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Research Article

Quantitative and Qualitative Comparison of Learning Outcomes in Mathematics Curricula of Different Countries in the Context of Mathematical Literacy Skills

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Abstract – In this qualitative study, written resources related to the curricula of the countries and 2022 PISA results were used to examine the learning outcomes in the mathematics curricula of different countries in quantitative and qualitative dimensions. In the quantitative dimension, other countries had higher PISA scores and rankings with fewer learning outcomes than Türkiye. In the qualitative dimension, it was observed that the outcomes were concentrated in the mathematical process of third mathematical literacy in Türkiye and Poland, and in the mathematical process of second mathematical literacy in Sweden and Denmark. Outcomes in Türkiye were found to be more complex and not evenly distributed across mathematical processes. Based on the findings, it is suggested that the mathematics learning outcomes should be reduced and distributed more evenly across the mathematical processes, and a renewed programme should be proposed to enable in-depth development of skills as well as knowledge.

Key words: Mathematical literacy skills, mathematical processes, mathematics curricula, learning outcomes.

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Introduction

In order to keep pace with the continuous change and development in mathematics education worldwide, it is inevitable to focus on improvements in mathematics teaching. As part of the ongoing effort to improve mathematics education, mathematics curricula need to be regularly revised. Although research on the comparison of curricula for the renewal of curricula is increasing both in Türkiye and worldwide (Bal İncebacak, 2022; Chung & Chung, 2008; Deveci, 2018; Güven & Gürdal, 2011; Öçal, 2017; Revina & Leung, 2018; Yang et al., 2017; Yavuz Topaloğlu & Balkan Kıyıcı, 2015; Xie & Carspecken, 2019), studies comparing the curricula of Türkiye and other countries generally focus on the similarities and differences of some or all of the curricula elements consisting of objectives, content, learning-teaching process and assessment and evaluation approaches (Erbilge, 2019; Çetinbağ, 2019; Çoban, 2011; Güzel et.al., 2010; Karataşlı, 2019; Yazıcıoğlu & Pektaş, 2018). In the process of curricula renewal, the learning outcomes to be gained with the target element, which is one of the basic components of the curricula, also have an important place. The fact that the changes made in the number of learning outcomes in the curricula in many curriculum renewals carried out many times in our country attract attention (Çobanoğlu & Yıldırım, 2021) suggests that the quantity of learning outcomes that meet the content of the curricula is important and is the first step in changing the quality of the curricula. In addition, there are study results in the literature that reveal the importance of the number of learning outcomes such as the fact that teaching leaves education behind due to the intensity of the programmes (Kahramanoğlu et al., 2016), that there are intensive programme contents (Çaycı, 2018), and that the programmes have not reached the desired level in terms of gaining the skills to be used in real life (Kaya & Karakaya, 2012). In this context, this research is directed as a quantitative comparison of the learning outcomes in the mathematics curricula of our country and different countries.

When it comes to the renewal of mathematics curricula, one of the important criteria taken into consideration is the international examinations that enable the determination of the leading countries in achievement. The comparison of different countries with international exams provides insights for countries in the revision, development and renewal of mathematics curricula. In this respect, the large-scale international exams administered by the Programme for International Student Assessment (PISA) provide countries with the opportunity to see their global rankings in terms of achievement in mathematics performance and their mathematical literacy levels, and to understand the literacy dimension in the

curricula and the literacy skills reflected by the curricula elements. Since increasing mathematical literacy is accepted as a common goal when countries design their programmes, this study aims to examine the mathematical processes of mathematical literacy skills in the programmes of the countries that are successful in the 2022 PISA exam in achieving this goal and to identify both similarities and differences by comparing them with the Turkish programme. This comparison will contribute to the literature by providing valuable information in the following sections of the study.

Among the 81 countries that participated in the 2022 PISA, Denmark and Poland are among the countries that stand out, ranking 13th and 15th in mathematics performance, respectively. Sweden, another selected country, ranks 22nd and demonstrates remarkable success by ranking among the top 25 countries in terms of 2022 PISA mathematics performance. However, Türkiye ranks 39th in terms of mathematics performance. In addition, 2022 PISA defines eight proficiency levels from the lowest to the highest: 1a, 1b, 1c, 2, 3, 4, 5 and 6 (MoNE, 2023). In terms of proficiency level, Türkiye is classified at Level 2, whereas the other three countries in the study are at Level 3. It is thought that the mathematical literacy skills reflected in the programmes play a role behind the proficiency levels and successful rankings in PISA. In this sense, it will be important to make comparisons by considering the target element of the programmes of these countries, which are selected because they are more successful than Türkiye in terms of both proficiency level and ranking, and to see to what extent mathematical literacy skills are included in mathematics lesson outcomes in order to determine the missing or defective situations in the curricula. When the literature is examined, it is seen that studies on the promotion and development of mathematical literacy focus on improving students' mathematical literacy skills through the creation of appropriate learning environments (Çilingir Altıner & Dinç Artut, 2017; Çilingir & Dinç Artut, 2016; Dibek et al., 2016; Gürbüz, 2014; Karakaş & Ezentaş, 2021; Köysüren & Üzel, 2018; Var & Altun, 2021). It has been realized that there is a need for research that focuses on the extent to which and in which mathematical processes mathematical literacy is included by addressing the goal element of the curricula. In this context, this study aims to compare the objectives in the mathematics curricula of Poland, Sweden, Denmark and Türkiye in terms of the mathematical processes of mathematical literacy, to examine their similarities and differences, and to determine the qualitative situation in the context of mathematical literacy skills. Thus, this study, which focuses on the subject, will provide an important reference point for future research.

The 21st century modern society needs not only content knowledge but also skills such as critical thinking, problem solving, decision making, creativity, innovation, questioning and reasoning skills. Mathematical literacy is one of the necessary components for the development of 21st century skills. In this context, the student, who should have the opportunity to directly experience these skills by building his/her own literacy, needs an environment where curricula are implemented in which mathematical literacy skills are structured as a whole by focusing on all processes. In the 2022 PISA assessment, mathematical literacy is the capacity of an individual to reason mathematically, formulate, use and interpret mathematics in order to solve various problems in real life. 2022 PISA measures how effectively countries prepare their students to use mathematics in all areas of their lives, including professional fields, as individuals equipped with 21st century skills (MoNE, 2023). The processes of 2022 PISA-defined mathematical literacy skills are outlined in Table 1.

Table 1 Processes of Mathematical Literacy Skills

Mathematical reasoning		
Formularisation	Utilisation	Interpretation and evaluation
-To be able to realise mathematical concepts -To be able to gain mathematical structure for a problem -Formulate in mathematical terms	-To be able to do arithmetic calculations, to solve equations, to make logical inferences based on assumptions, to make symbolic arrangements -To be able to extract mathematical information using tables and graphs, to be able to show and organise spatial shapes, to be able to analyse data	-To be able to transform mathematical solutions or reasoning into problem context -To be able to determine whether the mathematical results are reasonable and whether they make sense in the context of the problem

The mathematical reasoning process, which is the first of the mathematical literacy processes as outlined in Table 1, is the main process that covers the other processes. This process is the capacity to use mathematical concepts, tools and logic to conceptualise real-life problems or situations and to generate solutions for these problems or situations. Students who are mathematically literate in the process of mathematically formulating problems or situations have the ability to recognise mathematical concepts and ideas in the problems they encounter and to provide a mathematical structure to these problems. Students who are mathematically literate in using mathematical concepts, facts and processes in the third process have the ability to solve mathematically formulated problems by using appropriate mathematical tools to achieve mathematical results. In the last process, students who are mathematically literate in interpreting, applying and evaluating mathematical outputs have the

ability to reflect on mathematical solutions, results or inferences and interpret them in the context of real life problems that initiated the process (MoNE, 2023). In order to raise mathematically literate individuals who can cope with daily problems and to end the unfamiliarity with mathematical literacy as soon as possible, it is necessary to integrate the four processes mentioned in the curricula. Based on this necessity, this study is important in terms of showing the extent to which the learning outcomes in the mathematics curricula of the identified countries demonstrate mathematical literacy including the specified mathematical processes and will provide important inputs to the literature in terms of focusing on showing which processes of mathematical literacy the learning outcomes are equipped with. In this context, the study aims to investigate the reasons for the differences in mathematical literacy skills between Türkiye and Poland, Sweden and Denmark in terms of learning outcomes in mathematics curricula.

As a result, this research is a guide for addressing the learning outcome dimension by prioritising meaningful and in-depth learning in curricula and taking concrete steps to simplify and deepen the content. On the other hand, using the informative and guiding nature of PISA, which helps to predict the weight given to mathematical literacy by mathematics curricula on a global scale, the fact that the learning outcomes of successful countries will be compared with the learning outcomes of our programme for the purpose of raising mathematically literate individuals has the quality of shedding light on the curricula development process in order to develop and effectively use mathematical literacy skills. Based on the idea that the quantity and quality of learning outcomes have a role in raising individuals who have acquired literacy skills, it is thought that studies should be carried out to use the appropriate quantity, meaningful and deepening knowledge structures instead of too much information in the outcomes and to integrate essential skills, such as literacy, with the knowledge structure. In this study, it is aimed to quantitatively examine the learning outcomes in the mathematics curricula implemented in the second level of compulsory education in Poland, Sweden, Denmark and Türkiye and their performances according to 2022 PISA mathematics performances and mathematical literacy skills processes and to classify the learning outcomes in these programmes according to mathematical literacy skills processes. Within the scope of this main purpose, the following questions were answered.

1) How do Poland, Sweden, Denmark and Türkiye's mathematics learning outcomes, 2022 PISA mathematics performance and mathematical processes of mathematical literacy skills vary?

2) How are the mathematics learning outcomes of Poland, Sweden, Denmark and Türkiye classified according to the mathematical processes of the 2022 PISA mathematical literacy skills?

Method

The study, which aims to compare the learning outcomes of mathematics lessons in Poland, Sweden, Denmark and Türkiye quantitatively and qualitatively in terms of mathematical literacy skills, was carried out in order to reveal an existing situation. In this section of the study, research design, data collection, data analysis and validity and reliability are presented. In order to ensure conceptual integrity, the term "learning outcome" was used in this study instead of different expressions such as objective, outcome, etc. used in the selected countries to refer to the first element of the programme.

Research Design

This research was carried out using the document review approach, which is one of the qualitative research methods, to achieve the determined purpose. Document review is an approach that is effective in filling the gaps in the literature and enriching the knowledge in the research field based on the information obtained by in-depth analysis of written sources related to the research field (Creswell, 2017). In this context, the learning outcomes of the current mathematics curricula and the 2022 PISA mathematics literacy scores of Poland, Sweden, Denmark and Türkiye were examined in this study. The study analysed the similarities and differences in the mathematical literacy processes reflected in the learning outcomes of the mathematics curricula of these countries.

Data Collection

The data collection tools include the current mathematics curricula documents obtained from the websites of official institutions such as ministries of education, universities, and national education institutions of the identified countries, the 2018 mathematics curricula implemented in Türkiye, and the 2022 PISA Türkiye report published by the Ministry of National Education.

Data Analysis

The first step to start the data analysis process involved analysing the learning outcomes for mathematics in the current curricula of the selected countries and Türkiye. In this step, numerical data on mathematics learning outcomes for each country and Türkiye were collected and changes in the number of learning outcomes were analysed. Then, each country's 2022 PISA mathematics performances, their performances in mathematical literacy processes and their mathematical literacy levels were carefully analysed and compared to assess the general situation of the countries. Finally, a comprehensive evaluation was made to determine how the learning outcomes in the mathematics curricula of the countries were classified according to the 2022 PISA mathematical literacy processes and to identify similarities and differences in the classification. In this section, descriptive analysis technique is the preferred method for data analysis. This method allows the data to be systematically defined and organized based on certain themes (Yıldırım & Şimşek, 2008). In the context of 2022 PISA, formularisation, utilisation and interpretation mathematical processes constitute the themes of this study. The learning outcomes presented by the curricula of the identified countries were analyzed systematically in line with these themes. These analyses revealed how the curricula of different countries develop mathematical literacy skills and in which processes this skill is strong or weak. Finally, the findings of this analysis are meticulously described, presented in detailed tables and interpreted.

Validity and Reliability

In order to evaluate the reliability of the collected documents, the authors of the documents, the publication dates, the reliability of the publishing websites and the purpose of the documents were examined comprehensively. In order to ensure validity, the research process was planned in detail by the researchers, the agreement between the researchers was compared for the data obtained, and the findings obtained after data analysis were supported with numerical data and examples.

Findings and Discussions

The findings, which are presented in tables after analysing the data collected for the purpose of the research, consist of two sections to answer the two sub-questions of the research. In the first part, quantitative findings related to mathematics lesson learning outcomes and mathematical literacy skills are discussed. In the second part, the qualitative

dimension of the learning outcomes in mathematics curricula according to mathematical literacy processes is discussed.

Quantitative Findings on Mathematics Lesson Learning Outcome and Mathematical Literacy Skills

Number of Mathematics Learning Outcomes of Poland

In 2017, Poland undertook a comprehensive reform of its education system, to align it with the demands of the 21st century. As part of this reform, it extended the duration of compulsory education to 9 years, including pre-school education, by increasing the duration of compulsory education to 8 years. After compulsory education, students are offered a four-year general upper secondary education (Podstawa, 2018; Wojnak & Majorek, 2018). The primary and secondary school programme is divided into two phases under the reform. The first phase covers grades 1-3and aims to enable students to acquire basic skills and knowledge. The second phase, covering grades 4-8, aims for students to develop their knowledge and skills in more depth (Podstawa, 2017). The core programme for each lesson includes specific objectives and learning outcomes that students should achieve at the end of the lessons. The learning outcomes and learning areas determined for the mathematics lesson are presented in Table 2 for grades 4-6th.

Table 2 Poland 4-6th Grades Mathematics Lesson Learning Outcomes and Learning Areas

Learning areas	Number of learning outcomes
Numbers	54
Algebra	2
Geometry	36
Statistics	2
Problem solving	7
Total	101

Table 2 indicates that the Polish mathematics curricula for grades 4-6 includes 5 learning domains and 101 learning outcomes. Among these learning domains, the highest number of learning outcomes is in the learning domain of numbers. The lowest number of learning outcomes is in algebra and statistics learning areas.

Number of Mathematics Learning Outcomes of Sweden

Sweden changed its curricula in 2022, updating the curricula that had been in use since 2011 for all grade levels within compulsory education. The new curricula aims to simplify the learning outcomes and to increase students' participation in the learning process and teachers'

flexibility (Lidbäck, 2021). Compulsory education applies to all children between the ages of 6-16 and consists of four stages: pre-school, primary school, middle school and high school (Skolverket, 2022). The learning outcomes and learning areas for grades 4-6 of the Swedish mathematics curricula are presented in Table 3.

Table 3 *S*weden 4-6th Grades Mathematics Lesson Learning Outcomes and Learning Areas

Learning areas	Number of learning outcomes
Numbers	8
Algebra	5
Geometry	5
Probability and statistics	4
Relationships and change	3
Problem solving	2
Total	27

Table 3 shows that there are 6 learning domains and 27 learning outcomes in the Swedish mathematics curricula for grades 4-6. Among these learning domains, the highest number of learning outcomes is in the domain of numbers, while the lowest number of learning outcomes is in the domain of problem solving.

Number of Mathematics Learning Outcomes of Denmark

In Denmark, education is offered as compulsory education in grades 1-9 and optional education in grade 10 and is based on the national framework programme. Mathematics curricula start from grade 1 and continue until grade 10. At primary school level, the mathematics curricula for 2019 are organised into grades 1-3, grades 4-6 and grades 7-9 (Danmarks Læringsportal [EMU], 2019). The number of learning outcomes and learning areas of mathematics curricula in grades 4-6 are presented in Table 4.

Table 4 Denmark 4-6th Grades Mathematics Lesson Learning Outcomes and Learning Areas

Learning areas	Number of learning outcomes
Mathematical competences	26
Numbers and algebra	18
Geometry and measurement	24
Statistics and probability	12
Total	80

According to Table 4, there are 4 learning domains and 80 learning outcomes in the Danish mathematics curricula for grades 4-6. Among these learning areas, the area with the

highest number of learning outcomes is mathematical competences and the area with the lowest number of learning outcomes is statistics and probability.

Number of Mathematics Learning Outcomes of Türkiye

Türkiye has a 12-year compulsory education system. Mathematics curricula start from grade 1 and continue through grade 12. Mathematics curricula of 2018 are used at primary, middle and high school levels. The learning outcomes and learning areas of mathematics curricula for grades 5-8 are presented in Table 5.

Table 5 Türkiye 5-8th Grades Mathematics Lesson Learning Outcomes and Learning Areas

Learning areas	Number of learning outcomes
Numbers and operations	106
Algebra	23
Geometry and measurement	67
Data processing	14
Probability	5
Total	215

According to Table 5, there are 5 learning areas and 215 objectives in the current mathematics curricula. In the current mathematics curricula, the order from the highest number of objectives to the lowest number of objectives is numbers and operations, geometry and measurement, algebra, data processing and probability.

As a result, the total number of learning outcomes of the second level mathematics curricula of the countries are listed as Türkiye, Poland, Sweden and Denmark, respectively. The finding that Türkiye's mathematics curricula has the highest number of learning outcomes compared to the curricula of other countries in the total number of learning outcomes of the countries suggests that the content of the Turkish mathematics curricula is more intense compared to other countries.

Performance of Countries in 2022 PISA Mathematical Literacy Skills

The mathematical literacy performances and proficiency levels of Poland, Sweden, Denmark and Türkiye according to the 2022 PISA results and their performances according to mathematical processes are presented in Table 6.

Table 6 Countries' 2022 PISA Mathematical Literacy and Mathematical Processes Scores and Proficiency Levels

Country	Mathematics literacy score	Mathematics literacy proficiency level	Mathematical processes		
			Formularisation	Utilisation	Interpretation
Denmark	489	3	485	488	491
Poland	489	3	485	491	490
Sweden	482	3	474	481	478
Türkiye	453	2	451	452	455

As seen in Table 6, when the scores of the countries are analysed, it is seen that Türkiye's mathematical literacy performance is lower than the performance of other countries. In addition, while Türkiye's mathematical literacy proficiency level was 2, the other countries were found to be at the 3rd proficiency level. When the scores according to mathematical processes are analysed, it is seen that the performances in each process in Türkiye are considerably lower than the performances of other countries.

Qualitative Findings of Mathematics Lesson Learning Outcomes in the Context of Mathematical Literacy Skills

Mathematical reasoning, which is one of the processes needed to achieve mathematical literacy, was not used in the classification since it covers the other three processes. The processes of mathematical literacy skills included in the classification are formulating situations mathematically, using mathematical concepts, facts and processes, and interpreting, applying and evaluating mathematical outputs. The classification of the learning outcomes in the learning domains of the mathematics curricula of the countries according to these processes is given in tables for each country. In the tables, the number of learning outcomes in each learning domain, which reflects which process predominantly, was written in the relevant section of the table of the country and the classification of the existing learning outcomes was made.

Poland

The classification of the learning outcomes in the learning areas of the Polish mathematics curricula according to the mathematical literacy skill processes is given in Table 7.

Table 7 Distribution of Poland's Mathematics Learning Outcomes in Mathematical Processes

Learning areas	Mathematical processes		
	Formularisation process	Utilisation process	Interpretation process
Numbers	9	40	5
Algebra	2	-	-
Geometry and measurement	11	17	8
Statistics	-	2	-
Problem solving	2	1	4

As seen in Table 7, 24 learning outcomes of the Polish mathematics lesson are concentrated in the 2nd process, 60 learning outcomes are concentrated in the 3rd process and 17 learning outcomes are concentrated in the 4th process. In this case, it can be concluded that the learning outcomes are most concentrated in the 3rd process and least in the 4th process. As an example of learning outcomes aligned with mathematical processes, the outcome "Uses letter notation for unknown numerical quantities and writes simple algebraic expressions based on embedded knowledge in a practical context" is aligned with the formularisation process. Another example learning outcome, "Draws angles less than 180°." is associated with the process of utilisation. In addition, the learning outcome "Verifies the result of a text task." is an example of an outcome appropriate for the interpretation process. Although the number of outputs in the 4th mathematical process is the lowest, the fact that it is close to the number of outputs in the 2nd process shows that its amount is not to be underestimated. When we look at the distribution of mathematical processes according to learning areas, it is seen that all mathematical processes are mentioned in the areas of numbers, geometry and measurement and problem solving. In the learning domains of algebra and statistics, it is seen that the number of outcomes is low and there are mathematical processes that are not used in learning outcomes**.** It was determined that the mathematical processes of utilisation and interpretation were not used in the algebra learning area and the mathematical processes of formularisation and interpretation were not used in the statistics learning area.

When the structure of the learning outcomes in the Polish mathematics curricula is examined, it is seen that in most of the outcomes, the processes are included separately rather than intertwined. For example, it can be said that the outcome "Separates two-digit numbers into their prime factors" belonging to the learning domain of numbers is only for the 3rd process.

Sweden

The classification of the learning outcomes in the learning areas of the Swedish mathematics curricula according to mathematical literacy processes is given in Table 8.

Table 8 Distribution of Sweden's Mathematics Learning Outcomes in Mathematical Processes

Learning areas	Mathematical processes		
	Formularisation process	Utilisation process	Interpretation process
Numbers	5	2	1
Algebra	3	2	-
Geometry	2	1	2
Probability and statistics	1	2	1
Relationships and change	2	1	-
Problem solving	1	-	1

According to Table 8, it is seen that 14 of the 27 learning outcomes of the Swedish mathematics lesson are concentrated in the 2nd process, 8 in the 3rd process and 5 in the 4th process. In this case, it is seen that the learning outcomes are most concentrated in the 2nd process and least in the 4th process. As an example of learning outcomes aligned with mathematical processes, the outcome "Variables and their construction in simple algebraic expressions and equations" is aligned with the formularisation process. Another example of a learning outcome is "Using digital tools in calculations", which is associated with the utilisation process. In addition, the learning outcome "Evaluating the plausibility of predictions and calculations" is an example of an outcome appropriate for the interpretation process. However, although the distribution of outputs in the 3rd and 4th processes is low, since the total number of outputs is also low, it is seen that they are not negligible compared to the total number of outputs. When the distribution of mathematical processes according to learning areas is analysed, it is seen that all processes are mentioned in the learning areas of numbers, geometry, probability and statistics. In the learning outcomes in algebra, relationships and change and problem solving learning areas, it is determined that there are mathematical processes that are not used**.** It was determined that the mathematical process of interpretation was not used in algebra, relations and change learning areas and the mathematical process of utilisation was not used in problem solving learning area.

When the structure of the learning outcomes in the Swedish mathematics curricula is analysed, it is seen that in a few of the outcomes, process components and topics are intertwined rather than separately. For example, the outcome "Has knowledge about rational numbers, including negative numbers, and their properties, and how they can be divided and

used" belonging to the learning domain of numbers is utilised for both process 2nd and process 3rd.

Denmark

The classification of the learning outcomes in the learning areas of the Danish mathematics curricula according to mathematical literacy processes is given in Table 9.

Table 9 Distribution of Denmark's Mathematics Learning Outcomes in Mathematical Processes

Learning areas	Mathematical processes		
	Formularisation process	Utilisation process	Interpretation process
Mathematical competences	13	10	3
Numbers and algebra	9	7	2
Geometry and measurement	13	8	3
Statistics and probability	6	4	2

When Table 9 is analysed, it is seen that 41 of the learning outcomes of the mathematics lesson in Denmark are concentrated in the 2nd process, 29 in the 3rd process and 10 in the 4th process. As an example of learning outcomes aligned with mathematical processes, the outcome "The student can formulate simple algebraic expressions for calculations." is aligned with the formularisation process. Another example learning outcome, "The student can translate between everyday language and expressions using mathematical symbols" is associated with the process of utilisation. In addition, the learning outcome "The student can estimate and determine the perimeter and area." is an example of an outcome suitable for the interpretation process. In this case, it is seen that the learning outcomes are concentrated mostly in the 2nd process and least in the 4th process. It was determined that all processes were mentioned in the learning outcomes of the mathematics lesson. When the distribution of mathematical processes according to learning areas is analysed, it is seen that mathematical competencies, numbers and algebra, geometry and measurement, statistics and probability are mentioned in all areas.

When the structure of the learning outcomes in the Danish mathematics curricula is analysed, it is seen that most of the outcomes are not intertwined with the process components, but they are separated. For example, it can be said that the outcome "The student can use simple mathematical models" belonging to the learning domain of mathematical competences is only related to the 3rd process.

Türkiye

The classification of the learning outcomes in the learning areas of the 2018 mathematics curricula used at the second level in Türkiye according to mathematical literacy processes is given in Table 10.

Table 10 Distribution of Türkiye's Mathematics Learning Outcomes in Mathematical Processes

Learning areas	Mathematical processes		
	Formularisation process	Utilisation process	Interpretation process
Numbers and operations	30	70	6
Algebra	10	13	-
Geometry and measurement	27	39	1
Data processing	2	12	-
Probability	2	3	-

When Table 10 is analysed, it is seen that 137 learning outcomes are concentrated in the 3rd mathematical process in the mathematics lesson in Türkiye. 71 learning outcomes are concentrated in the 2nd mathematical process and the concentration in the 4th mathematical process is the lowest with 7 outcomes. It was determined that the learning outcomes of the mathematics lesson were not equally distributed among mathematical processes. When the distribution of mathematical processes according to learning areas is analysed, it is seen that all of the processes are mentioned in the areas of numbers and operations, geometry and measurement; but there are no learning outcomes for the 4th process in the learning areas of algebra, data processing and probability. As an example of learning outcomes that are compatible with mathematical processes, the outcome "Recognizes the equation with a first-order unknown and constructs an equation with a first-order unknown in accordance with the given real-life situations." is compatible with the formularisation process. Another sample learning outcome, "Expresses rational numbers in decimal notation." is associated with the process of utilisation. In addition, the learning outcome "Predicts the result of operations with fractions." is an example output suitable for the interpretation process.

When the structure of learning outcomes is analysed, it is seen that most of the learning outcomes in Türkiye are structured in a way to cover more than one process. For example, the outcome "Forms the surface area relation of a right circular cylinder; solves related problems." belonging to the 8th grade geometry learning domain is structured for both the 2nd and 3rd process.

Conclusions and Suggestions

Conclusions Related to The Quantitative Dimension

According to the findings of the quantitatively analysed learning outcomes, the number of learning outcomes for Sweden's mathematics curricula is 27, Denmark's learning outcomes is 80 and Poland's learning outcomes is 101, while the number of learning outcomes for Türkiye's mathematics curricula is 215. It is noteworthy that the number of learning outcomes of the Danish and Swedish mathematics curricula is quite low compared to Türkiye. In support of this result, Duygu (2013) and Çoban (2011) state that Türkiye's mathematics curricula has a higher number of learning outcomes compared to the other countries compared. When compared according to learning domains, the learning outcomes in learning domains such as "Numbers and Operations", "Algebra", "Geometry and Measurement", "Data Processing" and "Probability" in Türkiye's curricula are higher than the numerical values of learning outcomes in similar learning domains of other countries.

2022 PISA Mathematics literacy performances show that Sweden's score is 482, Denmark and Poland's score is 489. Türkiye's mathematical literacy score is 452. With these scores, it is seen that Poland, Sweden and Denmark are at the 3rd mathematical literacy proficiency level and Türkiye is at the 2nd mathematical literacy proficiency level. This suggests that there is a relationship between the number of learning outcomes and mathematical literacy success. This idea is consistent with the fact that having too many learning outcomes in a programme may have a negative effect on the depth and effectiveness of teaching (Hook et al., 2007; Schoen et al., 2011). As a matter of fact, according to Özgün-Koca and Şen (2002), the content density of the programmes has a negative effect on the development of mathematical literacy, and according to Buluş Kırıkkaya (2009), there are teacher opinions that there is a need to simplify the content and the number of learning outcomes in order to increase achievement. Similarly, according to Hobson (2001), one of the biggest obstacles for students to become mathematically literate is the high level of dense content in curricula. In addition, it is also stated in the literature that in programmes with a high number of learning outcomes, teachers have difficulty in completing the learning outcomes in the prescribed lesson times (Akpınar, 2004; Çaycı, 2018), they cannot use methods and techniques that will increase the active participation of students due to the concern of the programme (Ayvacı & Durmuş, 2013), and therefore the achievement of students who experience a decrease in their motivation (Dursun & Dede, 2004). In the 2022 PISA assessment, the fact that the countries that were successful but not included in the study

also had a low number of learning outcomes supports the findings of the study. For example, it is seen that Singapore ranked first in the 2022 PISA with the highest scores in mathematics performance and mathematical literacy processes, as in almost all of the international exams it participated in. In the study by Erdoğan et al. (2016) comparing the mathematics curricula of Türkiye and Singapore, it was stated that there were fewer learning outcomes in the mathematics curricula implemented in Singapore. Based on this result, it can be concluded that reducing the number of learning outcomes in the curricula will positively affect mathematics literacy.

In general terms, based on the finding that the mathematics curricula of the countries ranked higher in PISA are generally simpler and the number of learning outcomes is lower, it is recommended to make changes in the curricula of the mathematics lesson being implemented in Türkiye in order to deepen the content and to reduce the number of learning outcomes to a great extent. The significant decrease in the number of learning outcomes in the renewed curricula will pave the way for the development of mathematical literacy skills by further strengthening the educational approach that aims to build knowledge together with skills and the belief that students should focus on holistic development.

Conclusions Related to The Qualitative Dimension

When the learning outcomes are analysed qualitatively, it is seen that the reflections in the outcomes of the programmes designed to develop mathematical literacy differ. When the distribution of the learning outcomes in the programmes according to the mathematical processes of mathematical literacy is examined, it is seen that Poland's mathematics curricula has more learning outcomes in the process of using mathematical concepts, facts and processes, while Sweden and Denmark's curricula has more learning outcomes in the process of formulating situations mathematically. However, in these countries, other mathematical processes are also addressed to a sufficient extent and the processes are distributed to the outcomes in a balanced way. In Türkiye's mathematics curricula, there are more learning outcomes in the process of using mathematical concepts, facts and processes. This result suggests that individuals educated in Türkiye may have more mathematical literacy capacity in using mathematical concepts, facts and processes. In addition, it is seen that there are sufficient learning outcomes in the process of formulating situations mathematically, which is the second process; however, there are not enough learning outcomes that meet the fourth process. Based on this result, it can be said that not all mathematical literacy processes are sufficiently emphasised in mathematics lesson learning outcomes and the distribution is not

balanced. In the programmes of the three successful countries, learning outcomes of mathematical literacy skills were balanced in all processes, whereas in Türkiye, it was found that learning outcomes had an unbalanced distribution in terms of mathematical literacy skill processes. This situation suggests that there is a relationship between ensuring a balanced distribution of mathematical processes to outcomes and mathematical literacy success. As a matter of fact, a student with developed mathematical literacy benefits from mathematics at the highest level (Altun, 2015). It is thought that the PISA results applied on a global scale reflect this situation (MoNE, 2019; MoNE, 2023). This situation suggests that these three successful countries, which stand out with PISA, give priority to the development of mathematical literacy skills holistically while designing their curricula, and focus on the depth of skill development with its processes by going beyond traditional knowledge transfer. Based on this idea, it is considered important that mathematical literacy processes, which start with mathematical reasoning and continue with formulating, using and interpreting mathematics, should be handled in a holistic manner for a more effective mathematics teaching and mathematics success. In this respect, an integrated structure can be created in the curricula by placing the mathematical literacy skills and processes, which are necessary to include and use the skills needed in the 21st century in daily life, more balanced in the learning outcomes of the curricula and in the lesson contents that meet these outcomes. Aware that the practice and development of 21st century skills are intertwined with literacy skills, the mathematics teaching process is shaped around the idea that these skills are interrelated and necessary for use in daily life. A new curricula proposal that covers all processes of mathematical literacy in a balanced way will be a valuable resource for revising not only mathematics but also curricula in various other fields.

When the distribution of the learning outcomes in each mathematics learning domain in terms of mathematical processes is analysed, it is seen that in all of the countries participating in the study, including Türkiye, there are missing mathematical processes in some learning domains. This is thought to be due to the fact that the learning outcomes within the scope of learning areas tend to provide knowledge such as numbers, algebra, geometry and statistics rather than mathematical literacy. There is a need to include learning outcomes that adequately address all mathematical processes both in general and within the scope of each learning area in the curricula. Thus, it would be an important initiative to organise the outcomes or include new outcomes in each learning area of mathematics in a way to enable students to experience each process of mathematical literacy skills.

Although the mathematical process emphasised in the Turkish curricula is the same as in Poland, the reason for the difference in the achievement of Poland and Türkiye may be that most of the learning outcomes in Türkiye are structured in such a way that they cover more than one literacy process. The fact that the outcomes have a complex structure resulting from the intertwining of the mathematical processes that constitute the skill may make it necessary to follow teaching and learning practices in terms of mathematical literacy. As a matter of fact, it is also important to ensure the integration of literacy into the classroom (Steinberg, 2011) in the development of literacy skills. In this case, in order to gain mathematical literacy skills in the classroom, all the processes covered by the learning outcome must be fulfilled. In teaching and learning practices, the need to elaborate the internal dynamics of each mathematical process reflected in the learning outcome may affect the achievement of mathematical literacy. For this reason, as in Poland and other countries, it is recommended that the learning outcomes in the curricula should be arranged in a way that reflects a single mathematical literacy process. In cases where this arrangement is not made in the curricula, it can be said that it is a necessity to emphasise that its integration into the classroom is of vital importance. Although the outcomes and content of the curricula include mathematical literacy with all its processes in a holistic manner, it is the duty of teachers to effectively implement and transfer this curricula to students. In the literature, Höfer and Beckmann (2009), Altun and Akkaya (2014) and Lin and Tai (2015) state that one of the determining factors in the development of mathematical literacy is the role of mathematics teachers. Therefore, it should not be forgotten that teacher practices in the classroom have a great impact on student achievement as much as the renewal of the curricula. As a matter of fact, various studies emphasise the importance of teachers' mathematical literacy competencies in affecting their students' mathematics performance and draw attention to the importance of teachers' developing their own literacy skills (Botha, 2011; Genç, 2017).

This study, which was conducted to compare the distribution of the learning outcomes of the mathematics curricula of different countries in terms of mathematical literacy skills, was examined only depending on the learning outcomes specified in the curricula of the countries in line with the mathematical processes of mathematical literacy determined in 2022 PISA. For this reason, the study cannot fully understand how mathematics teaching in these countries is shaped in line with mathematical literacy. Based on the results obtained within the limits of the current study, it is suggested to create a holistic framework for developing mathematical literacy skills by examining the textbooks of the countries' mathematics lessons

or making more detailed comparisons by observing the mathematics teaching in the learning environment. In addition, in line with the results obtained from this study, the suggestion of making necessary regulations in the curricula and presenting designs to support mathematical literacy skills will contribute to the literature.

Compliance with Ethical Standards

Disclosure of potential conflicts of interest

The authors declare that no processes involved in conducting this study have the potential for conflicts of interest.

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CRediT author statement

First author is responsible for conceptualization methodology and writing, second author is responsible for reviewing and editing.

Research involving Human Participants and/or Animals

No data were obtained from human or animal subjects in this study. Data was collected only through document analysis. Therefore, ethical permission was not obtained.

Farklı Ülkelerin Matematik Öğretim Programlarındaki Öğrenme Çıktılarının Niceliksel ve Matematik Okuryazarlığı Becerisi Bağlamında Niteliksel olarak Karşılaştırılması

Özet:

Farklı ülkelerin matematik öğretim programlarındaki öğrenme çıktılarının niceliksel ve niteliksel boyutta incelenmesi amacıyla nitel modelde yürütülen bu çalışmada, ülkelerin öğretim programlarına yönelik yazılı kaynaklar ve 2022 PISA sonuçları kullanılmıştır. Niceliksel boyutta; diğer ülkeler Türkiye'den daha az öğrenme çıktısıyla daha yüksek PISA puanı ve sıralamasına sahiptir. Niteliksel boyutta; Türkiye ve Polonya'da üçüncü, İsveç ve Danimarka'da ikinci matematik okuryazarlığı matematiksel sürecinde çıktıların yoğunlaştığı görülmüştür. Türkiye'deki çıktıların diğerlerine göre karmaşık yapıda olduğu ve matematiksel süreçlere dengeli dağılmadığı saptanmıştır. Bulgulara dayanarak matematik öğrenme çıktılarının azaltılması ve matematiksel süreçlere daha eşit dağılımının sağlanmasıyla yenilenerek bilginin yanında becerilerin de derinlemesine geliştirilebilmesine olanak tanıyan bir program önerilmektedir.

Anahtar kelimeler: Matematik okuryazarlığı becerisi, matematiksel süreçler, matematik öğretim programı, öğrenme çıktısı.

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