

**Sustainability and Problem-Solving in Science Curricula: A QDA Miner Comparison of Türkiye and Singapore**

Aylin GÜNGÖR*, Hasan ÖZCAN**

Article Information	ABSTRACT
Received: 27.07.2025	This study aims to conduct a comparative analysis between the Century of Türkiye Education Model Science Curriculum (2024, Grades 3–8) and Singapore's Science Syllabus (2023 implementation, Primary 3–6 and Lower Secondary 1–2) to examine the role of sustainability competencies and higher-order cognitive skills, which are at the forefront of global educational approaches. In this study, a qualitative document analysis was conducted to thematically evaluate the current curricula of both countries. Thematic coding and content analysis were performed using the QDA Miner qualitative data analysis software. The analysis revealed that sustainability and higher-order cognitive skills are explicitly included in both curricula but with distinct pedagogical priorities. Singapore's curriculum exhibited a significantly greater emphasis on practice-based and inquiry-based higher-order skills, such as <i>Decision Making</i> (56.0% vs. Türkiye's 44.0%) and <i>Problem Solving</i> (54.8% vs. Türkiye's 45.2%). Conversely, the Turkish curriculum placed a stronger emphasis on the theoretical dimensions of sustainability, specifically <i>Future-Oriented Thinking</i> (59.1% vs. Singapore's 40.9%) and <i>Systems Thinking</i> (53.7% vs. Singapore's 46.3%). Although the Turkish curriculum has a vision defined at the strategic level, the findings suggest that its implementation could benefit from integrating more explicit, step-by-step guidance and case studies to match its strong theoretical foundation. Overall, the findings reveal the strengths and areas for improvement of both programmes, offering valuable insights for curriculum development, teacher education, and assessment systems. By shedding light on the pedagogical foundations of sustainability-oriented science education, the study contributes significantly to understanding how educational systems are adapting to the demands of 21st-century skills. Keywords: Science Curriculum, Sustainability, Problem Solving, The Century of Türkiye Education Model, Singapore.
Accepted: 15.11.2025	
Online First: 27.04.2026	
Published: 30.04.2026	
doi: 10.16986/hunefd.1752258	Article Type: Research Article

Citation Information: Gungör, A., & Özcan, H. (2026). Sustainability and Problem-Solving in Science Curricula: A QDA Miner Comparison of Türkiye and Singapore. *Hacettepe University Journal of Education*, 41(2), 301-316. <https://doi.org/10.16986/hunefd.1752258>

1. INTRODUCTION

Throughout history, individuals have continuously progressed in their pursuit of knowledge while seeking solutions to the problems they faced. Each new accumulation of knowledge has shaped the intellectual foundation for future generations. Science, which is an important part of this accumulation, serves as a fundamental discipline that develops the individual's ability to understand natural phenomena, explain them, and find solutions (Ministry of National Education [MoNE], 2024; Ministry of Education Singapore [MOE], 2024). With its emphasis on curiosity and inquiry-based structure, science increases the capacity of individuals to solve complex problems. In this context, it plays a crucial role in contributing directly to social development beyond individual growth (Tan et al., 2017).

However, in the 21st century, as digitalization has rapidly become widespread, individuals growing up surrounded by technology have not developed problem-solving skills. On the contrary, a heavy reliance on digital tools has led to the decline in individuals' critical and analytical thinking skills (Chu et al., 2021). This situation has led countries to restructure their education systems, and policies, to enhance students' higher-order thinking, scientific inquiry, and problem-solving skills. In this context, Türkiye has taken steps to become a knowledge society by integrating its traditional educational heritage with modern pedagogical approaches. Recently, restructuring the infrastructure through the Century of Türkiye Education Model, Türkiye aims to raise virtuous and effective individuals while also developing inquisitive, solution-oriented individuals equipped with scientific process skills (MoNE, 2024).

* Master's Student, Aksaray University Institute of Science STEM Education Department, Aksaray, TÜRKİYE, e-mail: aylin.gungor@asu.edu.tr (ORCID: 0009-0009-0356-1632)

** Prof. Dr., Aksaray University Faculty of Education Science Education Department, Aksaray, TÜRKİYE, e-mail: hozcan@aksaray.edu.tr (ORCID: 0000-0002-4210-7733)

The integration of cognitive development and higher-order thinking skills into education has become a global priority. In this context, many countries participate in international exams such as PISA (Programme for International Student Assessment) and TIMSS (Trends in International Mathematics and Science Study) to assess students' science literacy levels and problem-solving abilities. As can be seen in Figure 1, according to the 2022 PISA Report, Singapore achieved the highest results in science literacy, together with East Asian countries such as Japan, Macao-China, Taiwan, and South Korea also ranking high (PISA Report, 2022; TIMSS Report, 2023). These accomplishments can be attributed to countries prioritizing science education early, systematically employing inquiry-based learning strategies, adopting interdisciplinary approaches, and continuously improving teacher competencies (Tan et al., 2017; Chu et al., 2021).

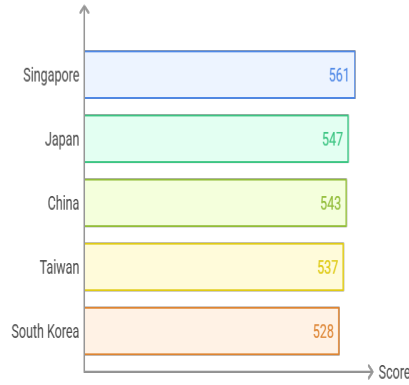


Figure 1. PISA 2022 Science literacy scores (Image created by the researcher using Canva software. Success in school).

As shown in Figure 2, there is a striking difference in balance between Türkiye's 2022 PISA and 2023 TIMSS results. In the PISA 2022, Türkiye ranked 34th out of 81 countries, achieving a score of 476 in science, and ranked 29th among OECD countries (OECD, 2023). While this indicates progress compared to previous assessments, it also reveals areas that need improvement relative to the international average (MoNE PISA, 2022). On the other hand, TIMSS 2023 results published in the same year presented a more positive picture for Türkiye. For 4th-grade science, Türkiye scored 570, ranking 4th among 58 countries globally and 1st among European countries. At the 8th grade level, it ranked 7th among 44 countries with a score of 530 (MoNE TIMSS, 2023). These results suggest that the reforms implemented, particularly in early years science education, have produced positive outcomes.

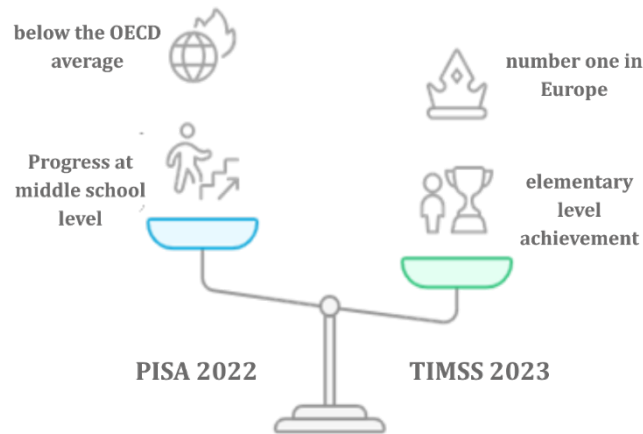


Figure 1. Strengths and Weaknesses in Science Education in Türkiye (Image created by the researcher using Canva software).

At this point, the innovative approach that the Century of Türkiye Education Model brings to education is remarkable. Taking inspiration from high-achieving countries, Türkiye's model is built on experiential learning, problem-based structuring, inquiry-based activities, interdisciplinary construct, and value-based teaching (MoNE, 2024). Such an approach helps students to connect science to real life activities, participate, in scientific thinking processes, and develop their ability to create solutions. This model has the potential to improve Türkiye's performance in international assessment systems. It goes beyond the knowledge transfer, focusing on high-level mental competencies such as scientific process skills, curiosity, critical thinking, and systematic analysis. This shows that the Century of Türkiye Education Model has a vision for science education that can compete on a global scale (MoNE, 2024).

The purpose of this study is to compare the secondary science curricula of Türkiye with Singapore, which has ranked the first in PISA and TIMSS exams. We evaluate how students integrate sustainability-based problem-solving skills into their daily lives to develop sustainable solutions. In particular, we discussed the curricula and pedagogical approaches that contribute to

Singapore's exceptional performance in international exams mentioned before (Karalı, Palancıoğlu & Aydemir, 2021). In this context, the following questions will be addressed:

To what extent are the Century of Türkiye Education Model and Singapore's secondary science programs effective in linking sustainability-based problem-solving skills to daily life?

When assessing the problem-solving outcomes in the science programs of both countries through QDA Miner analysis, what differences or similarities can be observed regarding the ability to develop sustainable solutions based on high-level cognitive skills?

In line with these questions, the outcomes of the curricula from both countries will be examined through a qualitative analysis method. Data will be coded thematically using the QDA Miner program, and both implicit and explicit messages related to problem-solving skills will be systematically analyzed. The findings aim to provide concrete recommendations for teachers, policymakers, and curriculum developers in terms of structuring science teaching with a focus on sustainability.

1.1. Background

1.1.1. The Role of Sustainability in Education

Contemporary approaches in science education not only conveys essential knowledge but also empowers students to deal with real-world problems in their daily lives (Martaningsih et al., 2022). In this context, prioritizing the development of solutions for environmental and social issues becomes crucial. Sustainable development has emerged as priority within education systems, leading to the increasing adoption of learning processes based on sustainability principles in science education programs (Aydın & Kıvanç, 2022; Sucuoğlu et al., 2023). Until 2030 UNESCO aims to equip individuals with sustainable life skills and integrate these skills into educational curricula (UNESCO, 2017).

Sustainability-oriented science education helps students understand natural phenomena and develop solutions to real-life problems by empowering them to make environmentally conscious decisions (Alath, 2020; MoNE, 2024). It also encourages individuals to create solutions, engage in critical thinking, and uphold social responsibility. High-level cognitive skills like problem-solving are fundamental in this process (Martaningsih et al., 2022). Skills such as analysis, synthesis, evaluation, and decision-making are crucial for solving complex sustainability problems (Varlık, 2025). For that reason, it is important to realize that science education programs have the potential to equip students with the mentioned skills. Science education helps individuals to examine their surroundings using the scientific method to create solutions. In the teaching process, problem-based scenarios related to daily life is regarded as an effective approach for students to better understand scientific concepts and internalize the information (Trott & Weinberg, 2020).

1.1.2. The Global Trend: The Rise of Sustainability and Higher-Order Cognitive Skills in Science Curricula

The global consensus on education is fundamentally shifting, driven by rapid technological advancements, complex socio-scientific issues, and the urgency of climate change (OECD, 2018; OECD 2022). Major international bodies like UNESCO, the Organization for Economic Co-operation and Development (OECD), and the United Nations (through the Sustainable Development Goals – SDGs) have explicitly positioned sustainability competencies and Higher-Order Cognitive Skills (HOCS) as essential learning outcomes (Kim & Care, 2020). This global prioritization stems from the need for students to move beyond rote knowledge to become active citizens capable of critical thinking, complex problem-solving, and future-oriented decision-making in the face of universal challenges (Luckin et al., 2021).

Despite this unified push, a significant implementation gap exists worldwide. While most modern curricula define these competencies at the strategic and visionary level, many systems struggle with integrating them effectively into daily classroom practice, teacher professional development, and standardized assessment methods (OECD, 2024). This divergence between intent and execution highlights a key research need: comparative analysis of how different national frameworks, such as those in Türkiye and Singapore, operationalize these globally critical concepts (Karalı et al., 2021).

1.1.3. Singapore's Science Education Approach

Singapore has developed an innovative science curriculum focusing on 21st-century skills to increase students' scientific literacy (Tan et al., 2017). Inquiry-based learning, sustainability-focused content, and interdisciplinary structure stand out as the three fundamental component for Singapore's curriculum (MOE, 2024). The inquiry-based learning approach focuses on the effective use of scientific process skills. It aims to improve students' fundamental competences including observation, hypothesis development, data collection, and interpretation. This program helps students to create knowledge rather than consuming it.

Moreover, the interdisciplinary learning strengthens students' ability to create multidimensional solutions to complex issues by connecting science with mathematics, engineering, technology, and social sciences (MOE, 2024). It helps students to make

connections between different disciplines, systemic analysis, and critical thinking (Boncukçu & Gök, 2023). Furthermore, sustainability-oriented content encourages students to become aware of environmental responsibility, in addition to acknowledging environmental issues, and adopting a solution-oriented approach (Karaarslan & Teksöz, 2024). This stratified structure provides a holistic approach for science education, aiming to increase students' competencies to solve problems in academic and everyday contexts. This structure also helps students develop high-level thinking skills and cope with real-life problems (Tan et al., 2017; Boncukçu & Gök, 2023; MOE, 2024).

1.1.4. Science Education in the Century of Türkiye Education Model

Prioritizing high-level thinking skills, the Century of Türkiye Education Model Curriculum has been established on a student-centred and value-oriented holistic structure. Its main purpose is to ensure that individuals acquire knowledge, gain the competence to understand this knowledge, associate it with different contexts, and effectively transform it (MoNE, 2024). In this curriculum, interdisciplinary relationships characterized by science, engineering, technology, and design are emphasized, while learning outcomes are integrated with components of conceptual understanding, values education, literacy, social-emotional learning, and field skills (MoNE, 2025).

The model aims to enhance students' individual and environmental awareness. It uses interdisciplinary and transdisciplinary learning scenarios to improve students' understanding of the natural world by emphasizing their active participation. It is designed to develop students' living skills by placing a great emphasis on sustainability (MoNE, 2024). In line with this approach, it seeks to enhance sensitivity to environmental issues, awareness of natural resource use, and capacity to create solutions to local and global issues. Additionally, using sustainability-oriented learning experiences, it aims to create social responsibility, entrepreneurship, and productivity (MoNE, 2025).

OECD's report on the 21st-century skills defines a set of fundamental skills for Türkiye, including creative thinking, critical thinking, problem solving, decision making, communication, research, and literacy related to information and communication technologies (ICT). However, OECD's (2018) report also mentions that assessment evaluation policies and teacher training programs have not yet been systematically structured. This indicates that there are still areas of growth to integrate these skills into the education system, through implementation and evaluation (OECD, 2018).

2. METHODOLOGY

2.1. Research Method and Data Collection

Within the scope of the study, document analysis, a qualitative research method, was employed (Fraenkel et al., 2023). We thematically analyzed the Science Curricula of Türkiye and Singapore, covering Grades 3–8, with a focus on sustainability competencies and Higher-Order Cognitive Skills (HOCS), in order to reveal the structural and pedagogical differences between the two countries. The data were collected from the 2024 Century of Türkiye Education Model Science Curriculum (Grades 3–8) and Singapore's 2023 Science Syllabus (Primary 3–6 and Lower Secondary 1–2), both officially published online by the respective Ministries of Education (MoNE, 2024; MOE, 2024). These curricula include all content standards, instructional approaches, and learning outcomes for their respective grade levels. During the data collection phase, both science curricula underwent a preliminary review in terms of sustainability competencies and problem-solving skills. The objectives, descriptions, and expected learning outcomes were examined to identify how these skills are represented and operationalized in each program.

2.2. Data Analysis

We analyzed the data employing the thematic analysis method utilizing QDA Miner software. The six-stage thematic analysis method proposed by Braun and Clarke (2006) was used. The stages included familiarizing with the data, generating initial codes, searching for themes, reviewing themes, and defining and naming themes.

The open coding method was applied following an inductive approach. During this process, codes were grouped into related themes based on similarity and conceptual relationships. These themes were then compared across both curricula to identify convergences and differences.

2.1.1. Coding Reliability

To ensure methodological rigor, several measures were implemented to enhance the reliability of the coding structure and findings. These measures included defining codes clearly, ensuring coding consistency, and verifying interpretations through validation procedures. The process aimed to maintain both internal and external validity of the results.

2.1.2. Code Definition and Reliability

The analysis utilized a focused coding frame consisting of 10 core competencies—seven for Sustainability (e.g., Systems Thinking, Future-Oriented Thinking, Taking Responsible Action) and three for Higher-Order Cognitive Skills (Problem Solving, Decision Making, Critical Thinking). Quantitative comparison was achieved by calculating word density for each competence within the curriculum texts, as presented in Table 1. Internal consistency was maintained, exemplified by the identical code count for Critical Thinking between Türkiye and Singapore (100 instances each).

A detailed coding manual defining each competency's operational criteria was developed. A second experienced researcher independently coded a subset of data using this manual. Consensus meetings were conducted until satisfactory inter-coder reliability was achieved.

2.1.3. Reliability and Interpretive Validity

Credibility was ensured by grounding thematic interpretations in quantitative evidence. For instance, the high coding rates for Systems Thinking (Türkiye: 53.7%) and Future-Oriented Thinking (Türkiye: 59.1%) reflected Türkiye's theoretical and strategic focus, whereas Singapore's higher Problem Solving (54.8%) and Decision Making (56.0%) rates indicated a practice-based pedagogical model. These interpretations were directly linked to the coded data and numerical outcomes.

Dependability was achieved through the audit trail maintained by QDA Miner software. Each coding step, from raw text to the 13 comparative codes and final themes, was systematically documented. This traceable process enhanced transparency and reproducibility.

Transferability was supported through detailed quantitative descriptions of all 10 competencies. Comparative percentages were presented in the findings section (Table 1; Figures 4 and 5) to allow contextual evaluation by other researchers. This detailed presentation provides opportunities to adapt the findings to similar curriculum studies.

3. FINDINGS

3.1. Comparison of Competences by Countries

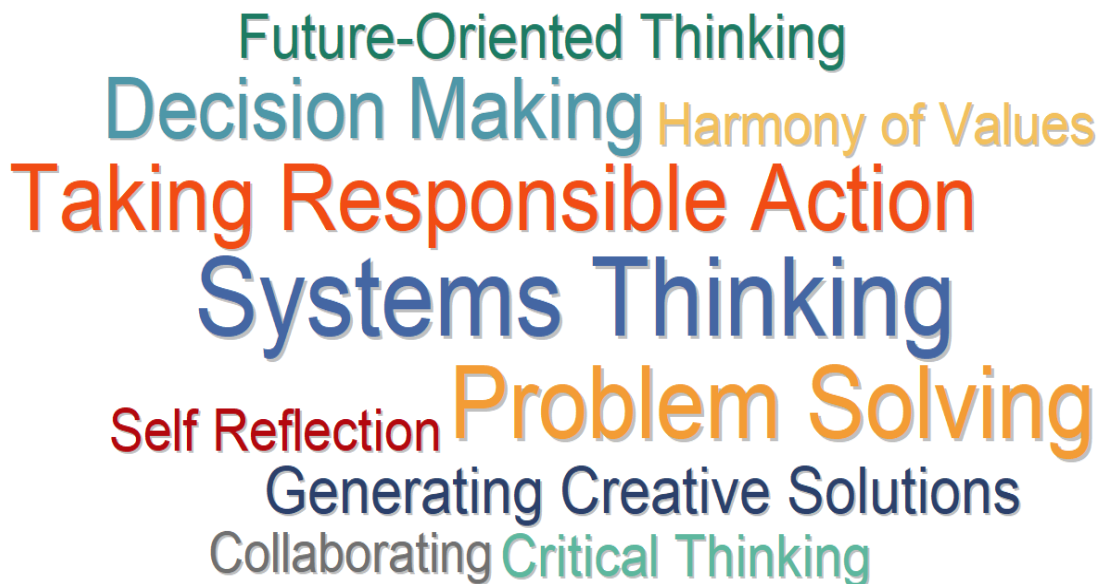


Figure 3. Code distribution of Türkiye and Singapore secondary science curricula (Image created from the data analysed by the researcher using QDA Miner software).

As shown in Figure 3, the comparative analysis shows the distribution of codes related to sustainability competencies and high-level skills that are prominent in the secondary science curricula of Türkiye and Singapore. These findings summarize the specific competencies and skills emphasized in the science programs of both countries.

Table 1.
Türkiye and Singapore Secondary Science Curricula Code Distribution

Competences	Competence Codes	Countries	
		Singapore	Türkiye
Sustainability Competences	Systems Thinking	163.64	210
	Future Oriented Thinking	81.82	130
	Values Alignment	90.91	110
	Cooperation	90.91	100
	Creative Solution Generation	118.18	110
	Self-Reflection	90.91	110
	Taking Responsible Action	163.64	150
Higher Order Thinking Skills	Problem Solving	145.45	200
	Decision Making	109.09	180
	Critical Thinking	100	100

As can be seen in Table 1 the analysis of curriculum texts in the Turkish Education Model reveals a strong emphasis on "Systems Thinking" and "Problem Solving" skills, as indicated by their high word density. This suggests that problem-solving processes and inter-system relationships are thoroughly defined in this model (MONE, 2025). On the other hand, Singapore's model address "Generating Creative Solutions" and "Taking Responsible Action" skills in a more comprehensive manner, focusing on environmental action strategies and innovation-oriented approaches (Ertan & Kaplan, 2023). Both countries have the same word count for "Critical Thinking" category. This indicates that this competency is equally distributed as a fundamental component of 21st-century skills (Gök & Sayıcı, 2022; Ülçay, 2024).

The high word count in the Turkish curriculum on "Future-Oriented Thinking" and "Decision Making" skills shows that the Century of Türkiye Education Model prioritizes decision-making mechanisms to achieve long-term sustainability goals (MoNE, 2025).

3.1.1. Comparison of Sustainability Competences by Code

The analysis of the data presented in Figure 4 reveals both similarities and significant differences in how sustainability competencies are addressed in the science curricula of Singapore and Türkiye. Systems Thinking competence plays a significant role in the science curricula of both countries. In Türkiye, this is represented by a rate of 53.7%, whereas in Singapore it is 46.3%. This shows that the Turkish curriculum places greater emphasis on Systems Thinking. The difference can be attributed to the theoretical emphasis on the concept of sustainability in the recent updates to the Turkish curriculum (Aydın & Kıvanç, 2022). In contrast, Singapore might be addressing this competence through systematic and well-established pedagogical structures (Gök & Sayıcı, 2022).

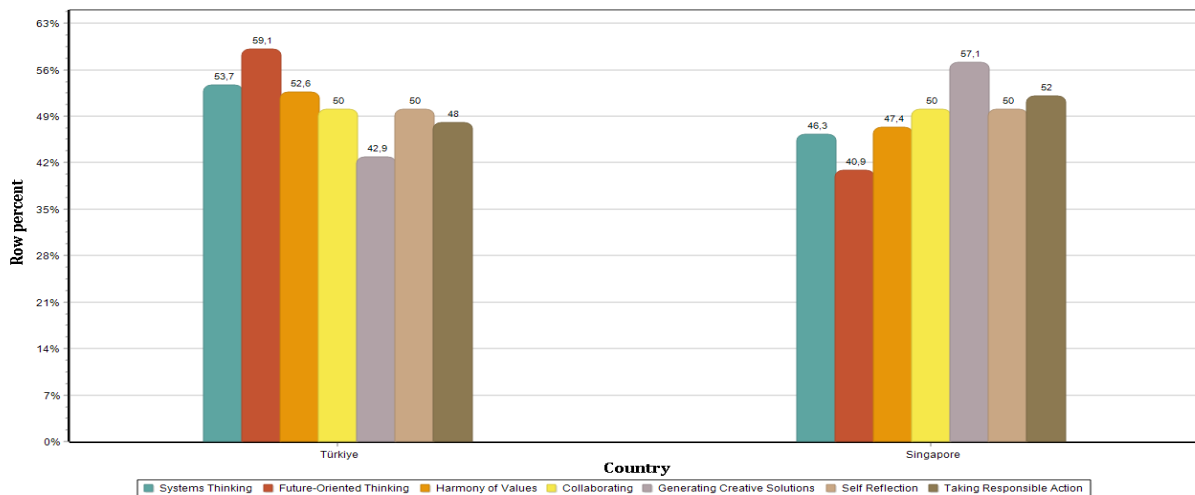


Figure4. Code ratios for sustainability competencies in Türkiye and Singapore (Image created from data analysed by the researcher using QDA Miner software).

A similar trend can be observed in the future-oriented thinking competency. Türkiye includes this skill in its curriculum at a high rate of 59.1%, while in Singapore, the rate remains at 40.9%. This high percentage in Türkiye reflects the Century of Türkiye Education Model's commitment to deeply integrating sustainability messages for future generations into the curriculum. Despite Singapore's lower rate, it could be compensated by its practice-oriented and integrated approaches (Tan, 2021). This notable difference indicates that Türkiye has made a significant investment in future-oriented sustainability. The Century of Türkiye Education Model strongly emphasizes environmental and ethical responsibility as part of the 21st-century skills for future generations (MoNE, 2025).

There is a similar situation concerning the competence of values congruence. While 52.6% of the Turkish curriculum incorporates this competency, the rate in Singapore stands at 47.4%. Although these percentages are relatively close, it is noteworthy that the Turkish curriculum explicitly addresses ethical, social, and environmental values. This indicates that Türkiye prioritizes value-based education at the program level (MoNE, 2025). In contrast, Singapore seems to integrate these values more holistically and implicitly through practice-based activities and STEM scenarios (Yeo & Tan, 2021).

Regarding collaboration competence, Singapore's science curriculum scores higher at 57.1%, compared to Türkiye's 42.9%. This difference may stem from Singapore's extensive and systematic use of project-based learning and teamwork practices within STEM education (Teo & Choy, 2021). On the other hand, in the Turkish curriculum, collaboration skills appear to be addressed primarily in the planning and content explanations, while the implementation aspect remains relatively limited (MoNE, 2024).

In the Singapore science curriculum, the competency for generating creative solutions is 52.6%, which is higher than Türkiye's 47.4%. This difference can be attributed to Singapore's long-standing focus on design thinking and innovation-based science education (Tan et al., 2021). In contrast, in Türkiye, these skills have had limited application in practical contexts. Türkiye's science curriculum positions creative problem-solving and innovation as goals, but previous programs in Türkiye have not effectively integrated these objectives into practical experiences (Gök & Sayıcı, 2022). The new "Century of Türkiye Education Model" aims to change this issue by providing students with concrete experiences to develop these skills (Ülçay, 2024). Self-reflection competence is equally represented in both countries, with a rate of 50%. This indicates that reflective skills such as evaluating learning processes, self-awareness, and self-assessment are considered important goals in the science curricula of both countries, particularly in Türkiye's new educational model (MoNE, 2025).

Regarding the competence to take responsible action, Singapore's program shows a slightly higher rate of 52%, compared to Türkiye's 48%. The science curricula in both countries aim to enhance students' awareness of responsibility and sensitivity to environmental issues (Karalı et al., 2021). The Singapore curriculum emphasizes concrete behavioral patterns, particularly through the 3R approach (Reduce, Reuse, Recycle), which aligns with sustainable resource management and raising scientifically literate individuals (Yazıcıoğlu, 2017). In contrast, the Century of Türkiye Education Model does not directly define these concepts with specific structured strategies like "5Rs." Instead, it addresses broader themes such as sustainable development awareness, career awareness, and entrepreneurship (MoNE, 2025). This suggests that Türkiye conveys environmental responsibility through value-based and holistic learning outcomes, with a growing diversification of practices in terms of content (MoNE, 2024; Ülçay, 2024).

Sustainability competencies are explicitly integrated into the curricula of both countries. However, the observed differences in percentages can be attributed to the maturity of each country's curriculum implementation. Singapore's curriculum provides a well-established and practice-oriented framework (Tan, 2021), while Türkiye's curriculum has been evolving to more clearly define and plan these competencies in light of recent comprehensive updates (MoNE, 2025; Ülçay, 2024). Consequently, some codes in Türkiye that show high representation may reflect a targeted vision; their practical application will become clearer over time. In contrast, Singapore is believed to incorporate these values and responsibilities through a transactional and experiential approach (Bayırlı, 2020). It is crucial to assess these differences not only through quantitative metrics but also by examining the depth of implementation, teacher competencies, and student experiences. The findings indicate that both countries are at different stages and have varying priorities in their approaches to sustainability literacy.

3.1.2. Comparison of Higher-Level Cognitive Competences by Codes

In Figure 5, the ratios of three essential competencies—Problem Solving, Decision Making, and Critical Thinking—coded under "Higher Level Cognitive Skills" in Türkiye and Singapore are presented. The data shows that all skills are represented at higher rates in the Singapore sample compared to Türkiye. Singapore places a 54.8% emphasis on problem-solving competence in its curriculum, which is higher than Türkiye's 45.2%. This considerable emphasis in Singapore can be attributed to the rich content in its problem-based learning (PBL) sessions, case studies, and project-based activities, which actively engage students in processes such as hypothesizing, designing experiments, and testing with evidence (Martaningsih et al., 2022; Ministry of Education Singapore [MOE], 2021). Although Türkiye also has a strong emphasis on problem-solving, the inclusion of standardized laboratory experiments and instruction focused on knowledge consolidation in its curricular materials suggests that Türkiye may lag slightly behind Singapore regarding content diversity and the richness of scenarios (Gök & Sayıcı, 2022; Karalı et al., 2021).

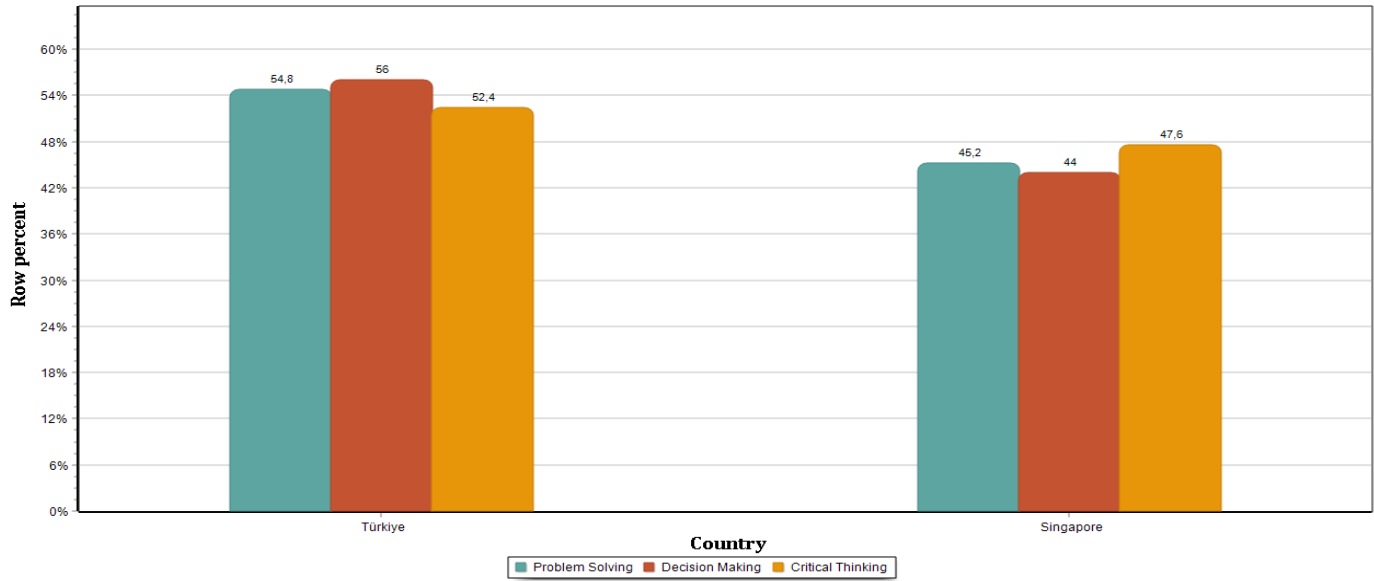


Figure 5. Ratios of codes related to high-level cognitive skills in Türkiye and Singapore (The figure was created from the data analysed by the researcher using QDA Miner software).

To enhance pedagogical approaches, incorporating more case examples—both in quantity and quality—into the Century of Türkiye Education Model science program's revisions will enable students to develop their problem-solving skills more comprehensively (MoNE, 2025; Ülçay, 2024). The international PISA 2022 report also indicates that problem-based and case-based learning approaches enhance students' deep-thinking skills, particularly in analyzing and solving complex real-world problems in science (OECD, 2024).

When analyzing decision-making competence, Singapore's curriculum, at 56.0%, is significantly higher than Türkiye's, which stands at 44.0%. This strong representation in Singapore can be attributed to the consistent inclusion of explicit steps related to systematic decision-making processes in the curriculum, such as "goal setting, comparing options, criteria-based evaluation, and drawing conclusions." In particular, constructs like "formulating research questions" and "comparing alternative technological solutions" are notable (Yeo et al., 2021; MOE, 2021; Muhammad Ariff et al., 2024). Although the Century of Türkiye Education Model supports decision-making elements through "end-of-unit assessments" and "in-class debates," these elements are infrequently presented in a clear, step-by-step roadmap in the curriculum, unlike in Singapore (Gök & Sayıcı, 2022; MoNE, 2024). This gap highlights the potential to enhance students' criterion-based reasoning skills by incorporating more pedagogical case studies and checklists (MoNE, 2025; Yazıcıoğlu & Pektaş, 2018).

The narrow difference of 4.8% between the curricula of Türkiye (47.6%) and Singapore (52.4%) in terms of critical thinking competence suggests that both educational systems emphasize skills like evaluating evidence, generating alternative hypotheses, and constructing scientific arguments with nearly equal intensity (MOE, 2024; MoNE, 2024). This indicates that critical thinking is addressed in a balanced manner as a universal requirement (Asigigan & Samur, 2021; International Labour Organization, 2021; Morgado, Leite, Dourado & Varela, 2025). The higher percentage in Singapore can be attributed to the inclusion of advanced topics in their curriculum, such as science ethics, decision-making under uncertainty, and multidimensional risk analysis (MOE, 2021-2024; Yeo & Tan, 2021). In Türkiye, utilizing socio-scientific case scenarios—such as environmental dilemmas and technology ethics—to enhance critical thinking skills is recommended (MoNE, 2024; Ülçay, 2024). The high rate in Singapore can be attributed to its focus on advanced topics such as decision-making in uncertain situations, multidimensional risk analysis, and science ethics (MOE, 2021-2024; Yeo & Tan, 2021).

These findings indicate that Singapore's science program addresses higher-order cognitive skills using case-based, systematic approaches as well as clear templates for decision-making processes. In contrast, while Türkiye's model has a solid structure, it could benefit from diversity in examples and step-by-step guidance (Gök & Sayıcı, 2022). This suggests that Türkiye has the potential to create practical applications using its theoretical strength (Ülçay, 2024).

These findings reveal that Singapore's curriculum emphasizes students' active involvement in decision-making and problem-solving using their scientific knowledge (Weng & Eng, 2021). On the other hand, higher-order cognitive skills may become more prominent in the new curriculum of Türkiye (Ülçay, 2024). This implies that Türkiye can effectively link high-level cognitive skills with practical applications in the new curriculum texts.

3.2. Comparative Analysis of Frequency Distributions of Competency Codes by Countries

In this section, we analyzed the frequency distributions of codes of sustainability competencies and higher-order cognitive skills. Doing this comparative analysis, we aimed to determine the extent to which specific competencies are emphasized in the texts. By examining the total coding rates, we can assess the pedagogical priorities of both programs from a quantitative perspective (Williams et al., 2021). This examination might help us to identify dominant skills in the curricula and highlights areas potential for development (Fraenkel et al., 2023). This finding can offer significant insights for curriculum development and implementation process.

3.2.1. Total Distribution of Code Frequencies of Sustainability Competencies in the The Century of Türkiye Education Model and Singapore Curricula

As seen in Figure 6, the "Systems Thinking" skill has the highest representation rate among sustainability competencies at 25.3%. This indicates that both countries address the relationships between science, nature, and society in a holistic manner, prioritizing cause-and-effect relationships (Karalı et al., 2021; MOE, 2024; MoNE, 2025). This shows that interdisciplinary thinking skills play a crucial role in both curricula.

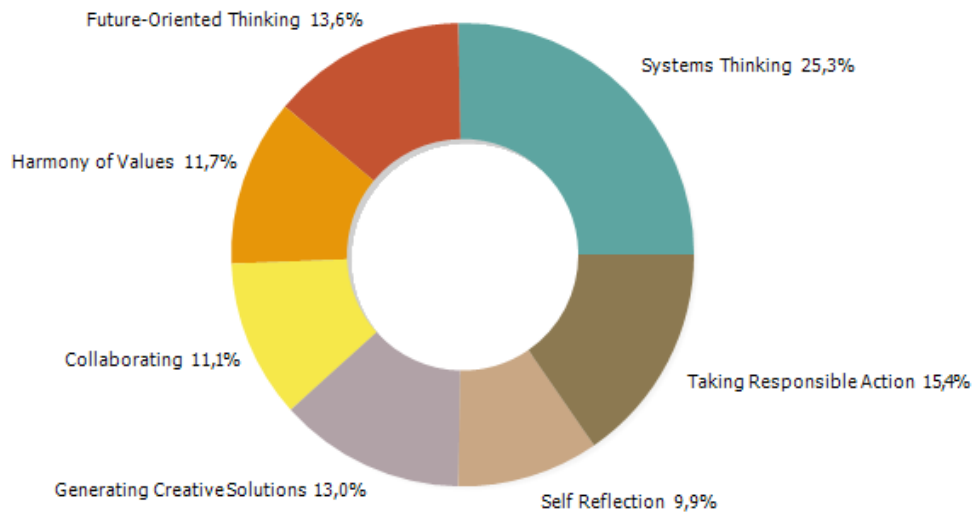


Figure 6. Code frequency distribution of Türkiye and Singapore's sustainability competencies (Visual created by the researcher using data analyzed with QDA Miner software).

The second code, "Taking Responsible Action" (15.4%), shows the importance of practices in environmental awareness as in 3R strategies (Reduce, Reuse, Recycle), and social responsibility (Gök & Sayıcı, 2022; OECD, 2022). This emphasis indicates that sustainability is addressed not only at a conceptual level but also through behaviors. Additionally, the strong focus on "Future Thinking" (13.6%) and "Creative Solution Generation" (13.0%) competencies suggests that sustainable development-oriented approaches, including long-term planning and the development of innovative solutions, are incorporated into educational curricula (Gorski et al., 2023). The ratios for "Values Alignment" (11.7%) and "Collaboration" (11.1%) are quite close, indicating that awareness of scientific ethics, social responsibility, and teamwork is addressed to a moderate extent in the curricula (Karaarslan & Teksöz, 2024; OECD, 2018). However, the "Self-Reflection" competence (9.9%) has the lowest percentage. This suggests that metacognitive processes such as self-evaluation, insight, and awareness of learning have not yet found adequate representation in the curriculum regarding sustainability (MoNE, 2023; Nguyen, 2023). When evaluating the frequency distribution of sustainability competencies, it becomes evident that the curricula strike a balanced approach between conceptual knowledge and practical action skills. The inclusion of individual-centered cognitive processes, such as self-awareness and self-evaluation, in curriculum structures can help students develop deep and lasting learning experiences. This is achieved by integrating their knowledge and actions related to sustainability issues with self-reflection skills (Ülçay, 2024).

3.2.2. Total Distribution of Code Frequencies of Higher-Level Cognitive Competencies in The Century of Türkiye Education Model and Singapore Curricula

Analysis of the coding data in Figure 7 shows that among higher-order cognitive skills, Problem Solving had the highest frequency at 40.3%. This indicates that science education curricula in both Türkiye and Singapore encourage students to adopt solution-oriented approaches by addressing real-life problems and prioritizing strategic thinking (Gök & Sayıcı, 2022; Karalı et al., 2021). The Decision-Making competency was represented with a 32.5% frequency, suggesting that skills such as comparing alternatives, predicting potential outcomes, and making informed choices hold significant value in the curricula (MOE, 2021; MoNE, 2024). This skill supports students' analytical thinking and their ability to take responsibility, especially when dealing with environmental issues characterized by uncertainty and complex scientific problems (Morgado et al., 2025).

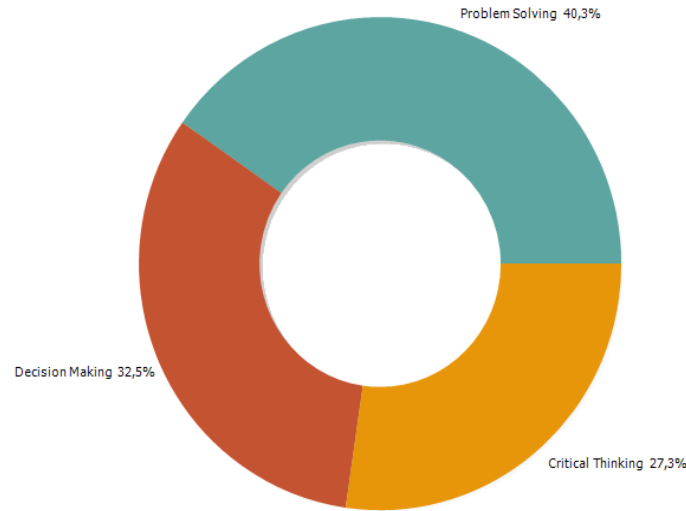


Figure 7. Code frequency distribution of Türkiye and Singapore's high-level cognitive competencies (Visual, created from data analyzed by the researcher using QDA Miner software).

The Critical Thinking skill, rated at 27.3%, aims to develop students' abilities in processes such as making evidence-based reasoning, analyzing arguments, and evaluating various perspectives (MoNE, 2025). This competency is particularly important for making informed decisions on socio-scientific issues, participating in scientific debates, and fostering critical attitudes towards information pollution (Gorski et al., 2023; van Laar et al., 2017). Upon analyzing the overall distribution, it becomes clear that these three high-level cognitive skills are integrated into a complementary structure within the curricula. However, problem-solving practices are emphasized more intensively (MOE, 2023; MoNE, 2024). This suggests that constructivist approaches in science education align well with pedagogical principles that encourage student learning through real-life problems (OECD, 2022; Tan et al., 2021). Nonetheless, the application of these principles in classroom practices may differ based on teachers' training, teaching strategies, and other contextual factors (Karaarslan & Teksöz, 2024; Nguyen, 2023).

3.3. Thematic Code Distribution of Competencies

This section presents the thematic distribution of sustainability and higher-level cognitive competencies identified in the curricula of Türkiye and Singapore. The visual representations generated by QDA Miner software were used to analyze the frequency and relationships of the codes, providing a comparative overview of how these competencies are structured and emphasized within each curriculum. In the following sub-sections (3.2.1 and 3.2.2), the thematic distributions of sustainability and higher-order cognitive competencies are discussed in detail, supported by graphical outputs obtained from QDA Miner analyses.

3.3.1. Thematic Code Distribution of Sustainability Competencies

The radar graph numbered 8 below, created using the thematic coding method, illustrates the representation of sustainability competencies in the science curricula of Türkiye and Singapore. An analysis of the graph shows that the dimensions of "Systems Thinking," "Taking Responsible Action," and "Generating Creative Solutions" are well represented in the programs of both countries. This finding aligns with previous analyses, indicating that sustainability competencies are integrated into the curricula with a holistic and solution oriented approach (Gök & Sayıcı, 2022; MoNE, 2025).

Notably, Singapore exhibits higher representation rates in "Creative Solution Generation" and "Future Thinking" competencies compared to Türkiye. This suggests that Singapore prioritizes design thinking, innovation, and future foresight skills in its curricula (Tan, 2021; Weng & Eng, 2021). Conversely, Türkiye shows strong representation in "Systems Thinking" and "Taking Responsible Action," highlighting its emphasis on helping students understand the interactions between nature, society, and science, as well as fostering environmental responsibility (MoNE, 2025; Ülçay, 2024).

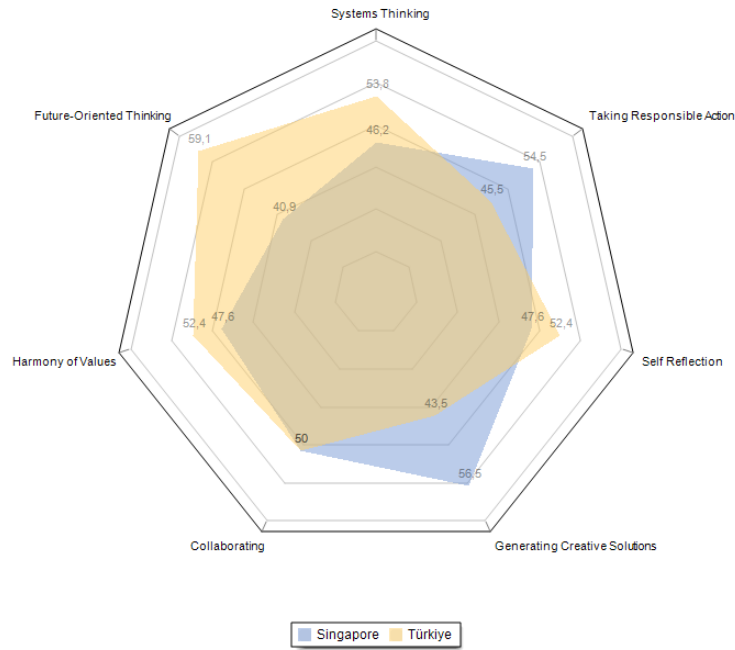


Figure 8. Thematic code distribution of Türkiye and Singapore's sustainability competencies (Visual created by the researcher using data analyzed with QDA Miner software).

Another significant finding reveals that "Self-Reflection" competence is underrepresented in both countries compared to other competencies. This indicates that metacognitive processes, such as internal awareness, self-assessment, and personal responsibility for learning should definitely be addressed in the curricula (Karaarslan & Teksöz, 2024; Silva et al., 2023). Overall, the thematic comparison of sustainability competencies via radar graphs shows areas for development in the curricula of both countries, providing valuable insights for future curriculum development processes.

3.3.2. Thematic Code Distribution of Higher-Level Cognitive Competences

A radar graph offers a meaningful comparison of higher-order thinking skills in the science curricula of both countries. As can be seen in Figure 9, cognitive processes such as "Analyzing," "Interpreting," and "Decision Making" are strongly represented in the programs of both countries.

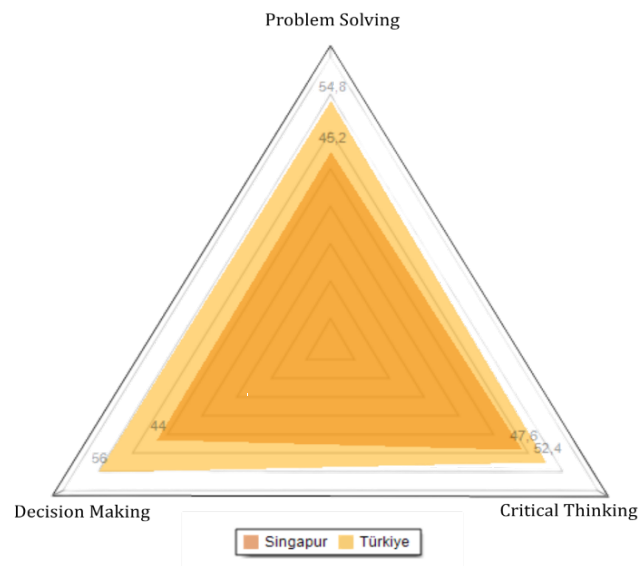


Figure 9. Thematic code distribution of Türkiye and Singapore's high-level cognitive competencies (Visual, created from data analyzed by the researcher using QDA Miner software).

This indicates that both countries aim for students to acquire knowledge as well as develop a deeper understanding through analysis, associating, and evaluation (Karalı et al., 2021). Singapore shows a higher representation in "Creative Thinking," "Problem Solving," and "Decision Making" compared to Türkiye. It indicates that Singapore places more emphasis on design-

oriented learning, creativity-based problem-solving, and alternative thinking (Gök & Sayıcı, 2022). This approach suggests that Singapore aims to raise adaptable individuals equipped with 21st-century skills (Tan et al., 2021).

On the other hand, Türkiye exhibits a high level of representation in the "Interpreting" and "Analyzing" dimensions. It might indicate that Türkiye prioritizes developing a critical perspective on information, establishing cause-and-effect relationships, and making connections between concepts (MoNE, 2025). In this regard, the Turkish curriculum emphasizes fostering students' data-driven inference and critical thinking abilities (MoNE, 2024). The graph highlights that skills such as "Complex Problem Solving" and "Synthesizing" are represented at relatively low rates in both countries. This may suggest that students' ability to handle multidimensional and interdisciplinary problems is not adequately supported in the educational programs (Ülçay, 2024). In conclusion, the graphs above shows that both Türkiye and Singapore include higher-order cognitive skills in their science programs at different levels, revealing the priorities and areas for development.

4. RESULTS, DISCUSSION AND RECOMMENDATIONS

In this study, we conducted a comparative analysis of science curricula of Türkiye and Singapore, focusing on sustainability-based problem-solving skills and higher-order cognitive competencies. The findings indicate that both countries systematically and clearly include sustainability and higher-order cognitive skills in their curricula (MOE, 2024; MoNE, 2025). However, while Singapore prioritizes practice-based and experience-oriented strategies (Tan et al., 2021), Türkiye demonstrates a strong vision at the content level but shows room for improvement in applying this vision to practices (MoNE, 2024).

The science curriculum in Singapore is structured around interdisciplinary, scenario-based, and inquiry-based approaches. This design particularly emphasizes skills such as creative solution generation, decision-making, and problem-solving (Tan, 2021). This approach is closely aligned with Singapore's educational policies focused on developing 21st-century skills (Teo & Choy, 2021). This observation strongly corroborates the global research emphasizing that education systems must translate aspirational goals into specific pedagogical practices for effective implementation. In contrast, Türkiye demonstrates a strong commitment to a holistic curriculum by incorporating competencies like systems thinking, future-oriented thinking, and values congruence at the text level, aiming for a long-term sustainability vision (MoNE, 2025). The pronounced emphasis on these macro-level competencies in the Turkish curriculum (evidenced by the highest coding rates in Future-Oriented Thinking at 59.1% and Systems Thinking at 53.7%) aligns with the global pattern of countries embedding skills primarily at the strategic, policy-driven level without robust implementation guidance. However, unless supported by teacher competencies, teaching materials, and effective assessment and evaluation systems, the impact of these advancements on classroom practices may remain limited.

Regarding higher-order cognitive skills, Singapore systematically cultivates abilities such as decision-making and problem-solving through case-based activities, multiple scenarios, and project-based learning initiatives (Gök & Sayıcı, 2022). This approach fosters a learning culture that encourages students not only to gain knowledge but also to apply it in the process of developing solutions (OECD, 2024). This confirms the international literature that the effective development and assessment of Higher-Order Cognitive Skills (HOCS) requires moving instruction beyond knowledge consolidation toward complex, authentic tasks embedded in real-world contexts (Aydın & Kıvanç, 2022; Sucuoğlu et al., 2023). In Türkiye, these skills are clearly outlined in the curriculum (MoNE, 2025); however, the lack of comprehensive implementation guidance could hinder their integration into learning processes (Ülçay, 2024). This implementation gap mirrors the structural challenge identified in many global education systems where the translation of conceptual understanding of 21st Century Skills into practical pedagogical support remains the major impediment to curriculum reform (Kim & Care, 2020).

The following suggestions are directly derived from the comparative analysis and are focused on addressing the observed gap between Türkiye's strong theoretical vision (high code counts in Systems Thinking/Future-Oriented Thinking) and the need for practice-based operationalization (where Singapore's coding rates for Decision Making/Collaboration were higher).

Curriculum Application Focus: To effectively promote sustainability and higher-level cognitive skills within the Century of Türkiye Education Model, the focus must shift from macro-level vision to scenario-based and experience-based teaching materials. This is essential to enhance abilities such as problem-solving and decision-making, where analysis showed a need for deeper integration compared to Singapore.

Targeted Teacher Professional Development (PBL/STEM): In-service training for science teachers should prioritize practical implementation of methods, specifically Problem-Based Learning (PBL), STEM approaches, and cognitive strategies. This must address the weak representation of implementation guidance observed in the curriculum text and support competencies like Collaboration (where Singapore scored 57.1% vs. Türkiye's 42.9%). Additionally, structures similar to those in Singapore that continuously support teachers' professional development should be established. **Assessment Reform for HOCS:** To accurately assess students' acquisition of higher-order thinking skills, alternative and non-dichotomous measurement tools that align with systemic and application-based skills should be utilized and integrated into the teaching process. This is crucial for effectively capturing complex processes like decision-making and problem-solving, rather than focusing solely on knowledge recall.

Systematic Monitoring and Evidence-Based Revision: Given the Century of Türkiye Education Model's strong theoretical foundation, small-scale pilot implementations of the updates should occur in various regions to gather empirical, practice-based evidence. Ongoing monitoring of the curriculum's effectiveness must be based on feedback from both teachers and students to

verify if the theoretical emphasis (e.g., in Systems Thinking) is translating into tangible classroom outcomes. Strategic Knowledge Exchange: Collaborative projects should be developed with successful education systems such as Singapore, specifically focusing on translating theoretical strengths into consistent pedagogical methods and structured teacher support systems. Mutual experience sharing should be facilitated through teacher exchange programs, student projects, and observed examples of curriculum implementation, particularly in structuring robust inquiry-based activities.

In conclusion, while the Century of Türkiye Education Model offers a solid theoretical framework for sustainability and higher-order thinking skills, systematic actions must be taken to strengthen this framework with practical classroom applications. Singapore's practice-based pedagogical richness can serve as a valuable guide for Türkiye. These comprehensive recommendations can make significant contributions to embedding sustainability and advanced cognitive competencies within the education system.

Research and Publication Ethics Statement

This research did not require ethical approval because it utilized secondary data and did not involve humans or animals. The authors used an AI translator in order to translate the manuscript into English. After using this AI tool, the authors reviewed and edited the content and take full responsibility for the content of the publication.

Contribution Rates of Authors to the Article

This article is a product of cooperative effort, with each author contributing according to their abilities, while the distribution of tasks and responsibilities aligned with individual circumstances and needs.

Statement of Interest

The authors confirm that there are no conflicts of interest.

5. REFERENCES

- Alatlı, B. K. (2020). Investigation of students' science literacy performances with stepwise linear modelling: PISA 2015 Türkiye and Singapore comparison. *Education and Science*, 45(202). <https://doi.org/10.15390/EB.2020.8188>
- Asigigan, S. I., & Samur, Y. (2021). The effect of gamified STEM practices on students' intrinsic motivation, critical thinking disposition levels, and perception of problem-solving skills. *International Journal of Education in Mathematics, Science, and Technology*, 9(2), 332-352. <https://doi.org/10.46328/ijemst.1157>
- Aydın, A., & Kıvanç, Z. (2022). Similarities of achievements for STEM activities in science curricula: Türkiye physical events / New Zealand physical world. *Hacettepe University Journal of Faculty of Education*, 37(1), 11-34. <https://doi.org/10.16986/HUJE.2020060878>
- Bayırlı, A. (2020). Comparison of Singapore education system with Turkish education system and implications for Türkiye. *International Journal of Academy of Social Sciences*, 4(4), 1103-1131. <https://doi.org/10.47994/usbad.830544>
- Boncukçu, G., & Gök, G. (2023). A problem-based learning activity to learn about sustainable development. *Science Activities*, 60(4), 185-200. <https://doi.org/10.1080/00368121.2023.225835>
- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77-101. <https://doi.org/10.1191/1478088706qp063oa>
- Chu, W. W., Ong, E. T., Ayop, S. K., Mohd Azmi, M. S., Abdullah, A. S., Abd Karim, N. S., & Tho, S. W. (2021). Innovative use of smartphone for audio STEM practical kit: pilot application for secondary school classroom. *Research in Science and Technological Education*, 41 (3), 1008-1030. <https://doi.org/10.1080/02635143.2021.1978963>
- Ertan Özen, N., & Kaplan, K. (2023). 21st century skills in Türkiye, Alberta, Korea and Singapore curricula. *Pamukkale University Journal of Faculty of Education*, 59, 322-339. <https://doi.org/10.9779.pauefd.1182195>
- Fraenkel, J., Wallen, N., & Hyun, H. (2023). *How to design and evaluate research in education* (11th ed.). McGraw-Hill Education. <https://www.mheducation.com/highered/product/How-to-Design-and-Evaluate-Research-in-Education-Fraenkel.html>
- Gorski, A.-T., Ranf, E.-D., Badea, D., Halmaghi, E.-E., & Gorski, H. (2023). Education for sustainability-Some bibliometric insights. *Sustainability*, 15(20), 14916. <https://doi.org/10.3390/su152014916>
- Gök, B., & Sayıcı, E. (2022). A comparative study of primary science curricula: The case of Türkiye, Singapore, Estonia. *West Anatolian Journal of Educational Sciences*, 13(2), 871-891. <https://doi.org/10.51460/baebd.1064766>

- International Labour Organization. (2021). *Global framework on core skills for life and work in the 21st century*. <https://www.ilo.org/publications/global-framework-core-skills-life-and-work-21st-century>
- Karaarslan Semiz, G., & Teksöz, G. (2024). Tracing system thinking skills in science curricula: A case study from Türkiye. *International Journal of Science and Mathematics Education*, 22, 515-536. <https://doi.org/10.1007/s10763-023-10383-w>
- Karalı, Y., Palancıoğlu, V. & Aydemir, H. (2021). Comparison of Türkiye and Singapore primary school science programmes, *Inonu University Journal of the Faculty of Education*, 22(1), 866-888. DOI: 10.17679/inuefd.883126
- Kim, H., & Care, E. (2020). *Capturing 21st century skills: Analysis of assessments in selected sub-Saharan African countries*. UNESCO Office in Dakar and The Brookings Institution. <https://unesdoc.unesco.org/ark:/48223/pf0000374052>
- Luckin, R., Issroff, K., Miller, K., Berkowitz, M., & Bier, M. C. (2021). *Future of Education and Skills 2030: Conceptual Learning Framework* (EDU/EDPC(2018)45/ANN2). Organisation for Economic Co-operation and Development. <https://static1.squarespace.com/static/5e26d2d6fcf7d67bbd37a92e/t/5e411f365af4111d703b7f91/1581326153625/Education-and-AI.pdf>
- Martaningsih, S. T., Maryani, I., Prasetya, D. S., Purwanti, S., Sayekti, I. C., Aziz, N. A. A., & Siwayanan, P. (2022). STEM problem-based learning module: A solution to overcome elementary students' poor problem-solving skills. *Pegem Journal of Education and Instruction*, 12(4), 340-348. <https://doi.org/10.47750/pegegog.12.04.35>
- Ministry of Education Singapore. (2021). *Science syllabus: Lower secondary (Express/Normal Academic)*. <https://www.moe.gov.sg/-/media/files/secondary/syllabuses/science/2021-science-lower-secondary-expressnormalacademic-syllabus.pdf>
- Ministry of Education Singapore. (2024). *Science teaching & learning syllabus: Primary three to six (Standard/Foundation) (Implementation starting with 2023 Primary Three cohort)*. https://www.moe.gov.sg/-/media/files/primary/syllabus/primary-science-syllabus-2023_may24.pdf
- Ministry of National Education. (2024). *Science curriculum (3rd, 4th, 5th, 6th, 7th, and 8th grades): Türkiye Century Education Model*. Board of Education and Discipline. <https://mufredat.meb.gov.tr>
- Ministry of National Education. (2024). *Türkiye Century Education Model: Common text*. <https://tymm.meb.gov.tr/ortak-metin>
- Ministry of National Education. (2023). *PISA 2022 Türkiye report*. General Directorate of Measurement, Evaluation and Examination Services. https://pisa.meb.gov.tr/meb_iys_dosyalar/2024_03/21120745_26152640_pisa2022_rapor.pdf
- Ministry of National Education. (2024). *TIMSS 2023 Türkiye report*. General Directorate of Measurement, Evaluation and Testing Services. https://odsgm.meb.gov.tr/meb_iys_dosyalar/2024_12/04111224_timss_2023_rapor_0412.pdf
- Morgado, S., Leite, L., Dourado, L., & Varela, P. (2025). Solving STEM-relevant problems: A study with prospective primary school teachers. *Education Sciences*, 15(2), 169. <https://doi.org/10.3390/educsci15020169>
- Muhammad Ariff, J., Jufri Haikal, N. F. N., Abd Aziz, N., & W. Zamri, W. F. H. B. (2024). A comparative study on approaches in engineering education systems in Malaysia, Singapore and Finland. *ASEAN Journal of Engineering Education*, 8(1), 41-48. <https://doi.org/10.11113/ajee2024.8n1.157>
- Nguyen, T. P. L. (2023). Integrating circular economy into STEM education: A promising pathway toward circular citizenship development. *Frontiers in Education*, 8, 1063755. <https://doi.org/10.3389/feduc.2023.1063755>
- Organisation for Economic Co-operation and Development (2022). Are Students Ready to Take on Environmental Challenges? <https://doi.org/10.1787/8abe655c-en>.
- Organisation for Economic Co-operation and Development (2023). *PISA 2022 Results (Volume I): The State of Learning and Equity in Education*. <https://doi.org/10.1787/53f23881-en>.
- Organisation for Economic Co-operation and Development (2018). *Education Policy Outlook 2018: Putting student learning at the centre*. <https://doi.org/10.1787/9789264301528-en>
- Organisation for Economic Co-operation and Development (2018). *Education and Skills 2030: Conceptual Learning Framework-Progress report of the OECD 2030 learning framework: 6th Informal Working Group (IWG) meeting, 23-25 October 2017, Paris, France* (Report No. EDU/EDPC (2017)25). [https://one.oecd.org/document/EDU/EDPC\(2017\)25/en/pdf](https://one.oecd.org/document/EDU/EDPC(2017)25/en/pdf)

Organisation for Economic Co-operation and Development (2024). *PISA 2022 results (Volume III): Creative Minds, Creative Schools*. <https://doi.org/10.1787/765ee8c2-en>.

Organisation for Economic Co-operation and Development (2024). *PISA 2022 results (Volume V): Learning strategies and attitudes for life* (PISA, No. V). OECD Publishing. <https://doi.org/10.1787/c2e44201-en>

Provalis Research (2025). *QDA Miner (Version 8.0) [Computer software]*. <https://provalisresearch.com/products/qualitative-data-analysis-software/>

Provalis Research (2020). *QDA Miner 6 user guide*. <https://q9j3s8w6.delivery.rocketcdn.me/Documents/QDAMiner6.pdf>

Silva, P. C., Rodrigues, A. V., & Vicente, P. N. (2023). Science curriculum for primary education: A comparative analysis between Portugal, England, United States, Australia and Singapore. *Education Policy Analysis Archives*, 31(97). <https://doi.org/10.14507/epaa.31.8192>

Sucuoğlu, H., Yasemin, D., & Yılmaz, T. (2023). Comparison of mathematics and science curriculum objectives, textbook questions and LGS questions. *Çukurova University Journal of Faculty of Education*, 52(2), 302-350. <https://doi.org/10.14812/cuefd.1187141>

Tan, L. S., Koh, E., Lee, S. S., Ponnusamy, L. D., & Tan, K. C. K. (2017). The complexities in fostering critical thinking through school-based curriculum innovation: Research evidence from Singapore. *Asia Pacific Journal of Education*, 37(4), 517-534. <https://doi.org/10.1080/02188791.2017.1389694>

Tan, O. S., Low, E. L., Tay, E. G., & Yan, Y. K. (2021). Introduction. In O. S. Tan, E. L. Low, E. G. Tay, & Y. K. Yan (Eds.), *Singapore Math and Science Education Innovation: Empowering Teaching and Learning through Policies and Practice: Singapore and International Perspectives* (Vol. 1). Springer. https://doi.org/10.1007/978-981-16-1357-9_1

Tan, O.S. (2021). Singapore Math and Science Education: The Larger Picture Beyond PISA Achievements and "Secret" Factors. In Tan, O.S., Low, E.L., Tay, E.G., Yan, Y.K. (eds) *Singapore Math and Science Education Innovation. Empowering Teaching and Learning through Policies and Practice: Singapore and International Perspectives*, vol 1. Springer. https://doi.org/10.1007/978-981-16-1357-9_2

Teo, T. W., & Choy, B. H. (2021). STEM Education in Singapore. In: Tan, O.S., Low, E.L., Tay, E.G., & Yan, Y.K. (eds) *Singapore Math and Science Education Innovation. Empowering Teaching and Learning through Policies and Practice: Singapore and International Perspectives*, vol 1. Springer, Singapore. https://doi.org/10.1007/978-981-16-1357-9_3

Trott, C. D., & Weinberg, A. E. (2020). Science education for sustainability: Strengthening children's science engagement with climate change learning and action. *Sustainability*, 12(16), 6400. <https://doi.org/10.3390/su12166400>

United Nations Educational, Scientific and Cultural Organization. (2017). *Education for sustainable development goals: Learning objectives*. <https://doi.org/10.54675/CGBA9153>

Ülçay, O. (2024). Türkiye century education model evaluation. *National Journal of Education, Society and World*, 1(2), 70-75. <https://doi.org/10.5281/zenodo.11097248>

van Laar, E., van Deursen, A. J. A. M., van Dijk, J. A. G. M., & de Haan, J. (2017). The relation between 21st-century skills and digital skills: A systematic literature review. *Computers in Human Behaviour*, 72, 577-588. <https://doi.org/10.1016/j.chb.2017.03.010>

Varlık, S. (2025). Research literacy, socio-scientific reasoning, and problem-solving skills in science teachers. *Journal of Baltic Science Education*, 24(2), 377-389. <https://doi.org/10.33225/jbse/25.24.377>

Weng, K. H., & Eng, G. T. (2021). K-12 school mathematics curriculum: Insights on development, renewal and future orientation. In O. S. Tan, E. L. Low, E. G. Tay, & Y. K. Yan (Eds.), *Singapore math and science education innovation: Empowering teaching and learning through policies and practice: Singapore and international perspectives* (Vol. 1, pp. 107-135). Springer. https://doi.org/10.1007/978-981-16-1357-9_7

Williams, M., Wiggins, R. D., & Vogt, W. P. (2021). *Beginning quantitative research*. SAGE Publications.

Yazıcıoğlu, Ö. (2017). *Comparison of Türkiye, Singapore and Kazakhstan science teaching programmes*. [Master's thesis] Kastamonu University.

Yazıcıoğlu, Ö., & Pektaş, M. (2018). A comparison of the middle school science programmes in Türkiye, Singapore and Kazakhstan. *International Electronic Journal of Elementary Education*, 11(2), 143-150. <https://doi.org/10.26822/iejee.2019248588>

Yeo, J., Chen, W., Tan, T. T. M., & Lee, Y. J. (2021). Innovative science and STEM pedagogies in Singapore. In O. S. Tan, E. L. Low, E. G. Tay, & Y. K. Yan (Eds.), *Singapore math and science education innovation: Empowering teaching and learning through policies and practice: Singapore and international perspectives*, Volume 1, pp. 201-218). Springer. https://doi.org/10.1007/978-981-16-1357-9_11

Yeo, J., Tan, K.C.D. (2021). Science Education in Singapore. In: Tan, O.S., Low, E.L., Tay, E.G., Yan, Y.K. (eds) *Singapore Math and Science Education Innovation. Empowering Teaching and Learning through Policies and Practice: Singapore and International Perspectives*, Volume 1, Springer. https://doi.org/10.1007/978-981-16-1357-9_6