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THE ABILITY OF TEACHERS TO TRANSLATE SYMBOLIC REPRESENTATION INTO VISUAL REPRESENTATION AND VICE VERSA: ADDITION OF INTEGERS

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ABSTRACT

The translation of representations entails a process of changing such representations from one form into another. In general, mathematics uses symbolic, visual (graphical),verbal, and tabular representations. This article discusses the results of a study on teachers' understanding of representations in mathematics and their implementation. It involves the ability of teachers to translate symbolic into graphical representations, and vice versa. The study is descriptive in nature and was conducted with a sample of 91 mathematics teachers from various districts in South Sumatera and Bangka Belitung provinces. The research data were collected from the results of a test on the addition of integers. The results revealed a very low ability among the teachers with regard to translating a symbolic representation into a graphical representation, with only 48.4% of the sample managing to correctly translate the representation. Conversely, the teachers' ability to translate a graphical representation into a symbolic representation was found to be quite good, with 75.8% of the sample able to correctly translate there presentation. The mistakes identified in the translation of symbolic representation to visual representation wereaddition not being presented in a number line, no result of addition being presented at all, the order of the number line not being presented clearly, misdirection or no direction of a number line, and no answers at all. Meanwhile, the mistakes identified inthe mathematics teachers' translations of a visual representation to a symbolic one were the result of the addition not being presented, incorrect order of the numbers to be added, and no answers at all.

Keywords: Adding integer; mathematics teachers; mathematics representation; symbolic; translation; visual.

INTRODUCTION

Mathematics can be represented in many forms, such as symbolic, visual, verbal, or tabular representations. It is very important to use mathematics representation as part of the teaching and learning of mathematics (Gulkilik & Arikan, 2012). The ability of students to effectively translate one representation into another reflects their understanding of mathematics concepts. The types of mathematics representation shown by students are thus expressions of the mathematical ideas they need in order to understand a range of concepts or problems and then find solutions to them (NCTM, 2000). Most teachers and researchers agree that the key to effectively understanding, communicating, and operating mathematics concepts is to connect and translate visual, tabular, symbolic, and verbal representations (Boose et al., 2011). Translation is defined as the process of changing representations from one form into another (Janvier, 1987).

Teachers, as one element of teaching and learning, must facilitate their students'acquisition of good mathematical representation skills. Zhonghe (2004) stated that teachers have to understand and develop many kinds of representation abilities in order for them to facilitate the conceptual understanding of students, and they must focus on developing transformations of concepts from one representation into other representations. Leinhardt et al. (1990) asserted that teachers must have good skills and knowledge in the area of mathematics representation. Teachers' ability to effectively use representations demonstrates that they have a comprehensive understanding of the topics they are teaching (Harries & Barmby, 2008; Heinze et al. 2009). In the context of student–teacher interactions, in order to help students build their representation skills, teachers must understand how the students perceive mathematics representation and how they connect one representation to others (Smith, 2003).

According to Bosse et al. (2011), many studies have been conducted to investigate the impact on students' achievement of teacher understanding and the implementation of mathematical representations in learning; however, few have sought to examine the impact of teachers' understanding and the difficulty faced by learners in translating different mathematical representations. On the one hand, many researchers have argued that the relationship between teachers' understanding of mathematical representation and its implementation is inconsistent, while many others, on the other hand, claim the relationship is consistent (Bosse et al., 2011). Teachers with a sufficient understanding of mathematical representation are able to translate mathematical representations from one representation to another.

Mathematical representation is an instrument that can be used to determine whether learners possess mathematical knowledge and mathematical ability (Liu, 2012), with the same applying to teachers. Thus, in order to identify teachers' level of mathematical knowledge and mathematical ability, we need to investigate their mathematical representation skills. The authors carried out an investigation into the abilities of teachers to translate all types of representations in the context of various mathematics topics. One of the abilities investigated was that of translating from symbolic representation to visual representation, and vice versa. The addition of integers is an example ofa topic in mathematics that can be illustrated using many styles of representation. Elementary, junior, and senior high school-level mathematics teachers should all possess a comprehensive understanding of the topic. Therefore, the aim of the research was to investigate the ability of mathematics teachers to translate representations illustrating this topic. In designing questions on the addition of integers, we were able to assess the teachers' mathematical representation abilities in terms of symbolic representation and visual representation. Kar and Isik (2011), in their study, found the teachers' ability to translate visual into symbolic representations to be unsatisfactory, especially among pre-service teachers, while Durkaya et al. (2011) concluded that pre-service teachers had inadequate visual representation skills.

Symbolic representation focuses on symbolic notation and the use of variables and formulas. There are five common forms of symbolic representation: equations, expressions, algebraic equations, algebraic expressions, and formulas. Symbolic representation is also known as algebraic representation. Graphical representation includes factorials, graphs, models, horizontal diagrams, vertical diagrams, and coordinate graphs. The symbolic representation for the sum of two integers is the sum expression, for instance, 6 + (-8) = -2. This sum expression can be translated into a visual or graphical representation by displaying the sum and result on an integer line.

METHOD

This aim of this study is to descriptively report on mathematics teachers' abilities to translate mathematical representations from symbolic representations into visual representations, and vice versa, focusing specifically on the addition of two integers. It form spart of wider research into teachers' abilities to translate all types of representations for certain topics in mathematics. The research sample comprised a total of 91 randomly selected mathematics teachers from junior high schools (SMPs), senior high schools (SMAs), and vocational schools (SMKs) inseveral districts and cities in South Sumatera and Bangka Belitung. Data were collected by testing the sample population with questions on the addition of two integers, where by the mathematics teachers were asked to translate a symbolic representation into a visual representation, and vice versa. The data were then analyzed by assessing the accuracy of the representations in terms of the standard required to answer the questions.

RESULTS AND DISCUSSION

1. Teachers' ability totranslate symbolic representation into visual representation

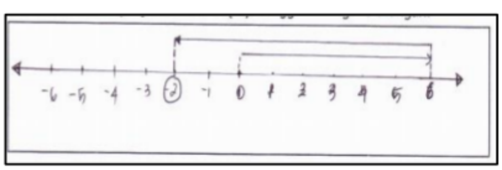
We used the teachers' answers to the following question to measure their ability to translatea symbolic representation into a visual representation:"Illustrate the sum of 6 + (-8) using a number line."While the question may appear to be very easy to answer, in practice many of the mathematics teacherswe tested gave unclear or incorrect answers. Mistakes were notably identified in the creation of a line to illustrate-8, and also ofa line for -2,with the latter being the result of the sum of the two numbers. A total of 44 teachers (48.4%) answered the question correctly, with the other 51.6% answering incorrectly. Details of the teachers' answers are given in Table 1.

The question required the teachers to illustrate the process for finding the sum of the two integers using anumber line. The rules for theaddition of two numbers using a number line are that the direction of the arrow for positive numbers is to the right, while the arrow direction for negative numbersis to the left. It is also very important to know the correct order in which to display the numbers when adding two numbers using a number line. Teachers must therefore know and distinguish between the first number, the second number, and the result of the operation to sum the two numbers. For instance, in 6 + (-8) = -2 , the first number is 6, the second number is -8, and the result is -2. The number 6 is thus expressed by an arrowextending to the right (positive) along the number line by the amount of 6 units, from the starting point of 0. The number (-8) is expressed by an arrow extending to the left (negative) by the amount of 8 units, from the number 6. The digit pointed to by the arrow extending from the second number is thus the result of the operationand is denoted by anarrow from the original point, which is 0, to the last digit, which is -2.

Table 1. Summary of Teachers' Mistakes in the Translation of Symbolic into Visual Representation

No.	Type of Mistake	Total	Percentage
1	Correctly drawing arrows forthe first and second numbers, circling the number for the result of the sum, but not drawing anarrow forthe result of the sum.	10	10.9%
2	Correctly drawing arrows forthe first and second numbers, but not circling the number forthe result of the sum, nor drawing anarrow for the result of the sum.	20	21.9%
3	Drawing arrows for all of the numbers, but the order for adding the numbers and the result of the sum were not shown clearly.	5	5.5%
4	Drawing arrows for all of the numbers, but the arrow direction for theresult of the sum was incorrect.	2	2.2%
5	Not indicating a direction for the numbers added and the result of the sum.	5	5.5%
6	Not giving answers at all.	5	5.5%

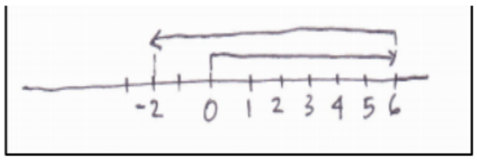
Table 1 shows that 10.9% of the teachers answered the question incorrectly by not drawing avisual representation for the result of the sum. Picture 1 illustrates thistype of mistake.



Picture 1. An example of a teacher's mistake

Picture 1 shows that while the teacher gave the correct answer in the form of a symbolic mathematics representation, they gave anincorrect answer in visual representation form. This finding may indicate that the teacher was familiar with symbolic representation or algebraic expression only, which is similar to the research finding by Monoyiou et al. (2007).

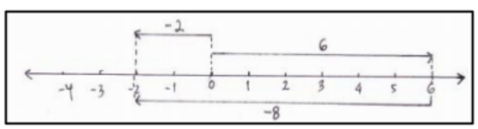
The most common mistake identified in the teachers' translation of symbolic representation to visual representation wasthat they correctly drew the arrows for the two numbers being added but failed to identify the sum of the numbers. Picture 2 illustrates thistype of mistake.



Picture 2. An example of a teacher's mistake

A total of 20 teachers (21.9%) gave an answer similar to that shown in Picture 2. This type of mistake serves to highlight an incomplete understanding among the teachers of what the question was asking. In reality, the most important element when attempting to solve any question is to first understand the problem that is being presented(Polya, 1990).

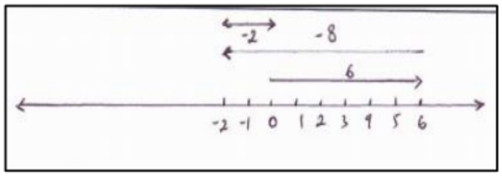
A furthermistake identified in the teachers' translation of symbolic representation to visual representation was that of not clearly showing the order of the numbers being added and the result of the sum. A total of 5 teachers (5.5%) were identified as having made this type of mistake. The order of the numbers being added and the result of the sum are important elements to get right when creating a visual representation as they can produce different meanings for the addition of two numbers. An example of this type of mistake is illustrated in Picture 3.



Picture 3. An example of a teacher's mistake

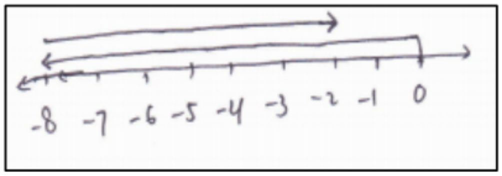
The answer shown inPicture 3 is incorrect with respect to answering the question "6+(-8)" asit conveys the meaning of the addition of the numbers "6+(-2)".

A third type of mistake identified inthe teachers' translations of symbolic representation to visual representation was anincorrect arrow direction for the result of the sum. Two teachers (2.2%) made this type of mistake, a sample of which is shown in Picture 4. Here, we can see that the teacher drew two directions for the arrow of the result of the sum, which is incorrect.



Picture 4. An example of a teacher's mistake

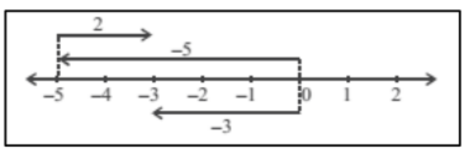
An additional mistake was not including a direction for the numbers being added and the result of the sum. This type of mistake was made by 5 teachers (5.5%), a sample of which is shown in Picture 5.



Picture 5. An example of a teacher's mistake

2. Teachers' ability totranslate visual representation into symbolic representation

The following question was designed to investigate the teachers' ability to translate visual representation into symbolic representation:"State the addition of the two numbers and theresult shown in Picture 6 in the form of an algebraic expression."



Picture 6. The question for thetranslation of visual representation into symbolic representation

The correct answer tothe question above is "(-5)+2=-3". A total of 69 out of 91 teachers (75.8%) gave the correct answer, while 22 teachers (24.2%) answered incorrectly. This finding illustrates that some teachers experience problems in translating visual representation into symbolic representation. The types of mistakes made by the teachers are outlined in Table 2.

Table1. Summary ofTeachers' Mistakesin the Translation of Visual into Symbolic Representation

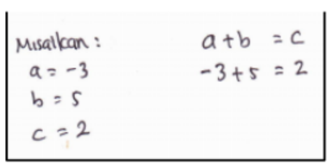
No.	Type of Mistake	Total	Percentage
1	Stating the algebraic expression for theaddition of two	6	6.6%

	numbers without stating the result of the sum.		
2	Stating the algebraic expression but withthe numbers to be added in the incorrect order.	8	8.8%
3	Stating the algebraic expression incorrectly by mixing all the numbers or not stating them at all.	8	8.8%

The first type of mistake identified with respect to the teachers' translation of visual representation into symbolic representation wasthat they wrote an algebraic expression containing only the two numbers being added without stating the expression for the result of the sum. The mistake was thus to write "-5+2" to symbolize the addition of the two numbers in Picture 6, as opposed to the full answer of "-5+2=3". A total of 6 teachers (10.9%) made this type of mistake.

Incorrectly stating the order of the numbers to be addedwas also acommon mistake made bymany of the teachers when translating the visual representation of the addition of two numbers into one using symbols. One example was where a teacher wrote "2+(-5)=3" to symbolize the visual representation in Picture 6, which has a different meaning and a different visual representation to"-5+2=3". A total of 8 teachers (8.8%) made this type of mistake when using symbols to represent the components in Picture 6.

A further mistake made by the teachers when attempting to symbolically express a visual representation of a two-number addition problem was to mix up all the numbers without appropriately distinguishing between the numbers being added and the result of the sum. An example of this type of mistake is where a teacher wrote "(-3)+5=2" to symbolize the visual representation contained in Picture 6, which is an incorrect answer. A total of 8 teachers (8.8%) were identified as having made this type of mistake. Picture 7 shows how a teacher made such a mistake in translating the visual representation from Picture 6 into a symbolic representation.



Picture 7. An example of a teacher's mistake intranslating the visual representation from Picture 6 into a symbolic representation

Based on the findings of this research, it can be said that the teachers' ability to translate a visual (graphic) representation into a symbolic representation is already good, since 75.8% of them were able to correctly answer the question. This reflects that the symbolic form of representation is commonly used by teachers in their teaching and learning. Pinar (2014) also stated that student teachers tend to use symbolic representation or algebraic representation, plus verbal representation, to solve mathematics problems.

CONCLUSIONS AND RECOMMENDATION

The ability of the teachers in this study to translate symbolic representations into visual representations in the case of the addition of integers was generally found to below, with only 48.9% of the 91 teachers in the sample performing well. At the same time, their ability to translate visual representations into symbolic representations in the case of the addition of integers was found to be good, with 75.8% of the 91 teachers sampled able to answer well. The types of mistakes identified when the teachers translated symbolic into visual representations related to using the incorrect order for adding the number sand not clearly showing the result of the sum; not drawing avisual representation for the result of the sum; correctly drawing arrows for the two numbers being added but not identifying the sum of the numbers; using an incorrect arrow direction for the result of the sum; and not including an arrow direction for the numbers being added and the result of the sum. Meanwhile, the types of mistakes identified when the teachers symbolized a visual representation of the addition of two numbers wereonly writing an algebraic expression for the two numbers being added without also including an expression for the result of the sum; and mixing all the numbers without appropriately distinguishing between the numbers being added and the result of the sum.

This research has not sought to conduct any deeper investigation into the types of mistakes made by the teachers; thus, it is recommended that any future research aims to determine why the teachers made such mistakes.

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