Math Manipulatives

Kenzie Dinsmoor

In a traditional grade-level mathematics classroom, the use of manipulatives has become essential in providing students with the knowledge to conceptualize basic math operation skills. This approach to instruction involves using physical tools to enhance student understanding of the mathematical content. Teachers are finding the need for using manipulatives to create effective, active, and engaging math lessons. Using manipulatives, or " tangible objects," can provide for a variety of learning styles and abilities within classrooms (Horan & Carr, 2018).

What are Manipulatives?

Horan and Carr (2018) define manipulatives as concrete objects that allow students hands-on experience while being actively engaged in the learning. There are multiple ways to use manipulatives. In the classroom, teachers are using manipulatives in a lesson as they introduce, practice or remediate a mathematical concept (Hidayah et al., 2021). These physical tools may include a variety of concrete objects that might be used at the elementary level such as counters, fraction strips, pattern blocks, cubes, geoboards, etc., for all kinds of math instruction.

Using manipulatives as an approach provides a foundation which will encourage critical thinking and students' ownership of their work. Teachers are able to have a vivid picture of student understanding in which they can determine the next appropriate steps (McDonough, 2016).

Origin of Manipulatives

Using math manipulatives dates back to earlier civilizations that used clay beads and wooden trays to help grasp mathematical concepts (Boggan et al., 2010). Throughout history, different types of manipulatives have been used to aid in comprehension of mathematical concepts.

We first hear about manipulatives being seen as educational tools for teaching in the late 1800s. Teachers were starting to use manipulatives to enhance their lessons and saw positive outcomes in their students' mathematical skills. In the 1900s, Italian physician and educator Maria Montessori developed the use of manipulatives with the goal in mind to enable children to learn through personal investigation and exploration (Hurst & Linsell, 2020). Today, using manipulatives stresses the importance of concrete operations in the primary stages of knowledge formation in young children. In a traditional mathematics class today, using manipulatives is well-established in the classroom.

Why are manipulatives important?

Based on psychologist Jean Piaget's research, children learn concepts through three levels of knowledge: concrete, pictorial, and abstract (Hurst & Linsell, 2020). As students manipulate objects,

they take the necessary first steps toward building understanding and internalizing math processes and procedures. Manipulating objects allows students to explore concepts at the first, or concrete level of understanding. Strategies and algorithms will be developed over time (Ojose, 2008).

Students need to understand the concept at the two levels of concrete and pictorial first before they can handle an abstract or symbolic level (Hurst & Linsell, 2020). To create mental images and models, it is necessary to use concrete manipulatives. Students who show an understanding of the concept at this physical or concrete level are well-positioned to move to the next level where they will be able to use representations of the objects in place of the real objects (Tirosh et al., 2018).

The use of concrete models can facilitate the development of number sense as well as develop the meaning of written symbols and help students develop a sense of place value (Hurst & Linsell, 2020). By using this method, teachers can get a better understanding of what students know, as well as identify misconceptions, so they can design interventions accordingly.

Understanding the interconnections of mathematical ideas can be improved by utilizing manipulatives. Using manipulatives to solve a problem can assist students in keeping track of what they did and explaining their ideas (Hurst & Linsell, 2020).

Student-Centered Approach

Student-centered learning has a variety of meanings in education. Students are encouraged to engage with their own ideas, experiment with new materials, and explore. A common description of student-centered learning is that students are at the center of their learning where the teacher is there to support and guide students' progress and learning (Keiler, 2018). So what makes math manipulatives student-centered?

Using math manipulatives fosters student engagement in a way that allows for students to explore different math concepts with hands-on learning materials (Hidayah et al., 2021). In an encyclopedia article, Stephan (2014) stated the following:

> Using math manipulatives is a learner-centered teaching approach to mathematics instruction that places heavy emphasis on the students taking responsibility for problem solving and inquiry. The teacher is viewed as a facilitator by posing problems and guiding students as they work with partners toward creating a solution. (p. 331)

Therefore, manipulatives are student-centered because students are able to play with tangible objects which are designed to give students a deeper understanding of mathematical concepts.

Outcomes of using Math Manipulatives

The use of manipulatives in the classroom greatly aids the development of strong mathematical foundations in young students. Research shows that there are benefits to using manipulatives to help teach a mathematical concept.

Academic

According to D’angelo and Iliev (2012), using manipulatives aids in furthering student comprehension of mathematical knowledge. As students are given the chance to explore on their own with the chosen manipulatives they are able to critically think and make connections in understanding the math concept. Data have shown that concrete objects can help children gain access to concepts and processes that might otherwise be inaccessible (Uttal, 1997). Looking at a specific group of students, English language learners’ (ELLs) comprehension increases immensely. Data have shown that ELLs, “improve in vocabulary development, oral proficiency, comprehension, and display enthusiasm to continue using the manipulatives” (Stapleton, 2014, p. 161). ELL students' comprehension increased because they had to interpret a directive with an action in solving the problem. Therefore, the use of hands-on, multi-sensory manipulatives to help students increase comprehension is encouraged.

Another connection is how the role of manipulatives and metacognition go hand in hand with young children's cognitive development. Metacognition is when one observes, tries, and reasons with various mathematical concepts. It is thinking about thinking; a way for student learning to be enhanced and for them to understand their own learning processes. Belenky et al. (2009) state, “metacognitive prompts are questions that ask students to reflect on various aspects of the learning materials and problem-solving process and have been hypothesized to facilitate abstraction and learning” (p. 103). Students given concrete manipulatives with metacognitive prompts have shown a better transfer of procedural skills than students given abstract manipulatives with problem focused prompts. As a result, the manipulatives utilized in mastering sophisticated cognitive skills taught in mathematics are critical to increasing comprehension.

The use of multi-sensory manipulatives as tools has been said to increase involvement and interaction in teaching ESL students. In a journal article, Stapleton (2014) stated the following:

> Students enjoy working with hands-on manipulatives which increase the opportunity for student involvement and interaction. Students who use the materials do not sit passively while the instructor attempts to verbally explain a concept. Students are encouraged to participate with other students, make connections with new concepts, and draw conclusions based on their understanding. (p. 162)

This brings us to the next point: visualization. Where some students learn best with visuals, math manipulatives also aid with being able to conceptualize a math problem (Carbonneau, 2013). While students can recall material from books and lectures for short periods of time, deep understanding and the ability to apply what they've learned to new contexts necessitate conceptual understanding anchored in actual interactions with concrete objects (D’angelo & Iliev, 2012).

Research shows that when manipulatives in mathematics are used effectively, student understanding and engagement increases because manipulatives aid in the understanding of visual concepts through the use of visuals, scaffolding learning, and engaging students in learning (Cockett, 2015). Students are able to link representations based on manipulatives with written, symbolic representations.

Affective

Authors Cockett and Kilgour (2015) did a quantitative study on the impact of using manipulatives in mathematics on student understanding, efficiency, engagement and enjoyment. During this study, several types of manipulatives were used with students participating in various mathematical activities. Observations were also part of collecting qualitative data. The results concluded that students were more engaged when using manipulatives, and that their perception of their learning environment improved in each of the three areas: enjoyment, understanding, and efficiency.

In addition to enjoyment, concrete things that imitate daily objects help youngsters learn concepts by allowing them to draw on their practical expertise. Students are building up their problem solving skills and making connections. Planning instructional engagement activities is a huge part of students' motivation. Manipulatives give that extra boost in creativity and an increase in skills in students. A Yale University study (Hurst & Linsell, 2020) found that simple objects kept elementary students involved and entertained with very high levels of attention and concentration. Manipulatives also allowed students to design and experiment to find a solution, which encourages social interaction (Berk, 1999).

Therefore, manipulatives are effective for the following reasons: they are multisensory, they represent ideas in more than one way, they promote communication among students, and they increase confidence, leading to less confusion and a deeper understanding.

Challenges with Manipulatives

Challenges are a natural part of mathematics. Research has confirmed that using math manipulatives produces positive outcomes in students’ cognitive development and skills; however, there are some challenges with using them. When students learn with manipulatives, they may become too reliant on the item and context (Boggan et al., 2010). If students are constantly using manipulatives, they might become a crutch, preventing students from learning more advanced problem-solving skills (Boggan et al., 2010). Students will have difficulty transferring new knowledge to new contexts (Boggan et al., 2010).

Effectiveness of Learning

Hidayah et al., (2021) stated, “the use of manipulatives is still limited to the use of classical and group learning. The students, therefore, could not repeat the math manipulatives instruction by themselves after class” (p. 539). The manipulatives' nature allows students to manipulate them in order to learn certain ideas. It is necessary to have manipulatives, but it is also important to know how to utilize them appropriately in a well-designed learning experience.

Manipulatives, like any other educational instrument, may aid or impede learning.

Conclusion

Using manipulatives is of value in the mathematics classroom, especially when students are making their own connections to problem-solving in relation to mathematical concepts.

When teaching mathematics, educators who are aware of their students' competency levels can

effectively scaffold content. To do so, teachers must first comprehend how their students think and why they think that way. Mathematical knowledge acquisition in early learners is dependent on student-centered mathematics education; consequently, educators should endeavor to provide a mathematically rich atmosphere in which children critically explore concepts, solve problems, and openly discuss their thoughts. Teachers who use tangible manipulatives effectively in their classrooms can have a favorable impact on their students' arithmetic skills. When it comes to employing manipulatives in the classroom, the advantages are infinite. The use of these tools enhances students' learning experiences, bridges the gap between the physical and abstract, and, ultimately, fosters life-long learning in curious young learners.

References

Belenky, D. M., & Nokes, T. J. (2009) Examining the role of manipulatives and metacognition on engagement, learning, and transfer. *The Journal of Problem Solving, 2*(2), 6. DOI: 10.7771/1932-6246.1061

Berk, E. G. (1999). Hands-on science: Using manipulatives in the classroom. *Principal*, *78*(4), 52.

Boggan, M., Harper, S., & Whitmire, A. (2010). Using manipulatives to teach elementary mathematics. *Journal of Instructional Pedagogies, 3*(1), 1-6.

Carbonneau, K. J., Marley, S. C., & Selig, J. P. (2013). A meta-analysis of the efficacy of teaching mathematics with concrete manipulatives. *Journal of Educational Psychology*, *105*(2), 380.

Cockett, A., & Kilgour, P. W. (2015). Mathematical manipulatives: Creating an environment for understanding, efficiency, engagement, and enjoyment. *Teach Collection of Christian Education*, *1*(1), 5.

D'angelo, F., & Iliev, N. (2012). *Teaching mathematics to young children through the use of concrete and virtual manipulatives* (ED534228). ERIC. https://files.eric.ed.gov/fulltext/ED534228.pdf

Hidayah, I., Isnarto, Masrukan, Asikin, M., & Margunani. (2021). Quality management of mathematics manipulative products to support students' higher order thinking Skills. *International Journal of Instruction*, *14*(1), 537–554.

Horan, E., & Carr, M. (2018). How much guidance do students need? An intervention study on kindergarten mathematics with manipulatives. *International Journal of Educational Psychology*, *7*(3), 286–316.

Hurst, C., & Linsell, C. (2020). Manipulatives and multiplicative thinking. *European Journal of STEM Education*, *5*(1), 04.

Keiler, L.S. Teachers' roles and identities in student-centered classrooms. *IJ STEM Ed, 5*, 34 (2018). https://edtechbooks.org/-TrXd

McDonough, A. (2016). Good concrete activity is good mental activity. *Australian Primary Mathematics Classroom, 21*(1), 3–7.

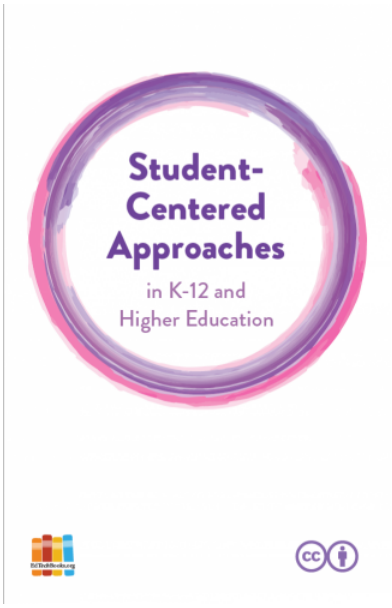
Ojose, B. (2008). Applying Piaget's theory of cognitive development to mathematics instruction. *The Mathematics Educator*, *18*(1), 26-30.

Stapleton, T. J. (2014). Multi-sensory, hands-on manipulatives and adult ESL. *NAMTA Journal*, *39*(3), 153-169.

Stephan M. (2014) Learner-centered teaching in mathematics education. *In: Lerman S. (eds) Encyclopedia of Mathematics Education.* Springer, Dordrecht. https://edtechbooks.org/-wVNq

Tirosh, D., Tsamir, P., Barkai, R., & Levenson, E. (2018). Engaging young children with mathematical activities involving different representations: Triangles, patterns, and counting objects. *Center for Educational Policy Studies Journal*, *8*(2), 9–30.

Uttal, D. H., Scudder, K. V., & DeLoache, J. S. (1997). Manipulatives as symbols: A new perspective on the use of concrete objects to teach mathematics. *Journal of Applied Developmental Psychology*, *18*(1), 37-54.



Dinsmoor, K. (2022). Math Manipulatives. In S. L. Mason (Ed.), *Student-Centered Approaches in K-12 and Higher Education*. EdTech Books. https://edtechbooks.org/student_centered/math_manipulatives