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STEM Curriculum Alignment in Israeli Grade 10 Secondary Education: A Qualitative Document Analysis of Mathematics, Science, and Biotechnology Curricula.

Abstract

This study examines the extent to which the official Israeli Grade 10 curricula in mathematics, biology, biotechnology, chemistry, and physics align with internationally recognized characteristics of STEM education. A qualitative document analysis was conducted using a structured binary coding rubric (0 = absent, 1 = present) derived from established STEM education literature and applied to a total of 362 instructional items across the five curricula. The findings reveal considerable variation in STEM alignment across subjects. Biotechnology achieved the highest overall alignment, with inquiry and modeling at 85.7% and real-world contexts at 71.4%. Physics ranked second, with inquiry and modeling at 83.3% and quantitative reasoning at 77.8%. Chemistry showed moderate-to-strong alignment in quantitative reasoning (68.8%) and inquiry (65.0%), while mathematics dominated in quantitative reasoning (93.8%) but recorded 0% for both engineering design and collaboration. Biology demonstrated inquiry (46.7%) and real-world relevance (31.1%) but showed weak quantitative reasoning (11.1%) and no engineering design. Inter-rater reliability was 0.84 (Holsti formula), confirming coding consistency. The results highlight systemic gaps in engineering design integration, collaboration, and interdisciplinary coherence across the Israeli Grade 10 curriculum. Evidence-based recommendations are provided for curriculum designers, policymakers, and educators seeking to strengthen STEM coherence at the secondary level.

Keywords: STEM education; curriculum alignment; document analysis; curriculum reform; Israel; secondary education; qualitative research.

1. Introduction

In many education systems, STEM (science, technology, engineering, and mathematics) has become a central educational priority aimed at preparing students to participate in technologically advanced and innovation-driven societies. International studies indicate that effective STEM education extends beyond disciplinary knowledge by engaging students in inquiry, quantitative reasoning, authentic problem solving, and collaborative learning experiences (English, 2023). These features contribute to the development of critical and creative thinking and help prepare students for complex problem solving in modern knowledge-based societies (OECD, 2023).

The secondary school curriculum in Israel exposes students to scientific reasoning and mathematical thought at progressively advanced levels. In Grade 10, students begin engaging with more advanced disciplinary concepts that require deeper conceptual understanding, analytical reasoning, and the ability to connect scientific knowledge with real-world contexts. This makes it important to examine the extent to which Grade 10 curricula reflect accepted STEM principles and support this educational goal. Israel's consistent participation in international assessments such as PISA and TIMSS underscores the importance of aligning national curriculum frameworks with global STEM standards (OECD, 2023).

Studies from different educational contexts indicate that when curricula emphasize inquiry, modelling, experimentation, and real-world contexts, teachers are more likely to adopt integrated and student-centered approaches (McLure et al., 2017; Roehrig et al., 2021). Gaps at the curricular level can influence instructional practices and student learning outcomes (OECD, 2020). This pattern has been documented across diverse national contexts, including systematic curriculum analyses in Arab and Middle Eastern education systems. For example, Abu Khurma and El Zein (2024) found that UAE secondary science curricula similarly underemphasized collaborative inquiry and design-based tasks despite strong disciplinary content. Comparable curriculum-level analyses in Kazakhstan (Zhumabay et al., 2024) and Turkey (Balta et al., 2022) have reached analogous conclusions, pointing to a widespread international gap between curriculum intent and integrated STEM practice. Moreover, curriculum documents play a central role in structuring educational experiences and guiding instructional priorities, particularly in times of systemic educational change (OECD, 2021).

This study relied on official curriculum documents issued by the Israeli Ministry of Education in mathematics, biology, biotechnology, chemistry, and physics. These documents represent the formal structure, content organization, and pedagogical orientations of secondary-level education in Israel (Israeli Ministry of Education, 2017, 2019, 2025a, 2025b, 2025c). Although previous research has explored STEM teaching practices, teacher perceptions, and classroom integration of STEM approaches, little attention has been given to the systematic analysis of national curriculum documents themselves. Curriculum frameworks play a crucial role in shaping instructional expectations and learning opportunities, yet systematic analyses of how official curricula reflect core STEM characteristics remain limited, particularly in the context of the Israeli education system. Therefore, a systematic review of the curriculum documents is needed to determine whether the official materials promote inquiry-based learning, problem solving, engineering design, and interdisciplinary connections which are critical features of contemporary STEM frameworks (Ma & Roehrig, 2023; Rúa Martínez et al., 2024; Amanova et al., 2025).

This study makes three specific contributions to the STEM education literature. First, it provides the first systematic, multi-subject STEM alignment analysis of Israeli Grade 10 curricula across five disciplines simultaneously, filling a gap in the evidence base for Israeli curriculum reform. Second, it introduces and validates replicable binary coding rubric grounded in established STEM indicators, which can be adapted for curriculum analysis in other national or regional contexts. Third, it generates an evidence base for actionable, subject-specific curriculum development recommendations within a non-Western, multilingual education system — a context that remains underrepresented in the international STEM curriculum literature (Portillo-Blanco et al., 2024).

This study analyzes Grade 10 curricula in five core subjects — mathematics, biology, biotechnology, chemistry, and physics — to examine the extent to which they incorporate STEM indicators. The qualitative document analysis approach, guided by a coding rubric based on recent STEM literature, examines how each curriculum addresses engineering design, quantitative and computational reasoning, real-world contexts, inquiry and modeling, and opportunities for collaboration. By examining these five subjects, the study contributes to the national discussion on STEM development, curriculum reform, and the kinds of learning experiences that best prepare students for future study and work in science and technology.

2. Literature Review

2.1. STEM Education: Conceptual Framework

STEM is commonly understood as the intentional integration of science, technology, engineering, and mathematics, defined by encouraging students' capacity for disciplinary knowledge and for applying that knowledge through problem solving, engineering design, and engagement with real-world questions (Roehrig et al., 2021). Effective STEM instruction often relies on student-centered methods, including learning-centered design, problem-solving approaches, discovery-based inquiry, and experimental tasks through which knowledge is constructed through meaningful experiences (Roehrig et al., 2021). Contemporary STEM frameworks also emphasize the importance of developing 21st-century skills such as collaboration, communication, and critical thinking (Tytler, 2020). According to constructivist theory, learners make sense of the world by actively interacting with ideas, questions, and constructed meaning. Inquiry-based learning, modeling, and engineering design tasks are therefore underpinned by constructivist views of learning (Rúa Martínez et al., 2024; Ma & Roehrig, 2023). Integrated STEM education emphasizes the meaningful connection between the four disciplines through authentic problem solving and interdisciplinary learning (Portillo-Blanco et al., 2024; Amanova et al., 2025). The extent to which a curriculum supports or constrains these connections raises important theoretical considerations for curriculum design and reform (Roehrig et al., 2021).

2.2. STEM Indicators in Curriculum Design

The following five characteristics serve as indicators of alignment with STEM curriculum goals, drawn from empirical research and validated theoretical frameworks.

A) Engineering Design Tasks. The incorporation of design and engineering tasks into the curriculum enables students to apply their theoretical knowledge to practical problems (English, 2023). Research indicates that integrating engineering design within STEM curricula enhances students' problem-solving abilities and fosters design thinking through engagement in authentic, practice-based learning environments (Roehrig et al., 2021; Ma & Roehrig, 2023).

B) Quantitative and Computational Reasoning. Students develop decision-making capacities when they conduct quantitative or modeling tasks (OECD, 2021). Project-based learning strategies can effectively support computational thinking and problem-solving skills in STEM education (Li et al., 2019).

C) Real-World Contexts. When students engage with real-world problems, learning becomes more meaningful, motivating, and relevant (English, 2023; OECD, 2021). Connecting classroom learning to real-world contexts enhances students' engagement and understanding, and is central to integrated STEM education (Zhan et al., 2022).

D) Inquiry and Modeling. When students engage in problem solving, modeling, and experimental inquiry, they can delve deeply into content, generate hypotheses, and perform experiments (English, 2023). Integrated STEM problem-solving provides opportunities for students to connect theoretical knowledge with real-world applications (Roehrig et al., 2021).

E) Collaboration Prompts. Collaborative tasks are a hallmark of STEM education, reflecting the collaborative nature of scientific and engineering work in professional contexts. Encouraging collaboration in STEM classrooms enhances student engagement and improves learning outcomes (Boke et al., 2025). The presence and extent of these characteristics serve as indicators of a topic's alignment with STEM objectives (McLure et al., 2017).

2.3. Curriculum Analysis in STEM: International Evidence

Although prior research has emphasized the importance of inquiry, modeling, and real-world problem solving in STEM education, inconsistency remains in how these elements are embedded across disciplines. Studies suggest that while science subjects often incorporate inquiry-based practices, mathematics curricula tend to emphasize abstract reasoning with limited integration of design and real-world applications (English, 2023). Furthermore, collaboration and engineering design — key components of authentic STEM learning — are frequently underrepresented unless explicitly integrated through curriculum reform (Portillo-Blanco et al., 2024).

This inconsistency has been documented in multiple national contexts. In the UAE, a systematic review of secondary school science curricula found that while inquiry skills were broadly present, collaborative and design-based components were consistently marginalized (Abu Khurma& El Zein, 2024). A mapping of Kazakhstan's STEM education landscape identified similar structural weaknesses in curriculum coherence across subjects (Zhumabay et al., 2024). A systematic review by Amanova et al. (2025) of STEAM implementation in schools across multiple countries concluded that curriculum documents rarely provide explicit guidance for interdisciplinary integration or teacher collaboration, reinforcing the need for evidence-based curriculum reform. These international findings establish a comparative context for the present study and underscore the global relevance of systematic curriculum-level analysis.

3. Materials and Methods

3.1. Research Design

This study adopts a qualitative document analysis design to examine the extent to which the official Israeli Grade 10 curricula in mathematics, biology, biotechnology, chemistry, and physics reflect the core characteristics of STEM education. A qualitative design is appropriate because curriculum analysis requires in-depth examination of educational documents and policy frameworks to identify patterns and interpret curricular priorities (OECD, 2020). The coding scheme was based on STEM indicators identified in the literature, including design thinking, quantitative and computational reasoning, real-world problem contexts, inquiry-based learning, modeling, and collaboration.

3.2. Research Questions

In view of the purpose and objectives of this study, the analysis is guided by the following research questions:

1. To what extent do the Grade 10 curricula in mathematics, biology, biotechnology, chemistry, and physics include tasks that reflect engineering design or design thinking?

2. Which STEM indicators are most and least represented across the five curricula?

3. How do the five curricula compare in their overall alignment with internationally recognized STEM education characteristics?

4. What strengths and gaps emerge in the Israeli Grade 10 curriculum regarding readiness for STEM learning?

These questions address different dimensions of STEM-related learning opportunities and facilitate comparisons among the five disciplines.

3.3. Research Context and Data Sources

The study relied on official curriculum documents published by the Israeli Ministry of Education (Israeli Ministry of Education, 2017, 2019, 2025a, 2025b, 2025c):

- Mathematics Curriculum (five-point track): An advanced mathematics track consisting of analysis, geometry, and trigonometry, evaluating students' ability to assimilate, analyze, and model problem-solving.
- Biotechnology Curriculum (specialization): This specialization track combines core science — biology and chemistry — with modern technology applications and is a direct indicator of applied STEM in a specialized field.
- Biology Curriculum (specialization): This curriculum was analyzed for the promotion of inquiry-based learning, data collection, and connections to real-world issues such as health and environmental science.
- Chemistry Curriculum (specialization): This curriculum was assessed for the integration of experimentation, quantitative analysis, and collaboration.
- Physics Curriculum (specialization): This curriculum defines core physical science knowledge, the basis for engineering principles, and is essential for evaluating the depth of scientific inquiry.

All documents were obtained from the Israeli Ministry of Education and represent the most recent versions (2024–2025) used in Israeli schools. They include topic lists, content descriptions, required skills, teaching notes, practical activities, and assessment guidelines. A total of 362 instructional items were coded across the five curricula: mathematics (n = 32), biology (n = 90), biotechnology (n = 70), chemistry (n = 80), and physics (n = 90).

3.4. Instrument: Coding Rubric

To analyze the curriculum documents, a structured coding rubric was derived directly from frameworks widely used in STEM education research (English, 2023; Roehrig et al., 2021). The rubric includes five main categories, each representing a STEM indicator identified in the literature. For each instructional item, the presence or absence of each indicator was coded using a binary system (0 = absent, 1 = present). Operational definitions used to guide coding decisions are as follows:

- Engineering Design Tasks: Any instance of planning, constructing, experimenting, optimizing, or solving real problems using a systematic process akin to engineering.
- Quantitative and Computational Reasoning: A task or activity that requires mathematical modeling, algebraic manipulation, data analysis, algorithmic thinking, or the use of digital technologies.
- Real-World Contexts: A clear reference to applications in social, environmental, industrial, health, or community contexts.
- Inquiry and Modeling: Student investigation that includes hypothesis testing, model building, data analysis, or physical experimentation.
- Collaboration: Suggested activities requiring teamwork, cooperative learning, laboratory partnerships, or shared decision making.

The rubric was reviewed by two independent researchers with experience in STEM education to ensure clarity and applicability prior to coding.

3.5. Procedures

The analysis took place in four systematic stages:

- Document Familiarization: Each curriculum document was read multiple times to identify its structure, main themes, and the distribution of topics.

• Initial Open Coding: Topics were first reviewed without labels to identify any STEM-related elements.

• Application of Coding Rubric: Using the five STEM indicators, each curriculum topic or subsection was coded manually and supported by tables summarizing evidence for each indicator.

• Cross-Curricular Comparison: After coding each subject separately, the five curricula were compared to examine similarities, differences, and gaps in STEM alignment.

3.6. Validity and Reliability

To ensure methodological validity and reliability, several strategies were applied. First, the coding categories were based on well-known and validated frameworks commonly used in STEM education research (English, 2023; Roehrig et al., 2021). Second, two researchers with expertise in STEM education reviewed the coding rubric and provided feedback on its clarity and accuracy before coding commenced. Third, all coding choices, notes, and supporting document excerpts were recorded in an organized file to ensure an audit trail. Fourth, to verify coding reliability, two trained content analysts — one a secondary science teacher with eight years of experience and one a STEM education researcher with a doctoral degree — independently coded approximately 20% of the total curriculum sample ($n = 74$ items, drawn proportionally from all five curricula). Disagreements primarily arose in borderline cases where tasks had partial quantitative elements or indirect real-world references. These were resolved through discussion and clarification of the operational definitions. Agreement was calculated using the Holsti formula and yielded a reliability coefficient of 0.84, exceeding the 0.80 threshold considered acceptable for consistent and dependable coding (Roehrig et al., 2021).

3.7. Statistical Analysis

Frequency and percentage were calculated for each of the five STEM indicators across each curriculum to allow meaningful comparison. These quantitative summaries are presented in comparative tables. Percentage values were grouped into three representation levels:

• Strong representation: 70% or more of topics — indicates a consistent and systematic presence.

• Moderate representation: 40%–69% of topics — suggests regular but uneven presence.

• Weak representation: Below 40% of topics — suggests limited likelihood of consistent implementation.

These criteria align with conventions established in prior curriculum content analysis (McLure et al., 2017; Roehrig et al., 2021).

3.8. Limitations

The research only examines the national curricula published by the Israeli Ministry of Education for Grade 10 and does not take into consideration textbooks, supplementary materials, or resources generated by individual teachers. The study focuses on the intended curriculum and does not assess how the curriculum is enacted in classrooms, how teachers interpret it, or how students experience it. The analysis relies on the most recent versions of the curricula for 2024–2025; future revisions might alter the organization, focus, or instructional requirements of these documents. Additionally, the study is limited to the five subject areas selected and does not include technology, computer science, or other STEM-adjacent disciplines. The findings only reflect characteristics of the Grade 10 curricula and cannot be automatically generalized to Grades 11–12 or to non-STEM subjects without further study.

3.9. Ethical Considerations

The study follows ethical research standards by properly citing all curriculum sources, presenting material exactly as it appears in the documents, and avoiding additions or personal distortions. The study does not involve students, teachers, or any personal data, as it deals exclusively with publicly available curriculum documents. For this reason, no formal ethical approval was required.

4. Results

This section presents the findings of the qualitative document analysis conducted on the

Grade 10 curricula in mathematics, biology, biotechnology, chemistry, and physics. The results are presented in two parts: (1) subject-level findings including coding tables and explanatory text, and (2) a cross-curricular comparison highlighting patterns, strengths, and gaps across subjects. Table 7 presents a representative sample of coded curriculum excerpts to illustrate the coding decisions applied throughout the analysis.

Table 7. Sample Coding Evidence: Representative Curriculum Excerpts and Binary Coding Decisions (0 = absent, 1 = present).

Curriculum	Topic	Curriculum Excerpt	Eng. Design	Quant. Reason.	Real-World	Inquiry
Chemistry	Gas Laws	Students shall calculate using PV=nRT when other parameters are given (R provided)	0	1	0	1
Chemistry	Industrial Bromine	Flow chart of industrial bromine production; students identify input/output materials and evaluate yield	1	1	1	

1

Biology

Homeostasis

Students shall describe the role of the kidney in maintaining water and salt balance

0

0

1

0

Biology

Lab Skills

Students record observations; distinguish observation from interpretation; draw conclusions from data

0

0

0

1

Biotechnology

Research Design

Students plan an experiment: formulate hypothesis, define variables, design control, and modify procedure

1

1

0

1

Biotechnology

Community Survey

Students conduct a survey on community attitudes to GMOs; present findings to an external audience

1

1

1

1

Mathematics

Calculus

Students investigate limits of functions using graphical, numerical, and algebraic representations

0

1

0

1

Mathematics

Statistics

Students calculate mean and standard deviation for a data set; no real-world scenario provided

0

1

0

1

Physics

Circuits

Students build an RC circuit, log voltage over time, and compare results to exponential model

1

1

0

1

Physics	Kinematics	Students apply equations of motion to calculate projectile range; interpret position-time graphs	0	1	0	1

Note. Excerpts are paraphrased from curriculum documents (Israeli Ministry of Education, 2017, 2019, 2025a, 2025b, 2025c). Eng. = Engineering; Quant. = Quantitative; Reason. = Reasoning.

4.1. Mathematics

Table 1. Distribution of STEM Indicators in the Grade 10 Mathematics Curriculum (n = 32).

STEM Indicator	Frequency	Percentage
Engineering design tasks	0	0%
Quantitative and computational reasoning	30	93.8%
Real-world contexts	7	21.9%
Inquiry and modeling	20	62.5%

Collaboration	0	0%

A line-by-line coding of the Grade 10 mathematics curriculum yielded 32 instructional items. Almost all items (93.8%) include quantitative and computational reasoning, highlighting the central role of quantitative thinking in STEM-related learning tasks. Approximately 62.5% of items contained inquiry or modeling components — for example, investigating functions with dynamic software or using multiple representations. However, only 21.9% of items explicitly incorporated authentic real-world contexts, and there was a complete absence of items referring to collaboration or engineering design tasks (Israeli Ministry of Education, 2025c).

4.2. Biology

Table 2. Distribution of STEM Indicators in the Grade 10 Biology Curriculum (n = 90).

STEM Indicator	Frequency	Percentage
Engineering design tasks	0	0.0%
Quantitative and computational reasoning	10	11.1%
Real-world contexts	28	31.1%
Inquiry and modeling	42	

		46.7%
Collaboration	5	5.6%

The line-by-line coding of the biology curriculum generated 90 instructional items. Inquiry and modeling was the most frequent STEM indicator (46.7%), especially in treatments of homeostasis, nervous system functioning, membrane transport, and metabolic processes. Real-world contexts were also present (31.1%), particularly regarding health, disease, environmental damage, and medical technologies such as artificial kidney treatment. Quantitative and computational components were not dominant (11.1%), primarily appearing in relation to physiological measurements and laboratory tests. References to laboratory work implied only limited collaboration (5.6%). None of the items were classified as engineering design tasks. In sum, the biology curriculum reflects a rich inquiry- and context-oriented approach to STEM but lacks specific design-based learning (Israeli Ministry of Education, 2017).

4.3. Biotechnology

Table 3. Distribution of STEM Indicators in the Grade 10 Biotechnology Curriculum (n = 70).

STEM Indicator	Frequency	Percentage
Engineering design tasks	48	68.6%
Quantitative and computational reasoning	42	60.0%

Real-world contexts	50	71.4%
Inquiry and modeling	60	85.7%
Collaboration	40	57.1%

After coding the biotechnology curriculum line by line, 70 instructional items were derived. Inquiry and modeling were the most dominant, appearing in 85.7% of coded items. This reflects the centrality of authentic research processes, hypothesis formulation, experimental design, and scientific communication within the subject. Real-world contexts were also common (71.4%), as students work with industrial, medical, environmental, and security applications of biotechnology in real research settings. Engineering design elements were significantly observed (68.6%), where students plan and build experimental systems, establish controls, and modify procedures. Quantitative and computational reasoning accounted for 60.0% of coded items, encompassing measurements, data processing, graphical representation, and survey analysis. Over half the items (57.1%) explicitly required collaboration, particularly in team-based research and community dialogue activities (Israeli Ministry of Education, 2025a).

4.4. Chemistry

Table 4. Distribution of STEM Indicators in the Grade 10 Chemistry Curriculum (n = 80).

STEM Indicator	Frequency	Percentage
Engineering design tasks		

	30	37.5%
Quantitative and computational reasoning	55	68.8%
Real-world contexts	40	50.0%
Inquiry and modeling	52	65.0%
Collaboration	10	12.5%

The chemistry curriculum was coded systematically to generate 80 instructional items. Quantitative and computational reasoning appeared as a central feature (68.8%), particularly in stoichiometry and gas laws. Approximately 65.0% of items involved inquiry and modeling, as students moved between macroscopic, microscopic, and symbolic levels; interpreted graphs and tables; and applied collision theory, concepts of equilibrium, and thermodynamic models. About half the items (50.0%) showed real-world contexts, mainly in areas such as environmental chemistry and food chemistry. Engineering design elements appeared in 37.5% of items, reflected in the design and interpretation of experimental procedures and flow charts of industrial processes. Explicit references to teamwork and collaboration were limited (12.5%) (Israeli Ministry of Education, 2025b).

4.5. Physics

Table 5. Distribution of STEM Indicators in the Grade 10 Physics Curriculum (n = 90).

STEM Indicator

	Frequency	Percentage
Engineering design tasks	60	66.7%
Quantitative and computational reasoning	70	77.8%
Real-world contexts	35	38.9%
Inquiry and modeling	75	83.3%
Collaboration	15	16.7%

The analysis of the physics curriculum yielded 90 instructional items across mechanics, electromagnetism, radiation, and matter. Inquiry and modeling was the most common STEM indicator (83.3%), with major emphasis on designing and interpreting experiments, using graphical representations, and working with idealized models (e.g., point mass, ideal gas, physical fields). Quantitative and computational reasoning was also extremely significant (77.8%), as formulas, graphs, and numerical solutions lie at the heart of almost every subtopic. Nearly two-thirds of the items (66.7%) displayed elements of engineering design, including laboratory setups, data-logging activities, and technological applications such as circuits, RC systems, satellites, and rockets. Real-world contexts were moderately present (38.9%). Explicit references to collaboration remained limited (16.7%) (Israeli

Ministry of Education, 2019).

4.6. Cross-Curricular Comparison

Table 6. STEM Indicator Percentages Across All Five Curricula.

STEM Indicator	Mathematics	Biology	Biotechnology	Chemistry	Physics
Engineering design tasks	0%	0.0%	68.6%	37.5%	66.7%
Quantitative and computational reasoning	93.8%	11.1%	60.0%	68.8%	77.8%
Real-world contexts	21.9%	31.1%	71.4%	50.0%	38.9%
Inquiry and modeling					

62.5%

46.7%

85.7%

65.0%

83.3%

Collaboration

0%

5.6%

57.1%

12.5%

16.7%

The overall interpretation of findings reveals a clear hierarchy of STEM alignment across the five curricula. Biotechnology demonstrated the highest and most comprehensive alignment across all five indicators. Physics showed the second strongest profile, particularly in inquiry, modeling, quantitative reasoning, and engineering design. Chemistry showed strong alignment with quantitative reasoning and contextual relevance. Mathematics strongly reflects quantitative aspects of STEM but shows little evidence of design, collaboration, or real-world context. Biology includes real-world context and inquiry but shows the weakest alignment in quantitative reasoning and engineering design.

5. Discussion

This section discusses the findings through the lens of the study's four research questions, drawing on both the quantitative summaries and the constructivist and integrated STEM frameworks established in the Literature Review. Where relevant, findings are interpreted in light of the epistemological orientation of each discipline — that is, the underlying assumptions about knowledge, inquiry, and learning that shape how each subject's curriculum is structured (English, 2023; Li et al., 2019; Roehrig et al., 2021).

5.1. Research Question 1: STEM Characteristics per Curriculum

The study found substantial variation in STEM alignment across the five curricula. From a constructivist perspective, this variation reflects meaningful differences in how each subject conceptualizes knowledge construction and student agency. The following analysis addresses each subject in turn.

Biotechnology: Comprehensive STEM Alignment Across All Indicators. The biotechnology curriculum demonstrated the highest and most comprehensive STEM alignment. With inquiry and modeling at 85.7%, real-world contexts at 71.4%, engineering design at 68.6%, quantitative reasoning at 60.0%, and collaboration at 57.1%, biotechnology is the only curriculum that achieved moderate-to-strong representation on all five indicators simultaneously. From a constructivist standpoint, this profile reflects a curriculum designed around knowledge construction through authentic practice: students do not merely learn about scientific processes — they enact them by planning experiments, interacting with communities, and communicating findings. This is consistent with what Roehrig et al. (2021) describe as the hallmark of effective integrated STEM: a curriculum that is coherent, contextually grounded, and oriented toward authentic problem-solving cycles. The curriculum's strong collaboration score (57.1%) is particularly noteworthy. It is the only subject where collaborative practice is systematically embedded rather than incidental, aligning with Boke et al.'s (2025) meta-analytic finding that collaboration significantly enhances STEM learning outcomes.

Physics: Strong Inquiry, Quantitative Reasoning, and Design Orientation. Physics exhibited the second strongest STEM alignment profile, with strength in inquiry and modeling (83.3%), quantitative and computational reasoning (77.8%), and engineering design (66.7%). From a constructivist perspective, the physics curriculum creates conditions for active meaning-making through experimentation, mathematical modeling, and the interpretation of phenomena using idealized representations. This profile is consistent with Li et al.'s (2019) emphasis on the central role of quantitative reasoning in STEM thinking. The primary weakness is collaboration (16.7%), which rarely appeared explicitly despite the inherently practical and experimental nature of physics. This gap suggests that the

Israeli physics curriculum treats collaborative learning as pedagogically peripheral — a structural choice that limits students' opportunities to develop the communication and teamwork skills that characterize professional scientific practice.

Chemistry: Strong in Quantitative Reasoning; Moderate in Design and Context. The chemistry curriculum demonstrates strong alignment with quantitative and computational reasoning (68.8%) and inquiry and modeling (65.0%), and moderate alignment with real-world contexts (50.0%). The presence of industrial process flow charts and environmental applications (water quality, corrosion, food chemistry) indicates that the curriculum partially bridges theoretical knowledge and applied contexts — consistent with constructivist emphases on contextually embedded learning. Engineering design tasks were present in 37.5% of items, placing this indicator at the upper boundary of the weak representation range. This suggests that while chemistry students engage in procedural experimental work, they are less frequently required to design, refine, or optimize experimental systems through a full engineering design cycle. Collaboration remained the weakest indicator (12.5%), reflecting a formal curriculum that prioritizes individual mastery over collaborative sense-making.

Mathematics: High in Quantitative Reasoning; Weak in Broader STEM Integration. The mathematics curriculum presents the most striking contrast: the strongest quantitative and computational reasoning score of all five subjects (93.8%) alongside zero for both engineering design and collaboration. From a constructivist perspective, this profile reveals a curriculum in which knowledge is primarily constructed through abstract symbolic manipulation rather than through social interaction or applied problem-solving. This is consistent with English's (2023) observation that mathematics curricula rarely integrate design and real-world STEM unless purposefully reformed. The practical consequence is that mathematics — the quantitative foundation of all STEM disciplines — fails to leverage its integrative potential. Students develop strong algorithmic and procedural skills but receive no curriculum-level encouragement to apply those skills collaboratively or in design contexts, reinforcing a disciplinary silo that integrated STEM education specifically aims to dismantle (Portillo-Blanco et al., 2024).

Biology: Inquiry-Oriented but Limited in Quantitative and Design Components. Biology demonstrated moderate alignment, with inquiry and modeling at 46.7% and real-world contexts at 31.1%. However, the curriculum showed weak quantitative reasoning (11.1%), absent engineering design (0%), and minimal collaboration (5.6%). From a constructivist perspective, the biology curriculum positions knowledge as primarily conceptual and descriptive: students learn about biological systems through elaborated explanations rather than through quantitative investigation or design tasks. This finding aligns with Tytler's (2020) observation that traditional biology curricula worldwide tend to emphasize conceptual understanding over quantitative or engineering integration. The contrast between biology (0% engineering design) and biotechnology (68.6% engineering design) is particularly instructive. Both subjects share content domains such as cell biology and genetics, yet the biotechnology curriculum's structural emphasis on authentic research and applied design results in dramatically higher STEM alignment across all five indicators. This comparison demonstrates that subject matter content alone does not determine STEM alignment — curricular design intent does.

Taken together, these findings confirm that STEM alignment is strongly shaped by the epistemological and pedagogical orientation of each discipline. Subjects organized around authentic inquiry and applied problem-solving — biotechnology and physics — demonstrate comprehensive STEM alignment consistent with constructivist learning principles. Subjects primarily structured around abstract knowledge or descriptive understanding achieve partial or selective alignment. Chemistry occupies a productive middle ground. These patterns confirm that STEM integration does not emerge naturally across disciplines and requires intentional curriculum design to achieve consistent representation (Portillo-Blanco et al., 2024; Amanova et al., 2025).

5.2. Research Question 2: Most and Least Represented Indicators

The most represented indicators were inquiry and modeling and quantitative and computational reasoning, both present at meaningful levels across all five subjects. The three science subjects consistently embedded inquiry through conceptual modeling and laboratory experimentation, reflecting strong alignment with inquiry-based learning traditions. Quantitative reasoning was a particular strength in mathematics, chemistry, and physics. The least representative indicators were engineering design and collaboration. Mathematics and biology recorded zero for engineering design, while it appeared strongly only in biotechnology and physics. This confirms English's (2023) finding that design thinking does not naturally appear in traditional science or mathematics curricula unless deliberately embedded. Collaboration was the weakest indicator overall: absent in mathematics, minimal in biology (5.6%), and marginal in chemistry (12.5%) and physics (16.7%). Only biotechnology reached moderate representation (57.1%). This reflects a systemic gap in promoting the collaborative dimension of STEM — despite the fact that scientific and engineering work in professional contexts is fundamentally collaborative and that collaboration has been shown to improve STEM learning outcomes (Boke et al., 2025).

5.3. Research Question 3: Cross-Curricular Comparison

The comparative results show a clear hierarchy: biotechnology (average alignment ~68.2%), physics (~56.7%), chemistry (~46.8%), biology (~19.0%), and mathematics (~35.6%). This ordering confirms that curricula closest to authentic scientific or engineering practice exhibit stronger STEM alignment, while those grounded in abstraction or descriptive understanding exhibit partial alignment. This is consistent with comparable findings from the UAE (Abu Khurma& El Zein, 2024), Kazakhstan (Zhumabay et al., 2024), and multi-country reviews (Amanova et al., 2025), all of which found that specialized or applied science tracks outperform general academic tracks on STEM alignment indicators. It also confirms that integration tends to emerge most naturally in inquiry-heavy disciplines but must be intentionally developed in others (Li et al., 2019).

5.4. Research Question 4: Strengths and Gaps

Strengths include excellent inquiry and modeling integration in physics (83.3%), chemistry (65.0%), and biotechnology (85.7%); strong quantitative reasoning in mathematics

(93.8%), chemistry (68.8%), and physics (77.8%); and meaningful real-world contextualization in biotechnology (71.4%), chemistry (50.0%), and biology (31.1%). Gaps include the near-total absence of engineering design in mathematics (0%) and biology (0%); insufficient collaboration across most subjects (absent in mathematics, minimal in biology at 5.6%); weak real-world contexts in mathematics (21.9%); limited quantitative reasoning in biology (11.1%); and subject fragmentation that restricts authentic interdisciplinary STEM learning. These gaps indicate that while the Israeli Grade 10 curriculum supports disciplinary inquiry and quantitative thinking, it has not yet achieved the interdisciplinary, collaborative, and design-based coherence that characterizes high-quality integrated STEM education (Roehrig et al., 2021; Portillo-Blanco et al., 2024).

6. Conclusions

This study provides the first systematic, multi-subject analysis of STEM alignment in Israeli Grade 10 curricula across five disciplines. The findings reveal that biotechnology and physics demonstrate the strongest STEM alignment, while mathematics and biology show selective and limited alignment despite their foundational role in STEM education. Chemistry occupies a productive but uneven middle ground.

Three specific contributions emerge from this work. First, the study fills an empirical gap by providing subject-specific, quantified evidence of STEM alignment in the Israeli secondary curriculum — evidence that has not previously been available to policymakers and curriculum designers. Second, the binary coding rubric developed and validated here offers a replicable methodological tool that can be adapted for STEM curriculum analysis in other national or regional contexts, contributing a transferable instrument to the field. Third, the findings situate the Israeli case within an emerging body of evidence from the Middle East and Central Asia, suggesting that the documented gaps in engineering design and collaboration are not unique to Israel but reflect broader patterns in how national curricula embed STEM principles.

Recommendations emerging from this study include:

- Expand engineering design tasks beyond physics and biotechnology to mathematics and biology. Specifically, the Israeli Ministry of Education should consider introducing a minimum of two design-based laboratory projects per school year in Grade 10 biology — for example, designing an artificial filtration system as a model of kidney function — building on the existing practical orientation of the biology curriculum.

- Enhance real-world contexts in the mathematics curriculum. Given that only 21.9% of mathematics items currently reference authentic contexts, revisions should require at least one real-world application per major topic unit, drawing on domains such as environmental modeling, economic analysis, and medical statistics.
- Strengthen quantitative and computational reasoning in biology-related curricula. The current 11.1% representation of quantitative reasoning in biology represents a serious gap. The Ministry should mandate quantitative data analysis tasks in at least 30% of biology instructional items.
- Strengthen collaboration across all subject curricula through explicit group-work requirements. The near-total absence of collaboration in mathematics and biology requires curriculum-level intervention, not merely pedagogical guidance, to ensure that collaborative learning is treated as a required component rather than an optional enhancement.
- Promote interdisciplinary integration in ways that reflect authentic STEM practices, for example by developing shared cross-subject projects that require students to apply mathematical reasoning to biology or chemistry investigations.
- Develop teacher competencies in digital technologies and facilitate partnerships between schools and industry to bridge the gap between intended and enacted curriculum.

Future research should examine how this curriculum alignment translates into classroom practice and student outcomes. Mixed-method studies combining document analysis with classroom observations and teacher interviews would provide deeper insights into STEM implementation. Longitudinal studies tracking changes following curriculum revision would strengthen the evidence base for policy. Additionally, comparative studies extending this analysis to Grades 11–12 or to parallel curricula in other Middle Eastern countries would help identify regional patterns and best practices in STEM curriculum design.

Author Contributions

The study was conceived, designed, executed, analyzed, and written entirely by the sole author.

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Conflicts of Interest

The author declares no conflicts of interest.

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