Curriculum and Policies of the Computer Science and Engineering Track in Saudi Secondary Education: International Alignment and Early Challenges

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Abstract

Korea In alignment with Saudi Vision 2030 and the United Nations Sustainable Development Goal 4 (SDG 4), the Kingdom of Saudi Arabia introduced the Secondary Education Tracks System in 2021 as a cornerstone reform in secondary education. A central feature of this initiative is the Computer Science and Engineering track (CSE), designed to enhance computer science curricular relevance, equip students with 21st-century digital competencies, and prepare them for participation in the knowledge economy. This study evaluates the reform by focusing on two key dimensions: the alignment of the Computer Science and Engineering track's curriculum and policies with international best practices (e.g., Finland, Singapore, Ontario) and the challenges and opportunities observed during its early implementation as part of the Saudi secondary education tracks system. A mixed-methods design was employed, integrating survey data from 2,818 stakeholders—including students, teachers, administrators, parents, and policymakers—supported with document analysis. Findings reveal encouraging progress: the reform has diversified curricula, expanded flexible learning tracks, and improved engagement through technology-enhanced and project-based learning approaches. However, persistent challenges remain, particularly regarding infrastructure disparities, equitable access to specialized tracks, and the availability of qualified educators and academic advisors. This research underscores that Computer Science and Engineering track's curriculum and policies within Saudi Arabia's secondary education tracks is a transformative initiative with significant potential to align with global models, provided that implementation challenges are addressed. Overall, the Tracks System represents a transformative step toward a more responsive and globally competitive education system in Saudi Arabia. To sustain momentum, the study recommends intensified investment in teacher professional development, digital resources, and stronger integration with higher education and labor market pathways.

Keywords: Computer Science Education; Secondary Education; Educational Reform; 21st-Century Skills; Education Policy

1. Introduction

The integration of Computer Science and Engineering track (CSE) into secondary education has become a global priority, as it equips students with essential competencies for the digital age, including computational thinking, problem-solving, and innovation. International experiences, such as those in Singapore, Finland, and the United States, demonstrate that early exposure to Computer Science fosters not only technical proficiency but also creativity, adaptability, and readiness for knowledge-based economies [1], [2].

In Saudi Arabia, the reform of secondary education under the Tracks System has positioned Computer Science and Engineering track (CSE) as a central track, reflecting the objectives of Vision 2030 to diversify the economy, build a competitive workforce, and enhance students' 21st-century skills. By embedding Computer Science into the national curriculum in Computer Science and Engineering track, the Kingdom seeks to bridge the gap between education and labor market demands, ensuring that future graduates are prepared to contribute effectively to technological innovation and sustainable development.

Education systems worldwide are undergoing profound transformations in response to the accelerating pace of technological, economic, and social change. The transition toward knowledge-based economies, coupled with the disruptive forces of globalization and the Fourth Industrial Revolution, has heightened the demand for new educational models that move beyond traditional, rigid curricula. Countries increasingly recognize the need to provide students with diverse learning opportunities that cultivate not only subject knowledge but also critical thinking, creativity, and adaptability [3].

Recent evidence from international reports indicates that secondary education reforms that diversify curricula and introduce specialized tracks can generate meaningful improvements in student outcomes. For example, the OECD's latest review of the Saudi education system highlights that raising educational performance requires not only curriculum redesign but also a stronger focus on teacher

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professional development, equity in access between rural and urban regions, and more robust mechanisms for evaluating instructional quality [4].

In parallel, international assessments such as the Programmed for International Student Assessment (PISA) have increasingly acted as catalysts for policy change.

Li et al. [5] argue that PISA has evolved beyond being a mere performance measurement tool into a form of "soft power" that pushes governments to adopt evidence-based practices, revamp assessment frameworks, and address learning gaps. These shifts have promoted broader debates on fairness, inclusion, and quality in secondary education globally.

Complementing this, comparative studies on track-based education systems suggest that flexible and diversified pathways, when implemented effectively, can enhance student engagement and smooth transitions into higher education or the labor market [6], [7]. Musset and Kureková [8] emphasize that countries such as Finland, Germany, and Singapore benefit from such systems, but their success largely depends on strong academic advising, teacher preparedness, and equitable access for all learners. The Kingdom of Saudi Arabia, as part of its ambitious Vision 2030 framework, has prioritized educational reform as a strategic lever for national transformation. Vision 2030 aims to diversify the economy, reduce reliance on oil revenues, and prepare citizens for active participation in global markets [9]. Within this agenda, education is positioned as both a driver of human capital development and a foundation for long-term sustainability.

In this context, the Secondary Education Tracks System was introduced in 2021 as one of the most comprehensive reforms in the Saudi education sector. The system restructures the final three years of K12 (secondary education) (Grades 10–12), offering students five distinct tracks:

i. General Education Track – maintaining core subjects while allowing broader elective choices.

ii. Health and Life Sciences Track – focusing on biology, chemistry, and health sciences in preparation for medical and allied health careers.

iii. Business and Administration Track – emphasizing economics, management, and entrepreneurship to prepare for commerce and administration.

iv. Computer Science and Engineering Track – integrating programming, robotics, and applied engineering to meet digital economy demands.

v. Sharia Track – deepening knowledge in religious, humanistic studies, and law while maintaining transferable skills.

The rationale for this restructuring is twofold. First, it reflects a recognition that one-size-fits-all education is inadequate in preparing youth for specialized higher education and labor market requirements. Second, it aligns with global models where diversified pathways allow students to explore talents, make informed career choices, and acquire relevant competencies [10].

Despite the ambitious goals, several challenges complicate implementation. Infrastructure disparities, particularly between urban and rural schools, limit equitable access to specialized tracks. Teacher preparedness, especially in new fields such as robotics and data science, remains uneven. Furthermore, the effectiveness of academic advising and career guidance is under scrutiny, with many students and parents lacking full awareness of the implications of track choices [11].

This paper seeks to examine the curriculum and policies of the Computer Science and Engineering (CSE) track in Saudi secondary education. Specifically, it evaluates the extent to which the track aligns with international best practices and identifies the challenges encountered during its early implementation. The study addresses two core research questions:

Research Questions

- To what extent does the Computer Science and Engineering track's curriculum and policies within Saudi Arabia's Secondary Education Tracks align with international best practices in secondary education reform?
- What key challenges and opportunities have emerged in the early implementation of the Computer Science and Engineering track under the Secondary Education Tracks System?

Research Objectives

The primary objective of this study is to evaluate the extent to which the Computer Science and Engineering track including curriculum and policies in Saudi Arabia's Secondary Education Tracks aligns with international best practices in secondary education reform. In doing so, the study seeks to identify the main challenges and opportunities that have emerged during the early stages of the curriculum's implementation. Based on these insights, the research also aspires to provide:

- evidence-based recommendations to enhance curriculum design,
- strengthen instructional quality, and

improve infrastructure readiness, thereby ensuring the sustainability and global competitiveness of the reform.

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Research significance

The significance of this study lies in its dual contribution to both educational policy and practice. By offering an empirical evaluation of the Computer Science and Engineering track's curriculum and policies within Saudi Arabia's Secondary Education Tracks, the research provides policymakers with evidence on areas of strength and critical gaps that require targeted improvement. It also offers practical insights for educators and curriculum developers seeking to enhance instructional quality and infrastructure readiness. At the scholarly level, the study contributes to the international literature on secondary education reform in contexts undergoing rapid socio-economic transformation, positioning the Saudi experience as a case study with implications for other nations integrating Computer Science education into large-scale curriculum reforms.

2. Literature Review

The reform of Computer Science curricula has emerged as a central pillar of secondary education transformation worldwide, reflecting the growing demand for digital skills in knowledge-based economies. International research highlights that early exposure to coding, computational thinking, and problem-based STEM learning fosters not only technical competence but also creativity, problem-solving, and adaptability—skills regarded as essential for the 21st century [1], [2]. As countries such as Singapore, Finland, and the United States integrate Computer Science across secondary tracks, Saudi Arabia's adoption of the Secondary Education tracks system in 2021 similarly positions Computer Science as a cornerstone of national educational reform under Vision 2030. Within this framework, the present study situates its review of literature by examining global trends, the Saudi context, and student outcomes in track-based systems, with a particular emphasis on the opportunities and challenges of implementing Computer Science and Engineering track.

2.1. Global Trends in Secondary Education Reform

Secondary education is widely acknowledged as a critical phase in human capital development. Around the world, reforms have increasingly emphasized flexibility, personalization, and the integration of digital technologies [3], [4], [12]. According to OECD's Future of Education and Skills 2030 report [3], future-ready systems must equip students with not only academic knowledge but also transversal competencies such as problem-solving, teamwork, and resilience. Finland serves as a global model for student-centered reform. Its education system emphasizes autonomy, choice, and trust in teachers [13]. Students in upper secondary education can customize their studies by combining general academic subjects with specialized electives. This flexibility is complemented by robust career guidance structures, ensuring informed transitions into higher education and employment.

Singapore, by contrast, offers a more structured but equally effective approach. The ministry of education has embedded STEM education and digital literacy across secondary curricula. High-quality teacher training and significant investment in infrastructure support these reforms [14]. The system also incorporates career guidance programs starting in lower secondary grades, helping students align their academic pathways with aspirations.

Ontario, Canada provides another instructive case. The province's secondary education framework integrates both academic and vocational tracks, ensuring pathways to universities, colleges, or direct employment [15]. Partnerships with industries and post-secondary institutions provide students with practical exposure to career options.

More recently, international assessments such as PISA have influenced reforms by shaping global benchmarks for educational quality. Li et al. [5] highlight how PISA has become a driver of curriculum innovation and equity-oriented policies, as governments respond to international comparisons to improve their systems. Similarly, OECD's Education at a Glance 2023 stresses the importance of flexible secondary pathways, noting that diversified options correlate with higher student engagement and smoother school-to-work transitions [16].

Collectively, these cases highlight the centrality of curriculum diversity, digital integration, and career guidance in effective reforms. They also underscore the global consensus that secondary education must evolve into a more adaptive and future-oriented stage—an imperative that strongly resonates with the Kingdom of Saudi Arabia's Vision 2030 reform agenda.

2.2. Secondary Education in Saudi Arabia

Prior to the tracks system, Saudi secondary education was largely uniform, with limited differentiation in subject offerings. Although effective in providing broad knowledge, this model struggled to accommodate diverse student interests or align with the evolving labor market. Alhussein [17] noted that secondary education outcomes often failed to match the needs of universities and employers, resulting in skill mismatches.

The launch of the tracks system in 2021 represented a strategic pivot toward international alignment. Early Ministry of Education reports [18] indicated that the reform aimed to:

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- Diversify curricula across five tracks.
- Introduce project-based and applied learning.
- Enhance digital integration through platforms such as Madarasati.
- Strengthen career counseling services.

Initial feedback was mixed. While many teachers and students welcomed the flexibility, concerns were raised regarding infrastructure readiness and teacher training, particularly for specialized subjects such as computer science and health sciences [19], [20].

Al-Anzi [21], in a study entitled "a comparative analytical study of the development of secondary school tracks and specialized academies in the Kingdom of Saudi Arabia in light of selected snternational experiences", examined the reform initiatives aimed at developing secondary education tracks and specialized academies in Saudi Arabia. Adopting a comparative methodology, the study found that the Kingdom's efforts to reform secondary education through the Tracks System are largely consistent with international experiences and best practices. The findings also highlighted that Saudi Arabia has embraced comprehensive economic and educational reforms designed to keep pace with global transformations, while formulating forward-looking strategies that focus on cultivating productive and active citizens.

2.3. Student Outcomes in Track-Based Systems

Global research demonstrates that students in specialized tracks often report higher levels of engagement, motivation, and achievement [10]. Evidence from Finland and Singapore confirms that exposure to diversified pathways not only fosters student interest but also increases the likelihood of pursuing higher education in fields aligned with track choices [13], [14].

More recent comparative studies emphasize that track-based systems can enhance performance when supported by strong guidance mechanisms. According to OECD's Education at a Glance 2023, students enrolled in flexible pathways demonstrate smoother transitions into tertiary education and the labor market, particularly when academic advising is embedded into the curriculum [16]. Similarly, results from the 2022 PISA cycle suggest that systems offering differentiated learning opportunities tend to reduce dropout rates and improve equity, provided that resources are distributed fairly [5].

In Saudi Arabia, Al-Thubaiti [11] found that students in specialized tracks such as Computer Science and Engineering track expressed greater satisfaction and motivation compared with peers in the General Track. However, gaps in academic advising and career guidance often left students and parents uncertain about the long-term implications of track choices. Addressing these gaps through structured counseling and partnerships with universities and industry is therefore essential to fully realize the objectives of Vision 2030.

Despite the growing body of literature on secondary education reforms in Saudi Arabia, most studies have approached the Tracks System from a general perspective. Prior research has largely focused on policy frameworks, the diversification of pathways, and the system's alignment with global trends such as flexibility, digital integration, and career readiness [3], [12], [22]. While these contributions provide valuable insights, they remain predominantly descriptive, with limited empirical evidence on curriculum effectiveness, student outcomes, or implementation challenges at the track-specific level.

This study addresses this gap by focusing on the Computer Science and Engineering (CSE) track as a central case through which the broader Tracks System can be examined in depth. International experiences from Finland, Singapore, and Ontario have shown that early integration of computer science enhances student engagement, achievement, and transitions to higher education and labor markets [14], [15], [23]. In the Saudi context, embedding Computer Science as a specialized track within the 2021 reform represents a strategic alignment with these practices. By combining quantitative performance indicators with qualitative stakeholder perspectives, this study seeks to provide a more comprehensive evaluation of both the global alignment and the early implementation challenges of the CSE track in Saudi secondary education.

3. Theoretical Framework

The evaluation of Saudi Arabia's secondary education tracks system is informed by several educational theories that provide lenses to interpret the reform's goals, design, and implementation. These theoretical perspectives highlight the pedagogical underpinnings of the reform and justify its alignment with international best practices.

3.1. Constructivism

Constructivist theory, pioneered by Piaget [24], and Vygotsky [25], emphasizes that learners actively construct knowledge through experiences and interactions. learning is not the passive absorption of information but rather a process of meaning-making shaped by prior knowledge and social context.

The tracks system reflects constructivist principles in multiple ways:

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- Student choice: By offering diverse tracks, the reform allows students to select track aligned with their interests, thereby increasing ownership of learning.

- Project-based learning: Specialized tracks, particularly computer science and engineering, emphasize applied projects such as robotics competitions or software development, which engage students in authentic problem-solving.

- Collaborative learning: The integration of group projects and labs encourages peer-to-peer learning, consistent with Vygotskian ideas of social constructivism.

Constructivism also provides a framework for understanding the reform's emphasis on personalization and flexibility, which are considered essential for preparing students for higher education and modern workplaces [26].

3.2. Connectivism

Connectivism, developed by Siemens [26], extends learning theory into the digital age. It posits that knowledge is distributed across networks of people, digital tools, and information sources. Learning occurs by navigating and connecting nodes within these networks.

The tracks system embodies connectivist principles through its heavy reliance on digital platforms such as Madarasati. These platforms enable students to access resources beyond the classroom, engage in blended learning, and interact with digital tools for simulations, coding, and virtual labs. Furthermore, the reform's emphasis on digital literacy aligns with connectivism's view that the ability to connect with and critically evaluate online information is itself a core competence.

In the Saudi context, the tracks system is designed not merely to improve academic achievement but also to transform students' outlooks on learning and careers. For example, students who enter the Health and Life Sciences track may reframe their understanding of medicine as both a scientific and social endeavor. Similarly, exposure to engineering projects may encourage students to perceive themselves as potential innovators or entrepreneurs.

4. Methodology

This study adopted a mixed-methods design, combining quantitative and qualitative approaches to provide a holistic evaluation of the secondary education tracks system focusing on Computer Science and Engineering track focusing on curriculum and policies.

4.1. Research Design

Mixed-methods research is widely recognized as a robust approach in educational and social sciences, as it allows for the triangulation of data, enhances validity, and captures both measurable outcomes and contextual insights [27], [28]. Scholars further emphasize that such designs are particularly valuable in policy evaluation and complex social systems, where neither quantitative nor qualitative methods alone are sufficient to provide a comprehensive picture [29], [30].

Data Collection and Instruments

As shown in Table 1, the survey sample comprised 2,818 respondents, with a majority of females (64.8%) compared to males (35.2%). Participants represented a diverse range of stakeholder groups, including students, teachers, administrators, and parents, ensuring that perspectives were captured from both educational practitioners and beneficiaries.

Table1. Distribution of Survey Participants by Gender

Gender	n	%
Male	993	35.2
Female	1825	64.8

The inclusion of multiple stakeholder categories allows for a comprehensive understanding of the CSE track's early implementation, as it reflects experiences from classroom instruction, school leadership, and family engagement. Such diversity enhances the validity of the findings by highlighting both shared and divergent views across gender and role groups.

Research Question 1

Alignment with International Best Practices. A document analysis was conducted, reviewing national policy documents, curriculum frameworks, teacher guides, and official implementation reports. These were systematically compared with international models from Finland, Singapore, Ontario, and other benchmark systems. This qualitative analysis was complemented by a survey of 2,818 stakeholders (students, teachers, administrators, and parents) to capture perceptions of alignment. The questionnaire results provided quantitative confirmation of the qualitative findings (see Table 2).

Structured questionnaire: questionnaire was developed to gather quantitative data from

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stakeholders. It consisted of two main sections aligned with the research questions:

i. Alignment with international best practices,

ii. Challenges and opportunities in early implementation.

Content validity was established through expert review by specialists in educational policy and comparative education. Reliability of the questionnaire was confirmed using Cronbach's alpha to ensure internal consistency.

Research Question 2

Challenges and Opportunities in Early Implementation. Data were drawn primarily from the questionnaire instrument, which measured participants' views on infrastructure readiness, teacher preparedness, student engagement, and advising services. In addition, qualitative insights from policy documents and implementation reports were used to contextualize and interpret the statistical results, ensuring a richer understanding of both barriers and opportunities. To complement survey data, a structured checklist was used to analyze official documents, strategic reports, and implementation guidelines. The checklist included criteria derived from international benchmarks (e.g., Finland, Singapore, Ontario–Canada, Ireland, UAE, New Zealand). It assessed areas such as policy clarity, curriculum design, student guidance systems, and resource allocation in computer science and engineering track.

4.2. Data Analysis

The integration of both strands of evidence allowed for triangulation, enhancing the validity of the findings and providing both a global and contextualized perspective on the reform:

- Quantitative - Statistical analyses included descriptive statistics (means, standard deviations, percentages) and inferential tests such as independent-samples t-tests and one-way ANOVA.
- Qualitative: Thematic coding of open survey responses that used document and policy review checklist, identifying recurring patterns related to strengths, challenges, and recommendations.
- Triangulation: Cross-validation of findings across quantitative and qualitative data.

5. Findings

This section presents the main findings of the study in direct relation to the two guiding research questions. The first part evaluates the extent to which the computer science and engineering track's curriculum and policies within Saudi Arabia's secondary education tracks aligns with international best practices in secondary education reform, with reference to models from Finland, Singapore, and Ontario. The second part explores the key challenges and opportunities that have characterized the early implementation of the Computer Science and Engineering track, particularly in relation to infrastructure readiness, teacher preparation, and equity of access. The results are thematically organized to highlight both areas of convergence with global standards and contextual factors that have shaped the track's initial impact in the Kingdom.

5.1. Alignment with international best practices

The findings showed that the computer science and engineering track including curriculum and policies in Saudi Arabia generally aligns with global models such as Finland, Singapore, and Ontario.

The analysis of policy documents, curriculum frameworks, and official guidelines revealed a high degree of consistency between the Saudi CSE track and international best practices, particularly in preparing students for STEM-oriented careers and the integration of computational thinking, digital literacy, and project-based learning. Comparisons with Finland, Singapore, and Ontario demonstrated similar emphases on flexibility, STEM orientation, and alignment with labor market needs.

Table 2. Stakeholder Perceptions of Alignment with International Best Practices (CSE Track, N = 2,818)

Dimension	Mean	SD	Interpretation
Curriculum relevance to labor needs	4.15	0.69	High alignment
Integration of computational skills	4.10	0.72	High alignment
Use of project-based learning	4.02	0.71	High alignment
Flexibility of learning pathways	3.93	0.74	Moderate to high
Personalized learning approaches	3.86	0.76	Moderate

To complement this qualitative analysis, survey data (see Table 2) captured stakeholder perceptions of this alignment. Respondents reported high ratings for curriculum relevance ($M = 4.15$, $SD = 0.69$) and integration of computational skills ($M = 4.10$, $SD = 0.72$), supporting the documentary evidence. A one-way ANOVA revealed significant group differences, $F(3, 2818) = 6.32$, $p < .001$, with teachers ($M = 4.20$) rating alignment higher than students ($M = 4.01$),

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while administrators and parents fell in between. Post hoc Tukey tests confirmed that the teacher–student difference was statistically significant.

Together, the document analysis and survey findings confirm that the Saudi CSE curriculum is largely consistent with international models, while highlighting areas (e.g., personalized learning) that require further development.

5.2. Challenges and Opportunities in Early Implementation

Although the reform has advanced significantly, challenges in early implementation remain, particularly in teacher preparedness and infrastructure, but opportunities in student engagement and technology integration were also evident.

Table 3. Challenges and Opportunities in Early Implementation of the CSE Track (N = 2,818)

Category	Key Findings
Challenges	Shortage of trained in pure Computer Science teachers; regional disparities in access to labs and connectivity; insufficient career guidance services.
Opportunities	Stronger student engagement in coding projects; adoption of robotics and AI-related activities; increased use of digital learning platforms; growing alignment with Vision 2030 workforce goals.

Note. Table presents qualitative findings derived from stakeholder survey responses (2024).

Table 4. Stakeholder Differences in Perceptions of Challenges and Opportunities in the CSE Track

Comparison Group	M	SD	t(df)	p
Students (Opportunities)	4.11	0.71	t(1620) = 4.62	< .001
Parents (Opportunities)	3.94	0.74		
Teachers (Challenges)	3.69	0.82	t(1150) = –3.54	< .001
Administrators (Challenges)	3.90	0.77		

Note. Independent-samples t-tests compared group perceptions: Students vs. Parents (n = 1,620); Teachers vs. Administrators (n = 1,150). Higher means reflect stronger agreement with reported items.

Table 3 summarizes the key challenges and opportunities reported by participants during the early implementation of the CSE track. The findings highlight systemic barriers, such as a shortage of qualified teachers in pure computer science fields, unequal access to infrastructure across regions, and limited career guidance services. These factors point to practical constraints that may hinder consistent implementation. At the same time, the opportunities identified—such as student enthusiasm for robotics, coding, and AI, and the integration of digital platforms—indicate strong potential for the track to enhance engagement and align with national workforce priorities under Vision 2030.

Table 4 illustrates statistically significant group differences in how stakeholders perceived challenges and opportunities within the CSE track. An independent-samples t-test showed that students ($M = 4.11$, $SD = 0.71$) reported significantly greater optimism about opportunities than parents ($M = 3.94$, $SD = 0.74$), $t(1620) = 4.62$, $p < .001$. Conversely, teachers ($M = 3.69$, $SD = 0.82$) perceived challenges more severely than administrators ($M = 3.90$, $SD = 0.77$), $t(1150) = –3.54$, $p < .001$. These findings suggest that, while students are highly motivated by the CSE track's promise for STEM careers, teachers remain cautious due to practical barriers, thus complementing the qualitative observations presented in Table 3.

6. Discussion

The comparative analysis underscores that Saudi Arabia's Secondary Education Tracks System reflects international best practices in diversifying pathways, promoting 21st-century skills, and connecting secondary education with both higher education and the labor market [14]. Ontario's model, however, illustrates how long-standing experience and institutionalized guidance frameworks can enhance flexibility and ensure smoother student transitions [15]. In the broader global discourse, the OECD [3] emphasizes that future-oriented education systems must balance flexibility, personalization, and skill integration to prepare learners for rapidly changing economies. Taken together, these insights suggest that while the Saudi model is well-aligned with global standards, its long-term success depends on addressing structural challenges in infrastructure and guidance to achieve the ambitious goals of Vision 2030.

6.1. Alignment with international best practices

The content analysis of international documents and comparative studies revealed that most secondary education systems worldwide are based on diversified learning tracks. These tracks allow students to choose tracks aligned with their interests, abilities, and aspirations, preparing them either for direct entry into the labor market or for continuing higher education. The analysis further showed that these tracks are strongly connected to 21st-century skills and the requirements of future careers. They typically include a set of core subjects common to all students, alongside specialized subjects unique to each track. Moreover, schools in many countries have the flexibility to create additional specialized tracks that

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respond to local community needs and emerging societal challenges. Overall, the findings indicate a high degree of convergence between the Saudi secondary education tracks System and international models in terms of structure, objectives, and implementation mechanisms.

Among the specialized tracks, the computer science and engineering track stands out as highly consistent with these global directions. This track equips students with essential digital and engineering competencies that are increasingly demanded in the era of the Fourth Industrial Revolution. By integrating advanced courses in programming, systems design, and applied engineering practices, it prepares students not only for immediate contributions to the labor market but also for further specialization in higher education. The alignment of this track with international best practices underscores its role in fostering innovation, problem-solving, and adaptability—skills that are critical for thriving in knowledge-based economies and addressing the rapidly evolving demands of future professions.

The findings indicate that the computer science and engineering track's curriculum and policies demonstrates strong alignment with global secondary education reforms, particularly in its emphasis on digital literacy, computational skills, and project-based learning. Similar to Finland's flexible curriculum model, which enhances student autonomy and motivation [13], and Singapore's structured STEM integration designed to prepare learners for participation in knowledge economies [14], the Saudi CSE track offers students opportunities to align their studies with both personal interests and labor market needs. Likewise, Ontario's dual academic–vocational system has illustrated that diversified curricula can strengthen pathways into higher education and employment [15], [23].

Nevertheless, alignment is not yet complete. Personalized learning remains less developed compared to international benchmarks, and some participants highlighted gaps in ensuring that all specialized tracks - including Computer Science - are equally accessible across regions. These findings echo Musset and Kureková's [16] argument that global alignment requires continuous refinement to remain responsive to diverse economic contexts and ensure inclusivity.

6.2. Challenges and opportunities in early implementation

The early implementation of the CSE track revealed a combination of meaningful opportunities and persistent challenges. On the positive side, students and teachers reported moderate but consistent improvements in engagement and STEM-related achievement. These findings align with Li et al. [5], who argue that specialized curricula can raise performance when accompanied by adequate guidance and resources. Notably, students expressed significantly greater optimism about opportunities compared to parents, highlighting that the CSE track resonates strongly with learners' aspirations for STEM futures.

Teacher preparedness emerged as a significant challenge in the implementation of the Tracks System. Teachers perceived these challenges more severely compared to administrators, reinforcing Fullan's [31] observation that reforms introducing new digital disciplines demand continuous and targeted professional development. Furthermore, the effectiveness of academic advising and career guidance remains under scrutiny, with many students and parents lacking sufficient awareness of the long-term implications of track choices [11].

In addition, infrastructure disparities, particularly between urban and rural schools, were highlighted in previous research [11]. As UNESCO [32] cautions, without equitable provision of labs, connectivity, and digital tools, reforms may inadvertently widen inequalities. This concern resonates with the Saudi context in some schools, where ensuring balanced access to the CSE track is essential to achieve the goals of Vision 2030.

Despite these challenges, opportunities are evident. Stakeholders emphasized the motivational value of coding and robotics, the effectiveness of project-based learning, and the growing use of digital platforms such as Madarasati. Collectively, these findings underscore that the Tracks System—and the CSE track in particular—is not merely a structural adjustment but a systemic transformation, requiring sustained governance, stakeholder engagement, and investment in teacher capacity and infrastructure to ensure its long-term success [11].

7. Conclusion and Recommendations

The findings confirm that the Computer Science and Engineering track's curriculum and policies within Saudi Arabia's Secondary Education Tracks System demonstrates strong alignment with international best practices, particularly in integrating digital competencies, project-based learning, and labor market relevance. However, persistent challenges - including teacher preparedness, infrastructure disparities, and limited academic advising - highlight the need for continued refinement. While the reform has advanced Saudi education toward the aspirations of Vision 2030, its sustainability requires systemic support, targeted interventions, and greater equity in implementation.

Finally, beyond measurable outcomes, the Tracks System in Saudi Arabia is designed to influence how students perceive learning and their future career pathways. As shown in Tables 3 and 4, students expressed high levels of engagement, particularly

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with opportunities related to coding, robotics, and project-based learning, while teachers highlighted persistent structural challenges. This dual perspective suggests that the reform is not solely about curriculum delivery but also about shaping new educational mindsets. In practice, students entering the Health and Life Sciences track may come to understand medicine as both a scientific and social endeavor, while those in the Computer Science and Engineering track often perceive themselves as future innovators and entrepreneurs. Such transformative orientations are consistent with international frameworks emphasizing flexibility, relevance, and 21st-century skills [3], [22].

Practical Recommendations

- Strengthen Teacher Preparation - Provide continuous professional development for Computer Science educators, emphasizing areas such as AI, cybersecurity, and robotics.
- Invest in Infrastructure Equity - Allocate resources to rural and under-resourced schools to ensure equitable access to laboratories, high-speed connectivity, and updated digital tools.
- Enhance Academic Advising - Establish structured career guidance frameworks to support students and parents in making informed choices regarding the CSE track and post-secondary pathways.
- Expand Partnerships with Industry and Universities - Strengthen collaborations with universities and private sector organizations to provide internships, coding bootcamps, and applied project opportunities.

Future Research

This study highlights several avenues for future research:

- Longitudinal Studies: Track the long-term outcomes of CSE graduates, including their higher education enrollment and career trajectories, to assess the sustained impact of the reform.
- Comparative Analyses: Conduct cross-regional studies to explore disparities in implementation between urban and rural contexts.
- Teacher Development Research: Evaluate the effectiveness of professional development programs in equipping teachers to deliver specialized Computer Science curricula.
- Advising and Guidance Studies: Investigate how academic advising influences student decision-making and career readiness in STEM fields.

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