Nonlinguistic Representations in Mathematics Instruction

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One of the most commonly used approaches in mathematics instruction is direct instruction. Direct instruction (also referred to as explicit instruction) is a method of teaching that has stood the test of time. It has been considered as a traditional way of teaching and has been proven to benefit students’ learning of math concepts. But most math teachers are already aware of the techniques used to form a lesson using this systematic approach. There is another teaching strategy that can be easily implemented into direct instructional lessons that has also been proven to have a positive impact on student learning: nonlinguistic representations.

Research has shown that the use of nonlinguistic representations during math instruction has a positive effect on student learning. New knowledge can be presented to students in two different forms: linguistic form and image form. Image forms can be “expressed as mental pictures or even physical sensations, such as smell, taste, touch, kinesthetic association, and sound (Marzano, Pickering, & Pollack, 2001, p. 73). These forms can include pictures, hands-on physical models, graphs and number lines, and any type of kinesthetic activity. According to the research done by Marzano et al. (2001), students are better able to learn and recall knowledge when it is presented to them in both linguistic and nonlinguistic forms, but the majority of the time new knowledge is only given to students in linguistic form, through lectures or readings (p. 73). During math instruction in particular, it is essential that new information be presented to students using both linguistic and nonlinguistic representations.

There are various ways nonlinguistic representations can be implemented into math lessons. Students can create pictures that represent many different things in math: algebraic expressions, equations, fraction operations, integer arithmetic, etc. Marzano et al. (2001) found that when students are asked to make visual models to represent what they are learning in math,
those students are automatically “elaborating” on their knowledge. When students elaborate on what they are learning, they have a deeper understanding of the concepts, and they will have an easier time recalling the information in the future (p. 74). In addition, students should also be asked to explain how their pictures represent the math problems. Marzano et al. (2001) state that, “the power of elaboration can be enhanced by asking students to explain and justify their elaborations” (p. 74). Other types of visual representations used in mathematics are diagrams and graphic organizers. Tree diagrams are a great tool to use when teaching students how to work with math problems that contain various choices or multiple solutions. Posamentier, Smith and Stepelman (2006) write that, “this strategy [tree diagrams] can arise in virtually any branch of mathematics, though not necessarily for every topic” (p. 84). They also give great ways this strategy can be implemented in various math lessons. For example, tree diagrams can be used for lessons that introduce or reinforce prime factorization. When showing students how to factor you can create a tree diagram with the whole class using questions strategies to break down a number into smaller numbers that create additional tree diagram branches. Once the tree diagram is complete, the class can come up with a way to identify the prime numbers they find as they continue making new branches (Posamenthier et al., 2006, p. 84). Once students have mastered this method of finding all the prime factors of a composite value, they will always be able to generate a mental image of the diagram or even physically draw it out for later problems that involve prime numbers. Marzano et al. (2001) found that, “drawing pictures or pictographs (i.e., symbolic pictures) to represent knowledge is a powerful way to generate nonlinguistic representations in the mind” (p. 82). If students are able to make and understand the connections between mathematic notations and mental/physical images, they will have a less difficult time recalling the information.
Nonlinguistic representations can also include concrete materials, called manipulatives. Marzano et al. (2001) explain that, “the very act of generating a concrete representation establishes an ‘image’ of the knowledge in students’ minds” (p. 78). Manipulatives are commonly used as math teaching tools, and when combined with other visual representations, can enhance student learning. Research has shown that Concrete-Representational-Abstract (CRA) teaching methods are very effective when teaching students who have learning disabilities or who struggle with new math concepts. Steedly, Dragoo, Arafeh, & Stephen (2008) describe the CRA teaching technique:

CRA is a three-part instructional strategy in which the teacher first uses concrete materials (such as colored chips, base-ten blocks, geometric figures, pattern blocks, or unifix cubes) to model the mathematical concept to be learned, then demonstrates the concept in representational terms (such as drawing pictures), and finally in abstract or symbolic terms (such as numbers, notation, or mathematical symbols). (p. 8)

According to a study done on various nonlinguistic representations, the CRA method of teaching has been shown to have “promising results” in the effects it has on student achievement in math (Gersten, Baker, & Chard, 2006). I have used the CRA approach many times in my own math instruction. The CRA technique can be implemented in many math lessons. I used the CRA approach when my first year algebra students learned how to combine integers (negative and positive whole numbers). Although my students had already been introduced to integers in previous classes, many still struggled adding and subtracting these numbers. First I had students draw a picture that they believed represented five plus negative two (5 + -2). I did not give my students any guidance or restrictions to their drawings. This was my way of accessing my students’ prior knowledge and understanding of the problem. Some pictures were very accurate,
while other pictures were difficult to comprehend or showed incorrect material. Once this was done, I introduced my class to “integer strips”. These strips are a manipulative used to show what happens when two numbers (positive, negative or both) are combined. After much guidance and practice, the students understood how to represent various integer addition/subtraction expressions. The next step was to transform the concrete model into a common visual model that all students could create. I asked my class to create visual representations, along with the algebraic expressions in math notation for each problem they were assigned. Many students embraced this technique and drew pictures on their next quiz. I believe the CRA approach of combining two nonlinguistic representation strategies had a positive impact on my students’ learning. It is also important to point out that according to Berkas & Pattison, “The National Council of Teachers of Mathematics (NCTM) recommends that, when using CRA, teachers make sure that students understand what has been taught at each step before moving instruction to the next stage” (as cited in Steedley et al., 2008, p. 8). Other research by Gersten et al. (2006) found that visual representations were not as useful unless students were given an adequate amount of time to practice and learn how to use them. In order for this approach to work, students must be able to connect all three CRA representations to each other, and they must be able to demonstrate this understanding before they use only the abstract representations (Berkas & Pattison, 2007).

Kinesthetic activities can also be used to enhance student knowledge of math concepts. These activities are physical motions that connect to the knowledge of a concept. Marzano et al. (2001) state that, “by definition, physical movement associated with specific knowledge generates a mental image of the knowledge in the mind of the learner” (p. 82). If a student can create a mental image to match the new knowledge learned, they are able to have a deeper
understanding of the concept and have an easier time recalling the information later. I use this method when students are introduced to their first twelve basic functions in Algebra II. Students need to know the function notations, the graphical representations and the basic characteristics of each function. I use “function arms” in my class to represent the different graphical representations. Students must represent each function and their characteristics using their arms and hands. This is a great way to get students to connect new knowledge to physical movement, and it also provides an opportunity to quickly assess student understanding during class.

There has been extensive research on how nonlinguistic representations can be implemented into math instruction and how it affects students’ learning on mathematical concepts. Steedley et al. (2008) state, “visual representations bring research-based options, tools, and alternatives to bear in meeting the instructional challenge of mathematics education” (p. 8). Marzano et al. (2001) have studied the effects of nonlinguistic representations on student learning in general. They found that when teachers help students create visual depictions of the learning material, there is strong improvement on student achievement. They also state “it has even been shown that explicitly engaging students in the creation of nonlinguistic representations stimulates and increases activity in the brain (p. 73). Research findings by Gersten, Baker, & Chard, presented at the Center of Instruction of Math Summit in 2006, show how visual and graphic representations enhance math instruction for special education and low-achieving students. Gersten et al. found that, “teaching students to use graphic representations of the underlying concepts of a problem results in moderate effects” (2006). The teaching strategies that had the largest effects on the students’ learning in math were direct instruction and student self-instruction/think-alouds. These were closely followed by visual representation strategies. The findings also show when nonlinguistic representations had the most positive effects on
student achievement. Gersten et al. (2006) found that, “the effect were larger when teachers provided students with multiple opportunities to apply graphic representations to specific problems”, and “when teachers taught students to select appropriate graphic representation and why a particular representation was most suitable”. When applied in the correct way, it has been shown that nonlinguistic representations will enhance math instruction in a way that promotes student achievement and learning improvement.

Nonlinguistic representations can be used in various different forms for math instruction: pictures/pictographs, manipulatives, and kinesthetic activities. When students are given opportunities to practice and master the use of these visual/physical depictions, they will be more successful in the understanding of the math concepts. Marzano et al. (2001) say that nonlinguistic depictions are “probably the most underused instructional strategy… [and] creating nonlinguistic representations helps students understand content in a whole new way” (p. 83). Theses nonlinguistic strategies can be simple to incorporate in day-to-day math lessons, and, when applied correctly, can be an effective way to improve student understanding.
References


