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Profiling Pseudo-True and Pseudo-False Thinking in Solving One-Variable Linear Equations Among Junior High Students

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ABSTRACT

Linear equations in one variable (LEOV) are among the first algebra topics taught in junior high school. A correct written answer on this topic does not guarantee that a student understands it, and a wrong answer does not prove that the student does not. Research on pseudo thinking has mostly examined other topics and has rarely compared students' written work with their oral reasoning on LEOV word problems. This study aimed to profile the pseudo-true and pseudo-false thinking of eighth-grade students when solving contextual LEOV problems. A qualitative descriptive design was used with 34 eighth-grade students at SMP Negeri 6 Jambi City. Data were collected through a written test of two contextual LEOV problems, semi-structured interviews, and documentation. Three students were selected purposively for in-depth analysis, and the data were analyzed through data reduction, data display, and conclusion drawing, with triangulation between test and interview data. Two of the three subjects showed pseudo-false thinking: their written solutions were wrong or inconsistent, but in the interviews they could explain how the information in the problems was related and which steps should have been taken. The third subject showed pseudo-true thinking, writing correct solutions without being able to justify the steps. Judging students only by their final answers would have misread all three. The study offers an indicator-based profile of pseudo thinking for LEOV word problems and suggests that teachers combine written tasks with explanation prompts or short reasoning interviews when assessing students.

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1. INTRODUCTION

School mathematics is meant to do more than make students fluent in calculation. Students should also be able to reason, connect ideas, and say why a step is taken. Success in mathematics depends largely on understanding the concepts behind a procedure, not merely on being able to carry it out [1]. In algebra, the difference between the two shows

up early. Linear equations in one variable (LEOV) are among the first algebraic topics in which students must translate a verbal situation into an equation, operate on it, and interpret the result in the original context [2].

In practice, many students find it difficult to link mathematical concepts with real situations, and their understanding often stays at the level of memorized steps [3], [4]. Under these conditions, a student may appear to understand a concept while the understanding is in fact incomplete, a condition known as pseudo thinking [5]. It comes in two forms. In pseudo-true thinking, the answer is correct but the reasoning behind it is not; in pseudo-false thinking, the answer is wrong even though the student holds a correct understanding [6]. For assessment this is a real problem: a teacher who checks only the final answer will give the first student too much credit and the second too little [7], [8].

Pseudo thinking has been documented in exponential equations [9], number patterns [10], set problems among STEM students [5], the area of obtuse triangles [4], the composition and inverse of functions [11], multiplicative thinking [12], negative integers [13], and systems of linear equations in two variables [14], with participants ranging from elementary school students [15] to students with autism [16]. Other studies have related pseudo thinking to cognitive style [17], learning style [18], and thinking errors in concept construction [19], and have proposed defragmentation and the transformation of pseudo thinking into real thinking as ways to restructure students' reasoning [1], [7], [20]. Most of these studies trace pseudo thinking back to procedure-oriented learning, little room for reflection, and weak mathematical representation [21], [22]. Studies on LEOV itself, including those in Indonesian schools, have mainly described errors and misconceptions in students' written work [23], [24] without checking whether those errors reflect what students actually understand.

This leaves two gaps. First, LEOV word problems at the junior high school level have received little attention as a setting for pseudo thinking, although this is the topic in which students first build algebraic models from everyday situations. Second, few studies set students' written answers side by side with their oral explanations of the same problem, so whether the mismatch runs one way (correct answer, weak reasoning) or the other (wrong answer, sound reasoning) is usually assumed rather than shown. We saw the same issue during preliminary observation at SMP Negeri 6 Jambi City, where eighth-grade students tended to follow procedures when solving LEOV problems without being able to say why each step was needed, and their written answers did not always reflect what they understood.

In this study, we compare students' written test answers with their interview explanations for the same LEOV word problems, using indicators that separate two subtypes of pseudo-true thinking from two subtypes of pseudo-false thinking. The aim is to identify and describe the pseudo-true and pseudo-false thinking of junior high school students when solving contextual LEOV problems. The findings add evidence on pseudo thinking from an early algebra topic, and they give teachers indicators they can use to spot pseudo thinking in students' work, along with a case for asking students to explain their answers during LEOV assessment.

2. METHOD

2.1. Research Design

This study used a qualitative descriptive design. We were interested in how students reasoned, not in how many answers they got right, and that called for a close reading of a small number of cases. The unit of analysis was each subject's response to each test item, examined together with the subject's explanations in the interview.

2.2. Research Setting and Participants

The study was conducted at SMP Negeri 6 Jambi City, Indonesia, in April. The participants were 34 eighth-grade students from one class who had studied LEOV in the seventh grade. All 34 students took the written test. Interview subjects were then selected by purposive sampling, with one criterion: the student's written answers showed indicators of pseudo thinking as defined in Table 1. Three students met this criterion and were coded S1, S2, and S3. Together, they represented both pseudo-true and pseudo-false response patterns.

2.3. Data Sources and Research Instruments

The data were primary data consisting of students' written answers, interview data, and documentation of the test and interview sessions. Three instruments were used. The first was a written test of two contextual LEOV problems. Item 1 asked students to find the registration fee and the price of a team T-shirt when the T-shirt cost Rp15,000 more than the registration fee and the total payment was Rp75,000. Item 2 described a donation in which every participant gave the same amount and the total collected was Rp540,000; students had to judge whether another student's conclusion that 11 participants had each given Rp45,000 was correct. Both items require students to model the situation with a linear equation, solve it, and check the result against the context. The second instrument was a semi-structured interview guideline whose questions followed the indicators in Table 1, for example asking students why a particular step was taken and whether their answer fitted the problem. The third was documentation in the form of photographs of the answer sheets and records of the interview sessions. Before use, the test and the interview guideline were validated by mathematics education lecturers, and both were revised according to their suggestions.

The test was built to expose gaps between the answer a student wrote and the thinking behind it. Table 1 lists the indicators used to identify pseudo thinking.

Table 1. Indicators of Pseudo-Thinking

Category	Indicator	Descriptors
Pseudo-True	**(PB1)** The student provides a correct answer to the question, but the underlying thinking process is incorrect.	(1) The final result is correct, but the steps of the solution do not follow the concept (e.g., incorrect operations/strategies). (2) There are 'skipped'/illogical steps but coincidentally produce the correct answer. (3) When asked to explain, the student cannot provide the correct reason or instead gives a reason that does not match the steps.
Pseudo-True	**(PB2)** The concept written by the student is correct, but their understanding of the concept is wrong	(1) Students write a model/formula/concept that seems correct (e.g., equation form/variables), but when interviewed, they are unable to explain the meaning of the concept. (2) The explanation only "follows the formula/example" without understanding why the steps are taken. (3) Unable to verify/interpret results according to the context of the problem.
Pseudo-False	**(PS1)** The student answers the question incorrectly, but can provide the reason correctly	(1) The final answer is wrong due to technical errors (calculation, miswriting, wrong substitution), but during the interview the student is able to explain the strategy/concept that should have been used. (2) Able to correctly mention "known–asked" and explain the relationship between information, even though the written result is wrong. (3) When prompted, the student can identify the mistake and correct it.
Pseudo-False	**(PS2)** The concept written by the student is incorrect, but their understanding of the concept is correct	(1) The student incorrectly writes the mathematical model (e.g., forms the equation incorrectly, uses wrong signs/variables), but during the interview is able to state the correct concept orally. (2) The student can explain why it must be "divided/subtracted" according to the context of the system of linear equations with one variables (LEOV), but is unable to represent it accurately with symbols. (3) There is a gap between oral understanding and written representation.

2.4. Data Collection Procedure

Data were collected in three stages. First, all 34 students completed the written test. Second, the selected subjects were interviewed individually; each interview began with the subject reading and explaining their own answer, followed by probing questions based on the indicators. Third, the answer sheets and interview sessions were documented.

2.5. Data Analysis

The data were analyzed using an interactive model consisting of data reduction, data display, and conclusion drawing. In the reduction stage, each written answer was examined against the indicators in Table 1, and the interview segments relevant to each indicator were selected. In the display stage, the written evidence and the corresponding interview evidence were arranged side by side for each subject and item. In the conclusion stage, each response was assigned to one of four categories (PB1, PB2, PS1, or PS2), and these categories were combined into a pseudo-thinking profile for each subject.

2.6. Trustworthiness and Ethical Considerations

Credibility was supported by method triangulation, that is, by comparing what each subject wrote with what the same subject explained in the interview, and by re-checking each categorization against the indicators in Table 1. Dependability and confirmability were supported by keeping the answer sheets, interview records, and categorization notes as an audit trail. Transferability was addressed by describing the setting, the tasks, and the subjects' responses in detail. Ethical procedures were followed throughout the study. Permission to collect data was obtained from the principal of SMP Negeri 6 Jambi City, and the mathematics teacher of the class was informed about the purpose and procedures of the study. Before the test and the interviews, the students were told what the study was about, that their participation was voluntary, that they could stop at any time, and that the results would not affect their school grades. Only students who agreed to take part were interviewed. Students' names were replaced with the codes S1, S2, and S3, and the answer sheets and interview records were used solely for research purposes.

3. RESULTS AND DISCUSSION

3.1. Results

The findings are reported subject by subject and item by item, followed by a summary table.

All 34 eighth-grade students completed the written test. Of these, three students showed indicators of pseudo thinking, and all three were analyzed in depth: S1 and S3, whose written answers to both items were incorrect or internally inconsistent, and S2, whose written answers to both items were correct. The expected solutions are given first. For Item 1, if x is the registration fee, the T-shirt costs x + 15,000, so $x + (x + 15{,}000) = 75{,}000$ and $x = 30{,}000$; the registration fee is Rp30,000 and the T-shirt costs Rp45,000. For Item 2, if n is the number of participants, $45{,}000n = 540{,}000$, so $n = 12$, which means the other student's conclusion of 11 participants is wrong.

3.1.1. Pseudo-Thinking Profile of the First Subject (S1)

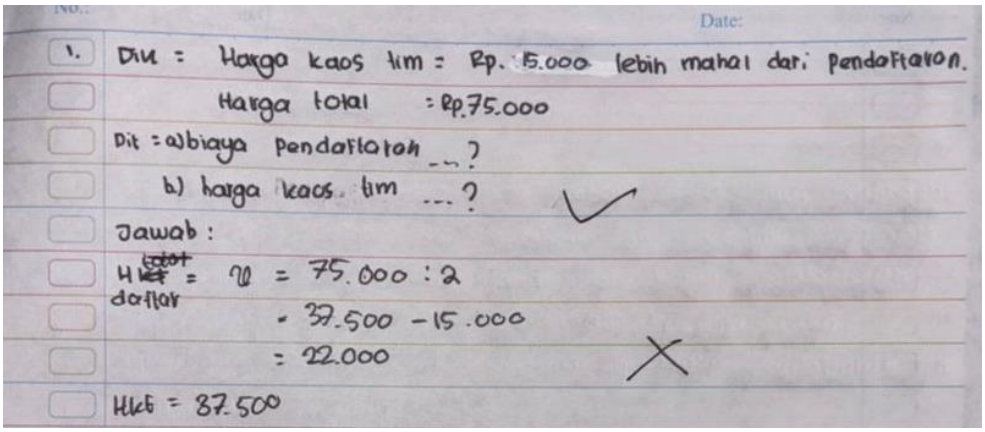

Figure 1. S1's Written Answer to Item 1

As Figure 1 shows, S1 wrote the known and asked information for Item 1 correctly: the T-shirt costs Rp15,000 more than the registration fee, and the total payment is Rp75,000. The solution, however, divided the total by two before taking the difference into account (75,000 : 2 = 37,500), then subtracted 15,000 and wrote 22,000 as the registration fee and 37,500 as the T-shirt price. These values do not satisfy the condition in the problem and do not add up to Rp75,000, and S1 did not check them. In the interview, S1 was able to explain the concept fairly well, although with some hesitation, and could describe how the information in the problem was related to the steps that should have been applied. Because the written answer was wrong while the explanation was correct, S1's response to Item 1 was classified as pseudo-false (PS1).

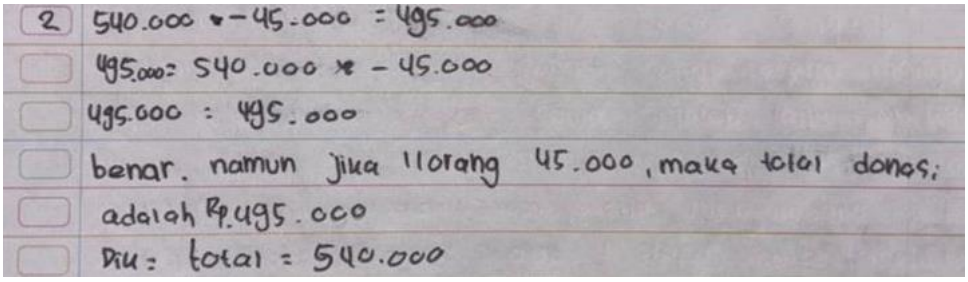

Figure 2. S1's Written Answer to Item 2

In Item 2 (Figure 2), S1 did not write the known information before computing. S1 subtracted 45,000 from 540,000 to obtain 495,000, a step that repeats the flawed reasoning presented in the problem instead of testing it. S1 then judged the other student's conclusion to be correct while also noting that 11 participants giving Rp45,000 each would produce a total of only Rp495,000, which contradicts the given total of Rp540,000. No equation was written. During the interview, however, S1 explained the solution correctly and in line with the context of the problem. Since the written representation was incorrect but the underlying understanding was correct, this response was classified as pseudo-false (PS2).

3.1.2. Pseudo-Thinking Profile of the Second Subject (S2)

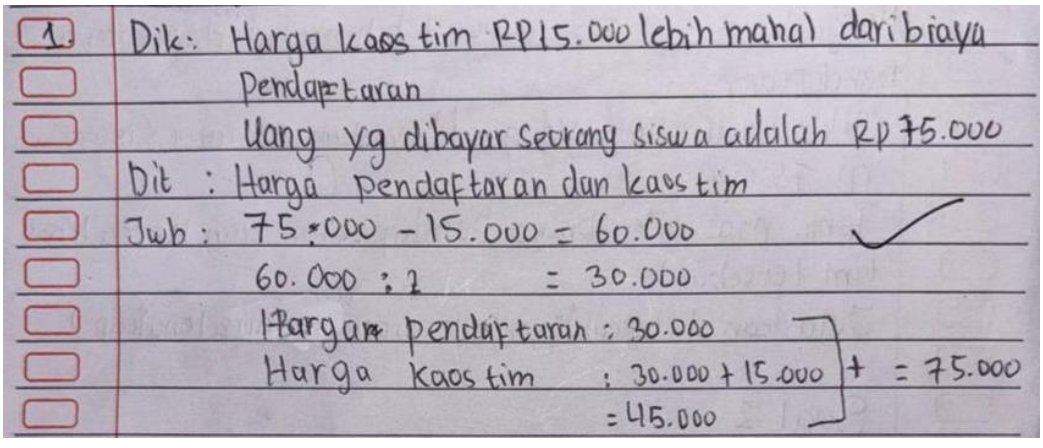

Figure 3. S2's Written Answer to Item 1

S2 identified the known and asked information accurately and solved Item 1 systematically (Figure 3): 75,000 − 15,000 = 60,000, then 60,000 : 2 = 30,000 for the registration fee, and 30,000 + 15,000 = 45,000 for the T-shirt. S2 also verified that the two prices add up to Rp75,000. In the interview, though, S2 had difficulty explaining why 15,000 had to be subtracted first and why the remainder was divided by two, and the explanations did not match the written procedure. The answer was right, but S2 could not justify it, so the response was classified as pseudo-true (PB1).

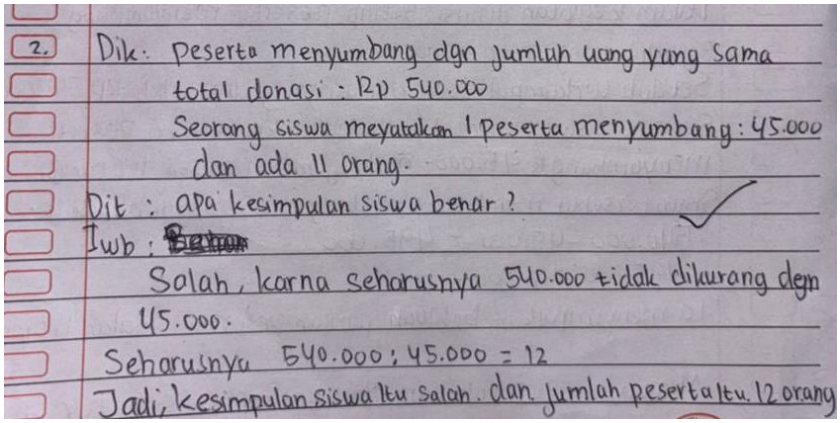

Figure 4. S2's Written Answer to Item 2

For Item 2 (Figure 4), S2 stated that the other student's conclusion was wrong, wrote that 540,000 should not have been reduced by 45,000, and computed 540,000 : 45,000 = 12 participants. The written answer is correct and uses the appropriate operation. In the interview, however, S2's explanation did not match the written steps, which suggests that S2 followed the procedure without a clear grasp of why it worked. The response was classified as pseudo-true (PB2): the concept was written correctly, but the understanding behind it was not accurate.

3.1.3. Pseudo-Thinking Profile of the Third Subject (S3)

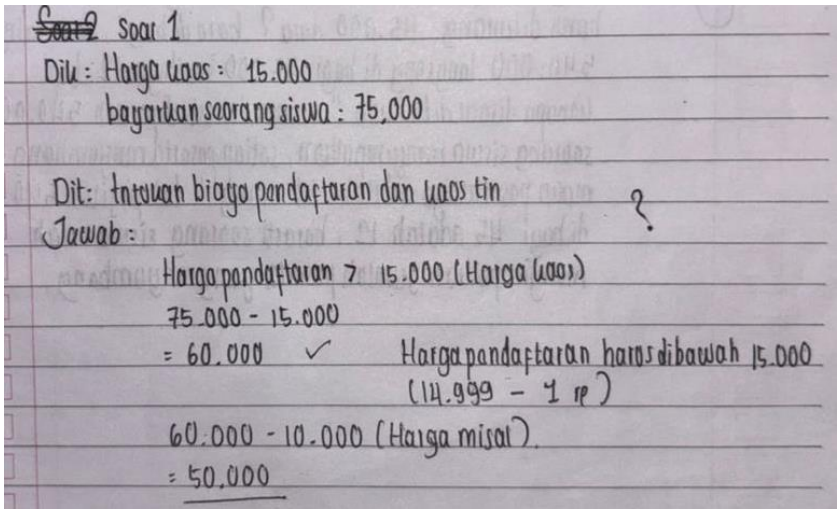

Figure 5. S3's Written Answer to Item 1

S3 misread the condition in Item 1, writing the T-shirt price as Rp15,000 rather than as Rp15,000 more than the registration fee (Figure 5). S3 correctly computed 75,000 − 15,000 = 60,000 but then assumed that the registration fee had to be less than Rp15,000, chose an arbitrary value of 10,000, and subtracted it to obtain 50,000. The written solution therefore shows no clear connection with an LEOV model. In the interview, S3 explained the correct solution coherently, showing that the understanding was better than the written answer suggested. The response was classified as pseudo-false (PS1).

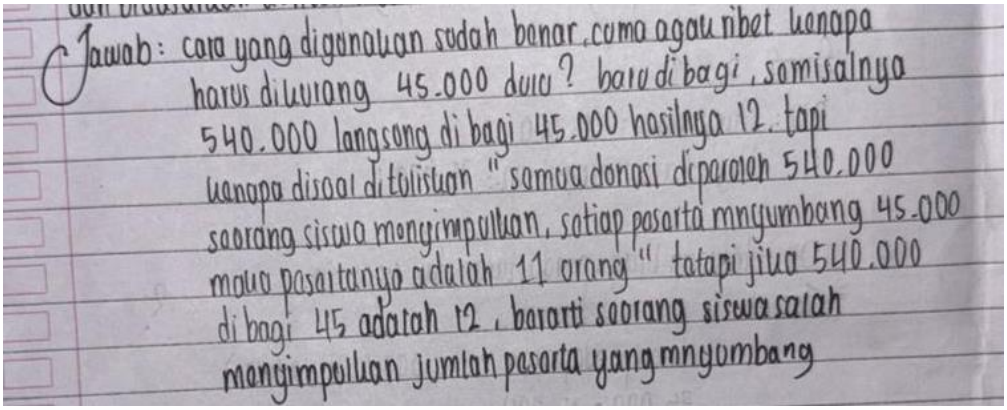

Figure 6. S3's Written Answer to Item 2

In Item 2 (Figure 6), S3 first wrote that the method in the problem was correct but unnecessarily complicated, asking why 45,000 had to be subtracted before dividing. S3 then divided 540,000 by 45,000, obtained 12, and concluded that the other student had drawn the wrong conclusion about the number of participants. The written response thus contains two conflicting judgments and states the solution in words rather than as an equation. In the interview, S3 explained the correct steps systematically. The gap between this oral explanation and the written representation places the response in the pseudo-false category (PS2).

Table 2 summarizes the categories assigned to each subject's responses.

Table 2. Summary of the Subjects' Pseudo-Thinking Categories

Subject	Item 1	Item 2	Profile
S1	PS1	PS2	Pseudo-false
S2	PB1	PB2	Pseudo-true
S3	PS1	PS2	Pseudo-false

S1 and S3 understood more than they managed to write down. S2 was the reverse case, with correct answers that S2 could not explain. Only one answer out of six was checked against the problem (S2, Item 1), and even there S2 could not say why the procedure worked.

3.2. Discussion

For all three students, the written answer to an LEOV word problem turned out to be a poor guide to what they understood. Two subjects showed pseudo-false thinking and

one showed pseudo-true thinking. These results fit the description of pseudo thinking as a state in which what students show does not match what they actually understand [1], and they illustrate both forms distinguished in the literature: correct answers resting on reasoning that cannot be justified, and wrong answers hiding sound reasoning [6].

For S1 and S3, things seem to go wrong when the word problem has to be turned into written mathematics. Both subjects identified the relevant information and could explain the solution orally, yet neither wrote an equation, and both made decisions on paper (dividing before subtracting, assuming an arbitrary price, accepting a flawed procedure) that they did not make when talking the problem through. Their understanding was there, but it was not yet organized enough to carry over into writing. Similar patterns have been reported in studies showing that wrong written answers can coexist with correct reasoning [6] and that students with pseudo thinking may master some parts of a process while struggling to express it [15]. The finding also agrees with LEOV studies that attribute errors to misconceptions and weak representation rather than to a complete lack of understanding [23], [24], and with work linking pseudo thinking to thinking errors such as misplaced concepts [19]. S3's reading of “Rp15,000 more than” as “Rp15,000” is an error of this kind, occurring at the comprehension stage [18].

S2 is a different case. S2 produced correct and well-organized solutions, and even checked one of them, but could not explain why the steps worked. This resembles the pseudo-procedures described by Hurst and Hurrell, in which students calculate correctly while relying on rules whose structure they do not understand [12], and it matches reports that students often follow solution procedures without grasping the concepts underneath [2], [17]. Pseudo-true thinking of this kind is difficult to detect, because a correct answer gives the teacher no reason to ask further questions [5]. It is also fragile: a procedure learned without its rationale tends to break down once the problem looks different [14].

The three profiles fit the conditions that earlier work associates with pseudo thinking [21], [22]: learning that emphasizes procedures over meaning [11], limited opportunities for students to explain and reflect on their thinking, and weak representational ability that makes it hard to connect a verbal situation with symbols [13], [20]. Learning habits that focus students on final answers [4] and gaps in conceptual understanding [3] reinforce these conditions. We would not read too much into the fact that two of the three subjects showed pseudo-false thinking; with three cases, the proportion says little about LEOV learners in general. Still, it may be that contextual LEOV problems, because they demand modeling, are especially likely to trip up students who reason well in words. This is worth testing with a larger group.

For teaching, the lesson is simple. A teacher who grades only final answers would overrate S2 and underrate S1 and S3. Asking students to justify one step in writing, or holding short reasoning interviews with selected students, can bring both kinds of mismatch to light. Requiring students to write the equation before computing and to check the result against the context may also reduce pseudo thinking, as can contextual problems, reflective discussion, and cognitive conflict, which earlier studies have used for this purpose [7], [14], [16], [19].

The study has clear limits. Only three subjects from one school were analyzed in depth, and the test consisted of two items, so the profiles cannot be generalized to junior high school students at large. The interviews were held after the test, so the subjects' explanations may reflect thinking that took place after, rather than during, the writing of their answers. Future studies could involve more subjects and items, use think-aloud protocols while students solve problems, and test instructional strategies such as scaffolding, cognitive conflict, and defragmentation for reducing pseudo thinking in LEOV.

4. CONCLUSION

We set out to describe how pseudo-true and pseudo-false thinking appear when eighth-grade students solve contextual LEOV problems. Both forms appeared, each as a mismatch between what students wrote and how they reasoned. S1 and S3 showed pseudo-false thinking: their written answers were wrong or inconsistent, yet they could explain the correct solution orally (PS1 and PS2). S2 showed pseudo-true thinking: the answers were correct, but S2 could not justify the steps (PB1 and PB2). The indicator-based profiles add LEOV word problems to the research on pseudo thinking, where the topic has received little attention. For teachers, the message is to ask for explanations, not just answers, when assessing LEOV. With only three subjects and two items, the findings need to be checked in larger samples, with more varied tasks, and in studies that test ways of reducing pseudo thinking.

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