AMOUNT OF INFORMATION IN MODELLING PROBLEMS: EXPLORING CONFIDENCE AND PERFORMANCE GAPS BETWEEN STUDENTS AND PRE-SERVICE TEACHERS

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This study examines whether performance and confidence gaps between students and pre-service teachers depend on the amount of information in modelling problems, and whether the confidence–performance correlation varies by type of problem and solver's profile. Using modelling problems with missing data (MD) and excess data (ED), we compared performance and confidence patterns across groups. Pre-service teachers outperformed students on ED-problems, while students exhibited lower confidence in MD-problems despite higher performance. The confidence–performance correlation remained stable for pre-service teachers but weakened for students on ED-problems. The findings highlight the importance of developing pre-service teachers' diagnostic competence to recognise metacognitive miscalibration in students.

INTRODUCTION

Mathematical modelling problems are increasingly emphasised for their potential to foster essential competencies in mathematics education. Yet, students often struggle throughout the modelling cycle and report low confidence when solving these tasks (Klock & Siller, 2020; Krawitz & Schukajlow, 2018). The amount of information, whether missing or excessive, may shape performance and confidence, as superfluous or incomplete data impose distinct cognitive and metacognitive demands (Ferrando et al., 2020).

Pre-service teachers also face the challenge of evaluating task appropriateness for students. Their previous experience may influence diagnostic competence, which is the ability to judge task complexity and suitability (Ferrando et al., 2025). Confidence plays a key role: alignment with performance suggests accurate self-assessment, while misalignment may indicate biased evaluations (Leuders et al., 2018). Examining gaps in confidence and performance between secondary students and pre-service teachers can reveal how information amount affects the metacognitive awareness that underlies diagnostic competence (Böswald & Schukajlow, 2023).

Accordingly, we address two research questions: (RQ1) Do the performance and confidence gaps between secondary school students and pre-service teachers depend on the amount of information included in the problem statement? and (RQ2) Are there differences in the strength of the confidence–performance association across problem types (ED vs. MD) and solver profiles?

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THEORETICAL FRAMEWORK

Amount of information in modelling problems

Modelling problems connect real-world contexts with mathematics by translating situations into mathematical representations and back (Niss & Blum, 2020). A key cognitive demand is constructing a situation model by structuring and simplifying the statement before solving (Leiß et al., 2019). Solvers must identify relevant data and, when information is missing, make plausible assumptions (García-Cerdá et al., in press; Krawitz & Schukajlow, 2018). Since the amount of information imposes different cognitive demands, problems are classified accordingly: Missing data (MD) problems require inferring missing information through assumptions and estimates (Krawitz et al., 2018), whereas excess data (ED) problems require the selection and justified prioritisation of relevant data (García-Cerdá et al., in press; Krawitz & Schukajlow, 2018). Figure 1 shows an example of each type of modelling problem.

Figure 1: MD-problem and an ED-problem used in the study

MD-problem	ED-problem
Last year students are preparing a concert on the basketball court in order to raise money for the end-of-year trip. Explain how you can find out the maximum number of people who can attend the concert.	**ED1:** Pablo is looking for a horsing school where his horse can have a box and receive food. He would also like to take riding courses at that school. About 15 minutes from his house, he finds two equestrian centers. BANNERT RIDING SCHOOL: Number of horses: 26; Stable and food per month: 180€; Price of the hour of riding: 15€ LARSEN RIDING SCHOOL: Number of horses: 52; Stable and food per month: 240€; Price per hour of riding: 12€ When is it worth going to Bannert and when to Larsen? Write your solution.

Performance and confidence in modelling problems

Performance in modelling problems involves developing an adequate mathematical model and correctly applying mathematical procedures to obtain a solution (Segura et al., 2025). Ferrando et al. (2020) suggest that the amount of information provided in a problem statement can influence how successfully a mathematical model is developed.

Confidence, understood as certainty in the correctness of one's own solution, has been little explored in complex problems such as modelling (Foster, 2016). The relationship between confidence and performance is well established in familiar problem types (Stankov et al., 2012), where individuals typically show alignment between their certainty and their actual performance. However, in complex problems such as modelling, students' confidence may be less reliably correlated with actual performance because their metacognitive awareness is still developing (Niederhand et al., 2021). In contrast, pre-service teachers with more mature metacognitive awareness may show stronger and more accurate confidence–performance alignment.

Yet it remains uncertain whether this relationship varies by problem type (MD vs. ED), as modelling problems with different information amounts have not been previously compared. Understanding how confidence–performance relationships differ between students and pre-service teachers, and whether they vary by problem type, is essential for developing diagnostic competence—the ability to judge task appropriateness and evaluate student understanding (Böswald & Schukajlow, 2023).

METHODOLOGY

Sample and data collection

This study involved two groups of participants. The first group included 188 students from Years 9 and 10 at a public secondary school in Valencia, Spain (49.48% girls and 50.52% boys). The second group consisted of 91 pre-service university students from a public university of Valencia, Spain (82.42% female and 17.58% male). All participants, and, in the case of secondary school students, their families, were informed about the aims and intended use of the collected data, in accordance with the ethical guidelines approved by the researchers' institution. Data collection took place during the 2023–2024 academic year for secondary school students and during 2024–2025 for pre-service teachers.

All participants solved a sequence of two MD-problems and two ED-problems in a 60-minute session (an example in Figure 1). After each problem, they reported their confidence using a five-point Likert scale ("I think my answer is correct"). To obtain performance and confidence for each type of problem, mean scores were calculated across the two problems of each type (MD and ED).

Data analysis

Performance was assessed using the coding scheme for modelling problems proposed by Segura et al. (2025), which scores 0 for incomplete models, 1 for complete models with procedural errors, and 2 for complete models without errors. Two researchers independently coded all responses, achieving high interrater reliability across problems (Cohen's Kappa $0.88 \leq \kappa \leq 0.98$). Confidence scores were obtained directly from the five-point Likert scale responses.

Mean scores were calculated across the two problems of each type (MD and ED) for both performance and confidence measures. Reliability (Cronbach's α) was acceptable for performance ($\alpha = 0.65$) and high for confidence ($\alpha = 0.85$) in secondary school students, and acceptable for both performance ($\alpha = 0.69$) and confidence ($\alpha = 0.79$) in pre-service teachers.

All statistical analyses were performed using SPSS software. To address RQ1, mixed-design ANOVAs were conducted separately for performance and confidence, with the amount of information (ED vs. MD) as a within-subject factor and solver profile (secondary school students vs. pre-service teachers) as a between-subject factor. Pairwise comparisons were used to examine whether performance and confidence gaps

between students and pre-service teachers varied by information amount (MD vs. ED). To address RQ2, Pearson correlations were computed to estimate the strength of the association between confidence and performance separately for each solver profile and information condition (ED and MD). Differences between correlations were examined using Fisher's Z transformation for independent samples (across profiles) and Steiger's Z test for dependent correlations (within profiles). Effect sizes (η^2, Cohen's d) are reported alongside significance tests.

RESULTS

Influence of the amount of information on performance gaps between secondary students and pre-service teachers

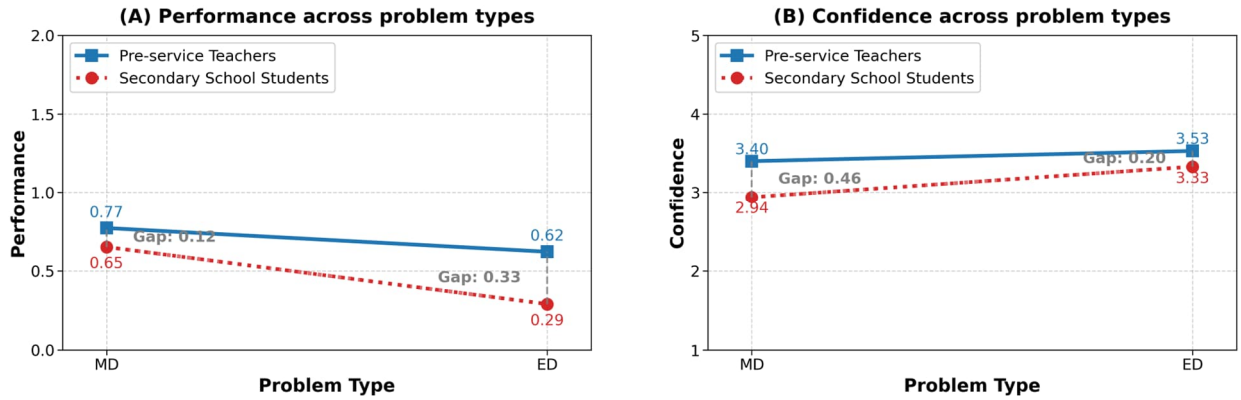
Table 1 shows mean performance scores for secondary school students (SS) and pre-service teachers (PST) for ED problems and MD problems.

Table 1: Mean performance (and Standard Deviation) by group and problem type

Solver profile	MD-Problems	ED-Problems
SS	0.65 (SD 0.68)	0.29 (SD 0.48)
PST	0.79 (SD 0.76)	0.61 (SD 0.64)

Pre-service teachers outperformed secondary school students, with the largest gap in ED problems (0.33 points) and the smallest in MD problems (0.12 points). While there are hardly any differences in performance between the two types of problems for pre-service teachers, in the case of students, performance is clearly lower in ED-problems. Results are presented in Figure 2 (A).

Figure 2: Performance and confidence by group across problem types



The mixed ANOVA revealed a significant interaction between information amount and solver profile ($F(1, 277) = 3.83$, $p < .05$, $\eta^2 = .02$). Pairwise comparisons showed that performance gaps between students and pre-service teachers were negligible in MD problems ($p = .12$) but substantial and statistically significant in ED problems ($p <$

.001), indicating that the performance advantage of pre-service teachers was concentrated in problems involving excess information.

Influence of the amount of information on confidence gaps between secondary students and pre-service teachers

Table 2 shows mean confidence scores for secondary school students (SS) and pre-service teachers (PST) for ED-problems and MD-problems.

Table 2: Mean confidence (and Standard Deviation) by group and problem type

Solver profile	MD-Problems	ED-Problems
SS	2.94 (SD 1.22)	3.33 (SD 1.20)
PST	3.41 (SD 1.02)	3.55 (SD 1.14)

Pre-service teachers reported higher confidence than secondary students, with the largest gap in MD problems (0.46 points) and a smaller gap in ED problems (0.20 points). While pre-service teachers showed similar confidence in both types of problems, students showed considerably lower confidence in MD-problems compared to ED-problems. Results are presented in Figure 2 (B).

Results from a mixed ANOVA showed that the interaction effect was significant ($F(1, 277) = 4.09$, $p < .05$, $\eta^2 = .02$). Pairwise comparisons revealed that confidence gaps between students and pre-service teachers were significant in MD-problems ($p < .01$) but negligible in ED-problems ($p = .16$), indicating that the confidence advantage of pre-service teachers was concentrated in problems involving missing information.

Influence of the amount of information and the solver profile on the relationship between confidence and performance

Pearson correlations revealed differential patterns by problem type and solver group. For students: confidence was moderately associated with performance for MD-problems ($r = .40$, $p < .01$) but weakly associated for ED-problems ($r = .17$, $p < .05$). For pre-service teachers: the association was weak for both types, significant only for MD-problems ($r = .24$, $p < .05$), for ED-problems the association was small and non-significant ($r = .20$, $p = .06$).

Steiger's Z tests examined whether the confidence–performance association differed between MD and ED within each solver profile. For students, the association was significantly stronger for MD-problems than for ED-problems ($Z = -2.67$, $p < 0.01$). For pre-service teachers, the correlations did not differ significantly between problem types ($Z = 0.37$, $p = 0.71$).

Fisher's Z transformation compared correlations between solver profiles for each problem type. For MD-problems, the difference between students and pre-service teachers was not statistically significant ($Z = 1.38$, $p = .17$). Similarly, no significant

differences emerged for ED-problems ($Z = -0.16$, $p = .87$). These results show that the confidence–performance association is more variable across problem types for students than for pre-service teachers, while between-group differences are not statistically significant for either problem type. This pattern contrasts with the performance gaps, where pre-service teachers' advantage was concentrated in ED-problems.

DISCUSSION

Influence of the amount of information on performance gaps (RQ1a)

The results show that the performance gap favours pre-service teachers in problems with excess data (ED) and is substantially attenuated in those with missing data (MD), suggesting that their advantage is associated with information management: constructing the situation and prioritising relevant data, filtering out irrelevant data, seems to be the differentiating factor in ED-problems. Conversely, when data must be obtained through estimation, the performance gap narrows, suggesting that both profiles draw on similar estimation strategies.

A plausible explanation links this advantage to the greater reading competence of pre-service teachers (García-Cerdá et al., in press). Their ability to handle information in the statement has a positive impact on how they organise the data and simplify the statement to construct a model of the situation (Leiß et al., 2019), which leads to more effective solution strategies and higher performance (Segura et al., 2025). For students, the presence of excess information increases cognitive load, making it more difficult to filter irrelevant data and construct accurate models.

Influence of the amount of information on confidence gaps (RQ1b)

The results show that while pre-service teachers maintain stable confidence in both types of problems, students show higher confidence in ED-problems despite markedly lower performance, indicating miscalibration of confidence (Niederhand et al., 2021). Consequently, there is a confidence gap between pre-service teachers and students for MD-problems that is attenuated for ED-problems.

The larger confidence gap in MD-problems indicates that students' confidence may be negatively affected by their lack of familiarity: MD-problems rarely appear in textbooks, which are full of word problems (Vicente et al., 2018). In contrast, students overestimate their confidence in ED-problems, which they perceive as more familiar because they identify them with conventional word problems. However, this superficial identification masks the actual challenge of selecting, prioritising and discarding data (García-Cerdá et al., in press; Krawitz & Schukajlow, 2018), creating an illusion of competence that explains the mismatch between confidence and performance in ED-problems. Pre-service teachers demonstrate a markedly different pattern: their stable and well-calibrated confidence across both problem types reflects

a more accurate diagnosis that both MD and ED problems are unconventional tasks, requiring distinct problem-solving approaches.

Relationship between confidence and performance (RQ2)

The results show two complementary patterns. First, across solver profiles: when comparing students and pre-service teachers on the same problem type, the confidence–performance correlation remains positive and consistent for both groups. This pattern is consistent with established findings on the stability of confidence-performance relationships across different contexts (Stankov et al., 2012). Second, across problem types: when comparing MD and ED within each solver profile, important differences emerge. Pre-service teachers maintain stable confidence-performance alignment across both problem types, whereas students show stronger alignment in MD-problems but miscalibrate in ED-problems. This reflects the differential metacognitive awareness identified in RQ1: students demonstrate more accurate self-monitoring when data is missing, but overestimate their confidence in ED-problems despite lower performance, which reinforces the need for targeted metacognitive interventions.

These findings suggest two instructional priorities. For students: explicitly teach the nature of different information conditions through carefully sequenced tasks, and provide targeted metacognitive feedback—particularly for ED-problems where overestimation of confidence is most pronounced. For pre-service teachers: develop their diagnostic competence to recognise confidence miscalibration in students, enabling more effective support for student learning. These priorities should inform teacher education programs aiming to foster diagnostic competence and metacognitive awareness.

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