

Cognitive Complexity in Elementary Mathematics Curriculum: A SOLO Analysis of the Maarif Model of the Century of Türkiye

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Abstract

This study investigates the cognitive complexity embedded in the Elementary School Mathematics Curriculum (Grades 1, 2, 3, and 4): The Maarif Model of the Century of Türkiye, using the SOLO (Structure of Observed Learning Outcomes) taxonomy as an analytical lens. Adopting a qualitative document analysis method, the study systematically examined all learning outcomes and their associated process components in the 2024 mathematics curriculum according to the SOLO taxonomy. The findings indicate a gradual progression in cognitive complexity across grade levels, with Multistructural and Relational components being most prevalent. While Unistructural components decrease significantly from Grade 1 to Grade 4, Extended Abstract components begin to emerge in Grade 2 and increase thereafter. However, the presence of Extended Abstract components remains limited, especially in earlier grades and in the theme Data-Driven Research/Probability of Events and Data-Driven Research. The results suggest that the curriculum is structured to support a transition from procedural fluency to conceptual understanding and generalization. Nonetheless, further emphasis on abstract reasoning and generalization tasks may enhance the curriculum's capacity to foster students who are able to engage in mathematical reasoning.



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Introduction

Curricula, one of the cornerstones of education systems, are structures meticulously designed to enable individuals attain knowledge, skills, and attitudes systematically (Print, 1993). Changing world, technological developments, the prominence of individual differences, and contemporary educational approaches necessitate the constant updating of curricula (Ornstein & Hunkins, 2017). In this context, with the impact of current studies in the field of mathematics education, changes in the concepts and skills targeted to be taught (e.g., statistical literacy, 21st century skills), and international assessment exams, such as

Programme for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS), it is inevitable to reorganize mathematics curricula (Li et al., 2025).

Mathematics curricula have moved beyond a structure in which only certain concepts and operations are taught to a structure that aims to help students acquire high-level skills (Findell et al., 2001; National Council of Teachers of Mathematics [NCTM], 2000). In line with this transformation, mathematical skills are clearly defined and emphasized in the curricula, such as problem solving, reasoning, mathematical communication, modeling, and representation, which are among the basic components of mathematics education and guide the program structure (Ministry of Education Singapore, 2021; Ministry of National Education [MoNE], 2018; 2024; Taguma et al., 2018). It is clearly seen that this change has come to light with the mathematics curriculum published in Türkiye in 2024.

2024 Elementary School Mathematics Curriculum

The elementary school mathematics curriculum in Türkiye has been renewed in 2024 within the scope of the “Maarif Model of the Century of Türkiye” and has undergone significant changes at the 1st-4th grades level. This new curriculum differs significantly from the 2018 curriculum in terms of its content structure, skill-focused approach, and learning-teaching process components. The 2024 Mathematics Curriculum has adopted a different structure and terminology from the previous curriculum in terms of content. Instead of learning domains (Numbers and Operations, Geometry, Measurement, Data Processing) in the 2018 curriculum, themes (Numbers and Quantities, From Operations to Algebraic Thinking, Geometry of Objects, Probability of Events and Data-Driven Research) replaced its place in the 2024 curriculum. Instead of the term “objective”, expressions such as “learning outcome” have begun to be used similarly, detailed explanations of themes the subheadings are redefined as “process components” (MoNE, 2024). In addition, sections describing process components outlining how learning outcomes can be addressed and learning-teaching practices explaining how instruction can be implemented were introduced, and differentiation strategies (enrichment and support) that take student diversity into account in classroom practices were exemplified (MoNE, 2024).

In the mathematics curriculum published in Türkiye from 2005 to 2018, skills such as problem solving, making connections, communication, and critical thinking were included in the curriculum objectives, but there were no clues about these skills in the outcomes or

objectives. The 2024 Elementary School Mathematics Curriculum was built directly on a “skill-based” approach. At the center of the curriculum are certain competencies and skills that students are targeted to gain. The Ministry of National Education has stated that while preparing the new curriculum, it aims to ensure that students are equipped with 21st century skills and has simplified the content in this direction and opened up space for skill-focused learning (MoNE, 2024). In line with this approach, the mathematics curriculum defines five main mathematics domain skills: mathematical reasoning, mathematical problem solving, mathematical representation, working with data and data-based decision making, and working with mathematical tools and technology. Each learning outcome is linked with a related domain skill as much as possible, and course activities are designed to support the development of these skills. The new curriculum, on the other hand, presents each learning outcome by pairing it with specific skills. For example, in the 2024 curriculum documents, each learning outcome is accompanied by the codes of related integrated skills (with abbreviations such as MAB1, MAB2) (Karabey & Erdoğan, 2023). This answers the question of which cognitive process each outcome of the curriculum serves. As a result, the 2024 mathematics curriculum provides a more systematic framework in terms of skill focus compared to the 2018 curriculum; in addition to what will be taught, it clarifies not only what will be taught but also which skills will be developed with which process steps. In addition, instead of an output such as “performs addition operations”, the curriculum now includes statements that include higher-level actions such as “making predictions by observing, collecting and analyzing data, or solving problems by developing a solution strategy”. This indicates that the level of performance expected from students by the 2024 curriculum has increased significantly and that active skill use has been integrated into the learning process.

Finally, the new curriculum introduces the concept of process components as an extension of the skill-focused approach. Mathematics domain skills are structured through sub-skills referred to as integrated skills in the curriculum. In cases where the general skills included in the model are not sufficient from a mathematics-specific perspective, mathematics-specific domain skills have been defined, and accordingly, five mathematics domain skills have been constructed. Integrated skills are defined as compound actions that include at least two process components and embody the process steps of a task. Through this structure, the sub-processes required to perform a comprehensive skill (e.g., problem

solving) are made explicit. Indeed, the problem-solving skill consists of integrated skills such as analyzing, interpreting, developing mathematical solutions, and reflecting, each of which, in turn, includes its own distinct process components (Karabey & Erdoğan, 2023).

Analysis of Curricula and Taxonomies

Analyzing curricula is extremely important both in terms of increasing the quality of curriculum development processes and in terms of making improvements by identifying deficiencies that may be encountered in practice (Posner, 2004). These analyses enable the evaluation of learning outcomes in terms of scope, process and skill dimensions. Different taxonomies are used for such analyses in the literature. Bloom Taxonomy (Bloom et al., 1956), Renewed Bloom Taxonomy (Krathwohl, 2002; Hess et al., 2009), cognitive demand of tasks (Stein & Smith, 1998) and the SOLO (Structure of the Observed Learning Outcome) Taxonomy (Biggs & Collis, 1982) are among the frequently used structures in this field.

Bloom Taxonomy classifies cognitive skills in a hierarchical structure at the levels of knowledge, comprehension, application, analysis, synthesis and evaluation (Anderson & Krathwohl, 2001). The revised Bloom Taxonomy transforms this structure into a two-dimensional matrix, allowing the types of knowledge (factual, conceptual, procedural and metacognitive) and cognitive processes (remembering, understanding, application, analysis, evaluation, creation) to be evaluated together. This two-dimensional structure provides a comprehensive framework for a more in-depth analysis of learning outcomes (Krathwohl, 2002; Hess et al., 2009). Although this structure emphasizes the level progression of the cognitive domain, it offers limited depth regarding the quality of learning. The Cognitive Demand framework (Stein & Smith, 1998) is an important tool for determining the level of mental processes involved in instructional tasks. In this framework, tasks are divided into four main categories: (1) memorizing tasks, (2) procedure without connections tasks, (3) procedure with connection tasks and (4) doing mathematics tasks. Using this framework in the analysis of curriculum allows the evaluation of learning outcomes in terms of cognitive demand required students to acquire mathematical ideas (Stein et al., 2000). Unlike these taxonomies, the SOLO Taxonomy focuses on the structural complexity of learning outcomes and offers the opportunity to qualitatively analyze the quality of student learning products. In this respect, although it has common points with the revised Bloom Taxonomy and cognitive demand frameworks, it differs in that it shows the evolution of students' thinking structures in a gradual and connected manner (Biggs, 2011). The SOLO Taxonomy reveals

how deeply and connectedly students understand a subject and distinguishes it from other taxonomies by representing the structure of learning with a vertical development model (Biggs & Collis, 1982). This model considers the student's cognitive progress not only as a quantitative increase, but also as a qualitative transformation. In addition, the SOLO Taxonomy is notable for providing a flexible and practical framework in areas such as instructional design, evaluation, and curriculum analysis (Biggs, 2011).

The SOLO (Structure of Observed Learning Outcomes) Taxonomy (Biggs & Collis, 1982) allows for the qualitative analysis of learning outcomes and consists of five basic levels:

Level 0 - Pre-structural: This is the stage where the student does not have any structure in the relevant subject and does not understand the purpose of the task.

Level 1 - Uni-structural: At this level, the student successfully completes only one aspect of the learning outcome. He/she provides a response that demonstrates understanding of a single concept or step, but does not make a deeper connection.

Level 2 - Multi-structural: This level refers to learning outcomes in which the student learns and presents more than one aspect but cannot establish an integrative connection between them. The student can take more than one correct step in a mathematical problem or list various aspects of a concept separately.

Level 3 - Relational: A learning outcome that reaches the relational structure level shows that the student has reached conceptual integrity on a subject. The student brings together multiple elements and explains the relationships between them, producing a holistic solution or understanding.

Level 4 - Extended abstract: At the abstract structure level, which is the highest level of the SOLO taxonomy, the student can transfer the information he has acquired to a new context, make generalizations and develop original inferences.

As progression occurs across these levels, learning moves surface-level engagement toward integrated and abstract reasoning. For this reason, the SOLO taxonomy has been widely used not only for student learning and assessment tasks but also the cognitive demands embedded in learning outcomes and process components (Biggs, 2011; Pegg, 2003). Considering its potential, the SOLO taxonomy has been used in various disciplines and levels.

Recent research applying the SOLO taxonomy within the context of the Maarif Model of the Century of Türkiye has provided important insights across different disciplines and

grade levels. Studies conducted at the preschool level (Kılıçgün, 2025), primary school mathematics (Kılıç, 2025), middle school mathematics (Özcan & Masal, 2025; Satmaz & Yabanova, 2024), social studies (Diktaş et al., 2025), and secondary-level mathematics and chemistry (Cihan & Doruk, 2024; Yaralı, 2025) consistently report a strong emphasis on multistructural and relational levels, with extended abstract outcomes becoming more prominent at upper grade levels. Collectively, these findings suggest that the Maarif Model prioritizes conceptual connections and higher-order reasoning over rote or isolated skill acquisition. A closer examination of these studies reveals a common methodological tendency to treat learning outcomes as the primary or sole unit of analysis, with process components either examined descriptively or discussed as supportive elements. For instance, Cihan and Doruk (2024), Satmaz and Yabanova (2024), and Özcan and Masal (2025) demonstrated that secondary and middle school mathematics curricula are heavily concentrated at the relational and extended abstract levels, while noting that foundational skills are embedded within process components rather than explicitly stated as outcomes.

Studies conducted at earlier educational levels further reinforce this observation. Kılıçgün (2025) found that both learning outcomes and process components in the preschool curriculum are predominantly relational, while Kılıç (2025) reported that the primary mathematics curriculum for Grades 1–4 is largely structured around multistructural and relational levels, with extended abstract components remaining limited. Although these studies acknowledge the presence of process components, they primarily aim to describe the overall cognitive complexity of the curriculum rather than to analyze how cognitive complexity is constructed through these components.

Different from the study of Kılıç (2025) which examined the same curriculum, the present study goes further by systematically analyzing both learning outcomes and their associated process components as independent units of analysis according to SOLO taxonomy. Although Kılıç (2025) states that learning outcomes and process components were examined, the reported findings focus on the distribution of process components across grades, without providing a distinct analysis of the cognitive complexity of the learning outcomes. In contrast, this study uses learning outcomes and process components as distinct primary units) which would provide a more comprehensive and nuanced evaluation of the Maarif Model.

In addition to this difference, this study examines how learning outcomes process components are distributed across SOLO levels within each mathematical theme at every grade level, unlike Kılıç's study (2025) which reports overall grade-level distributions. This thematic analysis reveals that cognitive complexity does not develop uniformly across themes. Some themes promote relational reasoning from early grades, whereas others rely more heavily on multistructural processes before integration occurs. Taken together, the significance of this study lies in its both learning- and process-oriented and thematically differentiated perspective on curriculum analysis. Therefore, this study aims to examine the distribution of SOLO levels across both learning outcomes and process components in the Elementary School Mathematics Curriculum (Grades 1-4): the Maarif Model of the Century of Türkiye, both by grade level and theme, in order to provide details how cognitive complexity is structured and progressively developed.

Therefore, this study aims to examine the distribution of SOLO levels across both learning outcomes and both learning outcomes and process components in the Elementary School Mathematics Curriculum (Grades 1-4): The Maarif Model of the Century of Türkiye, both by grade level and theme, in order to provide details how cognitive complexity is structured and progressively developed.

Methodology

Research Design

In this study, which aims to determine the levels of the learning outcomes and their corresponding process components in the Elementary School Mathematics Curriculum (Grades 1–4): the Maarif Model of the Century of Türkiye, according to the SOLO taxonomy, document analysis was employed as the research design. Document analysis is a qualitative research method that involves a systematic examination of written materials containing information about the phenomenon under investigation (Yildirim & Simsek, 2016; Bowen, 2009). This method allows for an in-depth and structured exploration of curriculum texts, enabling the identification of cognitive demands embedded within the outcomes. In this context, the 2024 Mathematics Curriculum was carefully reviewed to analyze the depth and structure of the learning objectives and their associated process components.

Data Collection and Analysis

The data for this study were obtained from the Elementary School Mathematics Curriculum (Grades 1–4): The Maarif Model of the Century of Türkiye, published by the

MoNE in 2024. The curriculum consists of learning outcomes that outline broad student competencies (e.g., “MAT.1.1.1. Uses numbers up to 20 to represent quantities”) and process components (a, b, c...) that specify the observable sub-skills required to achieve these outcomes. Each learning outcome and its associated process components were individually identified and systematically organized into a Microsoft Excel spreadsheet for analysis. Table 1 presents the number of learning outcomes and associated process components across each elementary grade level included in the curriculum.

Table 1. Distribution of learning outcomes and process components by grade level in the 2024 elementary school mathematics curriculum

Grade	Number of Learning Outcomes	Number of Process Components
1	19	48
2	25	82
3	33	105
4	34	101
Total	111	336

The data recorded in the Excel spreadsheet were analyzed using descriptive analysis, guided by the SOLO (Structure of Observed Learning Outcomes) taxonomy developed by Biggs and Collis (1982). The analysis focused on examining the cognitive complexity embedded in the curriculum by coding both the learning outcomes and their associated process components according to the corresponding SOLO levels.

Each learning outcome was first independently coded based on the level that it ultimately aimed to achieve. Then, the process components designed to achieve of that learning outcome were coded separately. This analysis made it possible to identify not only the cognitive complexity of the learning outcomes themselves, but also the range of cognitive complexities of process components. For example, the learning outcome “MAT.1.3.2. Ability to evaluate the equivalence of objects” was coded at the Extended Abstract level. The process components and their SOLO levels are given below:

- a) Determines a criterion for the equivalence of objects. (Multistructural)
- b) Performs measurement using information appropriate to the selected criterion. (Multistructural)
- c) Compares the results obtained from the measurement with the criterion. (Relational)
- ç) Makes a judgment based on the comparisons. (Relational)

As shown in parentheses, both the learning outcome and each process component were coded based on their cognitive demands. This example illustrates that while a learning outcome may be classified at a higher SOLO level, the process components designed to support that learning outcome may be at lower or different SOLO levels. Also, they may not reach the same level as the learning outcome itself.

During the coding process, each learning outcome and its associated process components were examined in relation to their intended cognitive complexity and commonly occurring indicator verbs for each level were revealed were identified. These verbs were used as cues to guide the coding process according to the SOLO taxonomy, rather than as the fixed determinants of that level. Table 2 indicates a systematic list of indicator verbs that were frequently associated with each level of the SOLO taxonomy.

Table 2. Common indicator verbs used to guide SOLO taxonomy levels

Unistructural [US]	Recognizes, shows, counts, expresses, notices, determines, names
Multistructural [MS]	Reads and writes, draws geometric shapes, explains in his/her own words, identifies appropriate representations, uses and applies the identified representation, identifies/separates /classifies according to its characteristics, benefits moels, identifies components/parts/elements, lists similarities and differences, expresses consistency, identifies the appropriate measurement tool, examines the use of operations, expresses operations in their own words, identifies the steps of the process, identifies concepts, identifies criteria/reviews the need for measurement tools/conducts measurements/compares with criteria, identifies daily life situations, makes plans, collects data, makes observations, lists, verbally expresses pattern rules, identifies what is given and what is required, applies a strategy, explains the results of the process, recognizes/examines/expresses relationships, separates/classifies, identifies steps, identifies/uses the necessary tools and technology.
Relational [R]	Identifies relationships between parts/steps, relates to experiences, relates operations/concepts/objects to each other, establishes relationships, rephrases relationships, makes judgments, estimates based on strategy, expresses consistency, converts operations into reverse/mathematical representations/operational language, interprets, evaluates, finds patterns, tests with examples, draws inferences, develops strategies, changes strategies, uses strategies, evaluates shortcuts, uses representations, converts data into appropriate mathematical representations, separates according to formal properties, performs logical checking, establishes logical relationships, makes appropriate selections/reflects on the process, analyzes, completes the part, reflects, establishes hierarchical relationships, checks the solution, formulates research questions.
Extended Abstract [EA]	Generalizes the pattern, generalizes strategies to different problems, makes assumptions, develops strategies according to estimations, evaluates its necessity, reflects the necessity, assesses the validity of the generalization with mathematical examples, assesses the congruence of objects, creates an original structure/model, synthesis models, formulates a problem, creates a relational whole, solves daily-life problems, structures operations, structures problem situations, decision making

As shown in Table 2, some verbs appear at multiple SOLO levels depending on the content and complexity of the learning outcome and process components. That is, the verbs were not coded mechanically. Accordingly, the same verb may be assigned to different

SOLO levels. Following the coding procedure described above, the distribution of both learning outcomes and their associated process components was further analyzed according to the themes defined in the curriculum. The results of this analysis were presented through frequency and percentage tables for each grade level. This approach enabled the identification of dominant levels of cognitive complexity within and across themes, without reducing learning outcomes to a single SOLO classification.

Validity and Reliability of the Study

To ensure the validity and reliability of this study, multiple strategies were implemented in accordance with established standards in qualitative research (Miles & Huberman, 1994). All learning outcomes and their corresponding process components in the curriculum were carefully analyzed. During the coding process, a systematic list of indicator verbs representing each level of the SOLO taxonomy was compiled to guide the classification process as previously described. Sample coding was included in the methodology section, and additional examples were also presented in the findings to increase transparency. To ensure the reliability of the study, both authors independently coded all learning outcomes and process components according to the SOLO taxonomy. Following independent coding, the assigned codes were compared. Instances of discrepancies (e.g., a learning outcome or process component coded as multistructural vs. relational) were resolved through discussion until consensus was reached.

Findings

This study presents a comprehensive analysis of elementary school mathematics learning outcomes (Grades 1-4) from the Maarif Model of Century of Türkiye Mathematics Curriculum through the lens of SOLO (Structure of Observed Learning Outcomes) taxonomy. The analysis examines the cognitive complexity embedded within learning outcomes and their corresponding process components across different themes and grade levels, revealing patterns in how mathematical understanding is developed throughout elementary education.

First-Grade Learning Outcomes and Process Components across SOLO Taxonomy Levels

At the Grade 1 level, 19 learning outcomes and their corresponding 48 process components were analyzed according to the SOLO taxonomy. Table 3 presents the distribution of SOLO levels (Unistructural, Multistructural, Relational, Extended Abstract) of

each learning outcome alongside the distribution of its associated process components, providing a comprehensive overview of the cognitive complexity embedded in the curriculum.

Table 3. The distribution of first-grade learning outcomes and process components across SOLO taxonomy levels

Learning Outcome	Learning Outcome Levels	Process Component Levels					Total
		Unistructural	Multistructural	Relational	Extended Abstract		
1.1.1.	MS	1	2	-	-	3	
1.1.2.	R	-	1	1	-	2	
1.1.3.	US	-	-	-	-	-	
1.1.4.	MS	1	2	-	-	3	
1.1.5.	US	-	-	-	-	-	
1.1.6.	R	1	-	1	-	2	
1.1.7.	R	-	-	3	-	3	
1.1.8.	R	-	1	2	-	3	
1.1.9.	US	-	-	-	-	-	
1.2.1.	R	1	-	1	-	2	
1.2.2.	R	-	1	3	-	4	
1.2.3.	R	-	2	1	-	3	
1.2.4.	R	-	1	2	-	3	
1.3.1.	R	-	1	1	-	2	
1.3.2.	EA	-	2	2	-	4	
1.3.3.	R	-	-	-	-	-	
1.3.4.	R	1	-	1	-	2	
1.3.5.	MS	1	3	-	-	4	
1.4.1.	R	-	4	4	-	8	
Total		6	20	22	0	48	

As can be seen from Table 3, Grade 1 includes a blend of cognitive complexities, predominantly prioritizing procedural fluency and conceptual connections. The analysis indicates that 63.1% (n=12) of the learning outcomes are situated at the Relational level, while 15.8% (n=3) are Unistructural, 15.8% (n=3) are Multistructural, and 5.3% (n=1) reach the Extended Abstract level. Of the 48 associated process components analyzed, 45.8% (n=22) align with Relational process components, such as determining relationships in number/shape patterns (MAT.1.1.6b) or analyzing connections between addition/subtraction components (MAT.1.2.2b). Multistructural process components, such as identifying directional terms in navigation (MAT.1.3.1a) or sorting geometric shapes by formal properties (MAT.1.3.5b) constitute 41.7% (n=20). A smaller percentage of the process components (12.5, n=6) includes Unistructural components such as recognizing geometric shapes in daily objects (MAT.1.3.4a) or naming classified shapes (MAT.1.3.5c). Notably, in

Grade 1, there are no process components in the Extended Abstract level, one learning outcome (MAT.1.3.2) was coded at this level. Furthermore, the distribution of cognitive complexity levels across process components within each theme of the program is detailed in Table 4.

Table 4. Distribution of SOLO taxonomy levels by theme in grade 1

Theme	Unistructural	Multistructural	Relational	Extended Abstract	Total
Numbers and Quantities	3 (18.8%)	6 (37.5%)	7 (43.7%)	0 (0%)	16
From Operations to Algebraic Thinking	1 (8.3%)	4 (33.3%)	7 (58.4%)	0 (0%)	12
Geometry of Objects	2 (16.7%)	6 (50.0%)	4 (33.3%)	0 (0%)	12
Data-Driven Research	0 (0%)	4 (50%)	4 (50%)	0 (0%)	8
Total	6 (12.5%)	20 (41.7%)	22 (45.8%)	0 (0%)	48

The Numbers and Quantities theme, which contains 16 process components, demonstrates a diverse distribution of SOLO levels: 18.8% (n=3) Unistructural, 37.5% (n=6) Multistructural, and 43.7% (n=7) Relational. This suggests that while students are expected to recognize and name numbers and quantities (Unistructural), they are also challenged to make connections between different representations of numbers and apply their understanding in simple problem-solving contexts. Compared to this theme, the From Operations to Algebraic Thinking theme, consisting of 12 process components, demonstrates a stronger emphasis on relational thinking with 58.4% (n=7). Consistent with this percentage, this theme has a limited number of Unistructural (8.3%, n=1) process components. Similarly, the Geometry of Objects theme exhibits a strong presence at the Multistructural level (50.0%, n=6), with 33.3% (n=4) of process components at the Relational level. In contrast, the Data-Driven Research theme, although it has the fewest components (8 in total), shows an even split between Multistructural and Relational levels (50%, n=4 each).

Second Grade Learning Outcomes and Process Components according to the SOLO Taxonomy

At the Grade 2 level, 25 learning outcomes and their corresponding 82 process components were analyzed according to the SOLO taxonomy. Table 5 presents the distribution of SOLO levels across each learning outcome and their associated process components across the process components, illustrating the program's progression toward advanced cognitive complexity.

Table 5. The distribution of second-grade learning outcomes and process components across SOLO taxonomy levels

Learning Outcome	Learning Outcome Levels	Process Component Levels				Total
		Unistructural	Multistructural	Relational	Extended Abstract	
2.1.1.	MS	1	2	-	-	3
2.1.2.	R	-	1	1	-	2
2.1.3.	US	-	-	-	-	-
2.1.4.	MS	-	1	1	1	3
2.1.5.	R	-	2	2	1	5
2.1.6.	R	-	-	3	-	3
2.1.7.	R	-	1	1	-	2
2.1.8.	R	-	1	1	-	2
2.1.9.	US	-	-	-	-	-
2.1.10.	EA	-	1	2	-	3
2.1.11.	R	-	-	3	-	3
2.2.1.	EA	-	3	4	3	10
2.2.2.	R	-	2	2	-	4
2.2.3.	R	-	1	2	-	3
2.2.4.	R	-	1	1	-	2
2.2.5.	R	-	3	1	-	4
2.2.6.	R	-	2	1	-	3
2.3.1.	MS	1	2	1	-	4
2.3.2.	EA	-	1	1	1	3
2.3.3.	EA	-	1	1	1	3
2.3.4.	R	-	2	1	-	3
2.3.5.	R	-	-	3	-	3
2.3.6.	R	-	2	4	-	6
2.3.7.	R	-	-	-	-	-
2.4.1.	EA	-	3	5	-	8
Total		2	32	41	7	82

As illustrated in Table 5, Grade 2 mathematics learning outcomes and process components demonstrate a progression in cognitive complexity, emphasizing relational understanding and introducing abstract reasoning. The analysis of learning outcomes shows that 60% (n=15) are situated at the Relational level, while 20% (n=5) reach the Extended Abstract level. The remaining outcomes are distributed between Multistructural (12%, n=3) and Unistructural (8%, n=2) levels. There is an increase in cognitive complexity of the learning outcomes compared to Grade 1. Among the 82 process components analyzed, 50.0% (n=41) align with Relational level, such as analyzing relationships in number patterns (MAT.2.1.10b) or expressing the meanings of equality within the contexts of addition, subtraction, multiplication, and division operations (MAT.2.2.6c). Multistructural components, including procedural skills applying the determined strategy or strategies for a

solution (MAT.2.2.1e) or categorizing different objects according to their formal properties (MAT.2.3.1b), constitute 39.0% (n=32). Extended Abstract components emerge at 8.5% (n=7), such as generalizing which problems a successful strategy or strategies can be applied to (MAT.2.2.1ğ) or creating original models by combining geometric shapes (MAT.2.3.3c). This level is important as it indicates a shift toward abstract thinking absent in Grade 1. The Unistructural level is represented by only two process components, such as naming geometric solids (MAT.2.3.1ç), constituting minimal (2.4%, n=2), reflecting reduced reliance on rote skills. The following table, Table 6, shows how cognitive complexity (SOLO levels) across the process components is distributed across the four themes in Grade 2.

Table 6. Distribution of SOLO taxonomy levels by theme in grade 2

Theme	Unistructural	Multistructural	Relational	Extended Abstract	Total
Numbers and Quantities	1 (3.8%)	9 (34.6%)	14 (53.8%)	2 (7.8%)	26
From Operations to Algebraic Thinking	0 (0%)	12 (46.2%)	11 (42.3%)	3 (11.5%)	26
Geometry of Objects	1 (4.5%)	8 (36.4%)	11 (50.0%)	2 (9.1%)	22
Data-Driven Research	0 (0%)	3 (37.5%)	5 (62.5%)	0 (0%)	8
Total	2 (2.4%)	32 (39.0%)	41 (50.0%)	7 (8.5%)	82

The analysis of Grade 2 learning outcomes and process components reveals thematic variations in cognitive complexity. While the Numbers and Quantities theme, comprising 26 process components, emphasizes Relational components (53.8%, n=14), the From Operations to Algebraic Thinking theme, consisting of 26 process components, focuses on Multistructural components (46.2%, n=12). Similarly, the Geometry of Objects theme (n=22) also places the emphasis on Relational components (50.0%, n=11). Notably, all three of these themes include Extended Abstract components ranging from 7.8% (n=2) to 11.5% (n=3). Contrary to these three themes, the Data-Driven Research theme lacks Extended Abstract components; instead, it focuses on Relational components (62.5%, n=5) and Multistructural components (37.5%, n=3).

Third Grade Learning Outcomes and Process Components according to the SOLO Taxonomy

At the Grade 3 level, 33 learning outcomes and their corresponding 105 process components were analyzed according to the SOLO taxonomy. Table 7 presents the SOLO levels associated with each learning outcome and its associated process components, offering insight into the cognitive demands placed on students.

Table 7. The distribution of third-grade learning outcomes and process components across SOLO taxonomy levels

Learning Outcome	Learning Outcome Levels	Process Component Levels				Total
		Unistructural	Multistructural	Relational	Extended Abstract	
3.1.1.	MS	1	2	-	-	3
3.1.2.	R	-	1	1	-	2
3.1.3.	MS	-	4	-	-	4
3.1.4.	MS	-	1	1	1	3
3.1.5.	MS	1	2	1	-	4
3.1.6.	R	-	-	-	-	-
3.1.7.	R	-	2	1	2	5
3.1.8.	R	-	-	3	-	3
3.1.9.	MS	1	2	-	-	3
3.1.10.	R	-	1	1	-	2
3.1.11.	R	-	1	1	-	2
3.1.12.	MS	-	-	-	-	-
3.1.13.	R	-	1	1	-	2
3.1.14.	R	-	-	3	-	3
3.1.15.	R	-	1	1	-	2
3.1.16.	R	-	1	2	-	3
3.2.1.	R	-	2	2	-	4
3.2.2.	R	-	1	1	-	2
3.2.3.	R	-	3	1	-	4
3.2.4.	R	-	1	1	-	2
3.2.5.	R	-	1	2	-	3
3.2.6.	EA	-	3	6	1	10
3.2.7.	EA	-	-	-	2	2
3.2.8.	R	-	2	1	-	3
3.3.1.	R	-	3	-	-	3
3.3.2.	MS	1	2	1	-	4
3.3.3.	MS	1	2	-	-	3
3.3.4.	R	-	-	3	-	3
3.3.5.	R	-	-	3	-	3
3.3.6.	R	-	1	1	-	2
3.3.7.	R	-	-	2	-	2
3.3.8.	EA	-	3	3	-	6
3.4.1.	EA	-	3	5	-	8
Total		5	46	48	6	105

As can be seen from Table 7, Grade 3 demonstrates a balanced distribution of cognitive complexity, with a strong emphasis on both procedural fluency and conceptual integration. The analysis of learning outcomes (n=33) indicates that 63.6% (n=21) are coded at the Relational level, while 12.1% (n=4) reach the Extended Abstract level. The remaining outcomes are classified as Multistructural (24.2%, n=8), with not outcomes coded at the

Unistructural level. Of the 105 process components analyzed, 43.8% (n=46) are classified as Multistructural, involving tasks such as identifying multiple features of geometric solids (MAT.3.3.1b) or posing research questions based on categorical and quantitative data (MAT.3.4.1b). Similarly, 45.7% (n=48) of the components fall under the Relational level, indicating a substantial focus on synthesizing and connecting mathematical ideas. Examples include determining the relationship between a whole and each of its equal parts (MAT.3.1.10b) or relating experiences with standard liquid measurement units to the estimated amount of liquid (MAT.3.3.5a). Extended Abstract components (5.7%, n=6) are few but important, indicating an increase toward more advanced reasoning skills such as generalizing numeric patterns (MAT.3.1.4c) and identifying transferable problem-solving strategies across different scenarios (MAT.3.2.6ğ). A small percentage of the components (4.8%, n=5) are at the Unistructural level, typically involving the identification of a single element such as expressing numbers as even or odd (MAT.3.1.5ç) or naming geometric shapes according to their number of edges (MAT.3.3.2ç). Furthermore, the distribution of SOLO Taxonomy levels across the process components associated with each theme in Grade 3 is summarized in Table 8.

Table 8. Distribution of SOLO taxonomy levels by theme in grade 3

Theme	Unistructural	Multistructural	Relational	Extended Abstract	Total
Numbers and Quantities	3 (7.3%)	19 (46.3%)	16 (39.0%)	3 (7.3%)	41
From Operations to Algebraic Thinking	0 (0%)	13 (43.3%)	14 (46.7%)	3 (10.0%)	30
Geometry of Objects	2 (7.7%)	11 (42.3%)	13 (50.0%)	0 (0%)	26
Data-Driven Research	0	3 (37.5%)	5 (62.5%)	0	8
Total	5 (4.8%)	46 (43.8%)	48 (45.7 %)	6 (5.7%)	105

The Numbers and Quantities theme, comprising 41 process components, is primarily represented at the Multistructural (46.3%, n=19) and Relational (39.0%, n=16) levels, with a small presence of Unistructural (7.3%, n=3) and Extended Abstract (7.3%, n=3) components. The From Operations to Algebraic Thinking theme, which includes 30 components, shows a similarly balanced distribution, with 46.7% (n=14) at the Relational level and 43.3% (n=13) at the Multistructural level. Notably, this theme has the highest proportion of Extended Abstract components (10%, n=3), indicating increased emphasis on generalizing and abstract

reasoning. In the Geometry of Objects theme, consisting of 26 components, half of the components (50.0%, n=13) are at the Relational level, while Multistructural outcomes account for 42.3% (n=11), and Unistructural components (7.7%, n=2) are minimal. Notably, this theme lacks any Extended Abstract components. Lastly, the Data-Driven Research theme, although limited to 8 components, emphasizes Relational (62.5%, n=5) and Multistructural (37.5%, n=3) levels, similar to the patterns observed in earlier grades, with no instances of Unistructural or Extended Abstract outcomes.

Fourth Grade Learning Outcomes and Process Components according to the SOLO Taxonomy

In Grade 4, a total of 34 learning outcomes and 101 associated process components were examined through the lens of the SOLO taxonomy. As detailed in Table 9, the classification of the learning outcomes and process components provides insight into the evolving cognitive demands of the curriculum.

Table 9. The distribution of fourth-grade learning outcomes and process components across SOLO taxonomy levels

Learning Outcome	Learning Outcome Levels	Process Component Levels				Total
		Unistructural	Multistructural	Relational	Extended Abstract	
4.1.1.	MS	1	2	-	-	3
4.1.2.	R	-	1	1	-	2
4.1.3.	MS	-	3	1	-	4
4.1.4.	EA	-	-	2	-	2
4.1.5.	EA	-	2	2	-	4
4.1.6.	MS	1	2	-	-	3
4.1.7.	MS	1	2	-	-	3
4.1.8.	R	-	1	1	-	2
4.1.9.	R	-	1	1	-	2
4.1.10.	R	-	1	1	-	2
4.1.11.	EA	-	-	1	1	2
4.1.12.	EA	-	1	2	-	3
4.1.13.	R	-	1	2	-	3
4.2.1.	R	-	1	1	-	2
4.2.2.	EA	-	-	-	2	2
4.2.3.	R	-	-	2	1	3
4.2.4.	EA	-	-	-	2	2
4.2.5.	R	-	1	1	-	2
4.2.6.	R	-	1	2	-	3
4.2.7.	EA	-	3	6	1	10
4.2.8.	EA	-	0	0	2	2
4.2.9.	R	-	2	1	-	3
4.3.1.	EA	-	-	1	1	2
4.3.2.	R	-	2	1	-	3
4.3.3.	MS	1	2	-	-	3

4.3.4.	R	-	0	3	-	3
4.3.5.	R	1	-	2	-	3
4.3.6.	EA	-	2	2	-	4
4.3.7.	MS	1	2	1	-	4
4.3.8.	R	-	2	1	-	3
4.3.9.	R	-	-	2	-	2
4.3.10.	EA	-	-	1	1	2
4.4.1	MS	-	-	-	-	-
4.4.2.	EA	-	3	5	-	8
Total		6	38	46	11	101

The analysis of Grade 4, comprising 34 outcomes and 102 associated process components, indicates a notable shift toward higher-order cognitive engagement. As shown in Table 9, nearly half of the learning outcomes (44.1%, n=15) are situated at the Relational level, while 20.6% (n=7) are coded at the Multistructural level. Since the remaining outcomes (35.3%, n=12) reach the Extended Abstract level as well as no outcomes coded at the Unistructural level, it could be stated that there is a significant increase in cognitive complexity compared to previous grades. Furthermore, the majority of process components are situated at the Relational level (45.5%, n=46), highlighting an emphasis on making connections, such as identifying hierarchical patterns while counting rhythmically (MAT.4.1.4a) or determining proportional relationships between quantities and their parts (MAT.4.1.10b). Then, Multistructural components constitute 37.6% (n=38), reflecting sustained attention to the coordination of multiple ideas, such as using visual representations to model different types of fractions (MAT.4.1.6c) or decomposing numbers for mental addition and subtraction (MAT.4.2.1a). A smaller percentage of the components (10.9%, n=11) are categorized as Extended Abstract such as reasoning through the structure of algorithms (MAT.4.2.2a) or constructing geometric shapes based on relational insights (MAT.4.3.1b), and is more frequent compared to the previous grades. Unistructural components reflect early-stage comprehension without requiring integration or analysis of multiple ideas such as recognizing representations of quantities (MAT.4.1.1a) and identifying angles based on real-life examples (MAT.4.3.5a), constitute 5.9% (n=6). The distribution of SOLO taxonomy levels across the process components for each theme in Grade 4 is also summarized in Table 10.

Table 10. Distribution of SOLO taxonomy levels by theme in grade 4

Theme	Unistructural	Multistructural	Relational	Extended Abstract	Total
Numbers and Quantities	3 (8.6%)	17 (48.6%)	14 (40.0%)	1 (2.9%)	35
From Operations to Algebraic Thinking	0 (0%)	8 (27.6%)	13 (44.8%)	8 (27.6%)	29
Geometry of Objects	3 (10.3%)	10 (34.5%)	14 (48.3%)	2 (6.9%)	29
Data-Driven Research	0 (0%)	3 (37.5%)	5 (62.5%)	0 (0%)	8
Total	6 (5.9%)	38 (37.6%)	46 (45.5%)	11 (10.9%)	101

At Grade 4 level, the Numbers and Quantities theme, comprising 35 process components, primarily includes Multistructural (48.6%, n=17) and Relational (40.0%, n=14) components. The From Operations to Algebraic Thinking theme, encompassing 29 process components, indicates a cognitively rich distribution as most of the process components are classified as Relational (44.8%, n=13) or Extended Abstract (27.6%, n=8). The Geometry of Objects theme, consisting of 29 process components, are dominated by Relational (48.3%, n=14) and Multistructural (34.5%, n=10) levels. Finally, the Data-Driven Research theme, including 8 process components, emphasizes Relational (62.5%, n=5) and Multistructural (37.5%, n=3) levels.

Discussion, Conclusion, and Recommendations

This study examined the cognitive complexity of both learning outcomes and their associated process components the Elementary School Mathematics Curriculum (Grades 1–4): The Maarif Model of the Century of Türkiye, using the SOLO taxonomy as an analytical framework. While learning outcomes represent the intended cognitive goals of instruction, process components represent the smaller, operationalized sub-skills through which learning outcomes are intended to be achieved. Accordingly, the findings of this study not only the cognitive complexity of the learning outcomes but also the cognitive complexity that students are likely to encounter during instruction. Within this scope, the findings indicate a developmental progression in cognitive complexity of the process components from Grade 1 through Grade 4.

Across all grade levels, the distribution of SOLO Taxonomy levels of learning outcomes and process components reveals that when all learning outcomes and their associated process components are considered collectively, it is seen that Multistructural and

Relational components are dominant. This distribution reflects the curriculum's intentional emphasis and focus on building coordinating multiple ideas and establishing conceptual links over rote learning or rote memorization. The relatively low proportion of Unistructural outcomes and components in upper grades further supports the interpretation that the curriculum gradually moves away from isolated recognition or naming skills. This pattern is actually consistent with developmental expectations of students, as younger students require more concrete learning experiences, whereas older students are better at integrating multiple ideas. From this perspective, the observed distribution of SOLO levels appears to be developmentally appropriate and aligned with students' cognitive growth from Grades 1 to 4. Actually, these findings align with the studies of Satmaz and Yabanova (2024) and Cihan and Doruk (2024), both studies report a dominance of Multistructural and Relational levels, with an increasing presence of Extended Abstract components as grade levels increase. On the other hand, these results show that 2024 mathematics curriculum differs significantly in terms of cognitive complexity compared to the 2018 curriculum. For instance, in their study examining 2018 secondary school mathematics learning outcomes, Acar and Peker (2023) found that the focus was primarily on the Unistructural level. Similarly, Doğan (2020) revealed that 2018 elementary school mathematics learning outcomes are mostly at the Unistructural and Multistructural level.

In the current study, actually, a progressive increase in cognitive complexity is evident across grade levels. Notably, the proportion of Relational level outcomes and components becomes more prominent from Grade 2 onwards (50%), alongside the first emergence of Extended Abstract components (8.5%). This pattern continues through Grades 3 and 4, suggesting that the curriculum is deliberately structured to promote higher-order thinking. Similarly, Unistructural components decrease from 18.8% in Grade 1 to just 5.9% in Grade 4. While this pattern suggests an intentional progression toward higher-order thinking, it should be interpreted cautiously. The analysis reveals that the SOLO level of a learning outcome does not always align with the highest SOLO level of its associated process components. In some cases, learning outcomes are formulated at a higher SOLO level than the levels reflected in their associated process components, suggesting that abstract or generalized goals are pedagogically scaffolded through lower-level skills. In other cases, learning outcomes are classified at a lower SOLO level than one or more of their process components, indicating that higher cognitive complexity may be embedded within

instructional processes. Nevertheless, the introduction and persistence of Extended Abstract components—although limited in proportion—indicate that opportunities for abstraction and generalization are embedded within the Maarif Model at earlier stages. Furthermore, this developmental progression aligns with the Maarif Model’s stated objective of nurturing mathematical reasoning skills, which encompass “analysis, interpretation, inference, and mathematical verification or proof” (MoNE, 2024, p. 28).

The distribution of cognitive complexity across themes indicates that Relational and Multistructural level components are particularly concentrated within the themes From Operations to Algebraic Thinking and Geometry of Objects. This distribution suggests a deliberate emphasis on developing structured reasoning and connecting mathematical concepts, aligning with the broader pedagogical goals of the Maarif Model. Yet, the limited number of Extended Abstract components, especially within the Data-Driven Research, where such components are entirely absent, indicates an area further progression, particularly if the goal is to strengthen students’ abilities to generalize and transfer knowledge across contexts.

In summary, the findings indicate that the Elementary School Mathematics Curriculum (Grades 1–4): The Maarif Model of the Century of Türkiye effectively advances cognitive complexity across grades, transitioning from foundational skills (Unistructural/Multistructural) to interconnected and abstract reasoning (Relational/Extended Abstract). The analysis also shows that the SOLO levels of learning outcomes and their process components do not always fully align, highlighting the complementary yet distinct roles of outcomes and components in structuring learning. Although the Maarif Model provides structured opportunities for students to build toward relational and abstract reasoning especially in upper grade, the scarcity of Extended Abstract learning outcomes and process components—especially in lower grades—highlights a gap in opportunities for students to generalize knowledge. Filling these gaps could further enhance the curriculum’s potential to support students not only in performing mathematical procedures, but also in transferring their knowledge, reflecting on it, and extending it.

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