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Original Article

An examination of the Türkiye Century Education Model science curriculum in terms of 21st-century skills using Q methodology

Mehmet Kart [1], Enver Türksoy [2], Gizem Bişkiner [3]

Abstract

This study examines classroom teachers' perceptions of the extent to which the updated Science Curriculum within the Türkiye Century Education Model (TYMM) supports the development of 21st-century skills. We used Q methodology to capture teachers' subjective viewpoints. Thirty-nine classroom teachers working in Kırşehir ranked 32 statements representing key 21st-century skills through a Q sort procedure. Factor analysis yielded three distinct perspectives, accounting for 60% of the total variance. Overall, teachers appraised the TYMM curriculum positively, especially for promoting collaboration, inquiry-oriented learning, and problem-solving. At the same time, they perceived the curriculum as less supportive in areas such as digital content creation, entrepreneurship, and flexibility. Teachers also pointed to implementation barriers, including limited technological infrastructure, insufficient instructional materials, and gaps in teachers' digital literacy. Finally, by leveraging Q methodology's capacity for multidimensional analysis, the study offers an original, teacher-centred account of how 21st-century skills are framed and perceived in curriculum work. The findings may inform education policy decisions, the design of teacher education and professional learning, and ongoing curriculum development.

Keywords

21st-century skills
Classroom teachers' perceptions
Q methodology
Science curriculum
Türkiye Century Education Model (TYMM)

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Introduction

Technological and social transformations have pushed education systems to move beyond a narrow focus on knowledge transmission toward more multifaceted structures that cultivate intellectual, digital, and social capacities. Curricula sit at the centre of this shift. By systematically organising learning experiences within and beyond school, they aim to develop the knowledge, skills, attitudes, and values required by contemporary society (Demirel, 2023). At this point, a brief terminological clarification is necessary regarding the use of curriculum and syllabus in this study. In some international traditions, curriculum refers to a broader framework that includes aims, content, pedagogy, and assessment, whereas syllabus may be used to denote a more bounded plan for content

[1] Department of Child Development, Faculty of Health Sciences, Kırşehir Ahi Evran University, Kırşehir, Türkiye, mehmet.kart@ahievran.edu.tr
[2] Department of Child Development, Faculty of Health Sciences, Kırşehir Ahi Evran University, Kırşehir, Türkiye, enverturksoy@ahievran.edu.tr
[3] Department of Child Development, Faculty of Health Sciences, Kırşehir Ahi Evran University, Kırşehir, Türkiye, biskiner.gizem@ogr.ahievran.edu.tr

coverage and sequencing. In Türkiye's education policy discourse and much of the national literature, however, these terms are often used interchangeably (Demirel, 2023). Accordingly, this study uses the two terms synonymously, with meaning determined by context.

As a core instrument for developing qualified individuals, curricula need to remain flexible and open to revision in order to respond to changing social and technological conditions (Kart & Şimşek, 2020; Kırkeser, 2021). Scientific advances and technological innovations, in particular, require learning processes that can be updated and implemented in practice (Bilir, 2025; Karakaya et al., 2024; Rüzgar, 2025). For this reason, contemporary curriculum design increasingly calls for approaches that are responsive to learners' evolving needs, foreground critical thinking and life skills, and sustain flexibility over time (Demir & Çelik, 2020; Karataş, 2024).

In Türkiye, recent years have seen a range of reform initiatives intended to align curricula with the demands of the era and to equip learners with broader competencies (Board of Education, 2017; Ministry of National Education [MoNE], 2024a). Within this context, MoNE introduced the Türkiye Century Education Model (TYMM) in 2024 as part of a comprehensive curriculum update. TYMM is presented as a student-centred model that foregrounds skills through a learning outcomes framework and seeks to structure learning and teaching processes more systematically (Board of Education, 2025; MoNE, 2024a). Beyond academic attainment, it aims to support students' social and emotional development, with particular attention to higher-order thinking skills such as critical thinking, problem solving, and creativity (Karataş, 2024; Turkish Education Association, 2024).

Importantly, TYMM is framed not only as a conceptual orientation but also as a reform initiative accompanied by implementation steps. According to MoNE's needs analyses, input was gathered from 17,000 students and from teachers through evaluation commissions established across 81 provinces. Based on these inputs, MoNE reported a need to reduce curricular cognitive load and to shift toward a more skills-oriented structure (MoNE, 2024a). In line with this direction, the model's functionality is being examined through pilot implementations initiated in the 2024-2025 academic year, alongside systematic in-service training intended to support teachers' enactment of the updated curricula (MoNE, 2024d, 2024e). For example, the "Research, Development, and Training Project" targeting vocational subject teachers in Imam Hatip High Schools is intended to strengthen teacher competencies and support effective implementation (MoNE, 2024b).

In addition, guide documents and implementation guidelines are intended to assist teachers with instructional planning, the selection of teaching strategies, and assessment practices (MoNE, 2024c). These resources aim to enhance teachers' capacity to translate TYMM's intended learning outcomes into classroom practice. Within this broader reform architecture, 21st-century skills are positioned as a set of knowledge, skills, and competencies that support learners' participation and success in an increasingly digital and complex world (Boyacı & Özer, 2019; Hamarat, 2019).

The curriculum adopts an integrated approach to students' development by attending to cognitive, affective, and social dimensions. This orientation is informed by 21st-century skills emphasised in the international literature (Partnership for 21st Century Learning [P21], 2019) and by research that links social and emotional competencies, such as self-awareness and self-regulation, with learning and academic outcomes. The curriculum also foregrounds inquiry-based learning and interdisciplinary connections, seeking to position learners not as passive recipients of information but as active participants in knowledge construction. Framed alongside education for sustainable development (UNESCO, 2017) and values education, this pedagogical architecture reflects a vision of developing learners who are academically competent, environmentally sensitive, socially responsible, and oriented toward national and spiritual values (Arslankara & Arslankara, 2024; Sezer & Dedeoğlu, 2024). Building on this conceptual background, the present study offers an evaluation of the curriculum from teachers' perspectives.

Although 21st-century skills are classified in different ways across the literature, one of the most widely used frameworks is that of P21 (Çoban et al., 2019; Yalçın, 2018). The P21 framework clusters these skills under three broad domains: (1) learning and innovation skills (critical thinking, problem solving, creativity, communication, and collaboration), (2) information, media, and technology literacy, and (3) life and career skills (initiative, flexibility, leadership, productivity, and responsibility) (P21, 2019). This framework highlights competencies that are widely considered central for learners' academic participation and longer-term life and career trajectories.

Within this broader skills discourse, TYMM is presented as a reform that seeks alignment with global competency frameworks while also foregrounding local and national value orientations. Some comparative accounts situate TYMM alongside international curriculum reforms in countries such as Canada, Finland, and Indonesia, where science and basic education curricula emphasise competencies including critical thinking, collaboration, media literacy, individualised learning, and interdisciplinary competence development (Amadi, 2023; Surya et al., 2022; Wang et al., 2018). However, the literature also suggests that such comparisons often remain at the level of surface features and provide limited explanatory depth regarding the theoretical assumptions underpinning TYMM and how these assumptions shape curriculum design (Arslankara & Arslankara, 2024; Sahlberg, 2015).

From this standpoint, recent discussions point to differences in the epistemological and axiological orientations attributed to TYMM in contrast to reforms commonly associated with Western curricular traditions. While some accounts characterise Canadian and Finnish reform trajectories as informed by Enlightenment and humanist traditions (Sahlberg, 2015), TYMM has been discussed as drawing on the Ottoman educational tradition as an epistemological reference point (Arslankara & Arslankara, 2024). Relatedly, the reform has been described as placing greater emphasis on positioning the learner within a social and national-religious value system, whereas some Western models foreground individual autonomy and secular value orientations (MoNE, 2024a; Wang et al., 2018). These distinctions are relevant because they can influence multiple curriculum components, including the articulation of educational aims and the ways in which key competencies are framed.

The 2024 curricula position competencies aligned with P21, such as critical and creative thinking, communication, research, decision making, the use of information technologies, and entrepreneurship, as cross-curricular skills across subject areas (MoNE, 2024a). These competencies are framed as important not only for academic learning but also for preparing learners for future social and occupational participation. In this respect, the science curriculum is particularly salient, as it is organised through learning areas that are intended to support the development of these skills.

For example, the unit "Let's Get to Know Matter: Mixing and Separating" is intended to strengthen students' critical thinking and scientific inquiry by engaging them in observation, classification, and hypothesis testing. The unit "In Pursuit of Light" promotes creative thinking through hands-on investigations that require communication and collaboration. Similarly, "Sustainable Cities and Communities" foregrounds decision making and problem solving by inviting students to analyse environmental issues and develop solutions. A particularly clear illustration appears in the "Electricity That Makes Our Lives Easier" unit, where the learning outcome focuses on "critically evaluating the use of renewable and non-renewable energy sources in electricity production." Such examples indicate how 21st-century skills are embedded within the intended learning outcomes of science instruction. International scholarship likewise highlights science education as a productive context for developing competencies such as critical thinking, problem solving, communication, and digital literacy (Alifah & Sukartono, 2023; Gu & Belland, 2015; Haryani et al., 2024).

Research on TYMM has so far tended to focus on the reform's philosophical underpinnings (Arslankara & Arslankara, 2024; Kurul, 2024; Sezer & Dedeoğlu, 2024) or on curriculum content and structure (Şanlı & Kırkeser, 2025; Taş et al., 2024). However, there remains a lack of practitioner-oriented, teacher-based evidence that examines how 21st-century skills are integrated into the renewed TYMM science curriculum from classroom teachers' perspectives. In particular, systematic, data-informed accounts are scarce regarding how classroom teachers interpret TYMM, which skills they prioritise, and what implementation challenges they encounter. Addressing this gap is important for supporting sustainable curriculum implementation and for strengthening the practical enactment of TYMM in schools.

Accordingly, this study aims to examine how classroom teachers perceive the TYMM science curriculum and to identify whether these perceptions cluster into distinct viewpoints regarding the curriculum's role in developing 21st-century skills. Teachers' perceptions constitute an important source of evidence for evaluating the trajectory of education reforms and their practical viability in school settings (Akça et al., 2023).

In line with this aim, the study goes beyond describing teachers' views by examining the rationales underpinning these views and the implementation experiences to which they are connected. Q methodology is particularly suitable here because it offers a systematic way to elicit and compare subjective judgements while also enabling the identification of shared viewpoints through quantitative analysis. By integrating qualitative perspectives with factor-analytic techniques, Q methodology provides a robust basis for examining how teachers appraise the extent and ways in which TYMM supports 21st-century skills. Through this approach, teachers' viewpoints were analysed to illuminate perceived strengths as well as areas for improvement.

The study addressed the following main research question: *How do classroom teachers' perceptions of the TYMM science curriculum differ with respect to fostering 21st-century skills?* To elaborate this question, four sub-questions were posed:

- What points of consensus emerge among teachers regarding 21st-century skills?
- Which 21st-century skills do classroom teachers prioritise?
- What opportunities and challenges do classroom teachers identify in relation to implementing TYMM?
- How are teachers' perceptions distributed across the identified viewpoints?

Method

This study aims to systematically examine classroom teachers' subjective viewpoints regarding the TYMM science curriculum, drawing on the role of teacher perceptions in shaping the success of education reforms. As a mixed-method approach, Q methodology offers a design that attends qualitatively to individuals' subjective perceptions while also supporting these data quantitatively through factor-analytic procedures (Stephenson, 1982; Watts & Stenner, 2012). By making teachers' multidimensional and value-laden judgements visible, including both cognitive and affective dimensions, the method enables analysis not only of what teachers think but also of which ideas they prioritise and the rationales underpinning those priorities.

In the context of a comprehensive, multi-actor curriculum reform such as TYMM, conventional surveys or fully open-ended interviews may be limited in capturing patterned viewpoints and shared priorities. Q methodology was therefore selected because it allows individuals to express their intellectual priorities through a ranked sorting task and to make the contextual grounds of these priorities visible. In this way, the method moves beyond purely descriptive accounts and enables teachers' views to be examined as conceptually organised patterns (Ramlo, 2021; Watts & Stenner, 2012), supporting more in-depth and multi-layered evidence about the feasibility of curriculum reforms.

These methodological advantages were operationalised through a structured Q sorting and rationale-elicitation process. The Q-sort, a core component of the approach, required participants to place the statements presented to them on a forced distribution grid according to a specified condition of instruction. The Q set used in this study was developed in line with the research questions and comprised 32 statements reflecting teachers' views and perceptions of the TYMM science curriculum.

The statements were designed to provide conceptual breadth and contrast, allowing participants to position their viewpoints through similarities and differences across the set.

After completing the Q sort, participants provided follow-up written rationales for the statements placed at the extreme ends of the distribution (+4 and -4). This step made the interpretive and contextual grounds of the numerical configurations more visible. The forced distribution format also supports clearer statistical differentiation of viewpoints during analysis. Through this integrated design, the study generated both quantitative and qualitative data: Q sorts constituted the quantitative component, while participants' written rationales constituted the qualitative component (Watts & Stenner, 2012). The factor-analytic results derived from Q sorts revealed the structural dimensions of teachers' perceptions, whereas written rationales provided depth regarding the reasoning and contextual conditions shaping those perceptions (Ramlo, 2021). Accordingly, teachers' perceptions of the TYMM science curriculum were interpreted holistically, not as isolated individual experiences but as viewpoints situated within and interacting with wider systemic conditions.

Population and Sample

The study group comprised 50 classroom teachers working in public primary schools in the central district of Kırşehir province during the 2024-2025 academic year. Participants were selected using predefined criteria. Although Q methodology commonly recommends a range of 40 to 60 participants, its purpose is not statistical generalisation but the identification of viewpoint diversity and depth of representation. Therefore, valid and meaningful results can also be obtained with smaller participant groups (Ramlo, 2021).

Participants were recruited through criterion sampling. This purposive sampling strategy enables in-depth and contextually grounded data collection in qualitative research by intentionally selecting individuals who have relevant knowledge and experience related to the phenomenon under investigation (Creswell & Creswell, 2022). Three criteria guided participant selection:

- actively working as a classroom teacher in the 2024-2025 academic year,
- having reviewed the TYMM science curriculum and participated in related in-service training,
- voluntary participation in the study.

Of the 50 classroom teachers who participated voluntarily, 39 (see Table 1) were included in the analysis because their Q sort rankings and follow-up written rationales were complete and suitable for analysis. This sample size meets the recommended minimum 2:1 participant-to-item ratio for a Q set consisting of 32 statements, supporting the reliability of the analysis (Watts & Stenner, 2012). This sampling structure enables a systematic examination of both shared and divergent patterns in teachers' perceptions.

Table 1. Demographic characteristics of participants

Demographic information	Variable	f
Gender	Female	17
	Male	22
Professional seniority	11-15 years	15
	16+ years	24
Education	Bachelor's degree	34
	Postgraduate degree	5
Number of TYMM-related in-service trainings received	1	2
	2 or more	37

Data Collection Tools

The Q set used in this study comprised statements reflecting eight core 21st-century skills highlighted in the TYMM science curriculum: critical thinking, creativity, collaboration, communication, digital literacy, problem solving, flexibility, and entrepreneurship. At least five statements were developed for each skill domain, resulting in an initial pool of 40 statements. This draft Q set was reviewed by six academics from the fields of primary education, science education, and Turkish language education in terms of content coverage, conceptual coherence, and language clarity. Based on expert feedback, some statements were simplified, ambiguities were addressed, and overlapping content was removed. At the end of this process, the final Q set included 32 statements, with four statements representing each skill domain. This structure strengthened the conceptual adequacy of the Q set and supported participants' use of the statements in a clear, balanced, and consistent manner during the sorting procedure.

Data Collection

Data were collected in two stages via the Q-TIP web platform (https://qtip.geography.wisc.edu/#/), following the technical requirements of Q methodology. Teachers who volunteered to participate were identified before the administration, and sessions were conducted at times and locations preferred by participants. In the first stage, participants received a brief orientation to the online system and were then presented with the 32-statement Q set. They were asked to rank the statements on a nine-column forced distribution grid ranging from -4 to +4. After completing the ranking, participants were given an opportunity to review their placements and make revisions where they considered it necessary to better reflect their viewpoints (Ramlo, 2021).

In the second stage, each participant provided written rationales for the two statements placed at +4 and the two statements placed at -4. The follow-up rationale stage took between 20 and 45 minutes. These accounts helped to illuminate the conceptual structure, pedagogical context, and perceptual justifications underpinning teachers' rankings. In this way, the study generated qualitative data that captured not only numerical priorities but also the contextual grounds of those priorities. This two-stage procedure enabled a more comprehensive, reliable, and interpretable analysis of teachers' perceptions of the TYMM science curriculum. An example Q sort produced by one participant (P5) is presented in Figure 1, and sample statements are provided in Table 2.

-4	-3	-2	-1	0	1	2	3	4
18	8	4	5	3	1	17	14	2
31	19	7	9	11	6	20	16	23
		24	25	12	10	22		
		29	26	21	13	28		
			32	27	15			

Figure 1. Sample Q sort (P5)

Table 2. Sample statements from the Q set

Statement No.	Statement
10	The curriculum supports students with different abilities to conduct research together.
8	The new curriculum offers opportunities for students to develop their artistic expression skills.
7	The curriculum enables students to develop innovative solutions.
12	The curriculum enhances students' collaborative problem-solving skills.

Data Analysis

Data analysis proceeded in two stages, quantitative and qualitative, in line with the study's mixed-method design. In the first stage, a correlation matrix was constructed from participants' Q sorts, and Principal Component Analysis was conducted. To determine the number of factors, the Kaiser-

Guttman criterion (eigenvalue > 1.0) was used as an initial guide to identify candidate factors. The final factor solution was then selected by considering multiple criteria together. Factors were retained if they (i) had an eigenvalue of at least 2.00, (ii) explained at least 5% of the total variance, (iii) included at least two participants who loaded statistically significantly on the factor, and (iv) yielded a conceptually interpretable pattern.

The significance threshold for factor loadings was calculated using the common Q methodology formula $1.96 \times (1/\sqrt{N})$, where N denotes the number of statements in the Q set (N = 32) (McKeown & Thomas, 2013; Watts & Stenner, 2012). For a 32-statement Q set, this yielded a loading threshold of ±0.35, which was used to identify meaningful loadings. Based on the combined criteria above, a three-factor structure accounting for 60% of the total variance was judged to provide the most meaningful solution. Varimax rotation was applied to enhance interpretability, and meaningful factor loadings were identified using the ±0.35 threshold. All quantitative analyses were conducted using Ken-Q (version 2.0).

In the qualitative component, participants' written rationales for the statements placed at the extreme ends of the distribution (+4 and -4) were analysed. These accounts were examined using the thematic analysis procedures outlined by Braun and Clarke (2021), including pre-coding, theme identification, review, definition, and reporting. Qualitative analysis was conducted by a team of three researchers using MAXQDA 2022. Coding was organised around predefined overarching themes derived from the research questions (e.g., critical thinking, digital literacy, entrepreneurship). To support coding consistency, researchers first coded independently and then compared and discussed their coding in joint evaluation meetings, reaching agreement on the final codes. This integrated analytic strategy combined numerical patterns with qualitative reasoning, enabling a systematic examination of both convergence and divergence across the identified factors and clarifying how teacher perceptions differed in structure and content.

Validity and Reliability

In this study, validity was addressed in terms of conceptual representation and content validity. The Q set was developed around eight core 21st-century skills identified within the P21 (2019) framework (critical thinking, creativity, collaboration, communication, digital literacy, problem solving, flexibility, and entrepreneurship). The draft set was reviewed by six academics with regard to content coverage, language clarity, and representativeness. Following expert review, the content validity ratio (CVR) was calculated for each statement using Lawshe's (1975) formula. The resulting values were evaluated against the critical values recommended for a six-expert panel (average CVR = 0.99). Item-level content validity index (I-CVI) values ranged from 0.83 to 1.00, satisfying the acceptance criteria outlined by Polit and Beck (2006). The scale-level content validity index (S-CVI) was 0.92. During this process, statements that were repetitive, ambiguous, or conceptually weak were removed, and revisions were made to ensure clarity and simplicity. Ultimately, a balanced Q set was established with four statements representing each skill domain, and this structure strengthened the conceptual coherence and content validity of the set.

Reliability was addressed through methodological consistency and interpretive credibility. The forced distribution structure used in Q sorting enabled participants' subjective judgements to be analysed systematically. In addition, participants were asked to provide written rationales for the statements they placed at the extreme ends of the distribution (+4 and −4). These accounts were examined through qualitative thematic analysis, which enhanced the accuracy of content interpretation. This procedure strengthened interpretive credibility and supported the validity of the findings by enabling data and analysis triangulation through the joint consideration of quantitative patterns and qualitative rationales.

The use of Ken-Q 2.0 for quantitative analysis and MAXQDA 2022 for qualitative analysis helped ensure the systematicity, transparency, and traceability of the research process. The participant-to-item ratio (39 participants and 32 statements) met the commonly recommended minimum, which supported the stability of the factor structure and contributed to the transferability of the findings and their potential re-use in similar contexts (Ramlo, 2021; Watts & Stenner, 2012). In this way, a coherent research process was established holistically, addressing validity and reliability at both the content and methodological levels.

Findings

This section examines whether classroom teachers evaluated the updated TYMM science curriculum similarly or whether their perceptions diverged with respect to the integration of 21st-century skills. Participants were coded as P1, P2, and so forth, regardless of gender. An asterisk (*) was used to indicate statistically significant factor loadings. Participants were ordered by factor weights, and the same coding convention was maintained when reporting the qualitative findings. To foreground qualitative content, participant statements are presented in italics. Participants' factor loadings and their distribution across factors are reported in detail in Table 3.

Table 3. Participants' Factor Loadings

No.	Participant code	Factor group-item number	Factor 1	Factor 2	Factor 3
38	P1	F1-1	.904*	-.286	.026
23	P2	F1-2	.899*	-.319	.023
12	P3	F1-3	.893*	-.256	-.096
22	P4	F1-4	.893*	-.170	-.058
17	P5	F1-5	.871*	-.150	.217
34	P6	F1-6	.871*	-.290	.118
5	P7	F1-7	.862*	-.111	.238
30	P8	F1-8	.857*	-.320	-.006
36	P9	F1-9	.854*	-.047	.099
33	P10	F1-10	.850*	.180	-.166
39	P11	F1-11	.847*	-.177	-.026
6	P12	F1-12	.844*	.274	.149
20	P13	F1-13	.787*	-.283	-.339
31	P14	F1-14	.727*	-.191	.186
35	P15	F1-15	.712*	-.104	.424
32	P16	F1-16	.705*	.034	-.261
8	P17	F1-17	.691*	.059	-.172
18	P18	F1-18	.653*	-.287	-.266
7	P19	F1-19	.634*	.435	-.204
16	P20	F1-20	.628*	.048	.006
26	P21	F1-21	.615*	.164	.122
4	P22	F1-22	.601*	.320	.172
15	P23	F1-23	.598*	.380	.074
28	P24	F1-24	.572*	-.434	-.336
25	P25	F1-25	.503*	.172	-.457
9	P26	F1-26	.481*	.011	.132
14	P27	F1-27	.476*	.424	-.290
3	P28	F1-28	.470*	-.290	-.136
11	P29	F1-29	.434*	.054	.382
29	P30	NS	.265	.142	-.081
2	P31	NS	.231	.132	.135

Table 3. Continued

No.	Participant code	Factor group-item number	Factor 1	Factor 2	Factor 3
37	P32	F2-1	.326	.751*	-.313
13	P33	F2-2	.525	.705*	.087
19	P34	F2-3	.483	.578*	.014
21	P35	F2-4	.21	.56*	-.046
1	P36	F2-5	.161	.541*	.056
10	P37	F2-6	.442	.472*	.239
27	P38	F3-1	.291	-.125	-.696*
24	P39	F3-2	.439	-.118	.671*
Eigenvalue			16.79	4.10	2.50
Percentage of variance explained			43	11	6

Note. * indicates statistically significant factor loadings (|loading| ≥ 0.35). NS denotes participants who did not load significantly on any factor.

Within the data analysis, Principal Component Analysis was conducted based on the correlation matrix derived from participants' Q-sorts, and Varimax rotation was applied to improve interpretability. In line with the criteria specified in the Method section, the three-factor solution was identified as providing the most meaningful structure. This three-factor solution accounts for 60% of the total variance across Q-sorts.

Table 3 reports factor loadings for all participants. For factor interpretation, only participants whose Q-sorts loaded statistically significantly on a single factor were included, consistent with the analytic principles recommended by Ramlo (2021). Each factor array was constructed using the weighted average of the representative participants' z-scores. This structure was used to map teachers' perceptions of the skills that TYMM aims to develop in students in a systematic manner. The three factors (Factors 1, 2, and 3) represent meaningful clusters reflecting teachers' evaluations of different skill domains within the curriculum.

The distinguishing features of the factors were interpreted by considering factor loadings, Q-sort values (Q-SV), z-scores, and significance levels (p) together. For presentation purposes, statistically significant factor loadings are marked with an asterisk (*). In addition, loadings significant at $p < .05$ are coded in blue, those significant at $p < .01$ in red, and consensus statements endorsed across all factors are coded in green. The statements that differentiate the factors are reported in the relevant tables with their Q-SV and z-scores, and the content-based rationales for these distinctions are presented to provide a basis for factor naming.

Finally, the quantitative patterns identified through factor analysis were supported by qualitative evidence obtained from participants' follow-up written rationales. These qualitative accounts were included not only to complement numerical findings but also to clarify the meaning and interpretive depth of the factors. In this way, teachers' perspectives were examined holistically, integrating statistical structure with content-based interpretation.

Findings Regarding Items Agreed Upon by Teachers in the Context of 21st-Century Skills

The findings indicate that classroom teachers share common views on several 21st-century skills. Across the three factors, participants reached consensus on seven statements. These consensus statements were identified through Q analysis and are reported in Table 4 together with their Q-sort values (Q-SV) and z-scores. Positive Q-SV and z-scores indicate alignment with the relevant factor, whereas negative values indicate an inverse orientation.

Table 4. Consensus statements regarding 21st-century skills within TYMM

Statement No.	Statement	Factor 1		Factor 2		Factor 3	
		Q-SV	z score	Q-SV	z score	Q-SV	z score
10	The curriculum supports students with different abilities to conduct research together.	2	0.78	1	.27	0	-0.03
11	The curriculum develops students' research skills for common goals.	1	.678	2	.7	1	.262
12	The curriculum enhances students' collaborative problem-solving skills.	0	.46	1	.085	1	.589
19	The curriculum offers opportunities to develop students' digital content creation skills.	-1	-.423	-1	-.503	-2	-.916
23	The curriculum enhances students' ability to generate solutions to real-life problems.	-1	-.537	0	-.273	-1	-.654
27	The curriculum supports students' ability to adapt to different research styles.	-2	-1.165	-4	-1.354	-4	-1.603
28	The curriculum helps students quickly adapt to new technologies and methods.	-2	-1.077	-2	-.883	-1	-.558

The strongest areas of agreement suggest that the curriculum is perceived as supporting collaboration, research, and problem solving. For instance, *"The curriculum supports students with different abilities to conduct research together"* (Statement 10) is placed on the positive side across the three factors (Factor 1: Q-SV = 2, z = 0.78; Factor 2: Q-SV = 1, z = 0.27; Factor 3: Q-SV = 0, z = -0.03). In a similar vein, *"The curriculum develops students' research skills for common goals"* (Statement 11) and *"The curriculum enhances students' collaborative problem-solving skills"* (Statement 12) are positioned on the positive side or close to neutral across factors (see Table 4). This pattern indicates shared recognition of TYMM's emphasis on collective learning processes.

However, a shared concern emerges regarding the development of digital skills and adaptation to technological change. Table 4 indicates negative placements across the three factors for *"The curriculum offers opportunities to develop students' digital content creation skills"* (Statement 19; Q-SV = -1 to -2; z = -0.423 to -0.916) and *"The curriculum helps students quickly adapt to new technologies and methods"* (Statement 28; Q-SV = -1 to -2; z = -0.558 to -1.077), pointing to a commonly perceived gap in relation to digital transformation and technological adaptation. Similarly, *"The curriculum supports students' ability to adapt to different research styles"* (Statement 27) receives consistently low placements across factors (Q-SV = -2 to -4; z = -1.165 to -1.603), suggesting strong consensus that the curriculum offers limited flexibility in responding to individual differences. Overall, teachers evaluate TYMM positively in terms of its contribution to collaboration and inquiry-oriented learning processes. At the same time, they agree that substantial improvement is needed in areas such as digital transformation, responsiveness to individual differences, and technological adaptation.

Quantitative and Qualitative Findings Related to Factor 1 (Focus on Critical Thinking and Creativity)

Factor 1 represents a viewpoint in which teachers prioritise critical thinking and creativity. This factor is the strongest, explaining 43% of the total variance with an eigenvalue of 16.79. Twenty-nine participants loaded significantly on this factor, indicating that a substantial proportion of the sample converged around a broadly similar perspective. The Q sorts of participants associated with Factor 1 are presented in Figure 2.

Figure 2. Factor 1 (Critical Thinking and Creativity Orientation) Q sort

When examining the statements that Factor 1 teachers evaluated negatively, three items related to digital literacy (-1), problem solving (-1), and flexibility and adaptability (-2), together with two items related to entrepreneurship (-4), stand out. These items reflect a shared critique that the TYMM science curriculum does not produce the expected impact in these domains. In this section, statements highlighted in red indicate those for which Factor 1 participants diverged significantly from participants in the other factors. This pattern points to differences in orientations, particularly regarding critical thinking, creativity, communication, digital literacy, and entrepreneurship.

A closer look at the relevant statements suggests that Factor 1 teachers express more negative orientations in areas such as communication, digital literacy-related affordances, and entrepreneurship, while adopting a more positive orientation toward collaboration and inquiry-oriented problem solving. Table 5 presents the distinguishing statements for Factor 1 with the highest and lowest Q-SV and z-score values.

Table 5. Q-SV and z-score values of distinguishing statements for Factor 1

Statement	**2**	**6**	**7**	**8**	**13**	**16**	**14**	**17**	**32**	**31**
Q-SV	4	3	3	1	1	0	0	0	-4	-4
z score	1.45	1.26	1.25	.74	.56	.26	.18	.15	-1.64	-1.84

Factor 1 indicates that teachers' views foreground students' critical thinking and creativity. The statements loading on this factor suggest that the curriculum encourages students to consider and evaluate different perspectives. For example, the statement *"Students evaluate different perspectives"* (Statement 2, Q-SV = 4, z = 1.45) strongly reflects this orientation. Likewise, *"Enables students to develop innovative solutions"* (Statement 7, Q-SV = 3, z = 1.25) indicates that the curriculum is perceived as supporting creativity alongside problem solving. The combination of high Q-SV values (≥ 3) and comparatively higher z-scores indicates strong convergence in teachers' perceptions that the TYMM science curriculum places a strong emphasis on developing critical thinking and creativity. This pattern suggests that these competencies are widely perceived as central within the reform.

In contrast, teachers' evaluations of entrepreneurship-related skills within the same factor are negative, as indicated by the low Q-SV and z-score values for the relevant statements. In addition, teachers' accounts in this group point to structural constraints affecting implementation, including limitations in technological infrastructure, teachers' competencies, and students' capacity to assume responsibility. For Factor 1, critiques of the curriculum's overall structure also come to the fore, and teachers note that a teacher-centred orientation is still perceived as prevalent.

Across the qualitative dataset, teachers reported encountering a range of difficulties when enacting the revised TYMM science curriculum. Teachers frequently referred to resource disparities between schools, limited access to digital tools, and insufficient opportunities to produce technology-supported content. One teacher described this as follows: *"Since the technological conditions and opportunities are not the same in every school, it does not appeal to every student, and sufficient content cannot be created due to the lack of adequate technological tools."* (P38)

Teachers also highlighted challenges related to their pedagogical capacity and working conditions. They noted that hardware limitations, classroom management difficulties, and inadequate physical school environments can negatively affect the feasibility of curriculum implementation. One teacher summarised these constraints as follows: *"The physical school environment is inadequate, the student classroom environment is lacking, and the teacher's equipment is inadequate."* (P17)

These critiques extended beyond teachers' conditions to include students' competencies in assuming individual responsibility, problem solving, and planning. Participants suggested that contextual influences, including limited parental support and low social awareness, may hinder students' development of these skills. One teacher expressed this view as follows: *"Children are somewhat inadequate in this sense because they are not sufficiently made aware by their parents about taking responsibility at home in real life."* (P23)

Participants also commented on the perceived effectiveness of curriculum components related to cultural transmission, student-centred learning, and Turkish language education. One teacher evaluated the cultural dimension of the curriculum as follows: *"The new curriculum allows us to transmit our Turkish culture from generation to generation through the Turkish language, both verbally and in writing; we learn the characteristics of our society better."* (P12)

In addition, teachers stated that higher-order competencies such as innovative thinking, cognitive flexibility, and a critical stance are not sufficiently developed in practice. They noted that this limitation, together with reliance on digital resources, may increase the risk of superficial learning and weaken deep learning and critical inquiry. One participant remarked: *"Since the new curriculum is based on children learning through research, children are curious about everything and learn by instantly researching the topic they are curious about thanks to the internet."* (P34)

Alongside these critiques, some teachers also emphasised that the curriculum supports collaboration and shared learning processes. From this perspective, when implemented as intended, the curriculum can increase students' willingness to engage in collaborative inquiry and can support higher-order cognitive development. One teacher expressed this as follows: *"When implemented in line with the objectives of the new curriculum, it increases the desire for collaborative research among students and supports their higher-level cognitive development."* (P22)

The quantitative results align with these qualitative accounts. Statements such as *"Students evaluate different perspectives"* (Q-SV = 4, z = 1.45) and *"Enables students to develop innovative solutions"* (Q-SV = 3, z = 1.25) indicate positive evaluations in these areas. By contrast, negative evaluations are evident for statements related to entrepreneurship (Q-SV = -4, z = -1.84) and digital literacy (Q-SV = -2, z = -1.165).

Taken together, the findings suggest that TYMM has considerable potential to support 21st-century skills such as creative thinking, problem solving, and collaboration. However, teachers' accounts indicate implementation-level limitations, particularly regarding digital transformation, individual competencies, and entrepreneurship. The consistent overlap between qualitative and quantitative evidence suggests that teachers' perceptions are shaped not only by individual experiences but also by pedagogical conditions and wider systemic realities.

Quantitative and Qualitative Findings Related to Factor 2 (Communication and Digital Literacy)

Factor 2 reflects a viewpoint in which teachers foreground communication and digital literacy. This factor accounts for 11% of the total variance, with an eigenvalue of 4.10, and constitutes the second strongest thematic cluster in the study. Six participants loaded on Factor 2, indicating a coherent conceptual pattern despite the smaller number of defining participants. The participant configuration for Factor 2 is presented in Figure 3.

-4	-3	-2	-1	0	1	2	3	4
The curriculum supports students' ability to adapt to different research styles.	The curriculum encourages students to develop innovative business ideas.	The curriculum enhances students' resource management and planning skills.	The curriculum enhances students' ability to draw evidence-based conclusions.	The curriculum raises students' awareness of online safety and ethical issues.	The curriculum enables students to develop innovative solutions.	The curriculum includes activities aimed at improving students' written communication skills.	The new curriculum enhances students' ability to use various communication tools effectively.	The curriculum develops students' skills in effectively using digital tools.
The new curriculum develops students' ability to take risks and use initiative.	The new curriculum develops students' ability to generate and evaluate alternative solutions.	The curriculum helps students quickly adapt to new technologies and methods.	The curriculum offers opportunities to develop students' digital content creation skills.	The curriculum encourages students to evaluate different perspectives.	The curriculum supports students with different abilities to conduct research together.	The new curriculum enhances students' ability to evaluate and analyse online information.	The curriculum aims to develop students' listening and comprehension skills.	The new curriculum focuses on developing students' oral communication skills.
		The new curriculum develops students' ability to analyse and evaluate information.	The curriculum includes activities that require students to use their imagination.	The new curriculum encourages students to generate original ideas.	The new curriculum offers opportunities for students to develop their artistic expression skills.	The curriculum encourages effective teamwork among students.		
		The new curriculum develops students' ability to evaluate arguments and construct their own arguments.	The curriculum develops students' ability to adapt to changing conditions.	The new curriculum develops students' ability to analyse complex problems.	The curriculum enhances students' collaborative problem-solving skills.	The curriculum develops students' research skills for common goals.		
			The new curriculum increases students' ability to cope with uncertainty.	The curriculum enhances students' ability to generate solutions to real-life problems.	The new curriculum offers opportunities for students to develop their leadership skills.			
				The curriculum helps students develop systematic problem-solving strategies.				

Figure 3. Factor 2 (Communication and Digital Literacy) Q sort

When examining the views associated with Factor 2, negative orientations toward several skill domains are evident. In particular, statements related to entrepreneurship (Q-SV = -2), critical thinking (Q-SV = -2, -1), digital literacy (Q-SV = -1), and flexibility and adaptability (Q-SV = -4, -2) stand out due to their low rankings. These statements reflect a shared perception among Factor 2 teachers that the curriculum offers limited support for these skills. In this section, statements highlighted in red indicate those for which Factor 2 participants diverged significantly from participants in the other factors. A closer examination of the distinguishing statements suggests a mixed pattern. While several statements foregrounding verbal communication and the effective use of communication/digital tools are placed strongly on the positive side (e.g., Statements 13, 15-17), less favourable placements are observed for creativity- and critical thinking-related statements, along with entrepreneurship and flexibility/adaptability. Table 6 presents the distinguishing statements specific to Factor 2 together with their Q-SV and z-score values.

Table 6. Q-SV and z-score values of distinguishing statements for Factor 2

Statement	13	15	16	17	14	18	32	2	5	1	4	31	3	24	29
Q-SV	4	4	3	3	2	2	1	1	0	-1	-1	-1	-2	-3	-4
z score	1.88	1.85	1.78	1.64	1.35	.88	.21	.12	-.05	-.33	-.38	-.57	-.95	-1.31	-1.87

Factor 2 indicates that teachers' views foreground students' development in communication and digital literacy. The statements defining this factor point to perceived support for students' verbal communication (Statement 13, Q-SV = 4, z = 1.88) and for listening and comprehension (Statement 15, Q-SV = 4, z = 1.85). In addition, *"students' effective use of various communication tools"* (Statement 16, Q-SV = 3, z = 1.78) and *"developing skills to effectively use digital tools"* (Statement 17, Q-SV = 3, z = 1.64) indicate that the curriculum is viewed as promoting communication- and technology-oriented learning. The positive placement of these statements, together with comparatively higher z-scores, suggests that communication and digital literacy are prominent within this viewpoint.

However, to contextualise this positive quantitative pattern, the qualitative evidence also points to several constraints raised by participants across the sample. Themes such as limited creativity, risk aversion, and digital addiction were salient. Participants stated that students showed limited development in generating new ideas and thinking independently. These concerns are reflected in comments such as *"Children's idea generation skills are insufficient"* (P37) and *"Children are weak in inventing new ideas and discoveries"* (P13). Similarly, teachers stated that risk-taking is not sufficiently supported, noting that *"There are no activities that develop risk-taking skills appropriate to the students' level of development."*

Perceived lack of change and limited curriculum impact also emerged as key critiques within this factor. Some teachers reported that they did not observe meaningful change in students, suggesting that the curriculum did not produce a noticeable difference in practice. Participants also frequently referred to students' passivity, limited critical thinking, and receptive learning orientations. One teacher described this as follows: *"The new generation of youth are not growing up to be solution-oriented because they like to be prepared by their families"* (P13), while another stated: *"Children do not have sufficient knowledge about arguments"* (P37).

Across the qualitative evidence, implementation challenges and educational inequalities also emerged as important concerns. Some teachers argued that differences in physical conditions and institutional resources across schools weaken feasibility. One participant expressed this view as follows: *"Its applicability is weak because there is no suitable environment for all schools."* (P1).

Quantitative and Qualitative Findings Related to Factor 3 (Problem Solving and Leadership Skills)

Factor 3 reflects a viewpoint that foregrounds problem solving and leadership skills. This factor accounts for 6% of the total variance, with an eigenvalue of 2.50, and constitutes the cluster with the most limited participant support in the study. Only two participants loaded on Factor 3, which suggests a distinct perspective while also indicating limited representativeness. Figure 4 presents the Q sorts of the participants associated with Factor 3.

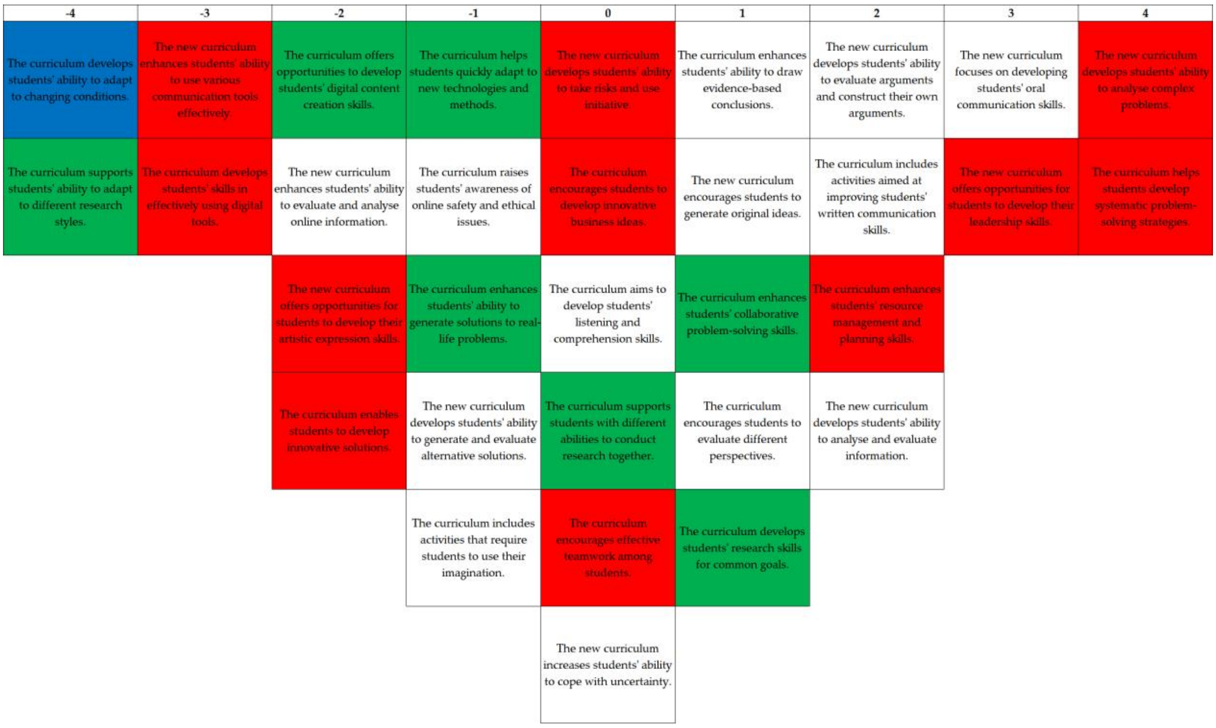

Figure 4. Factor 3 (Problem Solving and Leadership Skills) Q sort

When examining the views associated with Factor 3, less favourable evaluations are apparent across several skill domains. Specifically, low rankings were observed for statements related to creativity (two items, Q-SV = -2), communication (one item, Q-SV = -3), digital literacy (two items, Q-SV = -3), problem solving (one item, Q-SV = -1), and flexibility/adaptability (three items, including Q-SV = -4 and -1). This pattern suggests a shared critique among these teachers that the relevant skills are not sufficiently supported within TYMM. In this section, statements highlighted in red indicate those for which the participants loading on Factor 3 diverged markedly from participants in the other factors. A closer look at these distinguishing statements points to pronounced differences in orientations, especially regarding creativity, communication, digital literacy, and problem solving. In line with these divergences, Factor 3 teachers' evaluations of skills such as creativity, communication, and entrepreneurship are generally negative, whereas they display a more positive orientation toward collaboration. Table 7 reports the distinguishing statements for Factor 3 together with their Q-SV and z-score values.

Table 7. Q-SV and z-score values of distinguishing statements for Factor 3

Statement	**22**	**21**	**32**	**23**	**31**	**3**	**2**	**30**	**5**	**29**	**27**	**8**	**9**	**18**	**16**	**19**	**17**	**28**
Q-SV	4	3	3	2	2	2	1	1	1	0	-1	-1	-2	-2	-3	-3	-4	-4
z score	1.62	1.18	1.11	1.1	.92	.79	.7	.7	.53	-.05	-.08	-.34	-.64	-1.33	-1.7	-1.76	-1.92	-1.96

Factor 3 foregrounds the development of students' problem-solving, analytical, and leadership skills. Among the statements most strongly endorsed by participants, those related to developing systematic problem-solving strategies (Statement 22, Q-SV = 4, z = 1.62) and strengthening the ability to analyse complex problems (Statement 21, Q-SV = 3, z = 1.18) are particularly salient. In addition, *"producing solutions to real-life problems"* (Statement 23, Q-SV = 2, z = 1.10) and *"developing resource management and planning skills"* (Statement 31, Q-SV = 2, z = 0.92) suggest that the curriculum is perceived as aiming to equip students with organisational competencies alongside cognitive skills. Overall, the positive placement of these statements (Q-SV = 2-4), together with comparatively higher z-scores, indicates that these competencies are viewed as salient within this viewpoint.

Complementary qualitative evidence emphasised innovative approaches to teaching and sensitivity to students' developmental levels. In this respect, and in contrast to Factor 2's stronger emphasis on student characteristics, Factor 3 combines a positive orientation toward innovation with critiques related to access constraints and assessment processes. Accordingly, this factor reflects a balanced mix of critical and constructive viewpoints.

Interpreting the quantitative patterns alongside the qualitative evidence across participants helps clarify how teachers' field-based observations shape their curriculum appraisals. Several participants argued that a longstanding, test-oriented system reduces students' opportunities to express themselves. They suggested that this emphasis constrains students' ability to articulate their ideas orally and in writing, which in turn may limit the development of creative thinking and communication. One teacher described this as follows: *"The test method that has been applied for many years has reduced students' ability to express themselves."* (P24) In addition, some teachers working in disadvantaged contexts reported concerns about age appropriateness and resource limitations that negatively affect instruction. The statement *"It is not age-appropriate for children, and our resources are insufficient"* (P27) reflects this view.

At the same time, teachers generally welcomed the curriculum's emphasis on learning by doing. One participant explained: *"The curriculum emphasises learning by doing and aims to get students to express their knowledge in writing. It also aims to balance the use of computers and tablets."* (P24) Finally, some teachers framed TYMM's support for innovative educational approaches as a positive development. They particularly highlighted sensitivity to individual differences, student-centredness, and encouragement of critical thinking. The statement *"I think it's right because it supports innovation"* (P27) indicates that this orientation is valued by teachers.

Comparative Summary of Factors

Factor analysis revealed three distinct clusters of teacher perceptions regarding how the TYMM science curriculum supports 21st-century skills. Following the detailed quantitative and qualitative profiles of each factor, a comparative synthesis is presented in Table 8 and discussed below.

Table 8. Comparative summary across factors

Skill	**Factor 1 (Critical Thinking & Creativity)**	**Factor 2 (Communication & Digital Literacy)**	**Factor 3 (Problem Solving & Leadership)**	**Comment**
Critical thinking	+1.45	-0.95	+0.79	F1 highest, F2 lowest.
Creativity	+1.25	-1.31	-0.64	Only F1 positive; F2 and F3 negative.
Collaboration	+0.74	+0.88	+1.10	Positive in all factors; highest in F3.
Communication	+0.15	+1.64	-1.33	F2 distinctly positive; F1 slightly positive; F3 negative.
Digital literacy	-1.16	+1.35	-1.70	F2 positive; F1 and F3 negative (lowest in F3).
Problem solving	+0.56	-0.38	+1.62	Highest in F3; F1 positive; F2 negative.
Flexibility/adaptability	-1.08	-1.87	-1.96	Negative in all factors.
Entrepreneurship	-1.84	-0.57	-1.76	Negative in all factors (lowest in F1).

Table 8 highlights both clear areas of convergence and notable divergences in teachers' perceptions of the TYMM science curriculum. Collaboration is the only skill domain evaluated positively across all groups. By contrast, entrepreneurship and flexibility/adaptability are evaluated negatively across all factors, suggesting that these are the domains teachers most strongly perceive as requiring strengthening. The most pronounced divergence concerns digital literacy and communication: both are evaluated positively in Factor 2, whereas digital literacy is evaluated negatively in Factors 1 and 3. For communication, Factor 3 reflects a negative orientation, while Factor 1 remains only modestly positive.

Teachers' appraisals of TYMM suggest that curriculum enactment is shaped by both structural constraints and pedagogical opportunities. The three perspectives identified through factor analysis reflect overlapping concerns and priorities in these areas.

Among the principal implementation challenges, limitations in technological infrastructure, reported as particularly salient in rural contexts, stand out. Participants indicated that shortages of digital tools and equipment prevent the curriculum from reaching students equitably and constrain the development of digital competencies. Teachers also suggested that easy access to digital information can foster reliance on ready-made answers and digital dependency, which may weaken students' capacity for critical thinking and original idea generation. In addition, teachers reported that they do not feel sufficiently equipped in innovative teaching strategies and technology integration, which they perceived as reducing the curriculum's effectiveness. The enduring influence of a test-oriented system was also described as constraining students' communication and critical thinking, while a lack of age-appropriate materials and resources was cited as another barrier that negatively affects learning processes.

At the same time, teachers highlighted several opportunities associated with TYMM. The curriculum's emphasis on collaborative learning environments was viewed as supporting students' social and academic development. Learning by doing was described as strengthening analytical thinking and leadership by linking theoretical knowledge to practical contexts. Teachers also noted that balanced use of digital tools can counter excessive digital dependency and support students' ability to express their learning in writing. In addition, the curriculum was seen as encouraging critical thinking by supporting the evaluation of different perspectives and inquiry-oriented learning.

Overall, teachers' perceptions of TYMM cluster into three viewpoints consistent with the factor structure. Across all factors, there is shared endorsement of the curriculum's support for collaboration and inquiry-oriented learning. By contrast, dissatisfaction is evident in relation to digital skill development, technological adaptation, entrepreneurship, and flexibility. This distribution suggests a perceived misalignment between the curriculum's intended aims and the conditions shaping its enactment in practice.

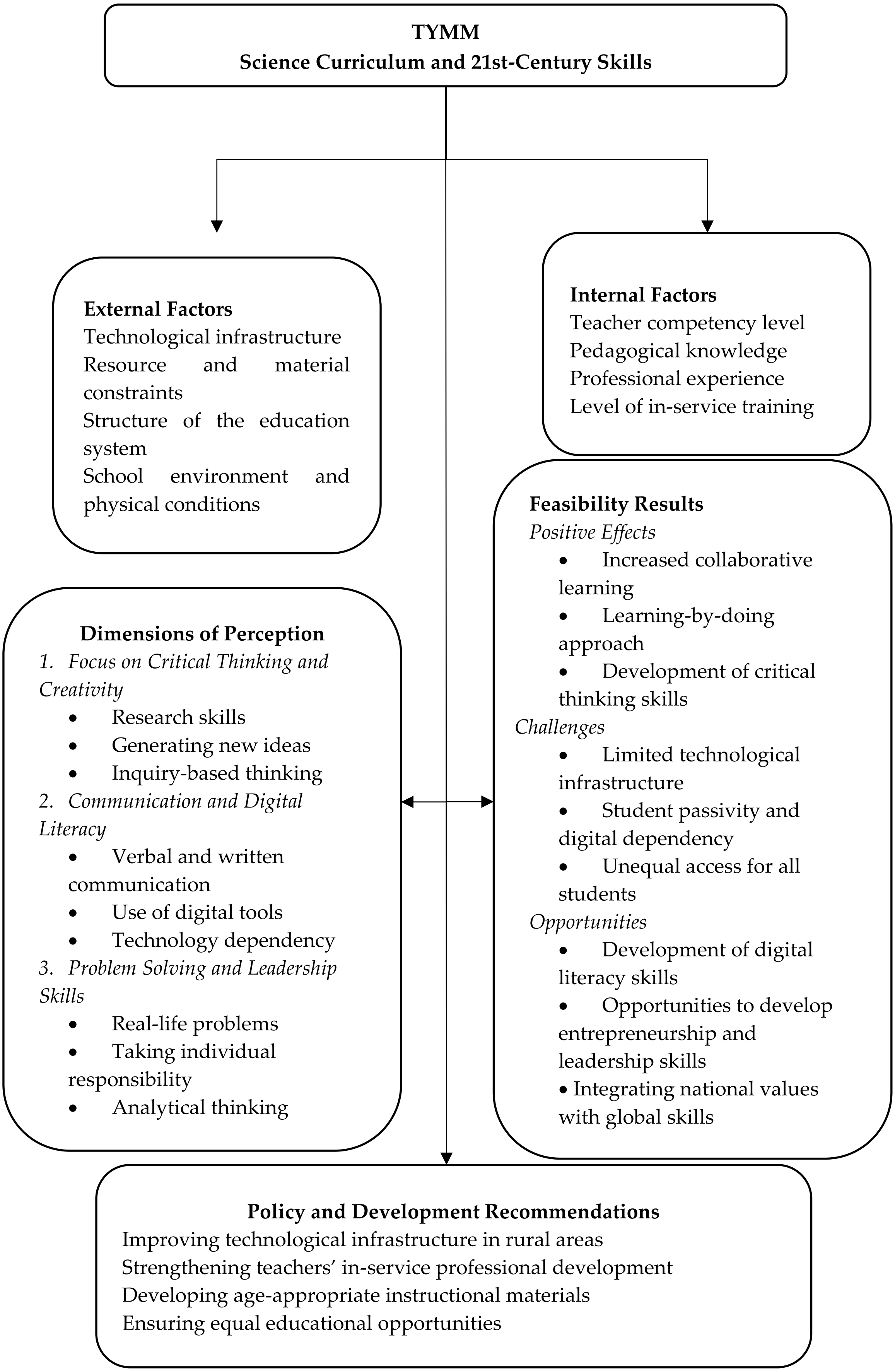

Figure 1. Teachers' Perceptions of the TYMM Science Curriculum: Factors, Effects, and Policy Recommendations

Results and Discussion

This study aimed to evaluate the updated science curriculum within the TYMM framework in relation to 21st-century skills, drawing on classroom teachers' perceptions. The Q methodology enabled the statistical grouping of teachers' subjective experiences and viewpoints, allowing a more comprehensive discussion of policy-practice alignment than would be possible through quantitative indicators alone.

The data indicate that teachers' views clustered into three thematic structures. Overall, the findings suggest that the curriculum is theoretically aligned with contemporary pedagogical approaches, yet this potential is not matched to the same extent in classroom enactment. Teachers emphasised the need to complement existing assessment practices with alternative, process-oriented models, noting that such approaches would be critical for making higher-order competencies, including creative thinking, critical inquiry, and problem solving, more visible and more readily developed.

In relation to critical thinking and creativity, teachers reported that the curriculum provides a conceptual basis for higher-order cognitive processes, such as analysis, synthesis, and evaluation (Bloom et al., 1956), as well as for the capacity to generate original ideas. The presence of creativity and problem-solving competencies among the future-oriented skills addressed in TYMM, in line with the contemporary skill priorities reflected in education indicators published by the Organisation for Economic Co-operation and Development (OECD, 2018), points to the curriculum's alignment with current educational directions. At the same time, as emphasised in the literature, it is necessary to create learning environments in which students can generate new ideas and do not hesitate to make mistakes (Alifah & Sukartono, 2023). Teachers' accounts suggest that students often avoid taking risks and that, although the curriculum foregrounds creative thinking, encouragement for such engagement is not sufficiently reinforced in practice. This pattern points to a need for entrepreneurship-oriented pedagogies that can translate creative thinking aims into classroom routines and for assessment approaches that foreground learning processes rather than outcomes alone.

The theme of digital literacy and communication suggests that structural conditions play a decisive role. While student-centred curriculum practices in digitalised learning environments are widely considered important, teachers reported that TYMM's strategic aims in this area, although incorporated into the curriculum, are not realised at the intended level due to infrastructure limitations and constrained pedagogical support in schools. Teachers' observations that students frequently turn to ready-made information and exhibit digital dependency further indicate constraints on the development of digital literacy (Amadi, 2023; Alifah & Sukartono, 2023). UNESCO's (2018) definition of digital literacy helps to contextualise these challenges; nevertheless, teachers described the effects of digital inequalities and socioeconomic differences on students' opportunities to engage meaningfully with technology (Amadi, 2023). In addition, variations in teachers' digital pedagogical competence (Chieng & Tan, 2021) and infrastructure shortcomings in disadvantaged contexts constitute major barriers to the effective use of technology as a cultural-cognitive tool in the sense highlighted by Vygotsky (1978). Accordingly, teacher professional development aimed at strengthening techno-pedagogical competence needs to be enhanced through an equity-oriented lens that explicitly addresses access and opportunity gaps.

Regarding leadership and problem-solving, teachers acknowledged the value of the curriculum's theoretical orientation toward these competencies but reported substantial implementation constraints linked to resource shortages and the continuing dominance of exam-oriented assessment. Bandura's (1995) self-efficacy theory and Kolb's (1984) experiential learning model suggest that higher-order competencies are more likely to develop in learning environments that provide opportunities for active participation, social interaction, and direct experience. Vygotsky's (1978) sociocultural perspective likewise emphasises that learning is constructed through social interaction. From this standpoint, classroom arrangements that enable students' active engagement and peer collaboration appear critical. However, teachers' accounts indicate that current classroom environments and implementation conditions can hinder the realisation of these aims.

Overall, the study suggests that the TYMM science curriculum provides a framework that is theoretically aligned with 21st-century skills, while structural and practical constraints limit the translation of this pedagogical potential into classroom enactment. The evidence indicates that limitations in technological infrastructure, particularly in rural and disadvantaged contexts, and variation in teachers' professional competencies directly shape students' opportunities to develop the skills targeted in the curriculum. At the same time, the findings highlight that student-centred and collaborative learning environments support not only academic learning but also students' social and emotional development. Strengthening alignment between the curriculum's intended aims and school-level realities therefore requires system-level support that addresses structural conditions, including infrastructure, teacher capacity, and assessment systems.

Limitations

A primary limitation of this study is that, consistent with the nature of Q methodology, the findings are not intended to support statistical generalisation. Of the 50 classroom teachers who volunteered to participate, data from 39 participants with complete and analysable Q sort rankings and follow-up written rationales were included in the analysis. Accordingly, the findings should be interpreted as reflecting the perspectives of this participant group drawn from Kırşehir province.

Second, the 32-statement Q set represents a bounded selection of statements, which constitutes a limitation. A different or more extensive statement pool might have yielded different priorities and patterns of consensus in teachers' perceptions.

A third limitation concerns the depth of qualitative evidence. Because participants provided rationales only for statements placed at the extreme ends of the distribution (+4 and -4), it was not possible to capture more nuanced viewpoints that may be located around the middle of the distribution.

The forced distribution format of Q methodology can also be considered a limitation. This structure produces relative prioritisation, meaning that a statement may be placed at the positive end because it is perceived as less problematic than others, rather than because it is viewed as unequivocally strong.

Finally, because the curriculum under evaluation has not yet been fully implemented across all grade levels, the results are necessarily oriented more toward potential implications and early feasibility conditions than toward fully established implementation outcomes.

Recommendations

To support effective enactment of the TYMM science curriculum, assessment systems should undergo a substantive shift. Moving beyond traditional, knowledge-focused examinations, it is important to expand the use of alternative assessment approaches that enable students to demonstrate higher-order competencies such as thinking, creating, and problem solving. In this respect, developing continuous and systematic professional learning opportunities that strengthen teachers' assessment literacy would be a strategic step toward improving the quality and credibility of assessment practices.

At the same time, strengthening digital literacy remains a critical priority. The findings indicate that limitations in technological infrastructure, particularly in rural and disadvantaged contexts, create a major barrier to the development of 21st-century skills. To prevent the deepening of digital inequality, infrastructure investments should be planned through an equity lens and ensure meaningful access for all students. In addition, sustainable educational resources should be developed to support both students' digital literacy and teachers' techno-pedagogical competencies, and the quality and effectiveness of in-service professional development in these areas should be enhanced.

The perceptual structures identified in this study also open important directions for future research. The factor map could be enriched through more in-depth qualitative inquiry. For example, ethnographic or case-based studies with teachers representing each factor could provide insight into how these perceptions translate into classroom pedagogy. Furthermore, the subjective viewpoints elicited through Q methodology could inform the development of a quantitative perception scale, enabling these perspectives to be examined with larger samples. Applying a similar design from the perspectives of students or parents would also allow a comparative analysis of how curriculum reform is perceived across stakeholder groups.

Finally, the curriculum's student-centred and socially and emotionally supportive orientation should be reinforced more systematically. Learning materials that are age-appropriate, contextually rich, and designed to elicit higher-order thinking should be developed, and experiential activities should be increased in line with learning-by-doing principles. Collaborative learning environments that support competencies such as empathy, leadership, and responsibility should have a more prominent place in curriculum enactment. In this context, comparative and monitoring-oriented research that can evaluate longer-term curriculum effects is important for the continuity and further development of TYMM.

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