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Translation of Representation: Capturing of Mathematical Errors in Verbal to Symbolic Representation Translation

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ABSTRACT

Students often face difficulties when translating mathematical problems from verbal statements into symbolic forms, a process that is fundamental to problem solving and mathematical reasoning. Understanding how such translation errors occur is important for strengthening both theory and classroom practice in mathematics education. This study aimed to analyze junior high school students' translation errors from verbal to symbolic representations in solving a contextual arithmetic problem. An exploratory qualitative design was employed, involving 32 students who completed the task, of whom 26 exhibited identifiable errors. Two focal participants were selected through purposive sampling for in-depth analysis, combining written work with interview data. The analysis identified two main categories of translation errors: implementation errors, which involved failures in coordinating or verifying representational attributes, and interpretation errors, which involved misidentifying the characteristics of elements during translation. The findings further revealed that intermediary visual representations played a dual role—supporting translation accuracy in some cases but also introducing additional sources of error in others. These results refine existing frameworks of error analysis by clarifying the role of verification stages and by distinguishing between implementation and interpretation errors in representational translation. Practically, the study high lights the need for instructional scaffolds that help students coordinate verbal, visual, and symbolic forms more effectively. Future research should expand the analysis across diverse mathematical topics and larger samples.

Keywords: mathematical translation errors, verbal to symbolic representation, multiple representations, error analysis, mathematics education

INTRODUCTION

The introduction serves as the gateway to this academic exploration, offering a comprehensive view of the subject matter and the trajectory of this research endeavor (1). It begins by contextualizing the research within the broader landscape of existing knowledge, elucidating the pivotal gaps and unexplored dimensions that prompt this investigation. Within this section, the foundational groundwork is laid, elucidation the significance and relevance of the study within its field, encapsulating both the current state of understanding and the inherent limitations that drive the quest for deeper comprehension (2).

Mathematics education is crucial for developing students' problem-solving skills, logical reasoning, and the ability to represent real-world situations in various

forms. Problem-solving is recognized as a fundamental skill in mathematics, essential for addressing real-world challenges and fostering critical thinking necessary for the 21st century (3). Effective teaching strategies, such as Polya's heuristic, can enhance students' problem-solving abilities by providing them with frameworks to tackle complex issues (4). Furthermore, integrating algebraic and computational thinking into the curriculum promotes logical reasoning and equips students with the skills needed for modern educational demands (5). Innovative educational tools, like the Jasper series, create engaging contexts for students to apply mathematical concepts to real-life scenarios, thereby enhancing their reasoning and communication skills (6). Overall, a comprehensive approach to mathematics education that emphasizes problem-solving is vital for preparing students to navigate and succeed in an increasingly complex world (7).

Translating verbal statements into symbolic representations poses significant challenges for students, impacting their mathematical reasoning and problem-solving abilities. Research indicates that students often struggle with comprehension, vocabulary, and the correct application of operations when faced with mathematical word problems, leading to errors in formulating equations and diagrams (8,9). The translation process involves several stages, including unpacking the source, preliminary coordination, constructing the target, and determining equivalence, which are critical for effective problem-solving (10,11). High-ability students tend to navigate these stages more successfully, often utilizing visual representations to enhance understanding (12). However, many students still exhibit difficulties, particularly in translating verbal to symbolic forms, underscoring the need for targeted instructional strategies to improve these essential skills (10).

Previous research has identified various types of student errors in mathematics problem-solving, particularly concerning representational transformations, such as verbal-to-symbolic and visual-to-symbolic translations. For instance, students often struggle with translating verbal information into symbolic forms, leading to misinterpretations and implementation errors that hinder their ability to maintain semantic congruence between representations (13,14). Additionally, students with lower mathematical abilities exhibit significant difficulties in semiotic representation skills, which are crucial for effective problem solving (15). Errors can manifest as lost representational attributes or disconnected connections, indicating a lack of understanding in constructing equivalent representations (16). These findings underscore the necessity for targeted instructional strategies to enhance students' translation skills, thereby improving their overall mathematical problem-solving capabilities (11).

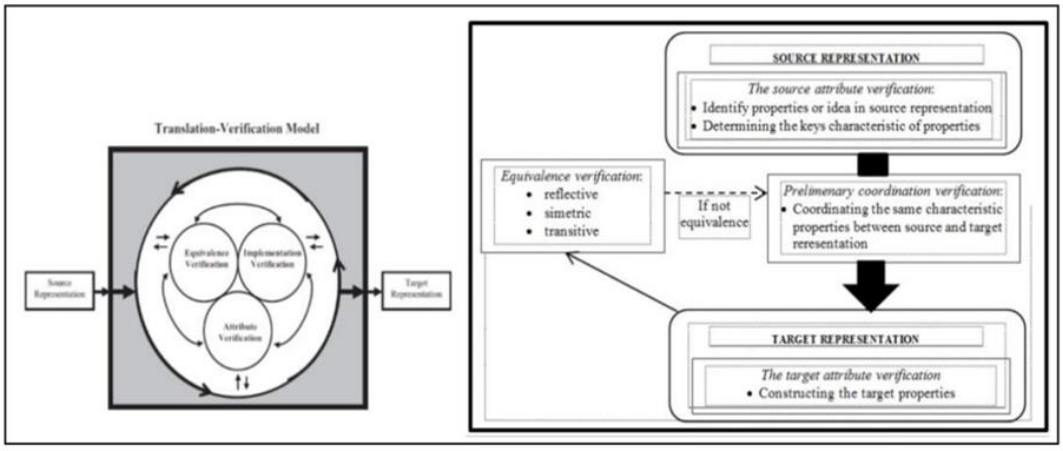

FIGURE 1. Mathematical Error (17)

In Figure 1, research on mathematical error analysis has identified various categories of errors, including conceptual, procedural, and representational errors, yet there remains a notable gap in understanding the translation processes between different representational modes. For instance, studies highlight that students often struggle with translating symbolic representations into verbal and graphical forms, leading to misinterpretations and implementation errors that disrupt semantic congruence (17). Furthermore, a systematic literature review identified five main error categories, emphasizing the need for improved pedagogical strategies to enhance students' translation skills (18). Additionally, research utilizing Newman's Error Analysis revealed that while many students can translate between some representations, a significant percentage struggle with verbal-to-graphical translations, indicating a critical area for educational intervention (19). Overall, addressing these translation challenges is essential for fostering deeper mathematical understanding and proficiency.

In mathematics education, representational translation from verbal to symbolic forms is crucial for developing mathematical literacy, yet many students encounter significant challenges in this process. Research indicates that students often struggle with unpacking verbal information, leading to errors in translation due to difficulties in identifying relevant mathematical operations and coordinating representations effectively (13,20). For instance, students frequently confuse arithmetic operations, such as distinguishing between multiplication and exponentiation, which complicates their ability to translate algebraic statements accurately (3). Additionally, a lack of comprehension and vocabulary, along with carelessness, further exacerbates these difficulties, as evidenced by studies showing that students often produce incomplete or incorrect translations when converting word problems into mathematical expressions (8). These findings highlight the need for targeted instructional strategies to enhance students' translation skills and overall mathematical understanding.

Research on translation errors from verbal to symbolic forms in middle school mathematics reveals several key challenges faced by students. Common errors include difficulties in interpreting the meaning of symbols, misidentifying operations (e.g., confusing product with exponent), and failing to maintain semantic congruence between representations (13). Specifically, students often struggle with breaking down information from verbal statements and coordinating it into symbolic expressions, leading to repeated errors in their translations (21). The types of errors identified include misinterpretation, arbitrary errors, and issues with the underlying arithmetic concepts, which significantly hinder their problem-solving abilities. Overall, these findings underscore the necessity for targeted instructional strategies to enhance students' translation skills and understanding of mathematical representations (21).

Therefore, the present study aims to analyze students' translation errors from verbal to symbolic representations, to classify the types of errors, and to provide an in-depth description of how these errors occur in the process of solving mathematical problems. Translating mathematical problems from verbal statements to symbolic representations is a critical step in problem-solving, as it requires students to interpret linguistic information accurately and express it in formal mathematical language (22). Previous studies have shown that many students struggle with this stage due to difficulties in understanding mathematical language, identifying relevant information, and applying appropriate symbols (23). By identifying and classifying these translation errors, this research provides deeper insights into students' cognitive processes and the specific challenges they face. The findings are expected to inform instructional practices and support the development of strategies

that can help students improve their mathematical reasoning and representation skills (24).

The study focuses on junior high school students' work on a social arithmetic problem, employing an exploratory qualitative approach that combines written task analysis with in-depth interviews to capture students' reasoning and representational choices. Social arithmetic problems provide an authentic context for exploring how students interpret everyday mathematical situations and transform them into symbolic representations (25). By analyzing students' written solutions, the study aims to identify their strategies, common errors, and patterns of symbolic translation. The use of in-depth interviews allows for a deeper understanding of students' thought processes, including how they make sense of problem statements and choose particular mathematical representations (26). This methodological approach provides a rich and detailed description of students' cognitive activity, making it possible to uncover subtle difficulties and misconceptions that may not be evident through written work alone (24). The findings are expected to contribute to the development of instructional practices that strengthen students' representational competence in mathematics learning.

This research contributes to the theoretical understanding of mathematical representation by offering a refined categorization of translation errors and by highlighting the role of intermediary visual representations in the translation process. Mathematical representation is not limited to verbal and symbolic forms; visual representations such as diagrams, tables, and sketches often serve as crucial mediating tools that support students' reasoning and problem-solving (22). These intermediary representations can bridge students' initial understanding of a problem and its formal symbolic expression, helping them clarify relationships and structure mathematical information more effectively (25). By systematically categorizing translation errors, this study provides a more nuanced view of how and where students struggle in moving between different representational modes. Furthermore, it emphasizes the importance of fostering representational fluency to improve students' conceptual understanding and problem-solving abilities.

Practically, the findings provide valuable insights for teachers and curriculum developers to design instructional strategies that anticipate common translation errors and foster students' ability to move fluently across verbal, visual, and symbolic forms in mathematics learning. Developing representational fluency is essential for supporting students in understanding mathematical concepts more deeply and flexibly. By recognizing typical patterns of translation errors, teachers can implement targeted interventions, such as scaffolding, the use of multiple representations, and explicit instruction on how to translate between different forms. Curriculum designers can also incorporate tasks that encourage students to visualize problems, make connections between representations, and reflect on their reasoning processes (8). Such approaches not only help reduce students' errors but also enhance their problem-solving skills, mathematical communication, and conceptual understanding, which are crucial for success in mathematics learning (18).

MATERIALS & METHODS

Research Design

This study employed an exploratory qualitative design, as it aimed to investigate in depth the errors made by students when translating mathematical problems from verbal to symbolic representation. Exploratory qualitative research is particularly suitable for examining phenomena that are complex, underexplored, and context dependent, as it allows researchers to uncover patterns of thinking and reasoning that are not easily captured through quantitative approaches (26). This approach emphasizes a rich,

descriptive understanding of students' cognitive processes in context, rather than generalizing findings across large populations. The central focus of the study was to analyze translation errors by systematically verifying each stage of students' representational translation, from understanding the verbal statement to constructing the corresponding symbolic expression. To deepen this analysis, in-depth interviews were conducted with selected participants to clarify their reasoning processes and explore their representational choices, thus providing comprehensive insights into the sources and nature of their translation errors.

Participant and Context

The research was conducted with 32 junior high school students who were asked to solve a contextual problem in social arithmetic (see Figure 1). The problem required students to translate verbal information into appropriate mathematical symbols and operations, reflecting the critical role of representational fluency in problem solving. Of the 32 participants, 26 committed identifiable translation errors. These participants were then grouped based on the type of representational process they used—either employing an intermediate visual representation, such as diagrams or tables, or attempting direct translation from verbal to symbolic form without any intermediary. This distinction is important because students who use intermediary visual representations often demonstrate different cognitive strategies and error patterns compared to those who rely solely on direct symbolic translation. Such grouping allows for a more nuanced analysis of how representational pathways influence students' success or failure in solving mathematical problems. From these groups, two focal participants were selected through purposive sampling for further analysis. The selection criteria considered (a) the types of errors identified in their written solutions and (b) their ability to articulate their reasoning during interviews. Participant P5 (coded as S11) and participant P25 (coded as S21) were chosen because they represented different error categories and both demonstrated the use of intermediary visual representations, which provided richer insights into the translation process. Purposive sampling was employed to ensure the selection of participants who could offer in-depth and information-rich data relevant to the research focus. This approach is widely used in qualitative research to select cases that best illuminate the phenomenon under investigation. By examining these focal participants' work, the study aimed to gain a deeper understanding of how different types of translation errors emerge and how intermediary visual representations influence students' reasoning pathways.

Participant and Context

All participants were given a problem that required integrating verbal, visual, and symbolic forms of representation. The task is presented below to illustrate the type of reasoning demanded from students: "Santi can make 20 pieces of cake from a block-shaped pan measuring 40 cm × 32 cm. Santi will sell the cake by putting it in a cake box. The height of the cake is the same as the height of the pan, while the height of the cake box is twice the height of the pan. If the cake box is circular with a diameter of 30 cm, how many cakes can be put in the box?" This problem was deliberately designed to engage students in multiple representational processes, requiring translation from verbal (Vb) to symbolic (Sb) representations, with or without the mediation of visual (Vs) representation. Such problems encourage students to interpret textual information, visualize geometric relationships, and apply mathematical operations to arrive at a solution. Research shows that students often benefit from using intermediary visual representations, such as diagrams or sketches, as these help them structure the information and make the symbolic translation more accurate. Contextual

problems like this are effective in assessing not only students' procedural skills but also their representational fluency and conceptual understanding.

Classification Error

Analysis of student work revealed two main categories of translation errors: implementation errors and interpretation errors. Implementation errors referred to mistakes in coordinating and checking equivalence between attributes of the source and target representations, while interpretation errors reflected incorrect determination of the characteristics of elements during translation. These error categories, combined with the presence or absence of intermediary visual representations, produced four distinct groups of translation errors (Table 1).

TABLE 1. Types of Representation Translation Errors and Their Frequencies

Error Type	Participants (n)	Vb → Sb with Vs Intermediary	Vb → Sb without Vs Intermediary
Implementation	9	P1, P5, P8, P9	P2, P3, P4, P6, P7
Interpretation	17	P11, P13, P14, P16, P18, P19, P24, P25	P10, P12, P15, P17, P20, P21, P22, P23, P26

Note: Vb = Verbal, Sb = Symbolic, Vs = Visual.

Data Collection Procedures

Data were collected through students' written solutions, classroom observations, and follow-up interviews with selected participants. The written responses provided evidence of the types of errors committed, while the interviews allowed deeper exploration of students' reasoning and representational choices. Additional data such as field notes, photographs, and video recordings were also gathered to enrich contextual understanding.

Data Analysis

The analysis followed a multi-stage process to ensure systematic and rigorous interpretation. First, interview data were transcribed and triangulated with students' written responses, field notes, and visual records. Second, the data were read repeatedly to gain a holistic understanding. Third, coding was conducted to categorize types of translation errors according to implementation or interpretation categories and the presence or absence of intermediary visual representations. Fourth, representational translation errors were described in detail, and each was mapped against the framework of translation verification stages (Figure 1). Fifth, unique or idiosyncratic errors were identified and analyzed to capture additional insights. Finally, conclusions were drawn by integrating findings across participants and data sources. To enhance the trustworthiness of the analysis, triangulation across multiple data sources was employed, and the coding framework was iteratively refined until consistency was achieved.

RESULT

First Subject

The results of the analysis of the work and interviews with the first subject are shown in Figure 3, which shows that: 1) At the source attribute verification stage, the subject unpacks the source by identifying the mathematical elements or ideas contained in it in the source representation in the form of verbal information on the question. Then confirm the definition and key characteristics of each mathematical element or idea through visual representation in the form of images. This is done by the subject to coordinate mathematical elements or ideas with mathematical elements or ideas that have the same characteristics in the target representation; 2) at the preliminary coordination verification stage, the subject has difficulty representing verbal information into internal information forms of symbolic representation; 3) at the target attribute verification stage, the subject finds it difficult to verify target representation; and 4) at the equivalence verification stage, the subject cannot confirm the requirements for equivalence relations, which include

reflective, symmetrical, and transitive. The results of problem-solving work and interviews by the first subject are seen in Figure 2.

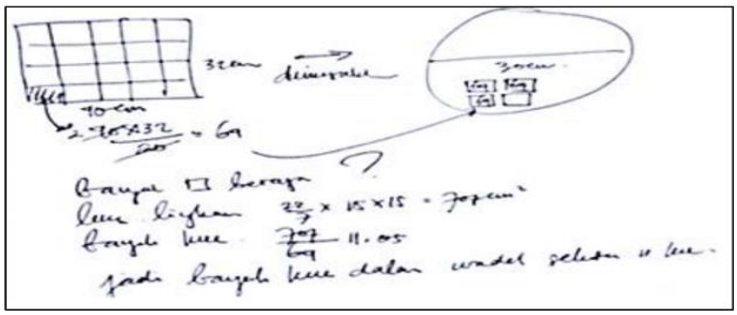

FIGURE 2. First Subject' Result

Interview result: Subject 1 stated that, "Because of the problem, I only know baking pans and cake cases, so here I give an example. The baking pan is square in shape, and the cake pan is circular in shape with a diameter of 30 cm. Then divide the baking sheet by 20, because there are 20 cakes. Because she asked how many cakes could be put in a cake box, For-example, the height of the baking pan and cake holder are the same. So, we can get the sum cake by dividing the area of the cake stand by the area of each cake. The area of each cake here can be calculated by multiplying 40 by 32, then dividing the result by 20 to get 64 per cake. So, the number of cakes is the area of the circle, namely 705 divided by 64, which results in 11.05, then rounded to 11. So, in the cake box, there are lots of cakes—about 11 cakes.

Second Subject

The results of the analysis of the work and interviews of the second subject are shown in Figure 4, which shows that: 1) at the source attribute verification stage, the subject carried out unpacking the source by identifying the mathematical elements or ideas contained within source representation in the form of verbal information in the question. Then confirm that the definition and key characteristics of each mathematical element or idea are provided in visual representation in the form of images. This is done by the subject to coordinate mathematical elements or ideas with mathematical elements or ideas that have the same characteristics in the target representation; 2) at the preliminary coordination verification stage, the subject represents the verbal information into information in the form of symbolic representation by writing the calculation formula correctly; 3) at the target attribute verification stage, the subject has difficulty verifying the target representation; and 4) at stage equivalence verification, the subject can confirm the terms of the equivalence relationship in the form of reflective, symmetrical, but not transitive properties. The results of the problem-solving work and the interview by the second subject are shown in Figure 3.

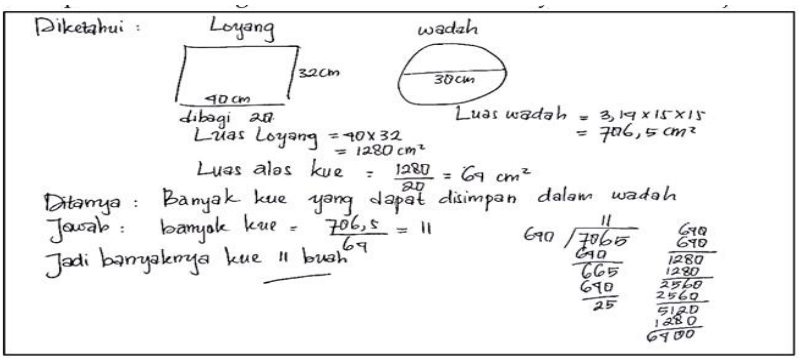

FIGURE 3. Second Subject' Result

Interview results: the second subject stated that, "From this question, I will draw a rectangle 40cm by 32 cm as a baking sheet and a circle as a cake container with a diameter of 30 cm. The baking sheet is divided into 20 like this (pointing picture created) because it looks like there are 20 cakes. Then the question is about moving each part of my shadow into the circle. Next, assuming the height of the pan and the height of the cake container, I assume the height of both cakes is the same, so we can get the number of cakes by dividing the area of the cake container by the base area of each cake. We can calculate the base area of each cake by multiplying 40 by 32 to get 1280, then dividing 1280 by 20 to get 64 per cake. So, the number of cakes is the area of the circle, namely 706.5 divided by 64.11. So, the final answer is 11.

DISCUSSION

This study found that students exhibited two main types of translation errors—implementation errors and interpretation errors—when translating from verbal to symbolic representations, with both focal participants demonstrating difficulties at different verification stages. Implementation errors occurred when students correctly understood the problem verbally but made mistakes in symbolizing or carrying out the mathematical operations, such as misapplying formulas or miscalculating dimensions. Interpretation errors, on the other hand, were related to students' misreading or misunderstanding of the verbal information itself, which led to inaccurate symbolic representations (13). These findings align with previous research indicating that translation between representations involves both comprehension and transformation processes, where difficulties can emerge at any stage (21). The fact that both focal participants struggled at different verification points highlights the complexity of representational translation and the need for instructional strategies that address both linguistic interpretation and symbolic implementation in mathematics learning (27). The findings confirm earlier research indicating that students experience persistent difficulties when shifting between representations. Translating from one representational form to another requires students to coordinate multiple cognitive steps, including interpreting the source representation, selecting appropriate mathematical structures, and constructing the target representation (22). Many students struggle not only with understanding the content of each representation but also with establishing coherent connections between them, which often leads to systematic errors in problem-solving (27). This persistent challenge highlights the cognitive demands of representational translation and supports the notion that fluency in multiple representations is not acquired automatically but must be explicitly taught and scaffolded (28). As such, these findings reinforce the importance of instructional strategies that help students develop representational flexibility and awareness of how different representations convey mathematical meaning. The students' representational understanding remains relatively low, particularly when tasks involve verbal contexts translated into formal mathematical symbols. This indicates that many students struggle to bridge the gap between everyday language and abstract mathematical notation, which is a critical step in mathematical problem-solving (29). Verbal problems require students to interpret contextual information, identify relevant mathematical relationships, and encode these into appropriate symbolic forms—a process that involves both linguistic comprehension and conceptual understanding (22). Similar to previous research, this study found that students often misinterpret key verbal information or incorrectly symbolize it, leading to systematic errors during problem-solving (8). These findings highlight the persistent nature of representational difficulties and emphasize the importance of instructional

approaches that explicitly support students in translating between verbal and symbolic representations.

However, the present study extends prior work by showing how intermediary visual representations can both assist and complicate the translation process, depending on how effectively students coordinate attributes across modes. On the one hand, visual representations such as diagrams, sketches, or tables can serve as cognitive bridges, helping students organize verbal information and facilitating a smoother transition into symbolic representations (28). When used effectively, these intermediary representations can enhance conceptual clarity, support problem structuring, and reduce cognitive load during problem-solving. On the other hand, when students misinterpret or inconsistently map attributes between visual and symbolic forms, these same representations can introduce additional layers of misunderstanding and error. This finding highlights the dual role of visual representations—as both a scaffold and a potential source of difficulty—underscoring the importance of teaching students how to coordinate multiple representational modes effectively (15).

These findings contribute to theories of multiple representations by clarifying how verification stages—source attributes, coordination, target attributes, and equivalence—can serve as diagnostic indicators of students' translation errors. Each of these stages reflects a critical step in how students process and transform information across different representational forms (30). Difficulties in identifying or interpreting source attributes often lead to misrepresenting problem elements, while challenges in coordination reflect students' struggles to map relationships accurately between modes. Errors at the target attributes stage are commonly linked to incorrect or incomplete symbolic construction, and problems with equivalence highlight students' inability to verify the consistency of their representations. Moreover, the study underscores the importance of distinguishing between implementation and interpretation errors, adding granularity to existing frameworks of mathematical error analysis. This distinction provides a more nuanced understanding of how translation difficulties emerge and allows for more targeted instructional interventions (21).

For classroom practice, the results suggest that teachers should provide explicit scaffolding to help students coordinate verbal, visual, and symbolic elements, rather than assuming these skills develop spontaneously. Representation is not an intuitive skill for many students; it requires structured guidance to build fluency and flexibility across multiple modes. Incorporating multiple representations in teaching, can significantly enhance students' ability to translate between forms, deepen conceptual understanding, and support more effective problem-solving.

However, simply exposing students to different representations is not sufficient. Teachers must also explicitly address potential pitfalls in translation processes, such as misinterpreting source information or misaligning visual and symbolic elements (27). By integrating targeted scaffolding strategies—such as guided visualization, modeling translation steps, and encouraging reflective verification—teachers can help students develop more robust representational competence and reduce common translation errors. The findings highlight the need for teacher education programs to explicitly prepare future teachers with strategies for teaching representational translation, ensuring that they can design learning activities that foster students' ability to move flexibly across different forms of representation. Research has shown that many teachers lack explicit training in how to scaffold students' use of multiple representations, often assuming that these skills will emerge naturally through practice. However, effective instruction requires teachers to strategically select, sequence, and connect verbal, visual,

and symbolic representations to support students' conceptual understanding (5). Teacher education should therefore emphasize not only content knowledge but also pedagogical content knowledge (PCK)—particularly how to help students overcome common translation difficulties (4). By equipping pre-service teachers with explicit instructional strategies, such as guided questioning, visual modeling, and structured verification processes, teacher education programs can play a critical role in improving classroom practices related to representational competence.

This study is limited by its small number of focal participants, which restricts the generalizability of the findings, and by its focus on a single type of contextual arithmetic problem. While the in-depth qualitative design provides rich insights into students' translation processes, it does not allow for broad claims about all learners or mathematical contexts (26). Future research should therefore explore translation errors across a wider range of mathematical topics, including algebra, geometry, and data analysis, to capture a more comprehensive picture of representational challenges. Additionally, employing larger and more diverse participant samples would enhance the external validity of findings and allow for comparative analyses across different student groups. Beyond descriptive analysis, future studies should also investigate instructional interventions that can effectively reduce translation errors and support representational fluency (28). Such research would contribute not only to the refinement of theoretical frameworks but also to the development of practical strategies for improving mathematics instruction.

Overall, the study demonstrates that translation errors between verbal and symbolic representations remain a significant obstacle for students, and that addressing these errors systematically can enhance both mathematical understanding and problem-solving competence. Many students continue to struggle with interpreting verbal information and accurately converting it into formal mathematical symbols, which often leads to procedural mistakes and conceptual misunderstandings (29). These challenges align with previous research showing that representational fluency is not an automatically acquired skill but requires explicit support and structured learning experiences (23). By identifying where and how translation errors occur— particularly at the stages of source interpretation, coordination, and equivalence—teachers can design targeted interventions to improve students' ability to navigate across representational modes (16). Strengthening this skill is crucial, as fluent movement between verbal and symbolic forms supports deeper conceptual understanding and more flexible problem-solving strategies.

CONCLUSION

This study analyzed students' translation errors from verbal to symbolic representations in solving a contextual arithmetic problem. The findings revealed two main categories of errors—implementation and interpretation—occurring across different verification stages, with intermediary visual representations playing a dual role in either supporting or complicating the translation process. Theoretically, these findings refine existing frameworks of error analysis by distinguishing between types of translation errors and by emphasizing the diagnostic value of verification stages in representational processes. Practically, the study provides insights for teachers to design instructional scaffolds that explicitly address translation difficulties and to promote more flexible use of verbal, visual, and symbolic forms in mathematics classrooms.

This research is limited by its small sample size and focus on a single problem context, which restricts generalizability. Future studies should expand to diverse mathematical topics, include larger and

more heterogeneous samples, and test instructional interventions aimed at reducing translation errors. Overall, the study underscores that translation errors remain a significant barrier to students' mathematical reasoning, and that systematically addressing these errors can contribute to improving mathematical understanding and problem— solving competence.

Declaration by Authors

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