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An Assessment in Terms of NCTM Content Standards: The Case of Early Childhood Education Undergraduate Programs

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NCTM Content Standards, early childhood education, mathematics education, teacher education.

Abstract: The aim of this study is to examine the content of mathematics education courses in preschool teacher education undergraduate programs at universities in Turkey based on the NCTM content standards. From this point of view, a total of 81 course contents in 74 universities were analyzed. The documents obtained were analyzed by content analysis method. As a result of the analysis, it was seen that the NCTM content standards that were most frequently included in the mathematics courses in the Preschool Teacher Education undergraduate programs were numbers and operations, geometry, and measurement. On the other hand, the least included standards were data analysis, probability and algebra. In courses focusing on mathematics education content, all standard areas are mostly covered together. However, there are also courses that include 3 and 4 NCTM content standards and courses that do not include NCTM content standards at all. In addition, only 2% of the courses that preschool teachers take as graduates focus on mathematics education.

Introduction

Mathematics is a discipline that offers a meaningful integrity based on relationships and patterns. It allows individuals to develop abstract thinking and analytical skills by relying on mathematical thinking processes such as reasoning, interpretation, and problem-solving. According to Burton (1984), mathematical thinking is a tool that organizes and processes information to help individuals make sense of their surroundings.

Mathematics education in early childhood holds critical importance for laying the foundation of these thinking skills. The National Council of Teachers of Mathematics (NCTM) and the National Association for the Education of Young Children (NAEYC) emphasize that high-quality, accessible, and effective mathematics education for young children forms the basis for future mathematical success. Rich mathematical experiences provided during this period contribute to children's ability to recognize patterns in their surroundings, establish connections, and develop problem-solving skills. During early childhood, children begin to notice and explore the mathematical dimensions of their environment (Sophian, 2003). In this process, they can compare quantities through developing number sense, determine direction and location in space using spatial skills, or attempt to solve real-life problems such as dividing a bowl of candy equally among friends (NAEYC, 2002). In this context, mathematics not only serves as a foundation for academic success but also helps children understand the world around them.

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Research shows that the skills and learning experiences acquired in early childhood have long-term effects on children's future development (Shonkoff and Phillips, 2000; Burns, et al., 2001; Van de Walle, 2012). Accordingly, various educational reforms emphasize the need for mathematics education to be effectively and systematically included in early childhood. With the increasing emphasis on the importance of mathematics education in early childhood in the literature, NCTM included early childhood for the first time in its Principles and Standards for School Mathematics in 2000. The principles and standards, based on six fundamental principles—equity, curriculum, teaching, learning, assessment, and technology—comprehensively present the understanding, knowledge, and skills that children from preschool to 12th grade should acquire in mathematics. NCTM has established two types of standards: Content Standards and Process Standards (NCTM, 2000).

The content standards established by NCTM (2000) encompass the mathematical content that children need to learn, including numbers and operations, algebra, geometry, measurement, data analysis, and probability. These standards consist of goals that can be implemented at every grade level, ensuring consistency across all levels of instruction. This consistency contributes to the development of children's knowledge and skills throughout their educational journey (NCTM, 2000).

The "Number and Operations" standard from the NCTM Content Standards aims for individuals to develop a deep understanding of counting and arithmetic and to recognize and be aware of the properties of number systems. At the core of this standard lies "number sense." Number sense refers to an individual's general understanding of numbers, operations, and the relationships between them, as well as the ability to evaluate situations involving numbers (Howden, 1989; McIntosh et al., 1992; Reys, 1994; Yang et al., 2008). In this context, providing children with experiences related to numbers and their relationships during early childhood supports the development of their computational skills and flexibility in arithmetic strategies in later years. Within the scope of the Number and Operations standard, the fundamental skills children are expected to acquire during early childhood include determining the number of elements in sets of objects and understanding the relationship between objects and numbers (NCTM, 2000; Fosnot and Dolk, 2001).

The "Algebra" standard, another Content Standard of NCTM, focuses on the analysis of relationships between quantities, the examination of patterns, the exploration of the properties of functions, the representation of mathematical expressions in various forms, and the understanding of processes of change (NCTM, 2000). Early algebra includes skills such as modeling real situations, establishing connections among symbols, language, and graphical representations, and generalizing arithmetic structures (Smith, 2008; Warren, 2010). Moreover, the algebraic experiences children gain starting from preschool provide a foundation for working with more complex algebraic structures at the middle and high school levels. During early childhood, skills such as classifying and ordering objects, recognizing patterns, continuing repeating patterns, and verbally predicting the next term are the abilities expected from students (Vinner and Dreyfus, 1989; NCTM, 2000).

Within the scope of the NCTM content standards, "Geometry" aims to help students gain knowledge about geometric shapes and structures and analyze the properties and relationships of these shapes (NCTM, 2000). Spatial visualization, defined as the process of forming mental representations of two- and three-dimensional objects, holds critical importance, particularly during early childhood (Duval, 2014; Dindyal, 2015). This skill represents one of the initial stages where children naturally encounter geometry (Elia et al., 2018). In the early years, children are expected to observe geometric shapes, recognize their properties, understand relationships among various shapes, and develop an awareness of two- and three-dimensional shapes through concrete experiences (NCTM, 2000; Elia and Gagatsis, 2003).

The "Measurement" standard refers to understanding what a measurable attribute is and evaluating the units and processes used in measuring these attributes (NCTM, 2000). Since measurement practices are a significant part of daily life, they hold a fundamental place starting from early childhood. These practices form the basis for learning more advanced concepts such as operations with numbers, statistical expressions, and functions (Sarama and Clements, 2009; Choi et al., 2020). In preschool,

measurement typically begins with length comparisons and expands to include concepts such as weight, time, and area. During this period, children should use techniques such as counting and estimation for measuring an object and gain experience with tools like rulers and scales (NCTM, 2000; Clements and Sarama, 2004).

The "Data Analysis and Probability" standard aims to enable children to formulate questions that can be answered with data, collect and organize data, and understand the relationship between data and probability (NCTM, 2000). Andrew (2009) and Polaki (2002) emphasize that children should explore data analysis and probability through concrete experiences in the early years and highlight the importance of providing opportunities to establish connections between these areas and other mathematical domains such as numbers, algebra, measurement, and geometry. In preschool, it is important for children to engage in simple data collection, organization, and sorting, as well as to explore concepts of probability and randomness through concrete experiences (Gelman and Glickman, 2000; NCTM, 2000; Hodnik-Cadez and Skrbec, 2011).

In the updated 2024 Preschool Education Program in Turkey, the objectives and indicators aimed to be instilled in children aged 36-72 months, in accordance with their developmental characteristics, have been specified. When these objectives and indicators are examined within the scope of the NCTM Content Standards, it has been determined that there are objectives and indicators covering all content standards (MEB, 2024). These objectives and indicators clearly demonstrate the necessity of incorporating the NCTM Content Standards in early childhood education.

For this reason, the inclusion of NCTM Content Standards in courses on Mathematics Education in Early Childhood within Preschool Teacher Education Undergraduate Programs is crucial for supporting children's mathematical skills. Therefore, this study aims to examine the content of compulsory and elective courses with the term "Mathematics" in their titles, offered in Preschool Teacher Education Undergraduate Programs at all universities in Turkey, in terms of the NCTM Content Standards.

In this study, the inclusion of the NCTM content standards—numbers and operations, algebra, geometry, measurement, data analysis, and probability—within the Preschool Teacher Education undergraduate programs was determined. In this context, the following questions were addressed: "What is the weight of mathematics education courses in Preschool Teacher Education undergraduate programs?", "To what extent do the contents of mathematics education courses in Preschool Teacher Education undergraduate programs include each of the NCTM standards?", and "What is the level of integration of NCTM standards in the course contents of mathematics education courses in Preschool Teacher Education undergraduate programs?"

Method

In this study, the content of courses focusing on mathematics in preschool teacher education undergraduate programs was examined in detail using the document analysis method. Document analysis is a systematic procedure applied to review or evaluate both printed and electronic materials. The documents analyzed in the study consist of texts created without the intervention of the researcher (Bowen, 2009).

The sample of the study consists of the course contents of compulsory and elective courses with the term "Mathematics" in their titles, offered in the Preschool Teacher Education undergraduate programs of the Education Faculties at 74 universities in Turkey as of the Fall semester of the 2024-2025 academic year. Information packages for a total of 88 courses were accessed; however, since data entries were missing in the information packages of 7 courses, the analyses were conducted on the contents of 81 courses.

The course contents were analyzed using descriptive analysis techniques, employing frequency and percentage statistics. Accordingly, the course contents addressing mathematics education offered by universities in Turkey were examined in detail in terms of the inclusion of the NCTM content standards.

Findings

The weight of mathematics education courses in Preschool Teacher Education undergraduate programs

The examination of the ECTS weights of courses that include mathematics education content in preschool teacher education undergraduate programs is presented in Table 1. Upon reviewing Table 1, it is observed that 74.07% of the mathematics education courses predominantly have an ECTS weight of 5. The number of courses with an ECTS weight above 5 is 5, while the number of courses with an ECTS weight below 5 is 15.

Table 1. ECTS weight distribution of courses on mathematics education

ECTS Values	f	The weight within the analyzed course contents. (%)*
3 ECTS	2	2.47%
4 ECTS	13	16.05%
5 ECTS	60	74.07%
6 ECTS	4	4.94%
7 ECTS	1	1.23%
Total	81	100.00%

*Proportioned within the courses included in the sample.

The weights of mathematics education courses were examined based on the ECTS required for graduation from the preschool teacher education program. The number of courses offered in the relevant programs of universities varies. Therefore, the weight of mathematics courses within the 240 ECTS required for graduation was calculated based on the number of universities. Accordingly, when the total weights of mathematics courses were examined, it was found that they had an average of 4.82±0.48 ECTS. This indicates that the courses containing mathematics education taken by a teacher candidate correspond to 2% of the total course weight (Table 2).

Table 2. The weight of mathematics education courses in the program

Statistics	$\bar{x}$	sd	Weight in the program*
Mathematics Course ECTS Values in an Undergraduate Program	4.82	0.48	0.02

*Calculated by proportioning the course contents on mathematics education in each undergraduate program to the 240 ECTS required for a student to graduate from the program.

The level of coverage of NCTM content standards in mathematics education courses in Preschool Teacher Education undergraduate programs

The mathematics education courses in preschool teacher education undergraduate programs were examined within the scope of the NCTM content standards, including numbers and operations, algebra, geometry, measurement, data analysis, and probability, and the findings are presented in Figure 1.

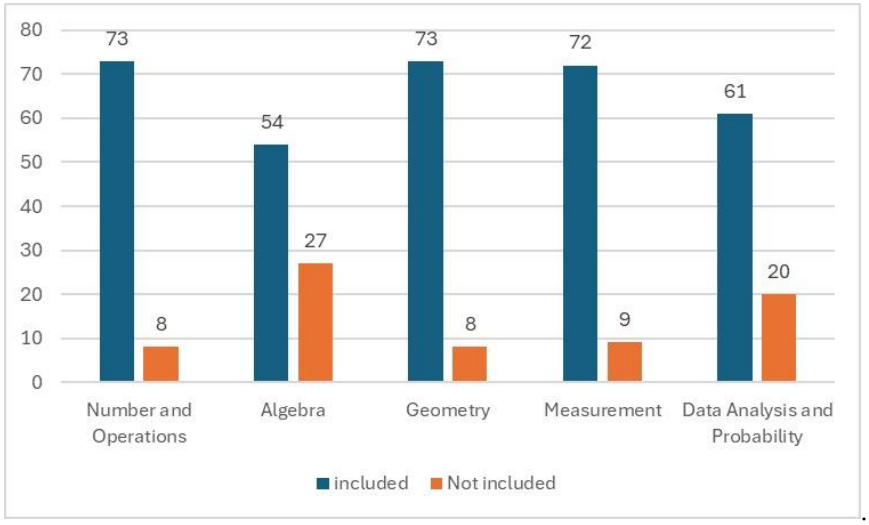

Figure 1. Distribution of NCTM content standards in course contents

When Figure 1 is examined, it is observed that the content standards of numbers and operations (f=73, 90.12%) and geometry (f=73, 90.12%) are the most frequently included in course contents. The next most common content area is measurement (f=72, 88.89%). In contrast, the standards less frequently included in course contents are algebra (f=54, 66.67%) and data analysis and probability (f=61, 75.31%).

The level of integration of NCTM standards in the course contents of mathematics education courses in Preschool Teacher Education undergraduate programs

When Table 3 is examined, more detailed findings regarding the course contents can be observed. There are 8 courses (9.88%) that do not include any NCTM content standards. Upon further examination of these course contents, topics such as "the development of mathematical thinking in early childhood," "fundamental teaching principles to be considered in preschool education programs for teaching mathematical concepts," and "mathematical concepts" are included.

Table 3. NCTM content standards taken together

NCTM Content Standards	f	%	Content standards not included
0 NCTM Content Standard	8	9.88%	-
1 NCTM Content Standard	0	0.00%	-
2 NCTM Content Standard	0	0.00%	-
3 NCTM Content Standard	9	11.11%	"Data Analysis and Probability-Algebra " (8) "Data Analysis and Probability- Measurement " (1)
4 NCTM Content Standard	14	17.28%	"Algebra" (11) "Data Analysis and Probability" (3)
5 NCTM Content Standard	50	61.73%	-
	81	100.00%	

There are 9 courses (11.11%) that address 3 NCTM content standards. In most of these courses, the content areas "Data Analysis and Probability-Algebra" (f=8) are not included, while 1 course does not include the content areas "Data Analysis and Probability-Measurement."

Courses addressing 4 NCTM content standards constitute 17.28% (f=14) of all the courses analyzed. In these course contents, the standards not included are "Algebra" (f=11) and "Data Analysis and Probability" (f=3).

On the other hand, courses that cover all 5 NCTM content standards make up 61.73% (f=50) of all courses. Holistically, among the courses focusing on mathematics education content in preschool teacher education programs, 61.73% include all standard areas, 17.28% include four, and 11.11% include three. Meanwhile, courses that do not address the standard content areas and instead focus on fundamental teaching principles and mathematical thinking processes are identified at 9.88%.

Conclusion and Discussion

It is observed that only 2% of the courses taken by preschool teachers at graduation focus on mathematics education. On the other hand, when the MEB Preschool Teacher Education Program (2024) is examined, NCTM mathematics content standards are largely included in the objectives and indicators. This highlights the importance of equipping preschool children with the necessary mathematical skills and further developing these skills in later years. To enable teacher candidates to build this foundation in children, an education and training program that addresses the relevant skills within the scope of all NCTM content standards should be provided. Additionally, the number of courses and ECTS credits related to mathematics education in the relevant undergraduate programs at universities could be increased.

As a result of examining the mathematics courses in preschool teacher education undergraduate programs, it has been observed that the most frequently included NCTM content standards are numbers and operations, geometry, and measurement. On the other hand, the least included standards are data analysis and probability and algebra. However, it is emphasized that children need to encounter these contents at an early age to address problems related to probability and data analysis (NCTM, 2000). Additionally, the updated MEB 2024 Preschool Teacher Education Program includes objectives such as "Establishes cause-and-effect relationships, evaluates charts created with objects/entities/symbols, makes decisions among options, performs basic coding" (MEB, 2024). These objectives indicate that activities covering data analysis and probability content should be included for children in early childhood (MEB, 2024). Furthermore, NCTM explains the algebra content standard in early childhood as a way to develop sequencing and ordering skills. It is noted that patterns, which fall under the algebra standard, help in understanding relationships between objects and events (such as rhythms, recurring situations, short-to-long relationships, ordering from smallest to largest, classification, and grouping) (Akman, 2002). Moreover, the MEB Preschool Education Program includes objectives such as "Develops various patterns," which align with the algebra standard (MEB, 2024). Therefore, it is recommended that preschool teacher education undergraduate programs include the algebra and data analysis and probability content standards as well.

In the majority of courses focusing on mathematics education content, all standard areas are addressed together. However, on the other hand, there are courses that include only 3 or 4 NCTM content standards while excluding certain standards altogether. In these courses, it has been observed that lesson plans for the relevant weeks are generally organized around mathematical skills without specifying any particular NCTM content standards. NCTM, NAEYC, and the National Council for Accreditation of Teacher Education (NCATE), the first accreditation organization established in the United States for teacher education, share a common vision. When examining the common points in the standards of these three professional organizations, standards such as "Preparing teachers with academic knowledge, skills, and competence in the field of mathematics; designing a problem-solving program to strengthen communication using mathematical language; and creating a comprehensive preschool program covering multiple subject areas" are evident (Sperry-Smith, 2006). Based on this, the necessity of addressing all NCTM content standards in the designated courses within undergraduate programs that prepare teachers becomes prominent.

In this research, the findings related to NCTM standards in undergraduate course contents may lead to challenges for teacher candidates in practice from the perspective of mathematics education. Although all NCTM standards are included in the MEB Preschool Education Program, the fact that not all preschool teacher candidates receive education on all NCTM content standards could potentially cause difficulties in the mathematics education they will implement with children in their professional lives. Furthermore, courses that do not comprehensively address all NCTM content standards may hinder students from acquiring mathematical knowledge and skills recognized at an international level. Insufficient emphasis on topic areas such as data analysis and probability, as well as algebra, could negatively affect students' capacity for mathematical thinking. In this context, it is recommended that all

NCTM Content Standards be provided inclusively and with sufficient emphasis in all Preschool Teacher Education Undergraduate Programs.

Future studies could contribute to the more comprehensive and balanced design of mathematical content in early childhood education by examining in greater detail the impact of course contents on students' academic and career development. Additionally, in-service training programs covering the relevant areas could be organized to support teachers in addressing gaps in their knowledge.

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