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The Effect of Numicon-based Intervention on Middle School Students' Mathematics Anxiety, Motivation, and Self-efficacy

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Abstract

The literature has frequently emphasized that learning yields meaningful results in environments where instructional methods involving concrete materials are used. This research aimed to examine the effect of intervention using the Numicon concrete material in the learning area of "Numbers and Operations" on sixth-graders' mathematics anxiety, motivation, and self-efficacy. A quasi-experimental design with pre-test and post-test control groups was used in this research that employed methods based on a quantitative approach. The data collection tools were scales for mathematics anxiety, motivation, and self-efficacy. The data analysis was performed using non-parametric tests, specifically the Mann-Whitney U test and the Wilcoxon signed-rank test. It was concluded that the intervention supported by the Numicon concrete material was effective in reducing mathematics anxiety and increasing mathematics self-efficacy among the experimental group students, but it was not effective in increasing their mathematics motivation.

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Introduction

In today's world, problems are constantly evolving and becoming more complex, thus challenging individuals to find solutions. Societies, on the other hand, suggest that solution-oriented individuals also produce creative outputs. This makes the type of individuals needed different. Therefore, new approaches are being adopted in education. In line with new approaches in mathematics education, student-centered programs in which individuals can construct and use knowledge in their minds are being developed (Ministry of National Education [MoNE], 2018; National Council of Teachers of Mathematics [NCTM], 2000). For individuals to understand the abstract structure of mathematics, to reason, and to see the reflections of what they have learned in their lives to create new knowledge, a meaningful mathematics learning and teaching experience is required. On the other hand, despite the importance of mathematics in human life, many students experience difficulties in understanding and doing mathematics, as reported by studies in the literature. Among the significant factors identified in studies investigating the reasons for these difficulties are the fear and anxiety students feel toward mathematics.

The most commonly used definition of mathematics anxiety is feelings of tension and anxiety that interfere with the manipulation of numbers and solving of mathematics problems in a variety of ordinary life and academic situations (Richardson & Suinn, 1972). According to Tobias and Weissbrod (1980), mathematics anxiety is panic, helplessness, and mental disorganization that arise while solving a mathematical problem. Willis (2010, as cited in Ruff & Boes, 2014) indicated that the emotional reactions of a student with mathematics anxiety can shut down the working memory necessary for learning and problem-solving, summarizing this condition as when students are stressed, they can't use their thinking brains. Wong (2005, as cited in Spangenberg, 2018) defines mathematics anxiety as the fear of any contact with mathematics, including communication with the mathematics teacher, written work, and evaluations. Ashcraft and Moore (2009) describe it as a negative emotional response to situations involving numbers and mathematical calculations. According to Fennema and Sherman (1976), mathematics anxiety is a strong sense of worry and fear experienced when the possibility of dealing with a math problem arises. Butterworth (1999, as cited in Bekdemir, 2010) believes that the cause of anxiety and hesitation is a lack of understanding and that understanding-based learning is much more effective than practice and drills.

Research has shown that mathematics anxiety negatively affects learning. In this context, schools and teachers in particular have important responsibilities. The methods used in mathematics teaching and teachers' approaches directly impact students' interests and curiosity in the subject. According to Singh et al. (2002), a student's performance in mathematics is related to factors such as attitude, strong desire, and motivation. These factors are also influenced by self-efficacy beliefs (Ordonez-Feliciano, 2009). Self-efficacy is defined as a generative capability in which cognitive, social, emotional, and behavioral sub-skills must be organized and effectively orchestrated to serve innumerable purposes (Bandura, 1997). When individuals believe that what they will do will not provide the desired results, they feel very little inclination to deal with difficult situations, hence their beliefs about self-efficacy affect their motivation and success (Pajares et al., 2007, as cited in Ordonez-Feliciano, 2009). Motivation is the degree of persistence in taking action and striving to achieve a goal (Adler et al., 2001). Mathematics motivation refers to a student's willingness to learn mathematics and actively participate in mathematical activities (Ispir et al., 2011). The view that motivation affects learning (Glynn et al., 2005) is supported by Palmer's (2007) observation that motivated students are attentive, take responsibility for their tasks, ask questions, and seem to be happy and willing to volunteer answers. Individuals' beliefs about what they can do also influence their goal-setting processes, interest in different tasks, and motivation (Ordonez-Feliciano, 2009).

Mathematics anxiety, self-efficacy, and motivation are among the factors that influence our understanding of mathematics. Additionally, the abstract nature of mathematics, its cumulative progression, and its unique rules cause difficulties for many students at every educational level. According to McCarthy (2009), one reason why students fail to develop mathematical concepts and meanings at the elementary level is that instructional techniques are not designed to promote their conceptual development, problem-solving, and higher-order thinking. Therefore, it is crucial to use concrete instructional materials that facilitate mathematics learning as well as employ methods and techniques that eliminate mathematics anxiety, increase motivation and self-efficacy, and provide knowledge to be constructed by students in learning environments. NCTM (2000) recommends using concrete materials to engage students actively in the process of mathematics learning. Concrete instructional materials are objects used to make abstract mathematical concepts tangible and easier to understand (Moyer, 2001). Objects specifically designed to represent mathematical concepts or real-life items can be used as concrete materials (Van de Walle et al., 2014). In this study, which arose from the understanding that to comprehend mathematics, students need to be interested in the subject, free from anxiety, and confident in their ability to succeed, was it aimed to examine the effect of an intervention supported by the Numicon concrete material in the subjects of operations with whole numbers and operations with fractions.

Definition and Characteristics of the Numicon Material

The Numicon concrete material, which has started to be used in mathematics teaching in recent years, has been defined in multiple ways based on the results of

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researchers' studies. These definitions highlight minor differences in addition to the common characteristics of Numicon depending on its features and the sample group of the research. It is noted that Numicon, first used in the United Kingdom, was designed to be implemented in coordination with mathematics teaching programs (Jenkins, 2013; Oxford University Press, 2024). Some of the definitions of the Numicon material are as follows.

According to Wing and Tacon (2007), Numicon is A multi-sensory approach to arithmetic teaching that uses patterns that are structured to encourage the understanding of number and number relationships. The abstract nature of the concept of numbers makes it difficult for children to comprehend the relationships between numbers and to develop mental representations. The multi-sensory system of Numicon breaks down each step used in teaching abstract numerical concepts and their relationships into small steps. This helps each student learn at his/her own pace and facilitates learning through visualization thanks to the characteristics of the material. Numicon is a multi-sensory system designed with a visual approach in multi-level sets for various mathematical skills, from early number awareness to multiplying and dividing, for developing number sense, such as counting and recognizing numbers (Atkinson et al., 2008; Nye et al., 2005; Oxford University Press, 2024). Numicon is a mathematics learning system that uses colored shapes to represent numbers and help children visualize mathematical concepts. The system is based on the principle that all children are born with an innate understanding of numbers, which can be developed through concrete, visual experiences (Oxford University Press, 2024). By providing information about position, action, pattern, color, and shape with the patterns it uses, Numicon aims to develop children's number concept (Ewan & Mair, 2002). Numicon uses a structured visual representation to explain the fixed order of the number system, that the "next" number is "one more", and how different numbers are related. Thus, it helps children explore mathematical concepts and understand key concepts such as addition, subtraction, ordering, and place values (Oxford University Press, 2024). Numicon consists of interlocking colored plastic shapes with different numbers of holes or perforated cells representing the physical magnitude of numbers from 1 to 10, colored pegs, and baseboards. The structure of Numicon demonstrates the patterns and relationships in the number system (Nye et al., 2005). Each plate of Numicon has a unique shape and pattern. The tactile awareness of the shapes develops students' awareness that the quantity remains the same even if the shape changes in orientation. It provides important information about the relationships of numbers to one another, such as bigger, smaller, and in between, even when they are not provided by the written numeral (Ewan & Mair, 2002). The shapes and plates in Numicon support permanent learning in children by facilitating the understanding of the relationship between the physical quantity represented by various numbers and the numbers themselves. A child who sees the plates in sequence will understand that six is two threes and five is one more than four. It is also quite easy to see whether a number is odd or even from each plate of Numicon. The fact that each plate has a different color serves as a cue about the identity of the plate in the early stage of learning (Ewan & Mair, 2002). On the other hand, the value of Numicon is evident in teaching activities planned to extend the number concept and number understanding from concrete to abstract (Atkinson et al., 2008). The pairing of numbers with colors and shapes is assumed to encourage mental imagery. One of the key features of the Numicon system is that it provides visual representations of whole numbers, thereby helping to develop mental imagery related to numbers and supporting mental arithmetic (Oxford University Press, 2024). Through the use of Numicon, children embed the number concept in their minds more firmly and richly, understand mathematics, enjoy it, and become motivated (Ewan & Mair, 2002; Nye et al., 2005).

Numicon is considered to be a concrete material and an approach that can be used for teaching mathematics in elementary and middle schools. According to Forder (2016), Numicon, developed by Oxford University Press, is a widely used and valuable tool employed by teachers worldwide to help children develop their mathematical and arithmetic skills. By using the plates in Numicon, it is possible to learn operations with whole numbers, fractions, decimal representations of given numbers, and percentage calculations. Figure 1 includes visuals related to the plates and shapes of the Numicon material, writing a two-digit number with Numicon shapes, the representation of unit fractions and simple fractions, and the addition of two numbers.

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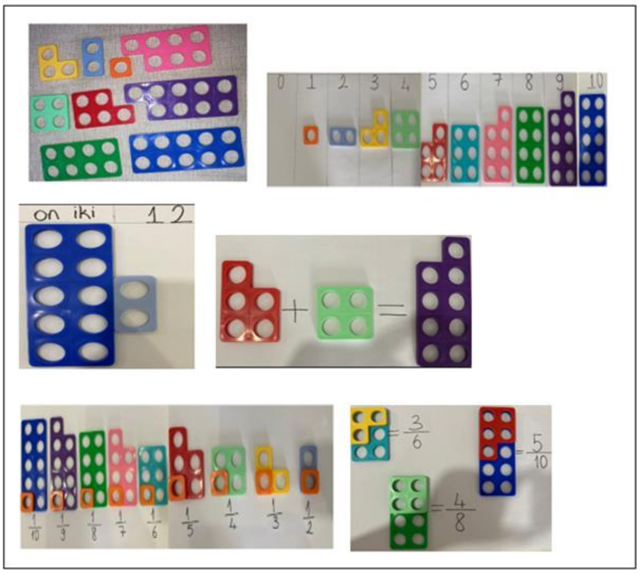

Figure 1. Visuals regarding numicon plates, addition, and fraction models

The Introduction and Theoretical Background of Numicon

The Numicon approach was first implemented in mainstream schools in the United Kingdom in 1996 to support children of all ages and abilities. Its significant success led to its use in the Wiltshire project for children with Down syndrome (Wing & Tacon, 2007). The use of the Numicon concrete material, known as a multi-sensory system, in mathematics teaching is based on the foundations of a project conducted by Tacon and et al. (2004). Based on their project aimed at children with Down syndrome, Nye and et al. (2005) revealed that children using Numicon showed better progress compared to those who did not. They noted that, in the project, the Numicon system allowed teaching staff to see what children were thinking, thereby gaining insights into their understanding and confusion, which positively influenced the learning process. Furthermore, they reported that the Numicon material captured children's interest, which helped them develop self-confidence and motivation to be successful in mathematics. The positive effects of the Numicon system were observed not only in children with special educational needs but also in all children in terms of acquiring mathematical skills. As a result, the system began to be implemented in all schools (Wing & Tacon, 2007).

The Numicon multi-sensory system is based on constructivist theory in terms of learning theories. Constructivist theory focuses on how individuals construct and process knowledge in their minds. According to Kubiak (2017), the construction of knowledge in the mind occurs through a network of neural connections. Direct participation in the learning process, an activity of the learner, is necessary for the establishment of these neural connections. Similarly, Fosnot (1996, as cited in Kubiak, 2017) states that learning should be understood as a complex and non-linear process rather than a linear one. In this context, it can be mentioned that the Numicon system is a multi-sensory method produced based on the foundation of constructivist theory (Kubiak, 2017).

Studies Conducted Using Numicon

When the literature on the use of Numicon is analyzed, it is seen that studies are generally conducted on students with Down syndrome. The studies primarily focus on developing students' number sense (Buckley, 2007; Ewan & Mair, 2002; Nye et al., 2005; Santos et al., 2022). These studies report improvements in recognizing numbers, performing operations with numbers, solving problems, using the number line, telling time from a digital clock, and counting from 1 to 100 among students with difficulties in learning mathematics. Additionally, there are a few studies involving students with low mathematical performance (Wing & Tacon, 2007), students with intellectual disabilities (Krauce, 2019; Todorova & Eyubova, 2018), or Down syndrome students (Santos et al., 2022) as well as typically developing students (Skevington, 2016). Studies on students with low mathematical performance or Down syndrome typically examine the effect of the Numicon system on teaching fundamental arithmetic and number concepts (Buckley, 2007; Churches, 2016; Skevington, 2016), its impact on developing number sense and number skills, and which characteristics of Numicon improve number sense (Rinaldi et al., 2020). These studies show that the use of the Numicon system helps improve the basic arithmetic and number skills, number sense, and number concepts of typically developing students, students with low mathematical performance, and students with Down syndrome (Buckley, 2007; Ewan & Mair, 2002; Jenkins, 2013; Nye et al., 2005; Santos et al., 2022; Tacon et al., 2004). It also aids in language development (Ewan & Mair, 2002) and enriches concept images (Ewan & Mair, 2002), enhances mathematical performance (Tacon et al., 2004), boosts motivation (Churches, 2016; Kubiak, 2017), and improves self-confidence (Churches, 2016; Kubiak, 2017) and self-esteem (Wing & Tacon, 2007). The sample group in studies using the Numicon multi-sensory system are generally preschool (Jenkins, 2013; Kubiak, 2017; Todorova & Eyubova, 2018) and primary school students (Kubiak, 2017; Skevington, 2016).

Churches (2016) conducted the only randomized controlled trial examining the effect of using Numicon on the number cognition of students aged 5-10 who perform poorly in mathematics. The study found a moderate significant improvement effect in favor of the post-test, indicating that students' mathematical achievement, self-confidence, and motivation increased. This study by Churches (2016) is significant as it provides evidence that color-coded tools like Numicon can contribute to the theory explaining the benefits of mathematical manipulatives in teaching (Rinaldi et al., 2020).

Nye and others (2005) aimed to develop number skills and teach simple mathematical operations that facilitate daily life for children with Down syndrome using Numicon, based on a new visual technique. Their findings indicated that children with Down syndrome who used Numicon made better progress in number skills compared to those who did not use it, although the difference was not statistically significant. However, the study highlighted significant outcomes regarding the increase in motivation and self-confidence among children with Down syndrome who used Numicon. This positive impact is attributed to the engaging nature of Numicon shapes and apparatus, which motivate children to interact with Numicon and build self-confidence in their mathematical studies upon achieving success. In addition, Nye and others (2005) also noted that Numicon is beneficial for non-Down syndrome students as well, enhancing their number and mathematical understanding. According to Kubiak (2017), using Numicon effectively develops mathematical skills in both healthy and special education students, boosting their self-confidence and motivation. Wing and Tacon (2007) further support this, stating that the Numicon system is particularly helpful for students struggling with mathematics and that its usage increases their self-esteem.

Buckley (2007) states that the Numicon approach is beneficial and enjoyable for teaching basic arithmetic and numbers to children with Down syndrome. According to Buckley, the Numicon approach provides many fun ways to help each child learn about the world of numbers. Santos and others (2022) also revealed that using Numicon positively impacts the development of number sense in children with Down syndrome. They emphasize that Numicon, due to its visual, spatial, and tactile characteristics, activates mental processes involved in constructing number sense. This makes it an inclusive material beneficial not only for children with Down syndrome but for all children. Supporting this conclusion, Tacon and others (2004) found that normally developing elementary school students showed significantly improved performance on standard tests and richer, more robust mental representation of number concepts after using Numicon. Skevington (2016) highlights in his study that using Numicon with fifth-grade students helped them grasp the division of whole numbers and the concept of fractions, as well as enhanced verbal communication among the students.

Todorova and Eyubova (2018) conducted a study using the Numicon method to help preschool children with intellectual disabilities discover relationships between numbers and solve numerical problems in their daily lives. Krauce (2019) reported that students with moderate intellectual disabilities made significant improvements in acquiring basic mathematics and communication skills thanks to the Numicon method. Jenkins (2013) implemented teaching activities using the Numicon material to enhance number sense among kindergarten students with varying degrees of mathematics learning difficulties. The study concluded that Numicon could be effectively used as an educational tool in a classroom or small group setting for such students. Rinaldi and others (2020) emphasized the importance of identifying which characteristics of Numicon aid in developing number sense. Their study focused on the Numicon and Numberjack materials, which match colors with size and numerals, respectively. The study group was categorized into those who internalized the colors and those who did not among the users of both colored materials. In this study conducted with children aged 6-10 using Numicon, which includes colored shapes representing quantities, and Numberjack, which includes colored numbers, it was found that children using both colorful educational tools performed better than their peers in numerical tests. However, they did not show the same level of achievement in mathematics tests.

The Importance of the Study

The use of concrete materials supports learning in mathematics education. Rendering the abstract structure of mathematics tangible and visual through materials particularly captures the interest of young students and helps them comprehend mathematical concepts. The findings from Churhes' (2016) study on young children with low performance in mathematics using Numicon are highly significant. The study demonstrated improvements in students' mathematical achievements, self-confidence, and motivation. Churhes' (2016) study suggests that color-coded tools like Numicon could contribute as manipulatives in mathematics education (Rinaldi et al., 2020). Similarly, studies using Numicon often aim to enhance number cognition and number sense among young students who face learning difficulties in mathematics (Jenkins, 2013; Wing & Tacon, 2007), those with Down syndrome (Buckley, 2007; Nye et al., 2005; Santos et al., 2022), or intellectual disabilities (Krauce, 2019;

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Todorova & Eyubova, 2018). Studies indicate that, at the end of the interventions, these students' motivation increased, their interest in the application grew as the material was engaging, and their self-confidence and self-esteem improved. Apart from a few studies evaluating both students with Down syndrome and normally developing students (Skevington, 2016; Tacon et al., 2004), no studies demonstrate the outcomes of using Numicon with normally developing students. Based on the perspective that Numicon is beneficial not only for students experiencing difficulties in learning mathematics or those with Down syndrome (Kubiak, 2017; Nye et al., 2005; Wing & Tacon, 2004), this research was conducted with normally developing sixth-grade students. Studies have shown that students struggle to understand mathematics from preschool to university levels, and as they progress to higher grades, they tend to drift away from mathematics classes. One reason for this is that students often fail to develop mathematical concepts and meanings at the elementary school level, and instructional techniques are not designed to promote conceptual development, problem-solving, and higher-order thinking (McCarthy, 2009). The most crucial duty of a teacher is to make the learning environment and students ready for the learning context. Besides using methods and techniques that eliminate or reduce mathematics anxiety, enhance motivation, and foster self-efficacy in learning environments where knowledge is constructed by students, employing concrete instructional materials that facilitate mathematics teaching is also highly important. According to Çelik (2007), concrete instructional materials make learning more enduring and meaningful by appealing to multiple senses of students. Based on this premise, it was aimed in this research to investigate the effect of using the concrete instructional material Numicon in mathematics teaching on mathematics anxiety, motivation, and self-efficacy of sixth-grade students at the normally developing level. Numicon is typically used to facilitate daily life and perform simple mathematical operations for students with Down syndrome and for those experiencing difficulties in learning mathematics. However, it is hypothesized that it could also be beneficial in mathematics education for all students, including middle school students. Therefore, this study was carried out to explore the potential benefits of using Numicon in mathematics teaching for middle school students. Thus, this research is expected to contribute to the relevant literature in this area. The research problem and sub-problems are presented below.

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Research Problem

What is the effect of intervention supported by the Numicon material on sixth-grade students' mathematics anxiety, mathematics motivation, and mathematics self-efficacy?

Sub-Problems of the Research

1. Is there a statistically significant difference between the scores obtained from the mathematics anxiety scale (MAS) by the experimental group (EG) students who received explanatory instruction supported by the Numicon material and by the control group (CG) students who received solely explanatory instruction?
2. Is there a statistically significant difference between the scores obtained from the mathematics motivation scale (MMS) by the EG students who received explanatory instruction supported by the Numicon material and by the CG students who received solely explanatory instruction?
3. Is there a statistically significant difference between the scores obtained from the mathematics self-efficacy scale (MSS) by the EG students who received explanatory instruction supported by the Numicon material and by the CG students who received solely explanatory instruction?
4. Is there a statistically significant difference between the pre-test and post-test scores on the mathematics anxiety, mathematics motivation, and mathematics self-efficacy scales for the EG students who received explanatory instruction supported by the Numicon material?
5. Is there a statistically significant difference between the pre-test and post-test scores on the mathematics anxiety, mathematics motivation, and mathematics self-efficacy scales for the CG students who received solely explanatory instruction?

Method

Research Model

In the research, a quasi-experimental design with a pre-test and post-test control group was used. In this model, measurements are applied sequentially preceding and following the intervention. This model provides significant statistical power to the researcher regarding the testing of the experimental intervention's effect on the dependent variable, allowing for the interpretation of findings within a cause-and-effect context (Büyüköztürk, 2011). Given that the study aimed to examine the effect of using the explanatory instruction

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supported by the Numicon material on middle school students' mathematics anxiety, motivation, and self-efficacy, this model was deemed appropriate. The study employed an EG and a CG. Table 1 shows the tests administered to both the experimental and control groups during the study period. The EG received explanatory instruction supported by the Numicon material, while the CG received solely explanatory instruction as recommended in the current curriculum (MoNE, 2018). The experimental design of the study is presented in Table 1.

Table 1. Experimental model of the research

	Pre-Test			Implementation	Post-Test		
	MAS	MMS	MSS		MAS	MMS	MSS
EG (N=14)	✓	✓	✓	Intervention through Explanatory Instruction Supported by the Numicon Material	✓	✓	✓
CG (N=15)	✓	✓	✓	Solely Explanatory Instruction	✓	✓	✓

In the research, appropriate data analysis techniques were used to conduct both inter-group (EG and CG) and intra-group (pre-test post-test) measurements (Büyüköztürk, 2019). The independent variable of the study is the intervention supported by the Numicon material, while the dependent variables are students' mathematics anxiety, mathematics motivation, and mathematics self-efficacy.

Study Group

The study group of this research consisted of sixth-grade students studying at a public middle school affiliated with the Ministry of National Education in a province located in the Western Black Sea Region of Türkiye. A convenience sampling method was employed in the research. The EG and the CG were determined by drawing lots using the existing groups. There were 14 students in the EG and 15 students in the CG. The students participated voluntarily in the research. To provide confidentiality, codes were used instead of the real names of the students. The school, where the intervention was made, had three sections of sixth-grade students. Since a convenience sampling method was employed, the classes of a mathematics teacher who stated that she could assist with the research and who had two sixth-grade sections were included in the study. Having the same teacher for both sections where the research was conducted is also important to avoid teacher-related factors' affecting the research results. Additionally, an analysis of the pre-test scores of the EG and CG on the mathematics anxiety, mathematics motivation, and mathematics self-efficacy scales showed that the two groups were equivalent in this context. An intervention was performed in the EG using the concrete material Numicon as well as the explanatory teaching method recommended by the mathematics curriculum (MoNE, 2018). In other words, the instruction in the EG was supported by the use of Numicon. The CG, on the other hand, received instruction solely through the explanatory teaching method recommended by the mathematics curriculum (MoNE, 2018). While the researchers performed the intervention in the EG, the current teacher taught in the CG following the normal procedure (explanatory teaching method). No other interventions were made in the CG.

Data Collection Tools

To gauge the effect of the implemented method on the mathematics anxiety of sixth-grade students, the *MAS* was utilized. The *MMS* was employed to evaluate its effect on mathematics motivation, and the *MSS* was used to measure its impact on mathematics self-efficacy. Each scale was administered twice to both the experimental and control groups, once before the intervention and once after it. Table 2 presents details about the data collection tools.

Table 2. Information about names and features of the data collection tools

		Scale Name		
		MAS (see. Annex 1)	MMS (see. Annex 2)	MSS (see. Annex 3)
Features	Purpose	To measure mathematics anxiety level	To measure motivation toward mathematics	To measure mathematics self-efficacy
	Developer	Bindak (2005)	Üzel et al. (2018)	Umay (2002)
	Scale Type and Number of Items	5-point Likert / 10 items (9 positive - 1 negative)	5-point Likert / 26 items (18 positive - 8 negative)	5-point Likert / 14 items (8 positive - 6 negative)
	Options	Always, Often, Sometimes, Rarely, Never	Strongly agree, Agree, Neutral, Disagree, Strongly disagree	Always, Often, Sometimes, Rarely, Never
	Cronbach's Alpha Coefficient	0.84	0.88	0.88
	The Minimum and Maximum Scores That Can Be Obtained	$1 \leq$ score ≤ 5 / $10 \leq$ score ≤ 50	$1 \leq$ score ≤ 5 / $26 \leq$ score ≤ 130	$1 \leq$ score ≤ 5 / $14 \leq$ score ≤ 70

from Each Item and In Total on The Scale			
Scoring	The negative items are scored as 5-4-3-2-1, while the positive items are scored as 1-2-3-4-5.	The positive items are scored as 5-4-3-2-1, while the negative items are scored as 1-2-3-4-5.	
Meaning of the Score	A high score indicates high mathematics anxiety.	A high score indicates high mathematics motivation.	A high score indicates high mathematics self-efficacy.

Implementation Process

Implementation based on the learning outcomes of the Operations with Whole Numbers and Operations with Fractions sub-areas of the Mathematics Curriculum (MoNE, 2018) was carried out in both groups. Sample learning outcomes of the lesson subject and the duration of the implementation are given in Table 3.

Table 3. Sample outcomes of the lesson subject and the duration of the implementation

Sample Outcomes of the Lesson Subject	Implementation Duration / Total Lesson Period
The student can solve and construct problems requiring arithmetic operations with whole numbers. The student can compare, order, and represent fractions on the number line. The student can perform addition and subtraction operations with fractions. The student can perform and interpret the multiplication of a whole number by a fraction. The student can perform and interpret the multiplication of two fractions. The student can solve problems that necessitate operations with fractions.	A total of 25 lesson periods over 5 weeks, with 5 periods per week

It is recommended in the Mathematics Curriculum that the explanatory teaching method and techniques that are based on this method be used in mathematics lessons (MoNE, 2018). In practice, the approach suggested by the current mathematics curriculum, which is Ausubel's (1963) meaningful learning from the learner's perspective and expository teaching from the teacher's perspective, was utilized. This method is related to the learners making meaning from the material presented to them (Ausubel, 2000). In this process, the teacher should select, organize, and make the content meaningful for the learner, and he/she should present and explain it with various materials. The contents prepared by the learning outcomes using the explanatory teaching method were implemented in both groups. This implementation is a teaching practice that follows the normal standard procedure. In addition to this practice, the presentation of the content in the EG was supported by the use of Numicon concrete material. The only difference between the implementation in the two groups was the use of Numicon in the EG.

For the EG, activities that necessitate the use of the Numicon material were prepared by the researchers in line with the learning outcomes of the subject. Opinions from two faculty members who are experts in the field of mathematics education were obtained for these activities, and necessary adjustments were made accordingly. All necessary permissions and ethical committee approvals required for the implementation were obtained. EG students and the teacher were informed about the upcoming intervention, and the Numicon concrete material was introduced. Subsequently, the intervention was started in the EG. No interventions were made to the CG except for the teaching that followed the normal standard procedure. At the beginning and end of the implementation, MAS, MMS, and MSS tests were administered to both groups as pre-tests and post-tests, and the process was completed. Examples from the intervention performed using Numicon in the EG are provided below.

Examples from the Intervention Performed Using Numicon

During the intervention made with the use of the Numicon material in the EG, the students were observed by the researchers, and they were asked to explain their answers during the activities. It was observed that they developed different solution strategies and achieved solutions during the activities. Below are some examples of the students' activities and explanations that emerged from the discussions.

In Figure 2, a student's response, where he arranged the fractions 5/8, 1/8, and 3/8 in an ascending order using Numicon, is shown. The student modeled the 8-celled green shape representing the denominator, the 1-celled orange shape representing the numerator for 1, the 3-celled yellow shape representing the numerator for 3, and the 5-celled red shape representing the numerator for 5. Since the fractions have equal denominators, the student ordered the fractions from the smallest to the greatest based on the number of orange, yellow, and red cells placed on top of the green shapes.

Figure 2. The student's response ordering the fractions from the smallest to the greatest using numicon

In the activity in Figure 3, the student was asked to find the sum of two fractions with equal denominators using Numicon. As shown in Figure 3, the student first placed the 7-celled pink shape representing the number 7 on the ground to model the fraction 5/7 using Numicon shapes. The student referred to this shape as the *denominator*. Then, for the number 5 in the numerator, the student placed the 5-celled red shape on top of the 7-celled pink shape. Similarly, the student modeled the fractions 1/7 and the resulting fraction 6/7. For this, the student used the 7-celled pink shape representing the *denominator*, and the 1-celled orange shape and the 6-celled green shape representing the *numerator*. In the response, the student modeled the sum of the two fractions by combining the orange and red Numicon shapes to form the 6-celled green shape, representing this as the *numerator* of the resulting fraction. Thus, 6 cells of the 7-celled pink *denominator* on the ground were modeled as green cells. Using this modeling with Numicon shapes, the student found the sum of the fractions 5/7 and 1/7 as 6/7.

Figure 3. The response of the student modeling the sum of two fractions with equal denominators using numicon

In the activity in Figure 4, the student was asked to find the result of multiplying the fractions 2/3 and 7/8 using Numicon.

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Figure 4. The response of the student modeling the multiplication of two fractions using numicon

In the activity in Figure 4, the student was initially asked to place the 3-celled yellow shape on the ground to represent the number 3. The student referred to this shape as the *denominator*. Then, the student placed the 2-celled gray shape representing the *numerator* 2 on top of the 3-celled yellow shape to model the fraction 2/3. Similarly, the student modeled the fraction 7/8 by using the 8-celled green shape and the 7-celled pink shape. The student stated that 24 was found by multiplying the numbers 3 and 8 in the denominators. Then, to represent the denominator, the student placed two 10-celled blue shapes and one 4-celled green shape on the ground, making up 24. For the numerator, the student placed one 10-celled blue shape and one 4-celled green shape on top of the denominator shapes representing 24. By counting the cells placed on top of the denominator, the student found 14/24. In this activity, several students reported finding the result by using a different solution strategy after similarly modeling the fractions 2/3 and 7/8. In discussions with these students, they explained their answers as follows: one student created three models of the fraction 7/8 and counted the cells, considering the total of 24 cells as the denominator. The student then took two of the three models of 7/8, counted the filled cells, and wrote 14 cells as the numerator. Thus, they modeled the result as 14/24. An example response from one of the students is illustrated in Figure 5. It can be said that the student who can perform this reasoning has achieved a conceptual understanding of the multiplication of fractions. The students also achieved multiplying the fractions 3/5 and 3/8 in a similar way.

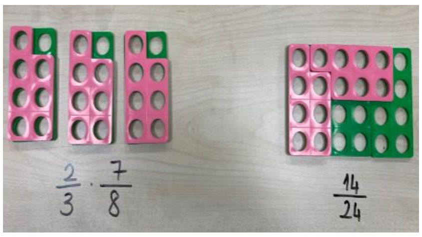

Figure 5. The student's response modeling the multiplication of the fractions 2/3 and 7/8 using a reasoning strategy

Examples of models created by the students to find the multiplication of the fraction 3/5 by 3/8 can be seen in Figure 6. In the response on the left side of Figure 6, it is seen that the student found a solution similar to the one explained in Figure 5.

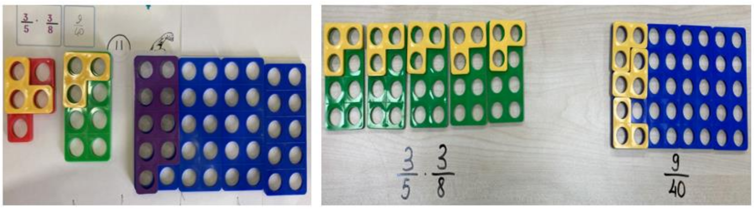

Figure 6. The responses of the students modeling the multiplication of the fractions 3/5 and 3/8

In the activity shown in Figure 7, the student was asked to find the result of multiplying a fraction by a whole number using Numicon.

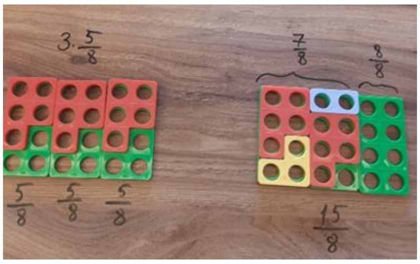

Figure 7. The student's modeling and answer for the operation 3.5/8

In Figure 7, the student first modeled the fraction 5/8 by using an 8-cell green and a 5-cell red Numicon shape. Since the task involved multiplying 5/8 by 3, the student created 3 models of the fraction 5/8. Subsequently, the student noticed the empty cells in the 8-cell shapes designated as the denominator, and considered completing the empty cells in the two 8-cell green shapes with the 5-cell red shapes found in the other green shape. Thus, the student transferred the 5-cell red shape from one model of 5/8 to the empty green cells in the other two models. Finally, the student placed one 5-cell red shape and a 3-cell yellow shape on one of the 8-cell green shapes, and a 2-cell blue shape, and another 5-cell red shape on the other 8-cell green shape. The student expressed the remaining 8-cell shape as 8/8. Later on, by counting the shapes placed on the green shapes, the student wrote the result as 15/8.

In Figure 8, a fraction problem is shown. The student was asked to solve this problem using Numicon. The problem is as follows: In a class, 2/7 of the students are fans of Beşiktaş, 2/7 are fans of Fenerbahçe, and 2/7 are fans of Galatasaray football teams. 3 students are fans of other football teams. What is the total number of students in the class?

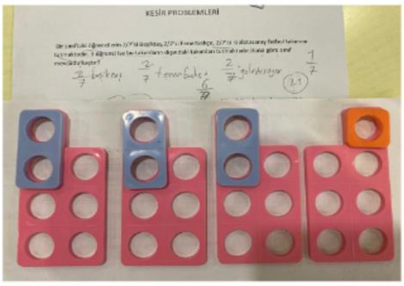

Figure 8. The answer of a student who solved a fraction problem by creating a model with numicon

In Figure 8, the student's solution is presented. In the discussion, the student explained the answer as follows: Initially, a model was created to represent the fraction 2/7 using the Numicon shapes by each team. Then, a 6-cell shape was placed on top of a 7-cell pink shape by considering filling the gaps in one shape with those from others. It was indicated that the remaining 1-cell shape in the 7-cell shape represented the 3 students mentioned in the problem. It was deduced that this 1-cell shape corresponded to the number 3. 3 was multiplied by the total of 7 cells representing the class size and the class size was found as 21.

In Figure 9, the student modeled a 3-minute conversation using a Numicon shape representing the number 3. Knowing there are 7 days in a week, the student assembled 3-cell shapes for each day, totaling them to represent 7 days. By counting the cells, the student concluded that he spoke for 21 minutes.

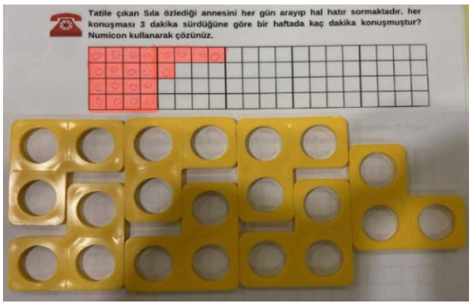

Figure 9. The answer of a student who solved a whole number problem by creating a model with numicon

Some sample photographs from the intervention in the EG are shown in Figure 10.

Figure 10. Sample photographs from the intervention performed using numicon in the EG

Data Analysis

Analysis of Data Obtained from MAS, MMS, and MSS

The data obtained in the study were analyzed using methods based on a quantitative approach. The independent variable of the study was the intervention supported by Numicon, and the dependent variables were the scores that students obtained from MAS, MMS, and MSS. The SPSS 22.00 statistical program was employed for data analysis. When the number of subjects is low, non-parametric statistical methods should be used instead of parametric methods (Büyüköztürk, 2019). Due to the insufficient number of students in the groups, the data analysis was conducted using non-parametric statistics, specifically the Mann-Whitney U test and the Wilcoxon signed ranks test (Büyüköztürk, 2011, 2019). Additionally, the r effect size value was calculated to determine the difference between groups according to Cohen's (1992) classification of small-medium-large effect sizes, using the formula $r = \frac{z}{\sqrt{n}}$ (Corder & Foreman, 2009, as cited in Cevahir, 2020; Karadimitriou & Marshall, n.d.). Effect sizes were classified as small for r values less than 0.30, medium for r values between 0.30 and 0.50, and large for r values of 0.50 and above.

Findings and Comments

In this section, the findings obtained from the data and interpretations are presented.

Descriptive Analysis Results of the Experimental and Control Groups

In Table 4, the means and standard deviations of the pre-test and post-test scores of the EG and CG on the mathematics anxiety, motivation, and self-efficacy scales are provided.

Table 4. Descriptive analysis results of the scores obtained from MAS, MMS, and MSS

Variables/ Scales	Group	N	Pre-test $\bar{X}$	sd	Post-test $\bar{X}$	sd
MAS	CG	15	41.40	6.231	41.20	7.053
	EG	14	44.57	5.402	45.29	7.819
MMS	CG	15	103.87	11.300	104.40	11.507
	EG	14	111.36	15.345	106.14	24.296
MSS	CG	15	49.47	7.210	49.93	9.852
	EG	14	44.50	7.481	59.71	8.042

It can be seen in Table 4 that the post-test mean score of the CG in MAS ($\bar{X}$= 41.20) is lower than their pre-test mean score ($\bar{X}$= 41.40), while the post-test mean score in MMS ($\bar{X}$= 104.40) is higher than their pre-test mean score ($\bar{X}$= 103.87), and the post-test mean score in MSS ($\bar{X}$= 49.93) is higher than their pre-test mean score ($\bar{X}$= 49.47). As for the EG, their post-test mean score in MAS ($\bar{X}$= 45.29) is higher than their pre-test mean score ($\bar{X}$= 44.57), and their post-test mean score in MSS ($\bar{X}$= 59.71) is higher than their pre-test mean score ($\bar{X}$= 44.50), while their post-test mean score in MMS ($\bar{X}$= 106.14) is lower than their pre-test mean score ($\bar{X}$= 111.36). Additionally, it can be seen from Table 4 that the post-test means scores of the EG in MMS ($\bar{X}$= 106.14) and MSS ($\bar{X}$= 59.71) are higher than those of the CG in MMS ($\bar{X}$= 104.40) and MSS ($\bar{X}$= 49.93), but the post-test mean score of the EG in MAS ($\bar{X}$= 45.29) is higher than the post-test mean score of the CG in MAS ($\bar{X}$= 41.20).

Mann-Whitney U Pre-Test Analysis Results Based on the Scores Obtained by the Experimental and Control Groups from MAS, MMS, and MSS

A Mann-Whitney U test was performed to reveal if there was a statistically significant difference between the pre-test scores of the EG students, who received instruction supported by the Numicon material, and the CG students, who received instruction using the explanatory teaching method as recommended by the current curriculum. The findings regarding the analysis are presented in Table 5.

Table 5. Mann-Whitney U pre-test analysis results of MAS, MMS, and MSS for EG and CG

Variables/ Scales	Group	N	$\bar{X}$	sd	Mean Rank	Rank Sum	U	z	p
MAS	CG	15	41.40	6.231	17.67	265.00	65.000	-1.775	.076
	EG	14	44.57	5.402	12.14	170.00			
MMS	CG	15	103.87	11.300	12.37	185.50	65.500	-1.726	.084
	EG	14	111.36	15.345	17.82	249.50			
MSS	CG	15	49.47	7.210	17.93	269.00	61.000	-1.924	.054
	EG	14	44.50	7.481	11.86	166.00			

The Mann-Whitney U test results for the pre-test scores obtained from MAS, MMS, and MSS scales by the EG and the CG are shown in Table 5. Based on this, it was concluded that there was no statistically significant difference between the two groups in MAS (U = 65.000, p > .05), MMS (U = 65.500, p > .05), and MSS (U = 61.000, p > .05). Therefore, it can be stated that the EG and CG were equivalent before the intervention.

Mann-Whitney U Post-Test Analysis Results Based on the Scores Obtained by the Experimental and Control Groups from MAS, MMS, and MSS

The presence of a statistically significant difference between the post-test scores received from MAS, MMS, and MSS by the EG students, who were taught using the Numicon material, and those received by the CG students, who were taught using explanatory instructional methods based on the current curriculum was tested via Mann-Whitney U test. The findings regarding the analysis are shown in Table 6.

Table 6. Mann-Whitney U post-test analysis results of MAS, MMS, and MSS for EG and CG

Variables/ Scales	Group	N	$\bar{X}$	sd	Mean Rank	Rank Sum	U	z	p
MAS	CG	15	41.20	7.053	18.33	275.00	55.000	-2.209	.027
	EG	14	45.29	7.819	11.43	160.00			
MMS	CG	15	104.40	11.507	13.40	201.00	81.000	-1.049	.294
	EG	14	106.14	24.296	16.71	234.00			
MSS	CG	15	49.93	9.852	11.33	170.00	50.000	-2.404	.016
	EG	14	59.71	8.042	18.93	265.00			

Table 6 shows the results of the Mann-Whitney U test regarding the post-test scores obtained from MAS, MMS, and MSS scales by the EG and CG. According to Table 6, a significant difference was found between the MAS post-test scores of the EG students, who received instruction supported by Numicon, and the MAS post-test scores of the CG students, who were taught using explanatory instructional methods based on the current curriculum (U= 55.000, p<.05). With z = -2.209 and n= 29, the identified difference had an effect size of r= 0.41, indicating a moderate effect, and explained 16% of the total variance by the independent variable Numicon concrete material-supported instruction ($r= 0.41$, $r^2= 0.16$). Considering the mean ranks, it was understood that the CG students had higher mathematics anxiety compared to the EG students. This finding suggests that the implementation supported by Numicon was more effective in reducing the mathematics anxiety of the EG students compared to the CG students. Similarly, a significant difference was observed between the MSS post-test scores of the EG students and of the CG students ($U= 50.000$, $p< .05$). With $z= -2.404$ and $n= 29$, the identified difference had an effect size of $r= 0.45$, indicating a moderate effect, and explained 22% of the total variance by the independent variable Numicon concrete material-supported instruction ($r= 0.45$, $r^2= 0.22$). Considering the mean ranks, it was seen that the EG students had higher mathematical self-efficacy compared to the CG students. This finding suggests that the implementation supported by Numicon was effective in increasing the mathematics self-efficacy of the EG students. On the other hand, it is understood in Table 6 that the implementation supported by Numicon did not have a significant effect on increasing the mathematics motivation of the EG students. Furthermore, it is seen that there was no significant difference between the MMS post-test scores of the EG students and the MMS post-test scores of the CG students based on the quasi-experimental study conducted ($U= 81.000$, $p > .05$). This finding indicates that the intervention supported by Numicon was not effective in fostering mathematics motivation of the EG students.

The Wilcoxon Signed-Rank Test Analysis Results Regarding the MAS, MMS, and MSS Scores of the EG

The analyses regarding whether there was a statistically significant difference between the pre-test and post-test MAS, MMS, and MSS scores of the EG students, who received Numicon-supported instruction, were performed using the Wilcoxon signed-rank test. Accordingly, the Wilcoxon signed-rank test results regarding the pre-test and post-test scores of the EG by each scale are presented in Table 7, indicating whether there was a statistically significant difference before and after the intervention.

Table 7. The Wilcoxon signed-rank test results regarding MAS, MMS, and MSS pre-test and post-test scores of the EG students

Variables/ Scales	Posttest-Pretest	N	Mean Rank	Rank Sum	z	p
MAS	Negative Rank	6	4.67	28.00	-.051**	.959
	Positive Rank	4	6.75	27.00		
	Equal	4	-	-		

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MMS	Negative Rank	7	5.71	40.00	-.079**	.937
	Positive Rank	5	7.60	38.00		
	Equal	2	-			
MSS	Negative Rank	2	2.25	4.50	-3.016*	.003
	Positive Rank	12	8.38	100.50		
	Equal	-				

*: Based on negative ranks
**: Based on positive ranks

It is indicated in Table 7 that there was no significant difference between the EG students' pre-test and post-test scores of MAS and MMS. According to this finding, it can be claimed that the instructional practice supported by the Numicon material had no statistical effect on reducing the EG students' mathematics anxiety ($z = -0.051$, $p > .05$) and increasing their mathematics motivation ($z = -0.079$, $p > .05$). On the other hand, Table 7 shows that there was a statistically significant difference between the pre-test and post-test MMS scores of the EG students ($z = -3.016$, $p < .05$). Based on this finding, it can be stated that the implementation supported by the Numicon material had a significant effect on increasing the EG students' mathematics self-efficacy.

The Wilcoxon Signed-Rank Test Analysis Results Regarding the MAS, MMS, and MSS Scores of the CG

The analyses regarding whether there was a statistically significant difference between the pre-test and post-test MAS, MMS, and MSS scores of the CG students, who received explanatory instruction based on the current curriculum (MoNE, 2018), were performed using the Wilcoxon signed-rank test. Accordingly, the Wilcoxon signed-rank test results regarding the pre-test and post-test scores of the CG by each scale are presented in Table 8.

Table 8. The Wilcoxon signed-rank test results regarding MAS, MMS, and MSS pre-test and post-test scores of the CG students

Variables/ Scales	Posttest-Pretest	N	Mean Rank	Rank Sum	z	p
MAS	Negative Rank	8	8.00	64.00	-.227**	.820
	Positive Rank	7	8.00	56.00		
	Equal	-	-	-		
MMS	Negative Rank	7	6.57	46.00	-.796*	.426
	Positive Rank	8	9.25	74.00		
	Equal	-	-	-		
MSS	Negative Rank	7	8.14	57.00	-.170*	.865
	Positive Rank	8	7.88	63.00		
	Equal	-	-	-		

*: Based on negative ranks
**: Based on positive ranks

It is reflected in Table 8 that there was no statistically significant difference between the CG students' pre-test and post-test scores regarding the mathematics anxiety (z= -0.227, p>.05), mathematics motivation (z= -0.796, p>.05), and mathematics self-efficacy (z= -0.170, p>.05). According to this finding, it can be said that the implementation conducted with explanatory instruction as recommended by the current curriculum had no statistical effect on reducing the CG students' mathematics anxiety, fostering their mathematics motivation, and enhancing their mathematics self-efficacy in CG students.

Conclusion, Discussion, and Implications

In this study, the effect of the Numicon material-supported intervention on the sixth-grade students' mathematics anxiety, motivation, and self-efficacy was investigated. In this quasi-experimental design, in which experimental and control groups were used, analyses were performed using non-parametric tests, Mann-Whitney U test, and the Wilcoxon signed-rank test, because of the non-normal distribution of the data and the small number of participants. According to the study, it was concluded that the instructional practice supported by the Numicon concrete material was effective in reducing/eliminating mathematics anxiety and increasing mathematics self-efficacy of the students in the experimental group compared to the students in the control group, who were taught using solely the explanatory instruction method. However, a similar effect was not observed in the experimental group in terms of increasing mathematics motivation compared to the control group. In other words, it was concluded that the implementation supported by the Numicon concrete material was not effective in fostering the mathematics motivation of the experimental group students compared to the control group students.

The results of the Wilcoxon signed-rank test analysis showed no significant difference between the EG students' mathematics anxiety and mathematics motivation scores obtained before and after the intervention. Accordingly, it can be said that the implementation supported by the Numicon concrete material had no significant effect on increasing the motivation and reducing/eliminating the anxiety of the experimental group students. On the other hand, it was found that the implementation supported by Numicon had a significant effect on increasing the mathematics self-efficacy of the experimental group students after the intervention compared to before. For the control group, the analysis results showed that the explanatory teaching method used in the implementation had no significant effect on reducing/eliminating the students' mathematics anxiety, increasing their mathematics motivation, or promoting their mathematics self-efficacy.

In the literature, studies using the Numicon concrete material have generally been carried out to develop a number sense of preschool or elementary school students with Down syndrome (Buckley, 2007; Ewan & Mair, 2002; Jenkins, 2013; Nye et al., 2005; Santos et al., 2022) or those experiencing difficulties in learning mathematics (Krauce, 2019; Todorova & Eyubova, 2018). However, some studies also indicate that the Numicon material can be beneficial for students with normal developmental levels (Skevington, 2016; Tacon et al., 2004). Based on this, the present study found that the Numicon material used as a supportive tool in teaching was effective in reducing mathematics anxiety and increasing mathematics self-efficacy of the sixth graders. However, the material did not have a statistically significant effect on increasing the students' mathematics motivation. The study also revealed that there was no statistically significant difference between the mathematics motivation scores of the experimental group students receiving instruction supported by the Numicon material and the control group students who were taught using the explanatory instruction method. Motivation is defined as the degree of persistence in an individual's effort to achieve a goal (Adler et al., 2001), while mathematics motivation refers to students' willingness to learn mathematics and their active participation in mathematical activities (Ispir et al., 2011). Based on this, it can be considered that the Numicon concrete material was not sufficiently engaging for the experimental group students. Churches (2016), in a study with students aged 5-10 who performed poorly in mathematics, reported that these students' self-confidence and mathematical motivation increased using the Numicon material. Similarly, Kubiak (2017) found that using Numicon with students aged 4 to 7, including those requiring special education and those with typical development, enhanced mathematical self-confidence and motivation in both groups. The results of the studies by Churches (2016) and Kubiak (2017) do not align with our finding that the implementation supported by the Numicon material did not have a significant effect on increasing mathematics motivation. Similarly, Wing and Tacon (2007) reported that the use of Numicon increased the self-esteem and motivation levels of students experiencing difficulties in learning mathematics. Nye and others (2005) noted that the use of Numicon improved the mathematics self-confidence and motivation of students with Down syndrome. The results of the studies by Wing and Tacon

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(2007), and Nye and others (2005) do not correspond with our finding regarding the increase in mathematics motivation.

In our study, a statistically significant difference was found between the mathematics anxiety scores of the experimental group students, who were taught using the Numicon material, and of the control group students, who were taught using the explanatory instruction method. Mathematics anxiety is defined as the feeling of panic, helplessness, and mental disorganization a student experiences when he/she encounters a math problem (Tobias & Weissbrod, 1980). According to Willis (2010), students experiencing math anxiety cannot utilize their working memory under stress (as cited in Ruff & Boes, 2014). Butterworth (1999) suggests that the most important reason for this is a lack of understanding and the failure to achieve comprehension-based learning (as cited in Bekdemir, 2010). Based on this, it can be inferred that using the Numicon material in mathematical activities and problem-solving helped the experimental group students understand mathematics better, thereby reducing negative emotions such as anxiety, panic, and fear. The use of the Numicon material provided a way for the experimental group students to establish a positive interaction with mathematics compared to the control group. This is because Numicon is defined as a multi-sensory system that offers visual and tactile opportunities for understanding mathematical concepts (Nye et al., 2005; Oxford University Press, 2024).

For the results of within-group analyses, no statistically significant difference was found when the pre-test and post-test scores received from the mathematics anxiety scale by both groups were compared. This finding is noteworthy for the experimental group. While a significant difference was observed in the scores obtained from the mathematics anxiety scale between the groups in favor of the experimental group, the within-group analysis did not reveal a significant difference in favor of the post-test in the experimental group. This might stem from that the experimental group students were not able to completely manage their feelings of anxiety, panic, fear, or stress towards mathematics during the intervention. On the other hand, using the Numicon material in teaching was found to create a significant difference in terms of mathematics self-efficacy of the experimental group students in both between-group and within-group analyses. When individuals believe that what they do will yield the desired results, they feel interest and motivation to do it, which is defined as self-efficacy (Pajares et al., 2007, as cited in Ordonez-Feliciano, 2009). Therefore, in this context, it can be said that the use of the Numicon material helped the experimental group students understand mathematics, in other words, organize their knowledge. As a result, it can be stated that the experimental group students believed they could do mathematical activities and solve problems, gained self-confidence, and increased their self-efficacy.

In our study, while the use of Numicon did not have a significant effect on mathematics motivation, the reasons for its impact on reducing mathematics anxiety and increasing mathematics self-efficacy can be discussed as follows. In this study, the Numicon material was used with typically developing students aged 10-11. The aforementioned studies, however, were conducted with students in need of special education or preschool students aged 4-7. In this context, the Numicon concrete material may not have sufficiently attracted the attention of the students in this study. However, the material's appeal to a multi-sensory system may have increased the students' self-confidence in their ability to learn the subject, thereby reducing their mathematics anxiety and increasing their mathematics self-efficacy. The Numicon material offers students many tactile and visual opportunities. This structure of Numicon may have aroused the students' interest in the subject. However, the sixth-grade students in this study may have found the Numicon material too simple. This could have increased their self-efficacy beliefs and reduced their anxiety, while not creating a significant effect on their motivation.

This study investigated the effects of using the Numicon material on the mathematics anxiety, motivation, and self-efficacy of the experimental group students. When considering the impact of the material on anxiety, motivation, and self-efficacy together, it was understood that it was effective in reducing/eliminating anxiety and increasing self-efficacy between the groups, yet not effective in increasing motivation. Additionally, within-group analyses showed that the material used in the experimental group was only effective in increasing the students' mathematics self-efficacy, with no impact on anxiety or motivation. This raises the question, "Is this due to the use of a concrete material in the experimental group, or specifically due to the use of the 'Numicon' concrete material?". In other words, "Would the same results have emerged if any concrete materials had been used?". Although the literature recommends the use of the Numicon material for all children, including those with special educational needs and those with typical development, the number of studies conducted on typically developing students is quite limited. It can be considered that the Numicon material contributed to the mathematical understanding of the sixth-grade students in this study; however, it was not effective in ensuring the continuity of participation in mathematical activities. Therefore, this may not have had any effect on promoting the experimental group students' mathematics motivation. However, the use of the Numicon material and its characteristics positively contributed to the self-efficacy of the experimental group students by stimulating their confidence in problem-solving.

Based on the results of this study, several implications are presented as follows. The findings of this study are significant in terms of observing the effect of a material, commonly used for students with Down syndrome or learning difficulties in mathematics, on mathematics anxiety, motivation, and self-efficacy of typically developing students. It is believed that these results can contribute to the literature in this context. However, the study has also some limitations, such as including a small sample over five weeks. Therefore, it is recommended that this study be conducted with a larger sample size over a longer duration and at different grade levels. Additionally, a qualitative study can be conducted by gathering students' opinions on the use of the Numicon material. It is believed that students' views can help explain the impact of the Numicon material on their mathematics anxiety, motivation, and self-efficacy. The experimental effects of concrete teaching materials and the Numicon material used in mathematics teaching on mathematics anxiety, motivation, and self-efficacy can be compared across different groups. The impact of the Numicon material on students' mathematics achievement can be investigated, and this effect on mathematics anxiety, motivation, and self-efficacy levels can also be questioned.

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Name of the board that carries out ethical assessment: Bartın University Social and Human Sciences Ethics Committee

The date and number of the ethical assessment decision: 22.06.2022/ E-23688910-050.01.04-2200058693

Author Contribution Statement

Neslihan USTA: *Conceptualization, literature review, method, data analysis, results, conclusion.*

Öykü BULUT: *Teaching practice, data collection, data analysis.*

Selen NALBANTOĞLU: *Teaching practice, data collection.*

Esma Berra UYSAL: *Teaching practice, data collection.*

Büşra ERTOP: *Teaching practice, data collection*

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Appendices

Appendix 1. English Translation of Mathematics Anxiety Scale-MAS

Statements	Always	Most of the time	Sometimes	Hardly ever	Never
1. When I think of math, I think of complicated, incomprehensible things					
2. I find it difficult to go up to the board during math classes.					
3. I always worry that I will be asked questions during math classes.					
4. I understand math now but I am worried that it will become increasingly difficult.					
5. I fear nothing else as much as I fear math exams.					
6. I'm afraid I won't pass my class because of math.					
7. When I attend a math class, I feel shriveled up with fear.					
8. I don't know how to study for math exams.					
9. For me, math is very fun.					
10. I'm afraid to ask questions in math class.					

Appendix 2. English Translation of Mathematics Motivation Scale-MMS

Statements	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1. I don't want to learn anything beyond what is taught to me in math classes.					
2. I enjoy answering difficult questions in math class.					
3. I study to learn more than what I am taught in class.					
4. I enjoy studying for math class.					
5. I review math lessons even when there is no exam.					
6. I review my notes before math class.					
7. Getting a low grade in math makes me unhappy.					
8. I like understanding math lessons.					
9. I want to get the highest grade in math class.					
10. I feel good when I succeed in school.					
11. I like being successful in math class.					
12. I'm not interested in math classes.					
13. I believe what we learn in math will make life easier.					
14. I think I'm wasting my time in math class.					
15. Math is related to real-life connections.					
16. I don't read math books other than textbooks.					
17. Math class is a burden for me.					
18. I don't like engaging in discussions about the topic in math class.					

19. I try to watch TV programs related to math.
20. Math classes frighten me.
21. I research and learn the things I'm curious about in math class.
22. Studying for math class relaxes me.
23. I consider the activities related to math class a waste of time.
24. Even if it's not enjoyable, math is a subject that must be learned.
26. I want to be the first to finish the questions we solve in math class.

Appendix 3.

English Translation of Mathematics Self-Efficacy Scale-MMS

Statements	Never	Seldom	Sometimes	Often	Always
1. I think that I can effectively use mathematics in my daily life.					
2. I think mathematically when planning my day/time.					
3. I think that mathematics is not a convenient occupation for me.					
4. I feel competent in solving mathematical problems.					
5. I can solve all kinds of mathematical problems if I try hard enough.					
6. I feel that I take missteps while solving problems.					
7. When I encounter an unexpected situation while solving a problem, I get flustered.					
8. I can wander through mathematical structures and theorems and make small new discoveries.					
9. When faced with a new situation in mathematics, I know how to behave.					
10. I believe it's impossible for me to be as proficient in mathematics as those around me.					
11. I believe most of the time spent solving problems is a waste.					
12. I realize that my self-confidence decreases when I study mathematics.					
13. I can easily assist others around me with problems related to mathematics.					
14. I can offer solutions to all kinds of problems in life through a mathematical approach.					

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