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CORRECT PROCEDURE AND UNCERTAIN UNDERSTANDING: A CASE STUDY OF PRODUCT RULE PERFORMANCE IN A MALE ENGINEERING STUDENT WITH MASCULINE LEARNING TENDENCIES

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ABSTRACT

This study examines whether procedural correctness in applying the product rule reflects secure conceptual understanding in a male Mechanical Engineering student at the Faculty of Science and Technology, Universitas Sembilanbelas November Kolaka, exhibiting "masculine" learning tendencies characterized in the literature by high self-assurance and a preference for memorized procedures over conceptual reasoning. Rather than conventional error analysis, this study investigates correct procedural performance accompanied by conceptual uncertainty. Using a descriptive qualitative single-case design, S2 was purposively selected from 15 male students who had completed a Calculus course at a university in Southeast Sulawesi. Selection was based on medium mathematical ability, determined from final course grades, and observable masculine learning characteristics, identified through four classroom observations using a checklist and a screening interview. Data were collected through a written test involving $F(x) = (3x^2 - 2x)(x^3 + 1)$, an in-depth interview, and documentation, then analyzed using the Miles and Huberman interactive model of data reduction, data display, and conclusion drawing. The written test showed that S2 correctly identified $u = 3x^2 - 2x$ and $v = x^3 + 1$, calculated (u'=6x-2) and ($v'=3x^2$), and applied (uv)'=u'v+uv' to obtain the correct derivative, $F'(x) = 15x^4 - 8x^3 + 6x - 2$. However, the interview revealed uncertainty about the correctness of his differentiation despite accurate calculations. This discrepancy between procedural success and conceptual uncertainty is interpreted through the distinction between procedural and conceptual knowledge, APOS theory, and literature on gendered patterns of mathematical confidence. The study recommends probing students' reasoning through interviews or think-aloud protocols, even when written answers are correct, because procedural fluency may conceal fragile, memorization-based understanding.

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1. INTRODUCTION

Differential calculus is a foundational branch of mathematics and a prerequisite for numerous advanced disciplines, including physics, engineering, and economics. Mastery of the derivative concept is widely regarded as one of the essential competencies within calculus instruction, and difficulties with this topic have been documented broadly across undergraduate mathematics education (Stylianides et al., 2024). The product rule is one of the standard differentiation techniques required for solving more complex problems, yet many students continue to struggle with its correct application (Dzimar et al., 2025). Errors in applying differentiation rules have been documented across a range of educational contexts. Sitepu doctoral case study in South Africa found that students commit interpretation, arbitrary, procedural, linear extrapolation, and conceptual errors when learning derivatives of trigonometric functions, largely rooted in the overgeneralization of previously learned rules (Umam et al., 2022). Found that grade 12 students' errors in differentiation rules stemmed from poor conceptual understanding and a weak grasp of prerequisite algebraic knowledge. Comparable difficulties have been reported for the chain rule (Abou-hayt, 2025), for logarithmic differentiation, and even historically among professional mathematicians deriving new differentiation rules, underscoring that such difficulties are not confined to novice learners alone(Vlcek & Sedova, 2025).

Within the Indonesian context, numerous studies have documented similar errors among students solving derivatives of algebraic functions, whether analyzed through Newman's Error Analysis or through more general error-categorization frameworks(Osei et al., 2026). Across these studies, errors are commonly classified as conceptual, procedural, or technical/systemic in nature a classification that has proven useful but that primarily describes incorrect final answers rather than the reasoning that may or may not accompany a correct one. At a deeper level, many of these findings can be traced to a persistent gap between procedural and conceptual knowledge(Edelsbrunner et al., 2023). A student may apply an algorithm correctly what Skemp (1976) terms “instrumental understanding” without grasping why the algorithm works, which Skemp calls “relational understanding.” This distinction matters because procedural fluency and conceptual understanding do not necessarily develop together, and one can outpace the other in either direction. APOS theory offers a complementary lens: a learner may operate correctly at the Action stage, following an externally prescribed sequence of steps, without having interiorized this action into a Process- or Object-level understanding of the function being differentiated (Tatira, 2024). Because a correct written answer can be produced through either route, procedural correctness alone cannot be assumed to indicate secure conceptual mastery.

The gap in the existing research is twofold. First, error-analysis studies, by design, examine incorrect solutions and say little about correct solutions

that may rest on fragile understanding. Second, limited attention has been given to how gendered learning tendencies interact with the procedural–conceptual distinction. A substantial body of research suggests that male students, as a group, tend to report higher self-assessed mathematical confidence than their objective ability would predict, a pattern often described as “male overconfidence” in the mathematics-and-gender literature (Rainsford & Foster, 2025). Related scholarship on masculinity and mathematics learning argues that dominant models of masculinity can encourage a performance-oriented, procedure-reliant approach to mathematics that prioritizes arriving at an answer quickly over understanding it deeply. However, whether this tendency manifests as unwarranted confidence in an incorrect answer, or conversely as a private uncertainty concealed behind an outwardly correct one, remains underexplored through in-depth qualitative case study rather than large-scale survey methodology (Ranaweera, 2024).

In contrast to the studies reviewed above, which classify incorrect solutions, this study is not concerned with errors: it examines a solution that is entirely correct yet accompanied by the student's own uncertainty about it. This study is therefore specifically focused on a single case: a male university student exhibiting typically “masculine” learning tendencies, solving the derivative of the function $F(x) = (3x^2 - 2x)(x^3 + 1)$ using the product rule. The central research question is: does procedural correctness in applying the product rule reflect secure conceptual understanding in this subject, and if not, what does the mismatch reveal about the relationship between masculine learning tendencies, self-confidence, and conceptual mastery in calculus? By combining a written test, documentation of the subject's actual work, and an in-depth interview, this study offers a fine-grained qualitative account that complements the largely quantitative gender-and-confidence literature and carries implications for diagnostic approaches to differentiation instruction that do not rely solely on the correctness of a final written answer.

2. METHOD

2.1 Research Design

This research employed a descriptive qualitative case study design, focusing on a single, purposively selected subject embedded within a small purposive sample. The case study approach was chosen because it allows an in-depth, contextualized examination of the relationship between a student's written performance and self-reported reasoning, a relationship that a survey-based or purely quantitative design cannot adequately capture(Müller et al., 2023).

2.2 Participants

The participants were 15 male Mechanical Engineering students from the Faculty of Science and Technology, Universitas Sembilanbelas November Kolaka, in Southeast Sulawesi, all of whom had completed the Calculus course covering differentiation. Participants were selected through a staged purposive procedure

using the following criteria: (1) male; (2) had completed the Calculus course and had prior exposure to the product rule; (3) medium mathematical ability; and (4) displayed "masculine" learning characteristics in the sense described (Turianda & Siregar, 2025). Each criterion was operationalized as follows. The selected subject is hereafter referred to as S2.

Mathematical ability. Mathematical ability was determined from the final Calculus course grades of all 15 students (M = 72.4, SD = 8.6). Students were classified as high (score ≥ M + SD), medium (M − SD ≤ score < M + SD), or low (score < M − SD). A total of 9 students fell in the medium category.

Masculine learning characteristics. These characteristics were identified using an observation checklist administered over four class meetings plus a screening interview, with three indicators drawn from Buchholtz & Vollstedt (2024): (1) high outward self-assurance (e.g., answering questions in class promptly and without visible hesitation); (2) a stated preference for applying memorized formulas over giving conceptual justifications; and (3) a performance orientation toward obtaining answers quickly. A student was categorized as exhibiting these characteristics when at least two of the three indicators were met. The instrument was validated by two experts in mathematics education, and inter-rater agreement was 0.86. These indicators capture outwardly observable classroom behavior only; the student's private confidence in his own work was explored separately in the interview, which is what allows a mismatch between the two to be detected.

Selection of S2. Of the 15 students, 9 met the medium-ability criterion, and 5 of them also met the criterion for masculine learning characteristics. From this group, S2 was chosen because he was the most communicative and most willing to be interviewed in depth, and he was recommended by his lecturer as a student who consistently displayed the targeted learning characteristics. The remaining students were not analyzed further.

2.3 Instruments and Data Collection

The primary data consisted of (1) a written test and (2) an in-depth, semi-structured interview. The written test required the subject to solve the following derivative problem using the product rule:



Figure 1. The written test item given to the subject

This written test served as the initial instrument to document S2's procedural performance. Meanwhile, the interview guide was developed to probe the reasoning behind each step taken in the written test, moving systematically from the identification of u and v, determination of u′ and v′, application of the product rule formula, to a reflective question about the product rule in general. Documentation of the subject's original written work was also collected as supporting data and is presented as Figure 2.

2.4 Data Analysis

Data were analyzed following the interactive model of Miles and Huberman (1994), comprising three concurrent activities: data reduction, data display, and conclusion drawing/verification. Data trustworthiness was established through method triangulation (Denzin, 1978; Sugiyono, 2019), in which the written test was cross-checked against the interview transcript to identify consistencies and discrepancies between demonstrated performance and self-reported understanding.

3. RESULTS AND DISCUSSION

3.1. Results

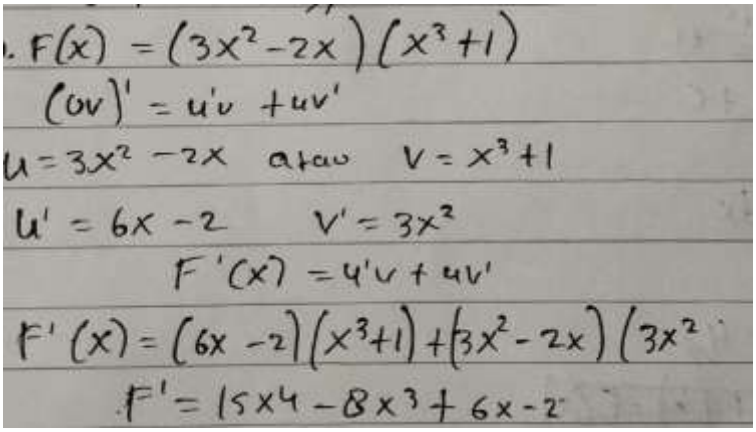


Figure 2. Subject S2's original written solution for $F(x) = (3x^2 - 2x)(x^3 + 1)$

Figure 2 presents the subject's (S2) original written solution to the test item. As shown, S2 correctly identified $u = 3x^2 - 2x$ and $v = x^3 + 1$, correctly derived $u' = 6x - 2$ and $v' = 3x^2$, and correctly substituted these terms into the product rule formula $(uv)' = u'v + uv'$. Table 1 summarizes the verification of each step against the expected correct procedure.

Table 1. Verification of Subject S2's Written Solution

Step	S2's Written Work	Expected Correct Step	Verification
Identify u and v	$u = 3x^2 - 2x$; $v = x^3 + 1$	$u = 3x^2 - 2x$; $v = x^3 + 1$	Correct

Step	S2's Written Work	Expected Correct Step	Verification
Differentiate u and v	$u' = 6x - 2$; $v' = 3x^2$	$u' = 6x - 2$; $v' = 3x^2$	Correct
Apply product rule	$F'(x) = (6x-2)(x^3+1) + (3x^2-2x)(3x^2)$	$F'(x) = u'v + uv'$	Correct
Simplify	$F' = 15x^4 - 8x^3 + 6x - 2$	$F'(x) = 15x^4 - 8x^3 + 6x - 2$	Correct

Unlike the error-oriented case studies reviewed in the introduction (Delastri & Lolang, 2023), S2's procedural execution contained no computational, notational, or conceptual missteps: every step in Table 1 matches the expected correct solution. Taken at face value, a written-test-only assessment would classify this response as a fully successful application of the product rule. An in-depth interview was then conducted to explore the reasoning behind these steps. The interview was structured to move systematically through the solution, beginning with the identification of u and v and ending with a reflective question about the product rule in general, so that each step verified in Table 1 could be checked against S2's own account of his reasoning. Eight excerpts drawn directly from the interview transcript with S2 (medium ability) are presented below.

Excerpt 1
Researcher: "In this problem, how did you decide which part to call u and which to call v?"
S2: "I just looked at the two parts that were multiplied together, so u is the first bracket and v is the second one. I don't really know if there's another way to decide, I just followed the example from class."
Excerpt 2
Researcher: "Can you explain how you got $u' = 6x - 2$?"
S2: "I used the power rule on each term, so $3x^2$ becomes 6x and $-2x$ becomes -2. But I'm not fully sure if I did it right, maybe I'm missing something."
Excerpt 3
Researcher: "And how about $v' = 3x^2$?"
S2: "Same thing, x^3 becomes $3x^2$ and the 1 disappears. I think it's correct, but honestly I always doubt myself here."
Excerpt 4
Researcher: "Can you explain the product rule formula you used?"
S2: "Yes, $u'v + uv'$. But I'm not sure how to differentiate u and v, so maybe I got it wrong."
Excerpt 5
Researcher: "How did you substitute your u, v, u', and v' into that formula?"

S2: "I just put (6x−2) times (x^3+1) and add ($3x^2$−2x) times ($3x^2$). I followed the formula, but I'm not confident I placed them in the right order."

Excerpt 6

Researcher: "Can you walk me through how you simplified the expression to get the final answer?"

S2: "I expanded everything and combined the like terms, so I got $15x^4 - 8x^3 + 6x - 2$. It matches what I expected, but I only double-checked the arithmetic, not really whether the whole method makes sense."

Excerpt 7

Researcher: "Overall, how confident are you that your final answer is correct?"

S2: "Actually I'm not too sure. Even though the number came out clean, I feel like I was just copying the steps without really understanding why they work."

Excerpt 8

Researcher: "Why do we need to differentiate u and v separately instead of just multiplying the whole function directly?"

S2: "Honestly, I don't really know the reason. I just remember that's the rule the lecturer gave us, so I use it. I never really thought about why it has to be like that."

Table 2 maps each of these eight excerpts onto the corresponding step of S2's written solution, alongside a brief characterization of the procedural accuracy and the self-reported confidence expressed in that excerpt.

Table 2. Mapping of Interview Excerpts to Written Steps, Procedural Accuracy, and Self-Reported Confidence

Excerpt	Corresponding Written Step	Procedural Accuracy	Self-Reported Confidence
1	Identify u and v	Correct	No procedure stated, but expressed uncertainty about method
2	Differentiate u	Correct	Uncertain ("maybe I'm missing something")
3	Differentiate v	Correct	Uncertain ("I always doubt myself here")
4	Apply product rule (formula)	Correct	Uncertain ("maybe I got it wrong")
5	Apply product rule (substitution)	Correct	Uncertain about ordering of terms

Excerpt	Corresponding Written Step	Procedural Accuracy	Self-Reported Confidence
6	Simplify	Correct	Confident in arithmetic only, not method
7	Overall result (reflective)	Correct (n/a)	Low; feels like "just copying the steps"
8	Conceptual rationale (why u, v separately)	Not answered	No awareness of underlying rationale

Taken together, table 2 shows that the mismatch first evident in Excerpt 4 was not an isolated remark but a consistent pattern across the entire solution process. In Excerpts 1 through 6, S2 was able to describe every procedural step accurately identifying u and v, differentiating each term, applying the product rule formula, substituting the results, and simplifying the expression yet in five of these six excerpts (2, 3, 4, 5, and 6) he simultaneously voiced some form of doubt about whether he had done that very step correctly. Excerpt 7 shows that this doubt was not confined to individual steps but extended to his overall assessment of the finished answer, despite the answer being fully correct. Excerpt 8 goes further, showing that S2 could not articulate why the product rule requires u and v to be differentiated separately at all, even though he had just carried out that separation correctly across Excerpts 1 through 3. Rather than the conceptual, procedural, or technical error categories reported in prior studies (Latip, 2026). the central finding of this case is a consistent, step-by-step mismatch between demonstrated procedural correctness and self-reported conceptual uncertainty, rather than a single isolated remark.

3.2. Discussion

This finding diverges from a straightforward "masculine overconfidence" narrative found in much of the gender-and-mathematics literature, in which male students are reported to display higher self-assessed confidence than their objective ability would predict (Rizki, 2024). Rather than displaying misplaced confidence in an incorrect answer, S2 displayed misplaced doubt in a correct one. Read through the lens, this pattern suggests that S2's procedural knowledge his "instrumental understanding" of the product rule had developed ahead of, or independently from, his conceptual knowledge of why the rule works and why u and v must be differentiated separately. In APOS terms (Tatira, 2024). S2 appears to operate competently at the Action level, correctly executing an externally prescribed sequence of steps, without having fully interiorized this action into a Process-level understanding that would give him confidence in his own reasoning.

This pattern carries an important practical implication. An instructor relying solely on written test scores would conclude that S2 has fully mastered the product

rule, when the interview instead reveals a fragile, memorization-based mastery that may not transfer to unfamiliar problems (Kartini, 2026). This is consistent with findings elsewhere that procedural fluency in differentiation can mask incomplete conceptual grounding by Herreros-torres & Gómez-ferragud (2026), and it echoes the broader concern that error-analysis frameworks focused only on incorrect final answers by Andini & Mukhlis, 2026), may overlook conceptual fragility that happens to produce a correct result.

Regarding the “masculine” framing of this case, the findings offer a more nuanced picture than the dominant-traditional-masculinity model described by Tandler & Proyer (2026) in which male students' orientation toward mathematics is characterized primarily by an outward performance of confidence and a preference for quick, procedure-driven answers. Here, S2's outward performance a fully correct written answer did not correspond to his privately reported confidence, suggesting that self-assurance and demonstrated competence can become decoupled in practice. This decoupling is significant because it means that a student's hidden uncertainty can go entirely undetected in classroom assessments that inspect only the final written product, allowing an underlying conceptual gap to persist unaddressed. This concern is broadly consistent with self-efficacy theory by Hepler et al., (2021), which holds that a student's self-efficacy beliefs not only objective procedural skill shape willingness to engage confidently with unfamiliar problems in the future, and it aligns with survey evidence that the relationship between self-efficacy and achievement can differ for male students relative to female students (Sperling et al., 2024).

Taken together, these results suggest that error-analysis research on differentiation should not treat a correct final answer as evidence, by itself, of secure conceptual mastery, particularly when examining how gendered learning tendencies shape the relationship between performance and confidence (Santosa et al., 2025). A written test alone would have rendered S2's conceptual uncertainty invisible; only the combination of test, documentation, and in-depth interview, analyzed through the (Miles, M.B, Huberman, A.M, & Saldana, 2014), model and cross-checked via triangulation was able to surface it.

It is also worth situating this finding against Newman's Error Analysis (NEA), one of the most widely used frameworks for classifying student mistakes in mathematics (Ananda et al., 2026). NEA identifies five stages at which an error can occur reading, comprehension, transformation, process skill, and encoding and typically assumes that a wrong final answer can be traced back to a breakdown at one of these stages. S2's case does not fit neatly into any of these categories, because no breakdown occurred at any stage: the problem was read, comprehended, transformed into the correct formula, processed accurately, and encoded correctly. What NEA-style frameworks are not designed to capture is a fifth possibility a correct performance accompanied by an unresolved, self-reported doubt about one

or more of those very stages. This suggests a boundary condition for error-analysis research more broadly: frameworks built to classify incorrect answers may need to be extended, or paired with interview-based methods, to detect what might be called a "covert" or "unrealized" error a gap in understanding that a correct answer, on this occasion, managed to paper over. Whether S2's understanding would survive a slightly modified version of the problem (for example, one requiring the product rule to be combined with the chain rule) is a question this single test item cannot answer, but the interview data raise it as a live concern rather than a merely speculative one.

These results also carry a concrete pedagogical implication for calculus instruction in Indonesian higher education. If procedural correctness can coexist with conceptual self-doubt, then instructors who rely exclusively on written quizzes or examinations to certify mastery of the product rule risk overlooking students who are, in effect, one unfamiliar problem away from failure. Building brief oral justification checks, short reflective writing prompts ("explain in your own words why we differentiate u and v separately"), or structured think-aloud exercises into routine instruction would allow lecturers to surface this kind of hidden uncertainty before it manifests as an error on a high-stakes assessment. Because self-efficacy beliefs shape how willingly a student attempts an unfamiliar problem in the future (Rosi Yulita, 2025), leaving S2's uncertainty unaddressed carries a risk beyond the immediate topic of the product rule: it may quietly erode his confidence in tackling more advanced differentiation problems later in the course, even though his procedural skill at this stage is entirely adequate.

Several limitations should be acknowledged. As a single-case study focused on one purposively selected subject, the findings describe a pattern rather than establish its prevalence, and cannot be generalized to male students, or to students exhibiting masculine learning tendencies, as a population(Blondé et al., 2024). It also remains possible that S2's expressed uncertainty reflected ordinary interview-situation caution a reluctance to claim confidence in front of a researcher rather than a deep and stable conceptual gap; distinguishing between these two possibilities would require either a repeated-measures design or a stimulated-recall interview conducted shortly after the test rather than after some delay. Future research involving a larger and more diverse set of subjects, including systematic comparison across gender and across ability levels, is needed to determine how often correct procedural performance is accompanied by this kind of unresolved conceptual doubt, and whether the pattern documented here is distinctive to masculine learning tendencies or is simply a more general feature of how calculus is learned.

4. CONCLUSION

This case study shows that procedural correctness in applying the product rule to the derivative of $F(x) = (3x^2 - 2x)(x^3 + 1)$ does not necessarily indicate secure

conceptual understanding. Subject S2, a male student exhibiting masculine learning tendencies, produced a fully correct written solution verified step by step in Table 1 yet expressed persistent uncertainty about the reasoning underlying his own correct steps, as documented in the interview excerpts (Table 2). As a single case based on self-report, this uncertainty should be read as indicative rather than conclusive. This finding underscores the importance of complementing written assessment with diagnostic interviews or other probes of student reasoning, since procedural success alone can conceal a fragile, memorization-based understanding that risks breaking down when the student encounters an unfamiliar problem. The implication for instruction is that teachers should not equate a correct final answer with conceptual mastery, and should instead build in opportunities such as brief oral checks or written justification prompts for students to articulate why each step of a procedure is valid. Further research involving a larger and more diverse set of subjects, including comparative analysis across gender, is recommended to determine how widely this "confident performance, uncertain understanding" pattern generalizes beyond the single case examined here.

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