errors observed stemmed from carelessness rather than a lack of understanding. However, one interviewed FI student (FI2) guessed an answer on question 2 after writing the equations, so not every FI error was technical. A one-size-fits-all intervention for all students, without considering where the gap occurs and the type of error, risks being ineffective in closing the gaps identified in this study. These suggestions follow from the pattern of errors observed here rather than from matching instruction to cognitive style, since the idea that information is easier to process when it matches a preferred cognitive style has been questioned (Kozhevnikov et al., 2014).

■ CONCLUSION

This study set out to describe where, across formulating, employing, and interpreting, the mathematical literacy of junior high school students on SPLDV breaks down, and how this differs between field-dependent and field-independent students. The findings show that the cognitive obstacle is not located at the same point for the two groups. For FD students, it appears early, at the passage from building a model to working with it: when the model is incomplete or taken from someone else, the later stages inherit the flaw, and when a procedure is carried out without being understood, it can be neither explained nor completed. For FI students, the group totals show the early stages as largely secure and the obstacle at the end, where a numerical answer has to be reconnected to the situation and checked against what the question asks; for individual students this pattern was weaker, with the largest drop split between the two transitions. The nature of the errors follows the same division: those of FD students were rooted in conceptual understanding and in dependence on the work of others, whereas those of FI students were technical, arising from haste and insufficient rereading of the question. Taken together, these results suggest that the gap between employing and interpreting is better understood as a difference in where each cognitive style meets its obstacle than as a uniform deficit.

These findings make an important contribution to mathematics education in junior high school: interventions to bridge the gap between the employing and interpreting stages need to be adjusted to where the gap occurs and to the type of error in each group, rather than standardized for the entire class. For FD students, reinforcement is needed during the employing stage, particularly in terms of their ability to independently formulate mathematical models and consistently complete written solutions through to the end. For FI students, reinforcement should focus on the habit of double-checking the final results against the problem context before drawing conclusions.

This study has limitations, including a small sample (24 students from a single school, seven of them FI, and four interviewed); therefore, these findings are descriptive and contextual in nature and cannot yet be widely generalized. Further limitations concern data collection and analysis. One interviewed student (FD10) reported consulting classmates during the written test, so written scores may not always reflect independent performance. During the interviews, the interviewer sometimes prompted students or clarified a procedure, which may have shaped later answers. The data were scored and coded by one researcher, and the results were discussed with the supervisors, but there was no independent double coding or member checking. Scores of zero do not distinguish a problem left blank from one answered incorrectly, so part of the decline at the later stages may reflect problems not reached. Future research is recommended to test these patterns of gaps in a larger, more diverse population, as well as to explore the effectiveness of learning interventions designed based on the location of gaps in each cognitive style.

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■ AUTHOR CONTRIBUTIONS

LHU: Writing – original draft, Conceptualization, Investigation, Resources, Visualization, Formal analysis; **SP:** Writing – review and editing, Methodology, Supervision, Validation; **JAD:** Writing – review and editing, Methodology, Supervision, Validation.

• **CONFLICT OF INTEREST**

The authors assert that there are no conflicts of interest pertaining to the research, authorship, or dissemination of this paper.

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■ DECLARATION OF AI USAGE

During the drafting of this manuscript, the writers used DeepL to translate it into English and Claude to enhance sentence structure and intelligibility. After using these tools, the writers evaluated and amended the material as needed and assume full accountability for the article's final content.

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