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Mathematical Communication of Vocational High School Students in Solving Papuan Ethnomathematics-Based Problems

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Abstract

This study examines how Indonesian vocational high school (SMK) students communicate mathematically while solving systems of three-variable linear equations (SPLTV) embedded in Papuan ethnomathematical contexts. Using a qualitative descriptive design, the study involved ten Grade 10 students representing ten vocational departments. Data were collected through students' written solutions to ethnomathematics-based SPLTV tasks (e.g., contexts involving culturally familiar objects such as noken and local economic practices) and follow-up semi-structured interviews intended to clarify students' reasoning, procedural choices, and interpretation of results. Analysis employed a rubric-guided coding scheme comprising three observable indicators of mathematical communication: (1) mathematical expression/modeling (translating contextual information into variables and SPLTV equations), (2) identifying relevant information and coherently explaining solution procedures, and (3) drawing contextual conclusions that interpret solutions in relation to the problem situation. To ensure consistent reporting, each indicator was evaluated by evidence source written work (W), interview evidence (I), or both (W+I) allowing the study to distinguish between students who understood an element but did not document it in writing. Findings indicate that all participants were able to construct an SPLTV model from the cultural context, and most were able to explain elimination–substitution procedures, although several omitted key communication components (e.g., "given/asked" statements or an explicit concluding sentence) in their written work. Overall, eight of ten students produced a valid contextual conclusion when evidence from written work and/or interviews was considered, whereas two students struggled with core procedural steps and therefore could not reach a meaningful conclusion. These results suggest that Papuan cultural contexts can support meaning-making and initial modeling, but explicit support for procedural fluency and written communication norms remains necessary to produce complete, accountable solutions.

Keywords: Mathematical Communication; Papuan Ethnomathematics; Problem Solving; Vocational High School; SPLTV

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INTRODUCTION

Mathematics education is expected to cultivate a set of interrelated competencies that enable learners to reason, represent, and communicate ideas effectively. The National Council of Teachers of Mathematics identifies five key process standards problem solving, communication, connections, reasoning, and representation as essential outcomes of school mathematics. Among these, mathematical communication occupies a central position because it allows ideas to be externalized, examined, refined, negotiated, and transformed through interaction with others and through reflection on one's own thinking (NCTM, 2000). In this sense, communication is not a "soft" add-on to mathematical competence; rather, it is a mechanism through which mathematical reasoning becomes visible and therefore teachable, assessable, and improvable.

NCTM (2000) conceptualizes communication as students' capacity to (1) organize and consolidate mathematical thinking through communication, (2) communicate reasoning clearly to peers, teachers, and others, (3) analyze and evaluate others' mathematical thinking and strategies, and (4) use precise mathematical language to express ideas. Importantly, these indicators imply that mathematical communication is multi-modal: learners communicate through written symbols, oral explanation, diagrams, tables, and structured argumentation. Contemporary work similarly emphasizes that students' reasoning becomes more robust when they can explain and justify their approaches in multiple forms (Jotangiya, 2021). Thus, investigating mathematical communication requires attention not only to correctness of answers but also to how students translate contexts into mathematical representations, articulate procedures, justify decisions, and close solution processes with clear conclusions.

Despite its recognized importance, research consistently reports persistent challenges in students' mathematical communication. Baran and Kabael (2021) found that students' mathematical communication remains relatively low, and Majid et al. (2022) reported continuing difficulties in students' ability to express mathematical ideas and reasoning. More recent studies show that communication weaknesses may vary across students and contexts; for example, differences in written mathematical communication by gender have been documented among junior high school students (Qirom et al., 2023). These findings collectively suggest that mathematical communication is not automatically acquired through routine instruction and that it can be sensitive to task features, classroom norms, and students' confidence in expressing ideas. Accordingly, strengthening mathematical communication demands both instructional interventions and careful qualitative assessment that can reveal how students construct and express mathematical meaning.

A key implication of this literature is that evaluating mathematical communication cannot rely solely on final answers; instead, it requires structured criteria and analytic tools. Qualitative assessments particularly those combining written work artifacts with interviews can provide deeper insight into students' reasoning and the communicative moves they use to explain solutions (Sholikha & Palupi, 2023; Zabidi et al., 2023). Studies also suggest that peer feedback and collaborative exchanges can strengthen students' mathematical writing and explanation skills, indicating that communication develops through interaction rather than through solitary practice (Yang, 2023; Sun et al., 2023). In Indonesian secondary settings, problem-based approaches have been reported to support creative thinking alongside mathematical communication, reinforcing the idea that communication is intertwined with problem-solving practices and the demand to justify solutions (Umam et al., 2021). However, to make such claims credible especially in qualitative work researchers must clarify what counts as "good communication," how evidence is coded, and how interpretations are checked.

For that reason, recent scholarship has emphasized the importance of rubrics and coding frameworks for assessing mathematical communication. Practical rubrics can make expectations explicit and support systematic interpretation of qualitative evidence (Habig, 2020). Rubrics also allow researchers to evaluate students' mathematical argumentation and explanation in structured activities, helping distinguish between partially articulated reasoning and well-justified communication (Lyon et al., 2020). Moreover, rubric-guided qualitative coding can improve the comparability and reliability of analyses across students and tasks (Davey & Morell, 2020), especially when researchers employ explicit indicator definitions and observable evidence rules. Coding schemes have been used to identify patterns in student responses and to differentiate types of reasoning and explanation (Vogelsang et al., 2021;

Muhammad et al., 2021). In short, a robust study of mathematical communication should not only cite a framework such as NCTM but also operationalize it through transparent rubrics and analytic procedures that connect claims to identifiable evidence in written work and interview data.

Alongside assessment concerns, another major direction in mathematics education research is the integration of cultural contexts into instruction and assessment. Ethnomathematics positions mathematics as embedded in cultural practices, artifacts, and ways of reasoning, and it argues that connecting school mathematics to local contexts can strengthen relevance and meaning for learners (Gusfitri et al., 2022; Romadon & Kartika, 2024). This perspective aligns with culturally responsive pedagogy, which emphasizes recognizing students' cultural experiences and using them as resources for learning (Tran & Schepers, 2023). In mathematics, culturally responsive approaches often take the form of contextualized word problems and modeling tasks that resonate with students' lived realities, thereby promoting engagement and deeper conceptual understanding (Nolan & Xenofontos, 2023; Steffensen & Kasari, 2023). Such approaches can also support equity by creating learning environments where students' identities and cultural narratives are affirmed rather than marginalized (Downing & McCoy, 2021). Moreover, culturally responsive modeling has been linked to richer classroom discourse and more meaningful mathematical engagement, particularly when tasks connect to authentic social or community issues (Clements et al., 2023; Jiménez-Silva et al., 2025; Leyva et al., 2025).

However, the ethnomathematics literature also highlights an important methodological challenge: cultural context must be integral to the mathematical activity rather than a superficial "story wrapper." Therefore, ethnomathematics task design requires careful validation to ensure both cultural authenticity and mathematical rigor. Research on developing ethnomathematics-based learning materials frequently emphasizes expert review and iterative refinement as mechanisms for ensuring cultural and content validity (Romadon & Kartika, 2024; Sunzuma & Umbara, 2025). Pilot studies and user feedback are also important for confirming that tasks are comprehensible, meaningful, and aligned with targeted mathematical concepts (Rahayu et al., 2025). Task design can be strengthened by explicitly mapping cultural elements, targeted concepts, expected representations, and learning trajectories (Sukestiyarno et al., 2023). These design principles are particularly relevant when the research aim includes communication outcomes, because the cultural context can influence how students choose representations, explain reasoning, and connect symbolic mathematics to real-world meanings.

In Papua, ethnomathematics offers a promising pathway for contextualizing mathematics through culturally salient artifacts and practices. Yanti and Maranta (2023) describe how Papuan ethnomathematics elements such as Asmat carvings and noken patterns can be incorporated into mathematical problems. Such contexts may help students interpret problems more meaningfully and provide concrete referents for mathematical modeling and explanation. Yet, for international readers and for rigorous evaluation, ethnomathematics integration must be demonstrated through clearly described tasks and analytic evidence. Without transparent description of how cultural objects are embedded into problem structure, readers cannot judge whether "ethnomathematics" functions as an epistemic resource (shaping reasoning and representation) or merely as contextual decoration.

This concern is especially important in vocational high schools, where mathematics is expected to support both academic development and workplace-oriented competencies. Vocational education commonly emphasizes applied learning and transferable skills, and communication competence is central to collaboration, technical reporting, and problem-solving in professional contexts (Conrick et al., 2020; Lotter et al., 2024). Studies in vocational settings suggest that real-world contexts and cooperative learning experiences can foster mathematical communication and collaborative problem-solving (Gani et al., 2025), while partnerships between schools and workplaces can strengthen the authenticity of learning tasks and the relevance of mathematical discourse (Lai, 2020). In the Indonesian context, mathematics is integral to vocational areas such as engineering, automotive technology, and information technology, where quantitative reasoning and clear communication support technical decision-making (Chang et al., 2023; Sucipto et al., 2020). Nevertheless, vocational mathematics education also faces challenges, including misalignment between school curricula and industry demands and concerns about graduate readiness (Sudarsono et al., 2022; Wajdi et al., 2022; Yusuf & Basrowi, 2023). Broader structural issues—such as skill mismatch and employment outcomes—reinforce the urgency of instructional approaches that build both conceptual understanding and communicative competence (Kulsum & Taufik, 2022; Rachmita et al., 2021).

Within SMK mathematics instruction, innovative approaches such as integrated project-based learning and technology-supported collaboration have been proposed to strengthen engagement and competence (Kurnaedi et al., 2022; Sudarsono et al., 2022). Mobile-based and digital learning tools have also been discussed as pathways for linking vocational learning to career readiness (Nurdianah et al., 2022). However, while these studies underscore the importance of contextual and applied learning in SMK, fewer studies have examined mathematical communication specifically as an analyzable construct particularly communication evidenced through students' written modeling, procedural explanation, and concluding statements—within culturally contextualized tasks. In Papua, Rumainur and Kogoya (2022) reported that an ethnomathematics approach positively influences SMK students' mathematical communication. This finding is important, yet it also raises a need for more precise and transparent qualitative description: what aspects of communication improve, what evidence supports the claim, and how do students communicate across modalities (written work versus verbal explanation)?

A further reason to study mathematical communication in SMK concerns the nature of algebraic topics that are foundational for vocational applications, including systems of linear equations in three variables (SPLTV). Solving SPLTV problems requires students to coordinate representations (equations, tables, and symbolic manipulation) and to communicate how quantities relate within a modeled situation. Research indicates that students' representation skills and algebraic thinking can be strengthened through instructional models that foreground representation and explanation (Anggraini & Pratiwi, 2024). Students' self-efficacy also appears related to their willingness to engage in mathematical communication in topics such as systems of linear equations, suggesting that confidence may mediate communication quality (A'yuni et al., 2024). Experiential and context-rich teaching materials have been associated with improved mathematical literacy in linear-equation topics, reinforcing the potential of applied contexts for supporting understanding (Desy et al., 2024). Likewise, instruction tailored to student characteristics may improve comprehension and application of linear systems (Mulia & Aziz, 2023). These studies support the plausibility that culturally contextualized SPLTV tasks—if designed authentically—could elicit richer representations and explanations. Yet, existing literature still leaves under-specified how students communicate their modeling decisions, procedural steps, and solution conclusions when the context is culturally grounded rather than generic.

Taken together, the literature suggests three needs that motivate the present study. First, although mathematical communication is widely recognized and frequently studied, persistent weaknesses remain, and rigorous qualitative assessment requires transparent rubrics and coding procedures (Habig, 2020; Lyon et al., 2020; Davey & Morell, 2020). Second, ethnomathematics and culturally responsive pedagogy offer promising approaches for contextualizing mathematics, but they require task transparency and validation to demonstrate authenticity and analytic credibility (Romadon & Kartika, 2024; Sunzuma & Umbara, 2025; Tran & Schepers, 2023). Third, vocational education contexts bring distinct goals and constraints, making communication competence particularly consequential; yet SMK-focused research on mathematical communication especially in Papua and in the SPLTV topic remains comparatively limited and often lacks cross-case synthesis grounded in clear evidence (Rumainur & Kogoya, 2022). Therefore, the claimed gap is not merely that “SMK is rarely studied,” but that there is a shortage of studies that (a) examine mathematical communication in SMK using explicit, rubric-guided qualitative coding, (b) employ culturally meaningful Papuan ethnomathematics tasks whose cultural and mathematical features are described transparently, and (c) analyze student communication patterns across cases rather than presenting isolated narratives.

In response to this gap, the present study focuses on vocational high school students’ mathematical communication when solving Papua ethnomathematics-based SPLTV problems. Guided by NCTM’s communication standard (NCTM, 2000), this study operationalizes mathematical communication into three observable indicators aligned with the demands of SPLTV problem solving: (1) expressing the contextual situation as a mathematical model (e.g., translating cultural-context quantities into equations), (2) identifying given/asked information and explaining solution procedures coherently (written and/or verbal), and (3) drawing mathematical conclusions from obtained solutions. This operationalization is consistent with the multi-modal character of communication emphasized in prior work (Jotangiya, 2021) and is suitable for rubric-based qualitative analysis of student artifacts and interview explanations (Vogelsang et al., 2021; Muhammad et al., 2021). In addition, because culturally contextualized tasks may affect students’ engagement, confidence, and representational choices, this study also examines supporting and inhibiting factors reported by students, in line with qualitative approaches that use interviews to reveal learners’ experiences and challenges (Sholikha & Palupi, 2023; Vedianty et al., 2024).

The study aims to contribute to mathematics education research in three ways. First, it provides a rubric-guided qualitative description of SMK students’ mathematical communication using evidence from both written work and interviews, responding to calls for transparent qualitative assessment practices. Second, it strengthens the ethnomathematics discourse by examining communication in tasks grounded in Papuan cultural elements, thereby clarifying how cultural context can shape representation and explanation rather than serving only as decorative context. Third, it situates the analysis within vocational education realities, where communication competence is foundational for applied reasoning and workforce readiness, and where culturally meaningful contexts may support engagement and relevance. Ultimately, the findings are expected to inform the design of culturally contextualized learning tasks and communication-focused instruction in SMK mathematics, particularly in Papua, while offering empirically grounded insights that can be discussed within broader international scholarship on mathematical communication and culturally responsive mathematics education.

METHOD

Research Design

This study used a qualitative descriptive design to develop a rich, evidence-based description of how Grade X vocational high school (Sekolah Menengah Kejuruan—SMK) students communicate mathematically while solving Papuan ethnomathematics-based problems on systems of linear equations in three variables (SPLTV). Qualitative descriptive designs are appropriate when the purpose is to document learning processes, reasoning expressions, and contextual influences in naturalistic settings (Vodičková et al., 2023; Silva et al., 2020). Consistent with qualitative mathematics education research, the analysis integrated student written work and semi-structured interviews to illuminate both the observable products of communication (written representations and procedures) and students’ underlying explanations (Mahfoodh, 2022; Yetkiner et al., 2022).

Setting and Participants

The study was conducted in an SMK that comprises 10 departments and is supported by six mathematics teachers. Participants were Grade X students drawn from these departments. To ensure anonymity, students' real names were replaced with acronyms, and the departmental distribution of participants is presented in Table 1 (Research Subjects). The cross-department structure is reported to provide contextual clarity about participants' vocational backgrounds and to support later cross-case interpretation of communication patterns.

Sampling Strategy and Rationale

Participants were selected using purposive sampling through consultation with mathematics teachers. The inclusion criteria were: (1) good mathematics achievement, (2) regular attendance, and (3) ability to express opinions during learning. This sampling approach was intended to generate information-rich cases in which students could articulate mathematical thinking clearly during interviews and in written work—an important consideration for studies focused on communication processes rather than population estimates (Sevimli & Ünal, 2022; Muhtarom et al., 2020).

At the same time, the study recognizes that selecting students with strong achievement and expressiveness can bias results upward (i.e., toward stronger communication), which constrains generalization to "typical" SMK learners. Therefore, claims are interpreted as describing mathematical communication within this purposively selected sample, and limitations are addressed explicitly in the Discussion.

Instruments

Ethnomathematics-based SPLTV Task

The primary instrument was a written problem set on SPLTV designed using Papuan ethnomathematics contexts. The cultural contexts were drawn from local Papuan elements referenced in the study background (e.g., cultural artifacts and patterns) to make modeling tasks meaningful and contextually grounded. Because ethnomathematics tasks must demonstrate authenticity and content alignment, the task design followed principles used in culturally contextualized problem development, emphasizing content validity and cultural appropriateness through expert judgment and iterative refinement (Oktiningrum & Wardhani, 2023; Fitri, 2025; Bela & Wewe, 2024; Kurniawan et al., 2023). In line with validation practices for culturally contextualized word problems, the task was reviewed for clarity, cultural relevance, and alignment to the targeted SPLTV concept (Sánchez-Barbero et al., 2022; Rivana et al., 2023).

To strengthen transparency (as required for peer evaluation), the revised manuscript specifies that the full problem text should be provided in an appendix and summarized in a task blueprint table (cultural element, SPLTV target concept, expected representations, and targeted communication indicator), consistent with recommendations for validated culturally grounded tasks (Norberg, 2025; Kumala, 2025; Vitoria et al., 2021).

Interview Protocol (Supporting and Inhibiting Factors)

A semi-structured interview guide was used to elicit students' explanations of how they interpreted the task, chose representations, and experienced supports or obstacles while communicating solutions. Interviews are widely used to complement written work analysis because they capture reasoning that may not appear in students' written responses (Mahfoodh, 2022; Novitasari et al., 2024). The interview protocol included prompts aligned to the communication indicators and probes about perceived enabling conditions (e.g., familiarity with context, confidence) and potential inhibiting conditions (e.g., confusion, time pressure). The protocol is reported in summarized form to enhance reproducibility and analytic traceability (Charamba & Dlamini-Nxumalo, 2022).

Data Collection Procedure

Data collection occurred in one scheduled session at the school. The ten selected students were gathered in one classroom and completed the ethnomathematics-based SPLTV written task. The testing situation is documented in Figure 1. Students' written work was collected as primary artifact data. After the written task, participants took part in individual semi-structured interviews to clarify their representations, procedures, and concluding statements, and to explore supporting/inhibiting factors.

Figure 1. Research subject working on the test

To preserve the naturalness of student expression, interviews were conducted in the language students used most comfortably during learning (with excerpts later translated into English for reporting when necessary). All data were anonymized using the acronyms listed in Table 1.

Table 1. Research Subjects

Subject No	Department	Acronym
1	Geomatics	ADH
2	Electrical Engineering	BA
3	Computer Network Engineering	FE
4	Audio Video	MOS
5	Welding	SH
6	Lathe Engineering	VLCS
7	Light Vehicle Engineering	RC
8	Motorcycle Engineering	GP
9	Building Design Modeling and Information	RA
10	Construction and Housing Engineering	DB

Analytic framework and data analysis

Communication indicators and evidence sources

This study's analytic framework was grounded in the NCTM conception of mathematical communication (NCTM, 2000) and was operationalized into three indicators aligned with the communicative demands of solving systems of linear equations in three variables (SPLTV). The first indicator, mathematical expression/modeling, refers to students' ability to translate the Papuan ethnomathematics context into mathematical representations. Evidence for this indicator included defining variables, organizing quantities from the problem situation, and constructing an SPLTV model (e.g., a coherent system of three linear equations). The second indicator, identifying information and explaining procedures, captured students' ability to communicate what is known and what is asked, and to explain the solution process coherently. Evidence included correctly stating given/unknown information, selecting and applying a solution method (e.g., elimination/substitution), presenting steps in a logical sequence, and using mathematical language and representations (symbols, equations, tables, or brief narrative explanation) appropriately. The third indicator, drawing conclusions, referred to producing a concluding statement that interprets the obtained solution in relation to the problem context (e.g., restating the meaning of numerical results using units or contextual labels, and confirming that the solution answers the question posed).

To ensure analytic transparency and prevent internal inconsistencies in reporting, each indicator was coded with an evidence-source tag: Written work (W) when the indicator was demonstrated in students' solution scripts; Interview (I) when the indicator was demonstrated only through students' verbal explanations during follow-up interviews; and Written + Interview (W+I) when evidence appeared in both sources. This distinction is particularly critical for the "drawing conclusions" indicator, because students may reach and understand a conclusion but fail to write it explicitly. Therefore, the study treats "drawing conclusions" as having two complementary forms: (a) written conclusion, indicated by an explicit concluding sentence/statement in the written solution that interprets the result in context, and/or (b) interview-confirmed conclusion, indicated by the student's ability to articulate the contextual meaning of the solution verbally during the interview. Using these evidence-source tags allows the manuscript to report results consistently (e.g., "8/10 wrote conclusions; 10/10 explained conclusions in interviews" if supported by the data) and supports triangulated interpretation, consistent with qualitative trustworthiness practices (Yetkiner et al., 2022; Salsabila, 2025).

Coding Process (deductive–inductive) and Cross-case Synthesis

Data analysis followed a deductive–inductive qualitative content strategy. Deductively, the three pre-specified indicators (modeling, procedure explanation, concluding) provided the initial coding categories, ensuring alignment between the research questions and the analytic framework. Inductively, the analysis then developed subcodes to capture recurring patterns in how students represented and communicated SPLTV solutions within the cultural-context task. For example, within the modeling indicator, students' approaches were subcoded according to how they translated context into equations (e.g., equation-first modeling that immediately defined variables and formed equations, versus table/organizer-first modeling that listed known values before formalizing equations). Within procedure explanation, subcodes differentiated students who provided stepwise narration of reasoning from those who relied on symbolic manipulation only with minimal explanation. These inductive refinements follow recommended qualitative coding practices, enabling researchers to describe not only whether students met an indicator but also *how* they expressed it (Yang et al., 2025; Sevimli & Ünal, 2022).

The analysis was conducted in two sequential stages. First, within-case analysis was performed for each participant by examining their written solution script and then linking it to the corresponding interview account. This within-case integration enabled the researchers to determine indicator attainment and clarify ambiguities in written work for instance, whether missing written conclusions reflected conceptual absence or simply an omission in written communication (Muhtarom et al., 2020; Ramadhan, 2025). In the manuscript, the within-case evidence is presented in the Findings section by participant (department and acronym), supported by visual artifacts of student work.

Second, a cross-case analysis was conducted to identify shared patterns and meaningful contrasts across the ten participants representing different departments. This stage supports synthesis beyond a set of isolated case notes by aggregating indicator evidence across cases and comparing the forms of communication used. Cross-case synthesis is reported through summary displays in the Findings, including Table 3 (Results of Drawing Conclusions from a Mathematical Problem), which consolidates evidence of students' conclusion-making performance and helps readers see overall patterns more directly than reading each case separately (Wahyuni & Jamaris, 2021). This cross-case stage also supports the manuscript's claims about supporting and inhibiting factors by examining whether the same enabling conditions recur across multiple interviews rather than appearing as single-case impressions.

Rubric guidance and reliability of judgments

To make interpretations such as "was able to…" methodologically defensible, the three indicators were implemented as an analytic rubric specifying observable criteria and decision rules for coding. Rubric-guided qualitative assessment is widely used to increase clarity, comparability, and interpretive discipline when analyzing open-ended student work (Habig, 2020; Lyon et al., 2020). In this study, the rubric defined what counts as sufficient evidence for each indicator (e.g., minimum requirements for a valid SPLTV model; features of coherent procedural explanation; elements of a contextualized concluding statement). The rubric also specified how evidence-source tags (W, I, W+I) were assigned to avoid conflating written and verbal performance. This approach supports more reliable comparisons across students and reduces the risk that claims depend solely on subjective impressions (Davey & Morell, 2020; Gradini, 2022; Zaenal & Heriyana, 2021).

To strengthen reliability, the coding process involved two coders (the researcher and a peer reviewer/colleague with expertise in mathematics education). The coders first conducted calibration coding on a subset of written solutions and interview excerpts to align interpretations of each rubric criterion. Disagreements were discussed, leading to refinement of definitions and decision rules (e.g., what qualifies as an "explicit conclusion," how to code partially stated givens/asks, or how to treat correct procedures with unclear narration). Such coder calibration and agreement procedures are recommended to reduce subjectivity and increase transparency in qualitative coding, especially when judgments are applied to student artifacts (Cole, 2023; Dehaibi & MacDonald, 2020; Theelen et al., 2024; Abd-El-Khalick et al., 2023). After calibration, the remaining dataset was coded, and any residual disagreements were resolved through consensus discussion and revisiting the original evidence. Throughout the process, an audit trail was maintained to document coding decisions, revisions to the rubric, and rationale for resolving ambiguous cases, thereby supporting confirmability of the analytic claims.

Trustworthiness and ethics

The trustworthiness and ethical integrity of this study were systematically established to ensure that the research process and findings are credible, dependable, and academically accountable. Credibility and dependability were strengthened through methodological triangulation by comparing students' written work with interview data across each analytical indicator (Yetkiner et al., 2022; Salsabila, 2025). This approach enabled cross-verification of evidence from multiple data sources, thereby reducing reliance on a single form of data and enhancing the robustness of interpretations. In addition, peer debriefing was conducted to critically examine emerging interpretations and to refine the assessment rubric and coding procedures. This process contributed to minimizing researcher bias and improving the consistency and accuracy of data categorization.

To further enhance credibility, limited member checking was implemented by confirming key interpretations particularly those related to conclusion statements and claims regarding supporting and inhibiting factors with participants during or immediately after the interviews (Mahfoodh, 2022). Confirmability was supported through the maintenance of an audit trail documenting analytical decisions, code revisions, and the assignment of evidence sources underlying each finding (Jupri et al., 2024). This documentation ensures transparency and allows the analytic process to be traced and verified by external reviewers.

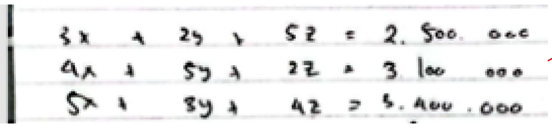
Ethically, participation in the study was voluntary and conducted with formal permission from the school. Students were informed about the purpose of the study, the intended use of the data, and the measures taken to ensure confidentiality. Identifiable information was removed and replaced with acronyms, as presented in Table 1, to safeguard participants' anonymity. All data, including written work and interview records, were securely stored and used exclusively for research purposes. Through these measures, the study adheres to established standards of qualitative rigor while upholding fundamental ethical principles in educational research.

RESULTS AND DISCUSSION

The presentation of the research findings is organized according to three indicators of mathematical communication as proposed by NCTM (2000): (1) the ability to construct mathematical expressions or models; (2) the ability to identify given and required information and to explain the solution procedures; and (3) the ability to draw conclusions from mathematical problems. To enhance the traceability of evidence and minimize interpretive inconsistencies, each indicator was analyzed based on two sources of evidence: written responses (W) on the worksheets (see the student answer artifacts/images in the findings section) and post-test interviews (I).

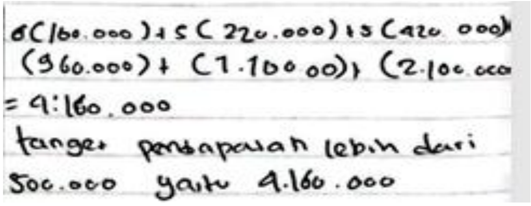
With specific regard to the indicator of drawing conclusions, this study distinguishes between written conclusions (i.e., the presence of an explicit concluding statement on the answer sheet) and/or interview-confirmed conclusions (i.e., the student's ability to verbally articulate the interpretation of the result). This distinction is essential, as several students were able to express appropriate conclusions during the interview but did not document them in their written responses. The responses of each participant are presented as follows.

Subject 1 (ADH) Geomatics Department


3x + 2y + 5z = 2.500.000
4x + 5y + 2z = 3.100.000
5x + 3y + 4z = 3.400.000

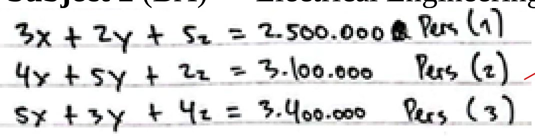
Subject 1 (ADH) was able to perform mathematical expression, namely representing real-life problems or events in the language of mathematical models.

In the written response, Subject 1 (ADH) did not explicitly state the known information, the question being asked, or the procedure to obtain the answer. However, based on the solution steps and the results of the interview, Subject 1 (ADH) was able to identify the given information, determine what was being asked, and explain the procedure to arrive at the solution.

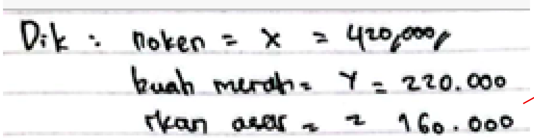

6(160.000) + 5(220.000) + 5(420.000)
(960.000) + (1.100.000) + (2.100.000)
= 4.160.000
tanger pendapatan lebih dari
500.000 yaitu 4.160.000

Subject 1 (ADH) was able to draw conclusions from a mathematical problem.

Subject 2 (BA) — Electrical Engineering Department


3x + 2y + 5z = 2.500.000 Pers (1)
4x + 5y + 2z = 3.100.000 Pers (2)
5x + 3y + 4z = 3.400.000 Pers (3)

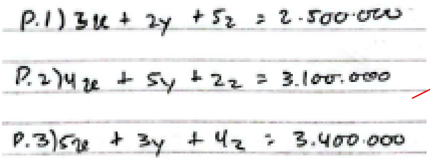
Subject 2 (BA) was able to perform mathematical expression, namely representing real-life problems or events in the language of mathematical models.


Dik : noken = x = 420.000,
buah merah = y = 220.000
ikan asar = z = 160.000

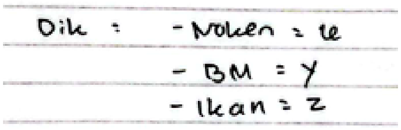
Subject 2 (BA) was able to identify the given information, determine what was being asked, and explain the procedure to obtain the answer.

In the written response, Subject 2 (BA) did not explicitly provide a conclusion to the mathematical problem. However, based on the solution steps and the results of the interview, Subject 2 (BA) was able to draw a conclusion from the mathematical problem.

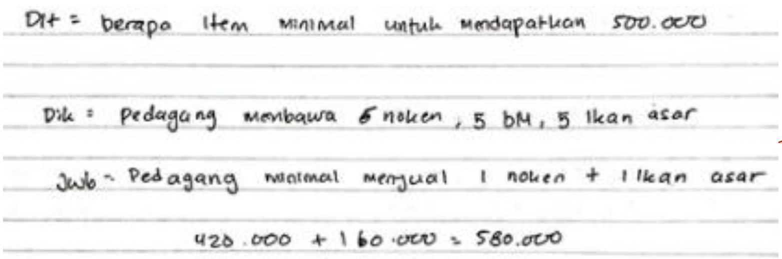
Subject 3 (FE) — Computer Network Engineering Department



Subject 3 (FE) was able to draw conclusions from a mathematical problem using the language of mathematical models.

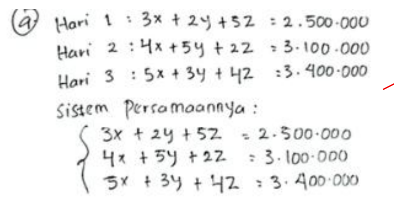


Subject 3 (FE) was able to identify the known information, determine what was being asked, and explain the procedure to obtain the answer.

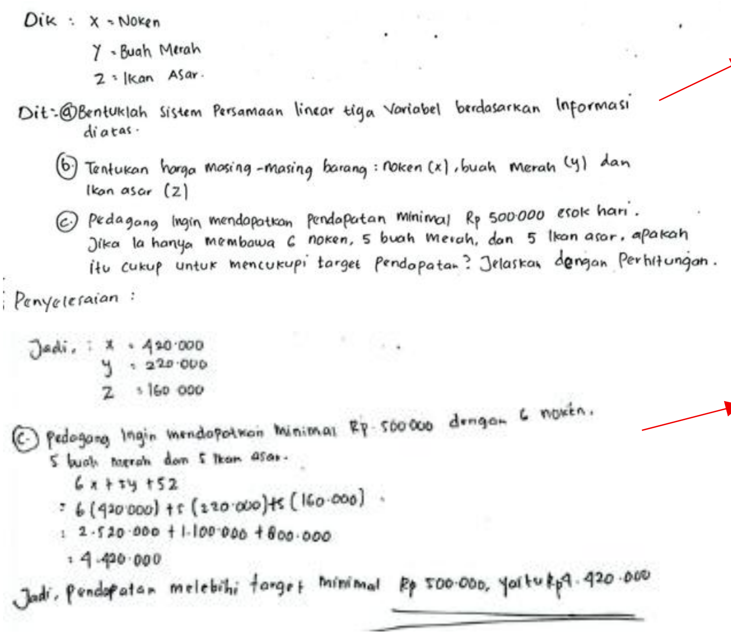


Subject 3 (FE) was able to draw conclusions from a mathematical problem.

Subject 4 (MOS) — Audio Video Department



Subject 4 (MOS) was able to draw conclusions from a mathematical problem using the language of mathematical models.



Subject 4 (MOS) was able to identify the given information, determine what was being asked, and explain the procedure to obtain the answer.

Subject 4 (MOS) was able to draw conclusions from a mathematical problem.

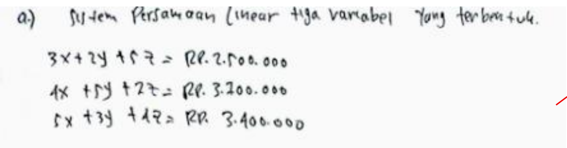
Subject 5 (SH) — Welding Department

In the written response, Subject 5 (SH) did not explicitly state the given information and the question being asked. However, based on the solution steps and the results of the interview, Subject 5 (SH) was able to identify the known information, determine what was being asked, and explain the procedure to obtain the answer. Similarly, in the written response, Subject 5 (SH) did not provide a conclusion to the mathematical problem. Nevertheless, based on the solution steps and the interview results, Subject 5 (SH) was able to draw a conclusion from the mathematical problem.


Penyelesaian.
Langkah pertama:
Misalkan
x = harga 1 noken (Rp)
y = harga 1 buah merah (Rp)
z = harga 1 ikan asar (Rp)
Dari soal:
Hari 1:
3x + 2y + 5z = 2.500.000
Hari 2:
4x + 5y + 2z = 3.100.000
Hari 3:
5x + 3y + 4z = 3.400.000
Sistem persamaan:
3x + 2y + 5z = 2.500.000
4x + 5y + 2z = 3.100.000
5x + 3y + 4z = 3.400.000

Subject 5 (SH) was able to draw conclusions from a mathematical problem using the language of mathematical models.

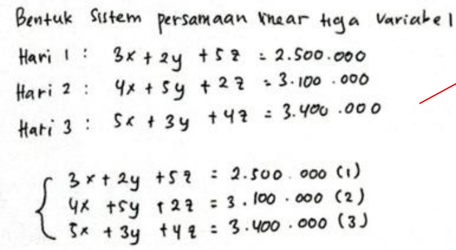
Subject 6 (VLCS) — Lathe Engineering Department


a) Sistem Persamaan linear tiga variabel yang terbentuk.
3x+2y+5z = RP. 2.500.000
4x+5y+2z = RP. 3.100.000
5x+3y+4z = RP. 3.400.000

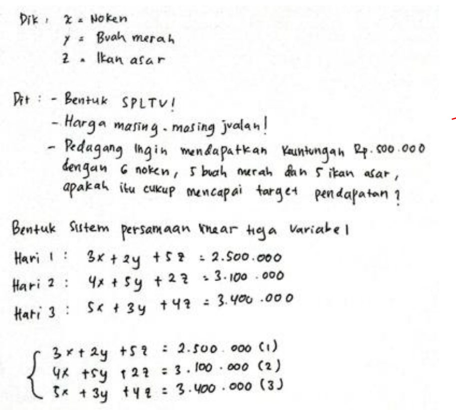
Subject 6 (VLCS) was able to draw conclusions from a mathematical problem using the language of mathematical models.

In the written response, Subject 6 (VLCS) did not explicitly state the given information and the question being asked. However, based on the solution steps and the results of the interview, Subject 6 (VLCS) was able to identify the known information, determine what was being asked, and explain the procedure to obtain the answer. Similarly, in the written response, Subject 6 (VLCS) did not provide a conclusion to the mathematical problem. Nevertheless, based on the solution steps and the interview results, Subject 6 (VLCS) was able to draw a conclusion from the mathematical problem.

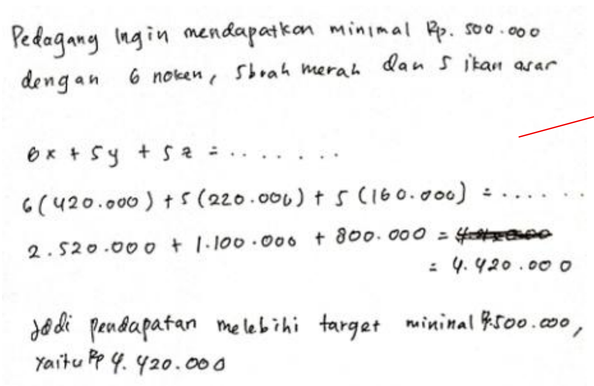
Subject 7 (RC) — Light Vehicle Engineering Department


Bentuk Sistem persamaan linear tiga variabel
Hari 1: 3x + 2y + 5z = 2.500.000
Hari 2: 4x + 5y + 2z = 3.100.000
Hari 3: 5x + 3y + 4z = 3.400.000
3x + 2y + 5z = 2.500.000 (1)
4x + 5y + 2z = 3.100.000 (2)
5x + 3y + 4z = 3.400.000 (3)

Subject 7 (RC) was able to draw conclusions from a mathematical problem using the language of mathematical models.


Dik: x = Noken
y = Buah merah
z = Ikan asar
Dit: - Bentuk SPLTV!
- Harga masing-masing jualan!
- Pedagang ingin mendapatkan keuntungan Rp 500.000 dengan 6 noken, 5 buah merah dan 5 ikan asar, apakah itu cukup mencapai target pendapatan?
Bentuk Sistem persamaan linear tiga variabel
Hari 1: 3x + 2y + 5z = 2.500.000
Hari 2: 4x + 5y + 2z = 3.100.000
Hari 3: 5x + 3y + 4z = 3.400.000
3x + 2y + 5z = 2.500.000 (1)
4x + 5y + 2z = 3.100.000 (2)
5x + 3y + 4z = 3.400.000 (3)

Subject 7 (RC) was able to identify the given information, determine what was being asked, and explain the procedure to obtain the answer.



Pedagang ingin mendapatkan minimal Rp. 500.000 dengan 6 noken, 5 buah merah dan 5 ikan asar

6x + 5y + 5z = ...

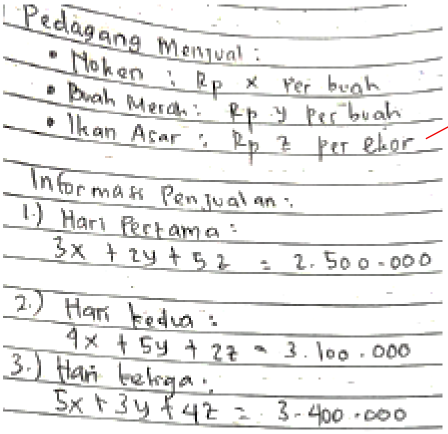
6(420.000) + 5(220.000) + 5(160.000) = ...

2.520.000 + 1.100.000 + 800.000 = ~~4.420.000~~
= 4.420.000

Jadi pendapatan melebihi target minimal Rp500.000, yaitu Rp 4.420.000

Subject 7 (RC) was able to draw conclusions from a mathematical problem.

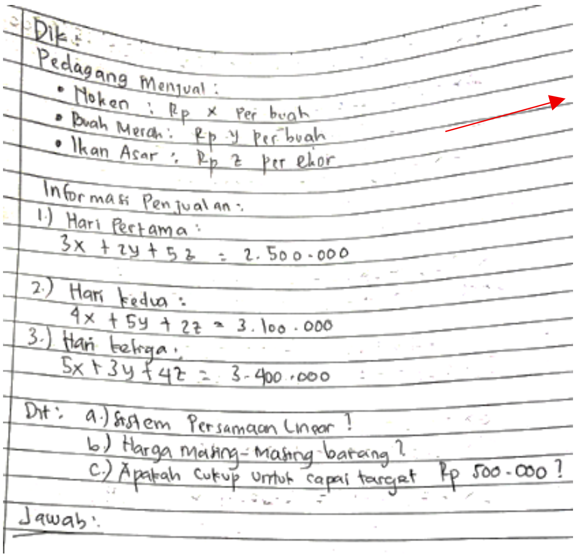
Subject 8 (GP) — Motorcycle Engineering Department



Pedagang Menjual :
• Noken : Rp x per buah
• Buah Merah : Rp y per buah
• Ikan Asar : Rp z per ekor

Informasi Penjualan :
1.) Hari Pertama :
3x + 2y + 5z = 2.500.000
2.) Hari kedua :
4x + 5y + 2z = 3.100.000
3.) Hari ketiga :
5x + 3y + 4z = 3.400.000

Subject 8 (GP) was able to draw conclusions from a mathematical problem using the language of mathematical models.



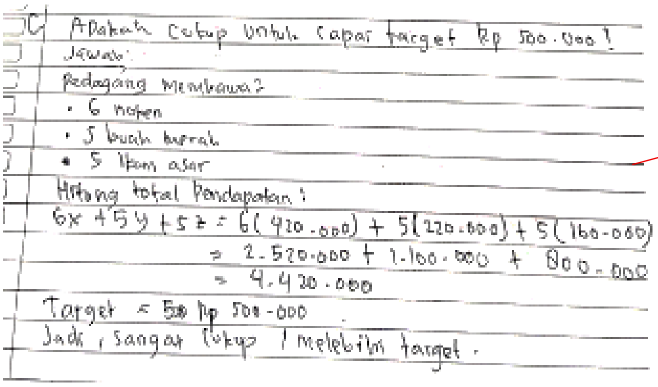
Dik :
Pedagang Menjual :
• Noken : Rp x per buah
• Buah Merah : Rp y per buah
• Ikan Asar : Rp z per ekor

Informasi Penjualan :
1.) Hari Pertama :
3x + 2y + 5z = 2.500.000
2.) Hari kedua :
4x + 5y + 2z = 3.100.000
3.) Hari ketiga :
5x + 3y + 4z = 3.400.000

Dit : a.) Sistem Persamaan Linear ?
b.) Harga masing-masing barang ?
c.) Apakah cukup untuk capai target Rp 500.000 ?

Jawab :

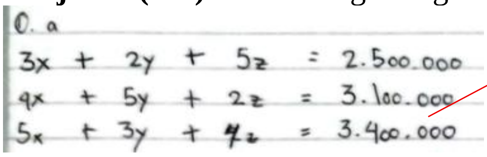
Subject 8 (GP) was able to identify the given information, determine what was being asked, and explain the procedure to obtain the answer.



c) Apakah cukup untuk capai target Rp 500.000 ?
Jawab :
Pedagang membawa ?
• 6 noken
• 5 buah merah
• 5 ikan asar
Hitung total Pendapatan :
6x + 5y + 5z = 6(420.000) + 5(220.000) + 5(160.000)
= 2.520.000 + 1.100.000 + 800.000
= 4.420.000
Target = Rp 500.000
Jadi, sangat cukup / melebihi target.

Subject 8 (GP) was able to draw conclusions from a mathematical problem.

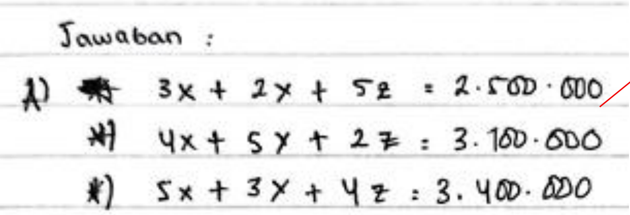
Subject 9 (RA) — Building Design Modeling and Information Department



Subject 9 (RA) was able to draw conclusions from a mathematical problem using the language of mathematical models.

In the written response, Subject 9 (RA) did not explicitly state the given information and the question being asked. However, based on the solution steps and the results of the interview, Subject 9 (RA) was able to identify the known information and determine what was being asked, but was unable to explain the procedure to obtain the answer. Similarly, in the written response, Subject 9 (RA) did not provide a conclusion to the mathematical problem. Based on the solution steps and the interview results, Subject 9 (RA) was also unable to draw a conclusion from the mathematical problem.

Subject 10 (DB) — Construction and Housing Engineering Department



Subject 10 (DB) was able to draw conclusions from a mathematical problem using the language of mathematical models.

In the written response, Subject 10 (DB) did not explicitly state the given information and the question being asked. However, based on the solution steps and the results of the interview, Subject 10 (DB) was able to identify the known information and determine what was being asked, but was unable to explain the procedure to obtain the answer. Similarly, in the written response, Subject 10 (DB) did not provide a conclusion to the mathematical problem. Based on the solution steps and the interview results, Subject 10 (DB) was also unable to draw a conclusion from the mathematical problem. In this study, the summary results of the interviews are presented in the following table.

Table 2. Summary of Interview Findings by Participant

No	Participant	Indicator 1	Indicator 2	Indicator 3	Remarks
1	ADH	Unable to state the mathematical model verbally, but demonstrated an accurate understanding of the problem context.	Correctly identified the given and required information; applied elimination and substitution appropriately.	Provided a clear oral conclusion, including the computed prices and confirmation that the income target was achieved.	Achieved (complete; oral conclusion).
2	BA	Did not explicitly articulate the model.	Appropriately defined variables and solved the SPLTV using elimination–substitution.	Was able to state the conclusion orally but did not write an explicit concluding statement.	Achieved (oral conclusion only).
3	FE	Did not explicitly articulate the model.	Appropriately defined variables and followed a correct solution procedure.	Reached a conclusion, but the phrasing regarding	Achieved.

No	Participant	Indicator 1	Indicator 2	Indicator 3	Remarks
				"profit" was not fully precise.	
4	MOS	Did not directly articulate the model.	Clearly identified what was known and asked and explained a systematic procedure.	Drew a correct conclusion and stated that the target was achieved.	Achieved.
5	SH	Did not explicitly articulate the model.	Correctly identified the given and required information; used a correct elimination procedure.	Drew a correct conclusion.	Achieved.
6	VLCS	Did not explicitly articulate the model.	Correctly identified the given and required information; used an appropriate procedure.	Drew a conclusion and compared the result with the target.	Achieved.
7	RC	Did not explicitly articulate the model.	Correctly identified the given and required information; used an appropriate procedure.	Drew a conclusion and stated that the target was achieved.	Achieved.
8	GP	Did not explicitly articulate the model.	Correctly identified the given and required information; used a correct elimination procedure.	Drew a conclusion very clearly.	Achieved.
9	RA	Unable to articulate the model.	Unable to solve the problem; did not yet understand elimination and substitution.	Unable to draw a conclusion.	Not achieved.
10	DB	Unable to articulate the model.	Unable to solve the problem; did not yet understand elimination and substitution.	Unable to draw a conclusion.	Not achieved.

Table 3. Cross-Case Matrix of Mathematical Communication Indicators by Evidence Source

Participant	Indicator 1	Indicator 2a	Indicator 2b	Indicator 3
ADH	W+I	I (not explicit in W)	W+I	W+I
BA	W+I	I (incomplete in W)	W+I	I only
FE	W+I	W+I	W+I	W+I
MOS	W+I	W+I	W+I	W+I
SH	W+I	I (not explicit in W)	W+I	I only
VLCS	W+I	I (not explicit in W)	W+I	I only
RC	W+I	W+I	W+I	W+I
GP	W+I	W+I	W+I	W+I
RA	I (variable meaning)	I	Not achieved	Not achieved
DB	I (variable meaning)	I	Not achieved	Not achieved

W = written evidence; I = interview evidence; W+I = both sources. Not achieved indicates insufficient evidence to meet the indicator. Indicator 2 is divided into 2a (identification of given/asked information) and 2b (explanation of procedures) to increase analytic transparency.

Indicator 1: Mathematical Expression/Modeling (SPLTV Variable Context)

Overall, students were able to translate Papuan ethnomathematical contexts (e.g., noken, ikan asar, and buah merah) into mathematical representations by assigning meaning to variables and establishing relations in a system of three-variable linear equations (SPLTV). During the interviews, several participants articulated their variable mappings explicitly, for example: "noken corresponds to x, buah merah corresponds to y, and ikan asar corresponds to z." This articulation indicates that students understood what each symbol represented within the model, suggesting that the cultural context functioned as a meaningful anchor at the initial stage of mathematical communication.

Interview evidence further indicated that the problem context was relatively familiar to most students. Participants reported recognizing and having encountered or purchased the objects featured in the tasks (e.g., "I know it," "I have seen it," "I have bought it"), implying that comprehending the narrative of the problem was generally not a primary barrier for the majority of participants. In this sense, contextual familiarity supported students' entry into modeling by reducing the cognitive load associated with interpreting the situation and enabling them to focus on representing it mathematically.

Indicator 2: Identifying Given–Asked Information and Explaining Solution Procedures

Limited explicitness in written work: knowing but not writing the "given/asked" components

Several students did not explicitly write the "given" and "asked" information in their solution sheets, yet they were able to state these components clearly during interviews. Three recurring reasons were identified. First, some students perceived the information as already transparent in the problem statement; for instance, ADH explained that the information was "clearly written in the question," and therefore did not need to be rewritten. Second, some students reported that they simply "already knew" the relevant information (e.g., VLCS). Third, omission also occurred due to forgetfulness or carelessness; SH explicitly stated that they "forgot." These patterns suggest that the absence of "given/asked" statements in written work does not necessarily indicate a lack of understanding. Rather, it may reflect students' written communication habits that prioritize computation over structured documentation of information and goals.

Procedural explanation: most students could articulate elimination–substitution coherently

Among the eight participants who were ultimately successful, most were able to explain the elimination and substitution steps in a coherent sequence, including the rationale for selecting operations to eliminate specific variables. For example, ADH stated an intention to "eliminate z," and then proceeded to explain how the process continued until values for x, y, and z were obtained, followed by substitution into the final part of the problem. Similar patterns were evident in other participants (e.g., FE, MOS, RC, and GP), who could describe the order of elimination, derive the required values, and then interpret the results in relation to the income target. Collectively, these explanations indicate that procedural communication when elicited orally was generally strong among most participants who reached a complete solution.

Points of breakdown in procedural communication: RA and DB

In contrast, RA reported difficulty specifically at the elimination stage, stating, "I am confused about how to eliminate," and further emphasized, "I do not yet understand elimination and substitution." DB similarly indicated an inability to continue the solution process ("I cannot do it"). These two cases suggest that the primary barrier was not the cultural context of the tasks but rather limited procedural mastery of SPLTV methods and the resulting inability to communicate a coherent solution pathway.

Indicator 3: Drawing Conclusions (Written vs. Interview-Confirmed)

Students' ability to draw conclusions was evaluated not only through the presence of an explicit concluding statement in their written solutions but also through interview confirmation conducted after the test. This distinction is critical because discrepancies were observed between what students documented in writing and what they could articulate verbally. Accordingly, the analysis did not rely solely on written artifacts; instead, it incorporated students' verbal clarifications as evidence of conceptual understanding and as a means of validating whether an appropriate contextual conclusion had been formed. Table 4 therefore reports each participant's conclusion status based on two evidence sources—written conclusions and interview-confirmed conclusions so that conclusions are represented consistently and transparently across cases.

Table 4. Conclusion Status by Evidence Source

Participant	Written conclusion (W)	Oral conclusion (I)	Brief note
ADH	Yes	Yes	The income target is more than 500,000.
BA	No	Yes	Did not write a conclusion: "It didn't occur to me, Ma'am."
FE	Yes	Yes	Interpreted the result relative to the target (student's wording).
MOS	Yes	Yes	Stated that the target was exceeded.
SH	No	Yes	Did not write a complete conclusion because they "forgot," but could conclude orally.
VLCS	No	Yes	Did not write the given information because they "already knew," but concluded orally.
RC	Yes	Yes	Stated that the income exceeded the target.
GP	Yes	Yes	Stated that it was "more than sufficient/exceeded the target."
RA	No	No	Did not reach a solution; unable to draw a conclusion.
DB	No	No	Did not complete the solution; unable to draw a conclusion.

By distinguishing evidence sources in Table 4, the findings are reported consistently: 8 of the 10 participants were able to draw an appropriate conclusion, whereas 2 participants (RA and DB) were unable to do so because they did not successfully complete the required procedures.

Discussion

Based on the research findings, this section emphasizes the theoretical significance of the results, the mechanisms that explain observed communication patterns, and the implications for instruction and assessment. Detailed achievements for each participant and the corresponding evidence sources are presented in Tables 2 and 4, as well as in the written-solution artifacts (photographs/scans of students' work) in the Findings section. Accordingly, the discussion does not reiterate participant-by-participant descriptions; instead, it interprets what these patterns imply for mathematical communication in the vocational high school (SMK) context and within Papuan ethnomathematics-based tasks.

Conceptually, the findings reinforce the NCTM (2000) framework that mathematical communication is not limited to "getting the correct answer," but entails the ability to externalize thinking through representations, mathematical language, and justification. In this study, mathematical communication emerged as a multi-modal practice, combining symbolic representations in written solutions and verbal articulation in interviews. Therefore, distinguishing evidence sources written responses (W) versus interview evidence (I) as summarized in Tables 3 and 4 constitutes an important methodological contribution, as it prevents interpretations that equate "not written" with "not capable." This reporting strategy aligns with the literature on assessing mathematical communication, which highlights the value of rubric-guided evaluation and triangulation to improve fairness and reliability in judgments

(Zakiah & Fajriadi, 2020; Pantaleon et al., 2023; Yunita & Siswanto, 2023; Novitasari et al., 2024; Anggraini et al., 2022).

The Role of Papuan Ethnomathematics: Context as a Catalyst for Meaning-Making and Representation

In this study, Papuan ethnomathematics functions as a pedagogical mechanism that strengthens students' contextual meaning-making and promotes more meaningful mathematical representations. When SPLTV tasks are constructed from culturally familiar objects—such as *noken*, *ikan asar*, and *buah merah*—students are provided with a "real-world referent" to interpret the problem situation before translating it into symbols and equations. This referent is crucial because mathematical communication does not begin with formulas; rather, it begins with articulating what is being represented through symbols, variables, or models (NCTM, 2000). In practice, the cultural context serves as a "meaning anchor" that reduces ambiguity when students assign variables (e.g., x, y, z) to real objects and then construct relationships expressed as a system of linear equations. Accordingly, cultural context is not merely a narrative ornament, but part of the representational structure that helps students connect mathematical language to everyday experience.

The ethnomathematics and culturally responsive pedagogy literature consistently indicates that tasks grounded in learners' lived experiences increase relevance and engagement, thereby encouraging students to express their mathematical ideas more confidently. In the Papuan context, the use of local artifacts such as *noken* can open space for students to interpret quantities, relationships, and magnitudes through familiar experiences, which in turn supports their willingness to justify choices and explain solution steps (Heriyanto & Astutik, 2021). Related evidence from the Indonesian context suggests that embedding local cultural elements in instruction or word problems enables students to build stronger connections between school mathematics and daily practices, making mathematical communication more "alive" and socially situated (Lidinillah et al., 2022). Similar strengthening is reported in studies that employ cultural contexts for modeling and word-problem design: authentic contexts help students communicate why they select particular representations (e.g., moving directly to equations versus organizing information in a table) and sustain the meaning of the symbols they use (Dominikus et al., 2024). Even in the development of culturally grounded mathematical literacy tasks, context has been shown to foster engagement and elicit richer explanations because students feel a sense of ownership over the narrative presented (Maulina, 2025).

Therefore, the "Papua" component in this study can be positioned as a representational context that facilitates the full communication trajectory: from cultural narrative to mathematical model and back to an interpretation of results that is meaningful within an economically plausible situation for vocational students. This function is particularly salient in vocational education, where students are expected not only to compute correctly but also to relate results to practical decisions (e.g., whether an income target has been met), making cultural context a bridge to contextualized applied mathematics (NCTM, 2000).

At the same time, the study highlights the limits of contextual strength: while meaningful contexts can ease situation comprehension and initial modeling, they do not automatically guarantee complete communication at the procedural stage or in the final closure of a solution. This aligns with mathematical modeling cycles emphasizing that successful modeling requires interpretation and validation after mathematical manipulation; without these stages, solutions risk becoming purely symbolic operations detached from contextual meaning (Blum & Leiss, 2007). Thus, Papuan ethnomathematics is effective as an entry point and a meaning enhancer, but high-quality mathematical communication still depends on procedural fluency in algebra (e.g., elimination/substitution) and the habit of presenting complete solutions—from modeling, to coherent procedural exposition, to an explicit interpretive conclusion that returns results to the original context (NCTM, 2000; Blum & Leiss, 2007).

Conclusion as a Critical Point of Communication: Interpretation–Validation and "Written Product" vs. "Oral Understanding"

One central finding (summarized in Table 4) is that students' ability to draw conclusions does not always appear in their written solutions, even when it can be confirmed through interviews. From a modeling perspective, a conclusion is not merely a closing sentence; it is a communicative act that returns mathematical results to the original context and validates their meaning (Blum & Leiss, 2007). For this reason, the contrast between "written conclusions" and "oral conclusions" mapped in Table 4 should be interpreted as an academic communication issue: some students demonstrate interpretive understanding, yet have not institutionalized it as a writing norm. Explanations such as "it did not occur to me" to write the conclusion indicate that interpretation–validation has not become an explicit expectation in students' solution practices, even though NCTM (2000) positions communication as a means to clarify, test, and refine ideas not merely to report final answers.

The pedagogical implication is therefore direct and actionable: instruction should treat contextual conclusion-making as a mandatory indicator of mathematical communication and evaluate it consistently through a rubric. A rubric that explicitly requires an "interpretive statement linking the obtained result to the problem context" can prompt students to formalize the closure of their solutions, thereby reducing the gap between oral understanding and written products. Such rubric-guided assessment is also supported by prior work emphasizing structured criteria to strengthen the reliability and fairness of evaluating students' mathematical communication (Zakiah & Fajriadi, 2020; Pantaleon et al., 2023; Yunita & Siswanto, 2023; Chung, 2025).

Gap in Written Explicitness: Communication Norms and the Need for Rubrics

Interview data revealed recurring reasons why students did not write "given/asked" statements or omitted specific components of their solutions (e.g., "it was already clear in the problem," "I already knew," or "I forgot"). This pattern is more appropriately interpreted as an issue of mathematical communication norms rather than a purely cognitive deficit. Research on assessment and classroom discourse suggests that students tend to align the form of their responses with prevailing classroom norms and evaluation expectations; when assessment primarily rewards final answers, written explanations are often compressed or treated as optional (Mokwana et al., 2024; Ningsih et al., 2025; Öksüz, 2023). From this perspective, the evidence-source distinctions in Table 3 (W, I, and W+I) provide empirical support for the claim that mathematical communication must be cultivated as a normalized practice, rather than assumed to develop spontaneously from problem-solving activity alone.

Practically, instruction should target three stable communication routines: (1) explicitly recording key information and the problem goal (given/asked), (2) narrating procedures coherently with attention to justification (why a step is taken, not merely what is done), and (3) closing the solution with an interpretive conclusion that links results back to the context. These routines can be guided through a concise rubric grounded in NCTM (2000) communication principles and applied consistently for formative feedback, so that students recognize communication as an essential dimension of solution quality rather than a cosmetic add-on (Zakiah & Fajriadi, 2020; Charizah & Kamiliyah, 2023; Bosch & Rice, 2024).

Vocational Lens: Why Mathematical Communication Matters in Indonesian Vocational High Schools

In vocational education, mathematics is not learned merely to satisfy curriculum requirements, but as a cognitive tool for interpreting workplace situations, managing quantitative information, and making rational, evidence-based decisions. Consequently, mathematical communication has strong functional value for SMK students: workplace settings demand the ability to explain procedures, interpret computational results, and justify data-driven decisions to supervisors, colleagues, and clients (Sucipto et al., 2020; Iskandar, 2024). In this sense, mathematical communication extends beyond "writing an answer." It includes explicitly stating what is known and what is being asked, articulating the rationale for selecting particular procedures, and closing solutions with conclusions that directly address practical goals. This orientation is consistent with the NCTM (2000) framework, which positions communication as a means of organizing thinking and constructing mathematical arguments that are intelligible to others competencies closely aligned with reporting and coordination demands in vocational environments.

This relevance becomes even more pronounced when mathematical tasks are grounded in contexts that students recognize as part of their lived world. In the present study, Papuan ethnomathematics contexts such as local economic scenarios involving culturally familiar objects and income targets can be understood as a distinctive form of applied mathematics: mathematics is used to model a realistic situation, and the resulting outputs are then interpreted to determine whether targets are met or whether specific actions should be taken. Research on contextual learning and mathematical modeling indicates that authentic contexts strengthen the connection between concepts and use, making it easier for students to recognize the "reasons" behind representations and computations (Kohen & Orenstein, 2021; Aprilia et al., 2023). In vocational education, such contexts do more than increase motivation; they cultivate an applied habit of mind—linking numerical results to consequential decisions (Tjahyadi & Hamidi, 2022; Sucipto et al., 2020). At the same time, ethnomathematics scholarship emphasizes that culturally grounded contexts can enhance perceived relevance and increase students' engagement in explaining their reasoning because they feel familiar with the situation being modeled (Heriyanto & Astutik, 2021; Lidinillah et al., 2022). Thus, integrating Papuan ethnomathematics into SMK tasks does not simply "localize" word problems; it strengthens the vocational function of mathematics as a tool for analyzing community-based economic situations.

Nevertheless, from a vocational perspective, mathematical communication must be understood as a competency that requires traceability. In workplace practice, solutions that cannot be followed step-by-step are difficult to verify and therefore difficult to trust, even when the final answer is correct. For this reason, the findings of this study—summarized in Tables 2–4 and supported by students' written-work artifacts in the Findings section—underscore the need for communication standards resembling a "work report": a clear information structure, procedures that can be audited, and explicit conclusions. This emphasis aligns with research showing that assessment rubrics for mathematical communication help students internalize expectations for explanation quality rather than focusing only on answer accuracy (Zakiah & Fajriadi, 2020; Pantaleon et al., 2023; Yunita & Siswanto, 2023). Moreover, prior literature suggests that strong mathematical communication is closely associated with reasoning and problem-solving capacity; therefore, strengthening communication is likely to improve students' conceptual understanding and the quality of their decision-making (Masfingatin et al., 2020; Rahmawati et al., 2023).

Direct Implications and the Study's Contribution

The contribution of this study becomes clearer when it is read as an attempt to improve how mathematical communication is assessed in Indonesian vocational high schools (SMK). First, the study demonstrates that local cultural contexts can strengthen meaning-making and support the construction of representations; however, complete mathematical communication still depends on procedural mastery and systematic writing practices (Heriyanto & Astutik, 2021; Blum & Leiss, 2007). In other words, culturally grounded tasks may facilitate students' entry into modeling, yet they do not automatically ensure that students will communicate procedures and conclusions in a fully accountable manner.

Second, the remaining challenges identified in this study are not primarily attributable to the cultural context itself, but to the completeness of written communication and the robustness of algebraic procedures (e.g., elimination and substitution), which are prerequisites for producing verifiable solutions. This interpretation aligns with research on error patterns and misconceptions in linear equation systems, which emphasizes the importance of diagnosing procedural difficulties and providing targeted scaffolding (Kasali et al., 2023; Buhaerah et al., 2022). Third, by separating written evidence (W) and interview evidence (I) across the findings tables, the study offers a more credible reporting model: "not written" does not necessarily mean "not capable," because interviews can reveal understanding that has not yet been articulated in written form (Novitasari et al., 2024; Anggraini et al., 2022). Such triangulated reporting is also consistent with methodological recommendations in education research that advocate using multiple data sources to strengthen interpretive validity (Ismail et al., 2023; Lestari et al., 2025).

From a practical standpoint, the study yields testable instructional recommendations. Papuan ethnomathematics should be retained as a modeling trigger, but "communication discipline" must be strengthened through explicit rubrics, formative feedback, and activities that bridge oral and written expression. Strategies such as Think–Talk–Write and structured discussions culminating in written summaries can normalize the routines of stating given/asked information, explaining procedures with justification, and closing solutions with interpretive conclusions (Hakim et al., 2021; Azizah et al., 2020; Retnowati & Ekayanti, 2020).

Evidence from related studies indicates that dialogic instruction combined with guided writing can strengthen both oral and written mathematical communication, making it particularly suitable for SMK settings where students are expected to explain and defend their procedures and decisions (Widodo et al., 2021; Rahmawati et al., 2023). Overall, the contribution of this study is not only to show that local cultural contexts increase meaningfulness, but also to provide a clear development pathway: positioning mathematical communication as a vocationally relevant competence that is measurable, teachable, and consistently assessable through transparent, evidence-based tools (NCTM, 2000; Sucipto et al., 2020; Iskandar, 2024).

CONCLUSION

Based on an analysis of vocational high school (SMK) students' mathematical communication when solving Papuan ethnomathematics-based SPLTV tasks, this study indicates that culturally grounded contexts (e.g., *noken*, *ikan asar*, and *buah merah*) support meaning-making by helping students connect real-world information to symbols, variables, and quantitative relationships within a mathematical model. With this "meaning anchor," most students were able to enter the early phases of problem solving in a more directed manner—interpreting the situation, assigning variables, and constructing an appropriate SPLTV model. However, success in initial modeling did not automatically translate into complete mathematical communication at the procedural stage or in the closure of solutions. In practice, full mathematical communication requires students to present coherent solution steps and to conclude with an explicit statement that interprets computed results in relation to the problem context.

The findings further show that some students could carry out calculations and justify their procedures during interviews, yet did not consistently document key communication components in writing (e.g., stating what is given/asked or providing an explicit concluding statement). This pattern suggests a gap between conceptual understanding and established habits of expressing that understanding in written form; therefore, the absence of certain written components should not be interpreted straightforwardly as lack of understanding, but may reflect response norms oriented toward final answers rather than complete explanations. Overall, eight of the ten students were able to draw an appropriate conclusion when performance was evaluated comprehensively using written evidence and/or oral explanations, whereas two students were unable to reach a meaningful conclusion due to difficulties with core SPLTV procedures, particularly elimination and substitution. Accordingly, the critical point of mathematical communication in this context lies not only in constructing a model, but also in procedural robustness and the ability to articulate step-by-step reasoning and contextual interpretation in a complete and accountable manner.

These conclusions affirm that integrating Papuan ethnomathematics is effective for enhancing meaningful engagement and supporting initial access to the problem, while improving the quality of students' mathematical communication still requires strengthening algebraic procedural skills and institutionalizing written communication standards—from structured presentation of information and coherent procedural reasoning to explicit, contextualized concluding statements.

RECOMMENDATION

Mathematics instruction in vocational high schools, particularly for SPLTV topics, should continue to employ Papuan ethnomathematics contexts to trigger modeling and strengthen relevance; however, it must simultaneously institutionalize written communication norms so that student solutions resemble a "work report"—clearly stating what is given and what is required, presenting a traceable procedural sequence, and ending with an explicit contextual conclusion. Operationally, teachers are encouraged to implement a concise mathematical communication rubric aligned with three indicators (modeling–procedure–conclusion) and to provide targeted formative feedback on components that students frequently omit, especially the written concluding statement. Instruction should also incorporate routines that bridge oral reasoning and written documentation, such as Think–Talk–Write or structured discussion followed by a short written summary, to normalize the habit of documenting reasoning rather than only producing final answers. To address failure cases such as RA and DB, procedural scaffolding for elimination–substitution should be prioritized—through graduated practice, step-by-step checks, and reinforcement of prerequisite concepts—before students are required to write interpretive conclusions. For future research, subsequent studies should include greater variation in student ability levels (high, medium, and low) and increase instrument transparency (e.g., providing full task texts and an indicator blueprint) to strengthen the credibility of peer evaluation and support cautious, bounded generalization.

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AUTHOR CONTRIBUTIONS STATEMENT
This study applies the Contributor Roles Taxonomy (CRediT) to describe the contributions of each author as follows:

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Dewi Kristika Findia Ning Tyas	✓	✓	✓	✓	✓	✓		✓	✓	✓			✓	
Marthinus Y. Ruamba	✓	✓		✓		✓		✓	✓	✓		✓		
Ririn Dwi Agustin			✓	✓		✓	✓	✓	✓		✓		✓	
Pujilestari							✓		✓			✓	✓	

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT
Authors state no conflict of interest.

INFORMED CONSENT
We have obtained informed consent from all individuals included in this study.

REFERENCES

Abd-El-Khalick, F., Summers, R., Brunner, J., Belarmino, J., & Myers, J. (2023). Development of VAScoR: A rubric to qualify and score responses to the views of nature of science (VNOS) questionnaire. Journal of Research in Science Teaching, 61(7), 1641-1688. https://doi.org/10.1002/tea.21916

Anggraini, A., Baharuddin, B., Pathuddin, P., Haerani, N., Sugita, G., & Murdiana, I. (2022). Analysis of Mathematic Communication Skill on Set Operations Reviewed from Mathematics Skill.. https://doi.org/10.2991/assehr.k.220707.015

Anggraini, W. and Pratiwi, W. (2024). Students' Algebraic Thinking Skills Through Creative Problem Solving Learning Models. Sjme (Supremum Journal of Mathematics Education), 8(1), 143-152. https://doi.org/10.35706/sjme.v8i1.10796

Aprilia, A., Asih, E., & Usdiyana, D. (2023). The Effect of Mathematical Habits of Mind and Early Mathematical Ability on Modeling Ability of High School Students. Jtam (Jurnal Teori Dan Aplikasi Matematika), 7(4), 914. https://doi.org/10.31764/jtam.v7i4.11924

A'yuni, Q., Faridah, S., Irawan, W., & Mukti, T. (2024). Influence Self-Efficacy on The Mathematical Communication Ability of Students in Material Linear Equation Systems. Mathline Jurnal Matematika Dan Pendidikan Matematika, 9(2), 305-318. https://doi.org/10.31943/mathline.v9i2.512

Azizah, N., Usodo, B., & Saputro, D. (2020). Teaching Materials based on Reciprocal Teaching to Improve Mathematical Communication Skills. International Journal of Multicultural and Multireligious Understanding, 7(8), 44. https://doi.org/10.18415/ijmmu.v7i8.1797

Baran, A. A., & Kabael, T. 2021. An investigation of eighth grade students' mathematical communication competency and affective characteristics. The Journal of Educational Research, 114(4), 367–380. https://doi.org/10.1080/00220671.2021.1948382

Bela, M. and Wewe, M. (2024). Integrating ethnomathematics into a transformation geometry module to enhance self-efficacy. Al-Jabar Jurnal Pendidikan Matematika, 15(2), 547-557. https://doi.org/10.24042/ajpm.v15i2.24564

Blum, W., & Leiss, D. (2007). How do students and teachers deal with modeling problems? In C. Haines, P. Galbraith, W. Blum, & S. Khan (Eds.), Mathematical modelling: Education, engineering and economics (pp. 222–231). Horwood Publishing.

Bosch, S. and Rice, D. (2024). An Evaluation of the Nunez Community College Quality Enhancement Program: Assessing the Impact of Embedded Conover Workplace Readiness® Modules on Students' Work Readiness. Sage Open, 14(2). https://doi.org/10.1177/21582440241251767

Buhaerah, M., Nasir, M., & JUSOFF, K. (2022). Scaffolding through cognitive mapping based on diagnosing students difficulties in solving problem. Journal for the Education of Gifted Young Scientists, 10(2), 207-220. https://doi.org/10.17478/jegys.1099807

Chang, C., Tsai, L., & Meliana, D. (2023). The Concept of Ocean Sustainability in High School: Measuring the Ocean Literacy of Vocational High School Students in Indonesia. Sustainability, 15(2), 1043. https://doi.org/10.3390/su15021043

Charamba, E. and Dlamini-Nxumalo, N. (2022). Same yardstick, different results: efficacy of rubrics in science education assessment. Eureka Social and Humanities, (4), 82-90. https://doi.org/10.21303/2504-5571.2022.002455

Charizah, M. and Kamiliyah, Z. (2023). Student Communication in Solving Tug of Taw Questions. JTME, 1(1), 48-55. https://doi.org/10.33367/jtme.v1i1.3507

Chung, N. (2025). Building a Rubric for Assessing Mathematical Communication Competence in Grade 5 Students. Journal of Science Educational Science, 155-164. https://doi.org/10.18173/2354-1075.2025-0079

Clements, D., Lizcano, R., & Sarama, J. (2023). Research and Pedagogies for Early Math. Education Sciences, 13(8), 839. https://doi.org/10.3390/educsci13080839

Cole, R. (2023). Inter-Rater Reliability Methods in Qualitative Case Study Research. Sociological Methods & Research, 53(4), 1944-1975. https://doi.org/10.1177/00491241231156971

Conrick, K., Moore, M., Abbotts, L., Widdice, L., Hoag, S., Kroshus, E., … & Vavilala, M. (2020). Community-Engaged Approach to the Development and Implementation of a Student-Centered Return to Learn Care Plan After Concussion. Journal of School Health, 90(11), 842-848. https://doi.org/10.1111/josh.12948

Davey, M. and Morell, J. (2020). Method for Using Rubric Ratings on Fishbone Diagrams to Compare Case Studies. Journal of Multidisciplinary Evaluation, 16(34), 56-64. https://doi.org/10.56645/jmde.v16i34.581

Dehaibi, N. and MacDonald, E. (2020). Investigating Inter-Rater Reliability of Qualitative Text Annotations in Machine Learning Datasets. Proceedings of the Design Society Design Conference, 1, 21-30. https://doi.org/10.1017/dsd.2020.153

Desy, A., Nursalam, N., Suharti, S., Mattoliang, L., & Baharuddin, B. (2024). Development of Mathematics Teaching Material based on Experiential Learning Model to Improve Students' Mathematical Literacy Skills. Itm Web of Conferences, 58, 03003. https://doi.org/10.1051/itmconf/20245803003

Dominikus, W., Madu, A., Blegur, I., & Jemamun, M. (2024). Ethnomathematics in Caci Dance of Manggarai Community and its Integration in Mathematics Learning. Journal of Law and Sustainable Development, 12(2), e3035. https://doi.org/10.55908/sdgs.v12i2.3035

Downing, G. and McCoy, W. (2021). Exploring Mathematics of the Sociopolitical Through Culturally Relevant Pedagogy in a College Algebra Course at a Historically Black College/University., Vol. 14 No. 1, Am America! Teaching Mathematic. https://doi.org/10.21423/jume-v14i1a413

Fitri, M. (2025). Development of an Ethnomathematics-Based Test Instrument to Measure and Foster Students' Critical Thinking Skills. Alphamath Journal of Mathematics Education. https://doi.org/10.30595/alphamath.v11i2.28771

Gani, A., Ruminda, R., & Bachtiar, B. (2025). From Projects to Practice: Integrating PjBL and CTL to Elevate Vocational EFL Students' Engagement. Jiip - Jurnal Ilmiah Ilmu Pendidikan, 8(10), 11369-11377. https://doi.org/10.54371/jiip.v8i10.9457

Gradini, E. (2022). Development of Rubric of Higher Order Thinking Skills Assessment on Mathematics Learning. Jtam (Jurnal Teori Dan Aplikasi Matematika), 6(1), 61. https://doi.org/10.31764/jtam.v6i1.5342

Gusfitri, W., Abdurrahman, A., Andrian, D., Nofriyandi, N., & Rezeki, S. (2022). Development of Mathematics Learning Tools Based on Ethnomathematics on Rectangular and Triangles in Junior High School. Prisma Sains Jurnal Pengkajian Ilmu Dan Pembelajaran Matematika Dan Ipa Ikip Mataram, 10(3), 609. https://doi.org/10.33394/j-ps.v10i3.5310

Habig, B. (2020). Practical Rubrics for Informal Science Education Studies: (1) a STEM Research Design Rubric for Assessing Study Design and a (2) STEM Impact Rubric for Measuring Evidence of Impact. Frontiers in Education, 5. https://doi.org/10.3389/feduc.2020.554806

Hakim, H., Daulay, L., & Listari, M. (2021). Kemampuan Komunikasi Matematis Ditinjau dari Gender Siswa. Farabi Jurnal Matematika Dan Pendidikan Matematika, 4(1), 18-23. https://doi.org/10.47662/farabi.v4i1.79

Heriyanto, B. and Astutik, H. (2021). Persepsi guru tentang etnomatematika di Kabupaten Sorong Papua Barat. Ethnomathematics Journal, 2(2). https://doi.org/10.21831/ej.v2i2.41134

Iskandar, A. (2024). Assessors in The South Sulawesi Provincial Level Vocational School Student Competency Competition (LKS). j. abdimas cendekiawan Indones., 1(2), 14-20. https://doi.org/10.56134/jaci.v1i2.89

Ismail, R., Yerizon, Y., & Fauzan, A. (2023). Exploring Self-Regulated Learning and Their Impact on Students' Mathematical Communication Skills on the Topic of Number Patterns With the Blended Learning System. Journal of Higher Education Theory and Practice, 23(16). https://doi.org/10.33423/jhetp.v23i16.6477

Jiménez-Silva, M., Martin, R., Restani, R., Abdelrahim, S., & Albano, T. (2025). Supporting Multilingual Students' Mathematical Discourse Through Teacher Professional Development Grounded in Design-Based Research: A Conceptual Framework. Education Sciences, 15(6), 778. https://doi.org/10.3390/educsci15060778

Jotangiya, P. (2021). Writing in Mathematics: A Synthesis of Evaluations, Interventions, and Surveys. EDU, 3(1), 52-110. https://doi.org/10.58213/education.v3i1.21

Jupri, A., Usdiyana, D., & Gozali, S. (2024). Teaching and learning processes for pre-service mathematics teachers: The case of systems of equations. Eurasia Journal of Mathematics Science and Technology Education, 20(8), em2482. https://doi.org/10.29333/ejmste/14858

Kasali, B., Yuliani, A., & Nurfauziah, P. (2023). Error Analysis of Senior High School Student's Problem Solving Ability on Three Variables Linear Equation System. (Jiml) Journal of Innovative Mathematics Learning, 6(4), 231-239. https://doi.org/10.22460/jiml.v6i4.18404

Kohen, Z. and Nitzan-Tamar, O. (2022). Contextual Mathematical Modelling: Problem-Solving Characterization and Feasibility. Education Sciences, 12(7), 454. https://doi.org/10.3390/educsci12070454

Kulsum, U. and Taufik, T. (2022). Community Satisfaction Index (SMI) Report At SMKN 1 Cibinong. Jurnal Pensil, 11(1), 10-19. https://doi.org/10.21009/jpensil.v11i1.18425

Kumala, F. (2025). Development of Educational Game Media With an Ethnomathematics Approach Based on Banyumas Culture and Science. Inspiramatika, 11(1), 152-176. https://doi.org/10.52166/inspiramatika.v11i1.9517

Kurnaedi, D., Widyarto, S., & Kahar, S. (2022). Collaborative E-Learning for Tangerang Vocational High School. Tech-E, 6(1), 50-55. https://doi.org/10.31253/te.v6i1.1770

Kurniawan, R., Suherman, S., Komarudin, K., Zarpellon, M., & Khalil, I. (2023). Designing Ethnomathematics-Enriched Teaching Materials for Fostering Mathematical Creative Thinking for Applications in Online Learning Environments. Online Learning in Educational Research (Oler), 3(2), 71-83. https://doi.org/10.58524/oler.v3i2.281

Lai, P. (2020). Expressivity in children with autism and Williams syndrome. Advances in Autism, 6(4), 277-288. https://doi.org/10.1108/aia-11-2019-0044

Lestari, N., Najih, M., Putri, I., Murtafiah, W., Yahya, F., & Suwarno, S. (2025). PISA Content Quantity-Standardized Test: Exploring Vocational Student's Mathematical Communication Skills. Tem Journal, 848-860. https://doi.org/10.18421/tem141-75

Leyva, L., Mitchell, N., Posada-Castañeda, R., Byrne, M., Luna-Bazán, R., Ashkenazy, Y., … & Abreu-Ramos, E. (2025). Racially-Affirming Community in Instructional Servingness for Latin* Students' Gateway Mathematics Classroom Participation. Aera Open, 11. https://doi.org/10.1177/23328584251367037

Lidinillah, D., Rahman, R., Wahyudin, W., & Aryanto, S. (2022). Integrating Sundanese Ethnomathematics into Mathematics Curriculum and Teaching: A Systematic Review from 2013 to 2020. Infinity Journal, 11(1), 33. https://doi.org/10.22460/infinity.v11i1.p33-54

Lotter, C., Crooks-Monastra, J., Irdam, G., & Yow, J. (2024). Challenges and supports for secondary science and mathematics teacher retention. School Science and Mathematics, 124(5), 307-322. https://doi.org/10.1111/ssm.12647

Lyon, J., Fennell, H., & Magana, A. (2020). Characterizing students' arguments and explanations of a discipline-based computational modeling activity. Computer Applications in Engineering Education, 28(4), 837-852. https://doi.org/10.1002/cae.22256

Mahfoodh, O. (2022). Factors Influencing Efl Students' Utilisation of Teacher Written Feedback. Teflin Journal - A Publication on the Teaching and Learning of English, 33(1), 98. https://doi.org/10.15639/teflinjournal.v33i1/98-122

Majid, Purwanto, As'ari, A. R., & Rahardjo, S. 2022. The Written Communication Ability of Table and Chair Setting Problem Solution for Mathematics Education Students. Journal of Positive School Psychology, 6(5), 2731–2748

Masfingatin, T., Maharani, S., Rufiana, I., & Sanwidi, A. (2020). Mathematics Communication of Middle School Students in Solving Geometry Problems Based on Spatial Intelligence.. https://doi.org/10.2991/assehr.k.200827.135

Maulina, S. (2025). Development of Mathematical Literacy Problems Based on the Ethnomathematics of Acehnese Culture. Jurnal Pendidikan Mipa, 26(4), 2077-2100. https://doi.org/10.23960/jpmipa.v26i4.pp2077-2100

Mokwana, L., Maoto, S., & Chuene, K. (2024). Transforming sociomathematical norms in a South African grade 11 classroom to enhance learners' mathematical proficiency. Eurasia Journal of Mathematics Science and Technology Education, 20(3), em2409. https://doi.org/10.29333/ejmste/14281

Muhammad, M., Purwanto, J., & Christiyansyah, O. (2021). Mathematical communication ability students based on learning motivation in the COVID-19 pandemic. Journal of Physics Conference Series, 1778(1), 012014. https://doi.org/10.1088/1742-6596/1778/1/012014

Muhtarom, M., Shodiqin, A., & Astriani, N. (2020). Exploring senior high school student's abilities in mathematical problem posing. Jramathedu (Journal of Research and Advances in Mathematics Education), 69-79. https://doi.org/10.23917/jramathedu.v5i1.9818

Mulia, T. and Aziz, T. (2023). Learning System of Linear Equations With Aptitude Treatment Interaction Model for Vocational High School. Kalamatika Jurnal Pendidikan Matematika, 8(2), 119-132. https://doi.org/10.22236/kalamatika.vol8no2.2023pp119-132

NCTM. 2000. Principles and standards for school mathematics. National Council of Teachers of Mathematics, Inc

Ningsih, E., Wawan, W., & Susandi, A. (2025). A Evaluating Teacher-Student Interaction and the Implementation of Sociomathematical Norms in Indonesian Mathematics Classrooms. J. Trans. Stud. Edu, 1(1), 1-16. https://doi.org/10.64268/jtse.v1i1.10

Nolan, K. and Xenofontos, C. (2023). The Role of Insights in Becoming a Culturally Responsive Mathematics Teacher. Education Sciences, 13(10), 1028. https://doi.org/10.3390/educsci13101028

Norberg, K. (2025). Using Generative AI to Foster Student Sense of Belonging in Mathematics. https://doi.org/10.31234/osf.io/yb93t_v1

Novitasari, M., Sumardjoko, B., Pramono, S., & Wasino, W. (2024). Child-Friendly Education: Fostering Mathematical Communication in Primary School Children. Journal of Ecohumanism, 3(7). https://doi.org/10.62754/joe.v3i7.4611

Nurdianah, E., Sudira, P., & Daryono, R. (2022). Mobile-Based Application to Integrate Vocational Learning and Career Learning in Mechatronics Engineering Vocational High School. Journal of Education Technology, 6(3), 431-441. https://doi.org/10.23887/jet.v6i3.43669

Öksüz, H. (2023). Ortaokul Matematik Öğretmenlerinin Sınıfta Kesirleri Öğretirken Oluşturmayı Hedefledikleri Sosyomatematik Normlarının Değerlendirilmesi. The

Journal of International Educational Sciences, 37(37), 1-23. https://doi.org/10.29228/inesjournal.73187

Oktiningrum, W. and Wardhani, D. (2023). Developing AKM Task with Ethnomathematics Based on Canva for Primary Students., 291-300. https://doi.org/10.2991/978-2-38476-072-5_29

Pantaleon, K., Juniati, D., & Lukito, A. (2023). Female Student Mathematical Communication Ability in the Proving Process: a Review Based on Math Anxiety. Bolema Boletim De Educação Matemática, 37(77), 1299-1316. https://doi.org/10.1590/1980-4415v37n77a18

Qirom, M., Dahlan, J., & Turmudi, T. (2023). Gender differences in written mathematical communication skills of junior high school students. Jurnal Elemen, 9(2), 509-525. https://doi.org/10.29408/jel.v9i2.14062

Rachmita, N., Wibowo, A., & Koestoer, R. (2021). Spatial Patterns of Expertise Suitability in the Ruminant SubSector of Subang Regency, West Java Province. Iop Conference Series Earth and Environmental Science, 940(1), 012011. https://doi.org/10.1088/1755-1315/940/1/012011

Rahmawati, A., Cholily, Y., & Zukhrufurrohmah, Z. (2023). Analyzing Students' Mathematical Communication Ability in Solving Numerical Literacy Problems. Mosharafa Jurnal Pendidikan Matematika, 12(1), 59-70. https://doi.org/10.31980/mosharafa.v12i1.752

Ramadhan, D. (2025). Exploring Students' Critical Thinking Skills Through an Analysis of Their Responses to Trigonometry Problems. Edukasiana Jurnal Inovasi Pendidikan, 4(3), 1337-1350. https://doi.org/10.56916/ejip.v4i3.2358

Retnowati, P. and Ekayanti, A. (2020). Think Talk Write Sebagai Upaya Meningkatkan Komunikasi Matematis Siswa. SIGMA, 6(1), 17. https://doi.org/10.36513/sigma.v6i2.863

Rivana, C., Agustina, D., & Widiastuti, S. (2023). Development of Blitar Tourism Place-Based Mathematics Story Problem Books. Josar (Journal of Students Academic Research), 8(1), 11-18. https://doi.org/10.35457/josar.v9i1.2625

Romadon, A. and Kartika, E. (2024). Development of Ethnomathematics Student Worksheets Based on Augmented Reality on Geometric Material. International Journal of Multidisciplinary Research and Analysis, 07(03). https://doi.org/10.47191/ijmra/v7-i03-23

Rumainur, S., & Kogoya, Y. (2022). Pengaruh pendekatan etnomatematika terhadap kemampuan komunikasi matematis siswa SMK di Papua. Jurnal Pendidikan dan Kebudayaan Papua, 5(1), 55–67.

Salsabila, S. (2025). Understanding Elementary Students' Difficulties in Mathematization of Pre-Algebra Problems. Mimbar Sekolah Dasar, 12(3), 559-576. https://doi.org/10.53400/mimbar-sd.v12i3.89167

Sánchez-Barbero, B., Cáceres, M., & Sánchez, J. (2022). Validation of a Scale to Assess the Reversibility of Thought in Verbal Arithmetic Problems. Acta Scientiae, 24(6), 370-401. https://doi.org/10.17648/acta.scientiae.7328

Sevimli, E. and Ünal, E. (2022). Is the STEM Approach Useful in Teaching Mathematics? Evaluating the Views of Mathematics Teachers. European Journal of Stem Education, 7(1), 01. https://doi.org/10.20897/ejsteme/11775

Sholikha, R. and Palupi, E. (2023). Komunikasi Matematika Siswa SMP Berkecerdasan Logis-Matematis, Linguistik, dan Spasial dalam Memecahkan Masalah Sistem Persamaan Linear Dua Variabel. Mathedunesa, 12(3), 1032-1060. https://doi.org/10.26740/mathedunesa.v12n3.p1032-1060

Silva, R., Gadanidis, G., Hughes, J., & Namukasa, I. (2020). Computational thinking as a heuristic endeavour: students' solutions of coding problems. Pro-Posições, 31. https://doi.org/10.1590/1980-6248-2018-0034

Steffensen, L. and Kasari, G. (2023). Integrating Societal Issues with Mathematical Modelling in Pre-Service Teacher Education. Education Sciences, 13(7), 721. https://doi.org/10.3390/educsci13070721

Sucipto, S., Dewi, E., Resti, N., & Santi, I. (2020). Improving The Performance of Alumni Achievement Assessment by Integrating Website-Based Tracer Study Information Systems and Telegram API. Teknik, 41(1), 72-77. https://doi.org/10.14710/teknik.v41i1.25307

Sudarsono, B., Tentama, F., Mulasari, S., Sukesi, T., Sulistyawati, S., Ghozali, F., … & Sofyan, H. (2022). Development of Integrated Project-based (PjBL-T) model to improve work readiness of vocational high school students. Jurnal Pendidikan Vokasi, 12(3), 222-235. https://doi.org/10.21831/jpv.v12i3.53158

Sukestiyarno, Y., Nugroho, K., Sugiman, S., & Waluya, B. (2023). Learning trajectory of non-Euclidean geometry through ethnomathematics learning approaches to improve spatial ability. Eurasia Journal of Mathematics Science and Technology Education, 19(6), em2285. https://doi.org/10.29333/ejmste/13269

Sun, Q., Chen, F., & Yin, S. (2023). The role and features of peer assessment feedback in college English writing. Frontiers in Psychology, 13. https://doi.org/10.3389/fpsyg.2022.1070618

Sunzuma, G. and Umbara, U. (2025). Ethnomathematics-based technology in Indonesia: A systematic review. Asian Journal for Mathematics Education, 4(1), 129-153. https://doi.org/10.1177/27527263241305812

Theelen, H., Vreuls, J., & Rutten, J. (2024). Doing Research with Help from ChatGPT: Promising Examples for Coding and Inter-Rater Reliability. International Journal of Technology in Education, 7(1), 1-18. https://doi.org/10.46328/ijte.537

Tjahyadi, S. and Hamidi, H. (2022). Media Pembelajaran: Produktif Boga. Comserva Jurnal Penelitian Dan Pengabdian Masyarakat, 2(5), 452-468. https://doi.org/10.59141/comserva.v2i5.343

Tran, L. and Schepers, O. (2023). Making mathematics meaningful for culturally and linguistically diverse students with a mathematics learning disability: a focus on culturally responsive practices. Frontiers in Education, 8. https://doi.org/10.3389/feduc.2023.1276423

Umam, K., Suryawati, S., Suhartati, S., & Hasbi, M. (2021). The Effects of Problem-Based Learning on Creative Thinking Skills and Mathematical Communication Abilities of Senior High School Students. Al Khawarizmi Jurnal Pendidikan Dan Pembelajaran Matematika, 5(1), 1. https://doi.org/10.22373/jppm.v5i1.9245

Vedianty, A., Nurhayati, D., Darmayanti, R., & Lestari, A. (2024). Application of the TPACK Framework in Digital Assessment of Elementary School Students' Mathematical Communication Skills Based on Level of Self-Confidence. DPJPM, 2(1), 34-42. https://doi.org/10.61650/dpjpm.v2i1.28

Vitoria, L., Monawati., M., Fauzi, F., & Mislinawati, M. (2021). Assessing the Effect of an Ethnomathematics Teaching Material on Students' Understanding of Mathematics. JPP (Jurnal Pendidikan Dan Pembelajaran), 28(1), 10-16. https://doi.org/10.17977/um047v27i12021p010

Vodičková, B., Mitašíková, P., & Slavíčková, M. (2023). Supportive Factors in Inclusive Mathematics Education: Mathematics Teachers' Perspective. Education Sciences, 13(5), 465. https://doi.org/10.3390/educsci13050465

Vogelsang, B., Röhrer, N., Fuchs, M., & Pilz, M. (2021). Cooperation Between Learning Venues and its Limits: The Hotel Industry in Cancún (Mexico). International Journal for Research in Vocational Education and Training, 8(4), 67-89. https://doi.org/10.13152/ijrvet.8.4.4

Wahyuni, Y. and Jamaris, J. (2021). Analysis of Students' Mathematical Reasoning Ability with the Constructivism Approach through Mobile Learning System. Asian Journal of Education and Social Studies, 55-60. https://doi.org/10.9734/ajess/2021/v24i130570

Wajdi, F., Huddin, M., & Maulana, D. (2022). Peningkatan Kompetensi SMK dengan Keterampilan Computer Aided Design. Jurnal Pemberdayaan Masyarakat Indonesia, 4(2), 231-243. https://doi.org/10.21632/jpmi.4.2.231-243

Widodo, H., Taufik, M., & Susanti, R. (2021). Application of Discovery Learning Model in Mathematics Learning to Determine Students' Mathematical Communication Ability. Mathematics Education Journal, 5(1). https://doi.org/10.22219/mej.v5i1.16008

Yang, X. (2023). Implementation of Informal Formative Assessment in An Elementary Math Classroom: A Case Study. Lnternational Electronic Journal of Elementary Education. https://doi.org/10.26822/iejee.2024.326

Yang, X., Chan, M., Kaur, B., Deng, J., Luo, J., & Wen, Y. (2025). International comparative studies in mathematics education: a scoping review of the literature from 2014 to 2023. ZDM, 57(4), 745-761. https://doi.org/10.1007/s11858-025-01700-4

Yanti, A. M., & Maranta, Y. (2023). Integrasi budaya lokal Papua dalam pembelajaran matematika sekolah menengah. Jurnal Pendidikan Matematika Indonesia, 8(2), 112–125.

Yetkiner, Z., Işıksal-Bostan, M., & Tekin-Sitrava, R. (2022). Prospective Teachers' Instructional Responses on the basis of Students' Functional Thinking: The Context of Pattern Generalization. International Journal for Mathematics Teaching and Learning, 23(2), 40-58. https://doi.org/10.4256/ijmtl.v23i2.438

Yunita, M. and Siswanto, R. (2023). Analysis of Mathematical Communication Ability in Solving Story Problems Based on Mathematical Ability and Gender. Mathline Jurnal Matematika Dan Pendidikan Matematika, 8(1), 181-193. https://doi.org/10.31943/mathline.v8i1.327

Yusuf, F. and Basrowi, B. (2023). The Effectiveness of the Internship Program for Vocational High School Students Using the CIPP Method. JTP - Jurnal Teknologi Pendidikan, 25(1), 15-28. https://doi.org/10.21009/jtp.v25i1.33553

Zabidi, Z., Abdullah, Z., & Sumintono, B. (2023). Exploring teacher collaboration: what's inside the Malaysian PLC black box?. Journal of Professional Capital and Community, 8(4), 313-331. https://doi.org/10.1108/jpcc-03-2023-0020

Zaenal, R. and Heriyana, T. (2021). Students' Mathematical Communication Skills in Solving Quadratic Equation Problems. Indo-Mathedu Intellectuals Journal, 2(2), 92-105. https://doi.org/10.54373/imeij.v2i2.24

Zakiah, N. and Fajriadi, D. (2020). Management of authentic assessment in mathematics lessons to develop 4C skills. Journal of Physics Conference Series, 1613(1), 012050. https://doi.org/10.1088/1742-6596/1613/1/012050