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Building a Sustainable Tomorrow: STEM Teaching and the Pursuit of Educational Sustainable Development Goals

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Abstract

This study investigates the extent to which STEM-based teaching contributes to achieving the United Nations' Sustainable Development Goals (SDGs) in education, as perceived by educators in Saudi Arabia. A sample of 173 educators, including teachers and supervisors trained in STEM methodologies, participated in a mixed-methods study employing a validated Likert-scale questionnaire. Statistical analysis (t-test, $p < 0.001$) revealed that STEM-based instruction holds significant potential for advancing SDGs, with notable variations across goals. Goal 4 (Quality Education) ranked highest, aligning with STEM's emphasis on critical thinking, equitable access, and teacher development. Conversely, Goal 2 (Zero Hunger) scored lowest, reflecting STEM's stronger focus on technical over socioeconomic challenges. Gender and role-based disparities emerged: female educators perceived STEM's impact on Goal 5 (Gender Equality) more positively than male supervisors, while males expressed greater confidence in STEM's relevance to Goal 1 (No Poverty). These differences highlight the influence of gender dynamics and professional roles on SDG prioritization. The study recommends adopting STEM as a core strategy for SDG-aligned education, particularly for environmental, technical, and economic goals (Goals 6, 7, 9). However, to address social and humanitarian targets (Goals 1, 2, 5), transitioning to an interdisciplinary STREAMS framework—integrating Reading, Arts, and Social Studies—is proposed. This approach bridges STEM's technical rigor with sociocultural context, fostering holistic problem-solving. Findings underscore the need for gender-inclusive policies, educator training in SDG integration, and curricular reforms to align Saudi Arabia's Vision 2030 with global sustainability agendas. Further research is urged to explore STREAMS' efficacy and longitudinal impacts of STEM on SDG achievement.

Keywords: STEM education, Sustainable Development Goals (SDGs), Saudi Arabia, gender disparities, STREAMS, curriculum reform.

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Introduction

Over the past decade, the interdisciplinary integration of science, technology, engineering, and mathematics (STEM) has emerged as a cornerstone of educational innovation, reshaping curricular frameworks and pedagogical practices globally. Since its formalization in the early 21st century, STEM education has evolved from a U.S.-centric response to workforce demands into a transnational movement, with scholarly discourse increasingly emphasizing its role in fostering critical thinking, creativity, and equitable access to technological literacy (Karp, 2025; AlAli, 2024). By 2025, this approach has solidified its position as a dominant paradigm in education policy, driving curriculum design and institutional reforms across diverse contexts, including the United States, European nations, and Asia-Pacific regions (Manasikana & Saputro, 2025).

The proliferation of specialized STEM-focused institutions underscores this trend. For instance, initiatives such as New York's schools for gifted students highlight targeted efforts to cultivate advanced competencies through accelerated and enriched programs, reflecting a broader commitment to nurturing talent in STEM disciplines (Karp, 2025). Concurrently, U.S. educational policies continue to prioritize early exposure to STEM, despite challenges such as funding instability and political shifts impacting diversity, equity, and inclusion (DEI) initiatives (Al-Barakat et al., 2025; Tytler, 2020). Organizations like Beyond100K and the California STEM Network have responded by advocating for equity-centered frameworks, ensuring underrepresented students remain central to STEM advancement strategies (George, 2024).

This global expansion is further evidenced by comparative studies examining pedagogical practices, which reveal localized adaptations of STEM integration to address socioeconomic disparities and workforce needs (AlAli et al., 2024). Meanwhile, emerging technologies like artificial intelligence (AI) and virtual reality (VR) are redefining instructional methodologies, enabling personalized learning and immersive experiences that align with 21st-century skill demands (AlAli, 2023). Such developments highlight the dynamic interplay between policy, innovation, and inclusivity in shaping the future of STEM education.

STEM education has emerged as a transformative force in U.S. K-12 curricular reform, positioning itself as a critical driver of national competitiveness in the global knowledge economy (Mosiakova et al., 2024). This paradigm shift responds to acute workforce demands, with projections indicating a 10.8% growth in STEM occupations by 2032 compared to non-STEM fields, necessitating systemic educational realignment to cultivate skilled professionals (Polivka et al., 2025). Contemporary research underscores that STEM pedagogies foster higher-order cognitive skills, including analytical reasoning, creative problem-solving, and technological fluency—competencies deemed indispensable for innovation in an era of rapid digital transformation (Ammar et al., 2024).

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Scholarship identifies three interdependent rationales for global STEM prioritization:

1. **Educational Imperative**: Equipping learners with advanced disciplinary knowledge and transdisciplinary competencies to navigate evolving labor markets (HIDIROĞLU & Karakaş, 2022).

2. **Economic Imperative**: Developing STEM-literate leadership to catalyze sustainable economic growth and technological sovereignty (Maisiri & Madzikanda, 2024).

3. **Talent Retention Imperative**: Implementing systemic strategies to retain high-potential individuals through institutional support and career pathway development (Abiwu & Martins, 2024).

These imperatives have gained particular traction in the Arab Gulf region, exemplified by Saudi Arabia's Vision 2030 human capital development agenda. With over 85% of emerging global careers requiring STEM competencies (Di Battista et al., 2023), Saudi policymakers have institutionalized STEM through the 2017 National Center for STEM Development—a tripartite initiative comprising:

- **STEM Science Centers**: Extracurricular hubs operating in Jeddah, Asir, Taif, and Qassim, delivering project-based learning during non-school hours.
- **School STEM Centers**: 32 government-funded centers (projected to expand to 72) staffed by specialists trained in integrated STEM pedagogies.
- **Classroom Integration**: A phased national curriculum overhaul to embed STEM principles across K-12 subjects by 2025.

Complementing governmental efforts, public-private partnerships like the Aramco-STEM Talent Initiative demonstrate cross-sector collaboration, providing advanced training for gifted students through mentorship and industry-linked projects (Alamri, 2023). This multilayered approach reflects Saudi Arabia's strategic alignment of educational infrastructure with post-oil economic diversification goals, positioning STEM as both a pedagogical framework and socioeconomic imperative.

Contemporary global discourse has positioned sustainable development as a cross-cutting priority, permeating policymaking, industry practices, and educational agendas alike. The United Nations' 2030 Agenda, operationalized through 17 Sustainable Development Goals (SDGs), establishes an integrated framework for addressing socio-technical challenges spanning environmental stewardship, equitable resource distribution, and inclusive technological advancement. Central to this framework is SDG 4" Quality Education" which functions as both a standalone objective and an enabling mechanism for achieving the remaining 16 goals through human capital development (Saleh & AlAli, 2025).

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A critical analysis reveals synergistic potential between STEM education's transdisciplinary problem-solving paradigm and the SDGs' multifaceted targets. For instance, STEM pedagogies inherently address (Surahman, 2024; Jakfar et al., 2024; Ling et al., 2019):

- **SDG 7 (Affordable Clean Energy)**: Cultivating innovation in renewable technologies through engineering design challenges.
- **SDG 9 (Industry Innovation)**: Developing computational thinking and digital literacy for smart infrastructure solutions.
- **SDG 13 (Climate Action)**: Enabling data-driven environmental modeling and systems analysis.

This alignment extends beyond technical applications to encompass social equity dimensions. By democratizing access to STEM competencies, education systems can directly advance **SDG 5 (Gender Equality)** through targeted programming for underrepresented groups and **SDG 10 (Reduced Inequalities)** via localized curriculum adaptations in marginalized communities. The systemic nature of STEM—integrating scientific inquiry with ethical considerations of technological impact—further resonates with the SDGs' emphasis on responsible innovation (Surahman, 2024; Al-Hassan et al., 2025).

The authors posit that institutionalizing STEM frameworks within national education strategies offers a viable pathway for SDG implementation. This proposition aligns with emerging evidence from OECD nations, where STEM-skilled workforces correlate strongly with progress in sustainability indices, particularly in water management (SDG 6) and sustainable cities (SDG 11). Such findings underscore the necessity of reorienting teacher training programs and curricular standards to explicitly link STEM competencies with sustainability literacy dual-capacity approach now being piloted through UNESCO's STEM for SDGs initiative.

Literature Review

Sustainable Development Goals (SDGs) and Educational Paradigms

Sustainable development constitutes a multidimensional progression mechanism through which societies transition toward equitable socioeconomic advancement while maintaining ecological integrity. Contemporary scholarship conceptualizes this process as a dynamic interplay between resource optimization, intergenerational equity, and cultural preservation (Abunasser et al., 2022). The foundational Brundtland Commission definition "development that meets present needs without compromising future generations' capabilities"—has evolved into a global governance framework through the United Nations' 2030 Agenda, which operationalizes 17 SDGs as measurable benchmarks for planetary and societal well-being (Jakfar et al., 2024).

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Critical analysis reveals three evolutionary phases in sustainable development discourse:

1. **Technocentric Phase (1980s–2000s)**: Emphasized environmental conservation through technological innovation (e.g., Abdullah's 1983 definition of eco-appropriate technologies).

2. **Human Capital Phase (2010s)**: Prioritized education and institutional capacity-building as drivers of SDG achievement (Al-Barakat et al., 2022).

3. **Systems Thinking Phase (Post-2020)**: Reconceptualizes sustainability as a complex adaptive system requiring transdisciplinary competencies (Ling et al., 2019).

The 2030 Agenda positions SDG 4 (Quality Education) as both an independent objective and a catalytic enabler for remaining goals. UNESCO's *Education for Sustainable Development: A Roadmap* (2023) identifies eight core competencies that reconfigure pedagogical practices to address sustainability challenges as illustrate in Table 1:

Table 1. Competencies for Reconfiguring Pedagogical Practices to Address Sustainability Challenges

Competency	Operational Definition	SDG Alignment
Systems Thinking	Analyzing socio-ecological interdependencies in local-global contexts	SDG 11, 13
Anticipatory Governance	Envisioning future scenarios through risk assessment and preventive action	SDG 9, 12
Normative Negotiation	Reconciling ethical values and conflicting stakeholder interests	SDG 5, 10
Strategic Collaboration	Co-designing context-specific solutions with multi-sectoral partners	SDG 17
Critical Reflection	Deconstructing power structures and unsustainable paradigms	SDG 16
Empathic Engagement	Fostering intercultural dialogue through perspective-taking	SDG 4.7
Metacognitive Regulation	Aligning individual agency with collective sustainability objectives	Cross-cutting
Integrative Problem-Solving	Synthesizing disciplinary knowledge to address wicked problems	SDG 6, 7, 15

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Empirical studies demonstrate that nations implementing competency-based ESD frameworks achieve 23% faster progress on SDG indices compared to conventional curricula (Global Education Monitoring Report, 2023). However, challenges persist in balancing universal sustainability principles with cultural sovereignty, particularly in Global South contexts where indigenous knowledge systems often conflict with Western developmental paradigms (Tikly, 2022).

Redefining STEM Pedagogy: An Integrated Framework for Contemporary Education

The STEM (Science, Technology, Engineering, and Mathematics) approach has emerged as a dynamic pedagogical framework, yet its conceptual ambiguity persists due to multifaceted implementations across global and regional contexts. Scholarly discourse identifies four primary orientations: (1) discipline-specific expansion, (2) institutional specialization (e.g., STEM-focused schools), (3) programmatic interventions, and (4) project-based curricular models (Perales & Aróstegui, 2024). This terminological plurality necessitates context-specific operational definitions. For this study, STEM education is defined as *an interdisciplinary pedagogy that dismantles traditional subject silos to create cohesive, real-world learning experiences through the integration of science, technology, engineering design, and mathematics* (AlAli, 2024).

Core Disciplinary Constructs

- **Science (S)**: Encompasses systematic inquiry into physical, biological, and earth/space systems, emphasizing evidence-based reasoning.
- **Technology (T)**: The iterative design and application of tools, processes, and systems to address human challenges.
- **Engineering (E)**: Problem-solving through the integration of scientific principles and technological innovation to develop solutions.
- **Mathematics (M)**: The foundational language for modeling phenomena, analyzing data, and quantifying relationships across STEM domains.

Principles of Effective STEM Integration

Central to STEM pedagogy is the principle of *authentic integration*, which transcends superficial subject alignment to foster synergistic learning. Current research identifies three hierarchical levels of integration (Hallström et al., 2023):

1. **Multidisciplinary**: Thematic cohesion across distinct disciplines (e.g., exploring climate change through separate science and math lessons).
2. **Interdisciplinary**: Blending concepts/skills from two or more disciplines to address shared problems (e.g., using engineering design to apply physics and calculus principles).

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3. **Transdisciplinary**: Student-driven, real-world projects requiring holistic application of STEM knowledge (e.g., designing sustainable urban infrastructure).

Instructional Models and Curricular Design

Bybee's (2018) framework for STEM integration delineates nine pedagogical strategies, ranging from single-subject emphasis to full quad-disciplinary synthesis. Prioritize Contemporary adaptations (Lee, 2024; Ogan-Bekiroglu & Caner, 2018):

- **Problem/Project-Based Learning (PBL)**: Engaging learners in complex, open-ended challenges mirroring professional STEM workflows.
- **Convergent Pedagogies**: Aligning assessment practices with integrated competencies, such as systems thinking and computational modeling.

Empirical studies underscore that transdisciplinary models yield 28% higher gains in critical thinking and innovation skills compared to siloed approaches. However, successful implementation requires systemic support, including teacher professional development in collaborative curriculum design and resource allocation for hands-on learning tools (Sims et al., 2025).

STEM education is anchored in five core pedagogical principles that collectively foster authentic interdisciplinary learning and workforce readiness (AlAli et al., 2024):

1. **Interdisciplinary Integration**: Seamless synthesis of science, technology, engineering, and mathematics through problem-centered frameworks.
2. **Life-Relevant Contextualization**: Bridging abstract concepts to real-world applications to enhance learner engagement and transferability.
3. **21st-Century Skill Cultivation**: Systematic development of critical thinking, creative problem-solving, and collaborative competencies essential for technological societies.
4. **Challenge-Based Motivation**: Immersive scenarios requiring students to apply knowledge through iterative design processes.
5. **Differentiated Instructional Design**: Adaptive strategies accommodating diverse learning modalities and cultural perspectives.

Operationalizing STEM Principles

Effective implementation necessitates six evidence-based practices as illustrate in Table 2 (Asenov–Student, 2024):

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Table 2: Six Evidence-Based Practices Essential for the Effective Implementation of STEM Principles

Practice	Implementation Strategy	Outcome
Contextualized Motivation	Scenario-based learning anchored in local/global issues (e.g., sustainable energy systems)	Increased intrinsic engagement (↑32%)
Engineering Design Cycles	Multiphase projects incorporating prototyping, testing, and redesign	Enhanced problem-solving efficacy (ES=0.71)
Productive Failure	Structured reflection on iterative design flaws	Improved metacognitive regulation
Disciplinary Synergy	Co-teaching models integrating science inquiry with mathematical modeling	Deeper conceptual integration
Student-Centered Pedagogy	Hybrid PBL-flipped classroom approaches	Autonomous learning capacity development
Collaborative Discourse	Role-based team projects with peer evaluation protocols	Communication skill maturation (↑41%)

Prior research has extensively explored STEM education, underscoring its significance and innovative contributions to the educational landscape. AlAli et al. (2024) study highlighted the critical role of the school environment in implementing the STEM approach, demonstrating that higher levels of institutional readiness—encompassing both physical and social dimensions—enhance the integration of science, technology, engineering, and mathematics. The study recommended the development of a structured professional development plan for teachers, tailored to STEM-based pedagogical strategies.

Regarding teacher development, Zhou et al. (2023) findings indicated that training programs incorporating the STEM approach and metacognitive strategies significantly enhance teachers' pedagogical knowledge, technical expertise in teaching mathematics, and personal professional growth. Similarly, Weng (2020) found that STEM-focused training programs mitigate challenges teachers face in adopting this approach, fostering positive attitudes and improving self-efficacy in STEM instruction. However, the study emphasized the necessity of sustained, in-depth training to maximize effectiveness.

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Conversely, Grancharova (2024) identified challenges in implementing creative teaching within the STEM framework, noting its inherent complexities. Papadopoulou (2024) research further revealed that training in the STEAM (STEM + Arts) approach is less effective for pre-primary teachers compared to their counterparts in middle and secondary schools, advocating for additional targeted training to address this disparity.

In terms of student outcomes, Ningtyas et al. (2024) study demonstrated that a STEM-based curriculum positively influences students' systems thinking skills, enabling them to adopt a holistic perspective and understand interconnected system processes. Additionally, Astawan et al. (2023) research affirmed that STEM education enhances students' conceptual understanding and fosters creative thinking, underscoring its multifaceted benefits for learner development.

Research Problem

In 2015, the United Nations General Assembly adopted the 2030 Agenda for Sustainable Development, a global framework designed to steer humanity toward a sustainable future. This agenda encompasses 17 Sustainable Development Goals (SDGs) aimed at fostering a peaceful, prosperous, and equitable existence for all, both presently and for future generations. Distinctively, these goals are universally applicable, transcending national boundaries and requiring collective action from all countries.

The responsibility for achieving these goals rests with both governmental and private institutions, with educational institutions playing a pivotal role. Education serves as the cornerstone for realizing the SDGs, underpinning the attainment of the 2030 Vision as envisioned by the General Assembly. Educational methodologies and philosophies vary across nations and institutions, yet the STEM (Science, Technology, Engineering, and Mathematics) approach has gained global prominence, including in the Kingdom of Saudi Arabia. This approach emphasizes problem-solving through the integration of scientific inquiry, technological innovation, engineering design, and mathematical reasoning, addressing real-world challenges relevant to students' lives.

Given the alignment between the SDGs' focus on resolving humanitarian and environmental issues and the STEM approach's emphasis on practical problem-solving, it is imperative to evaluate the efficacy of STEM-based education in contributing to these goals. Such an assessment, grounded in the perspectives of educators experienced with the STEM approach, is essential to ensure that resources—financial, human, and temporal—are not expended ineffectively. Uninformed adoption of the STEM approach without rigorous evaluation risks undermining the pursuit of the SDGs. Consequently, this study seeks to address the following research questions:

1. To what extent does STEM-based education contribute to achieving the Sustainable Development Goals in education, according to educators' perspectives?

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2. What are the primary objectives of STEM-based teaching?

3. Are there statistically significant differences in the perceptions of supervisors and teachers regarding the capacity of STEM-based education to achieve the Sustainable Development Goals in education?

4. Are there statistically significant differences in educators' perceptions of the ability of STEM-based education to achieve the Sustainable Development Goals in education based on gender?

This inquiry aims to provide evidence-based insights to guide educational policy and practice, ensuring alignment with the global sustainability agenda.

Significance of Study

The significance of this study is underscored by its contributions to both theoretical and practical domains, as outlined below:

This research aligns global priorities by examining the intersection of the United Nations' Sustainable Development Goals (SDGs) and educational practices, with a specific focus on the STEM (Science, Technology, Engineering, and Mathematics) approach. By exploring the potential of STEM-based education to advance the SDGs, the study elucidates the theoretical framework underpinning this modern pedagogical strategy. It identifies specific objectives achievable through STEM-based teaching, thereby providing a robust foundation for integrating global sustainability goals into educational curricula. This analysis is critical to ensuring that initiatives to incorporate SDGs into STEM education are evidence-based, minimizing the risk of inefficient resource allocation prior to the implementation of pilot programs.

The study offers practical value by proposing a structured plan to prioritize and integrate the SDGs within STEM-based education. This framework facilitates the effective incorporation of sustainability goals into teaching practices, optimizing the use of time, effort, and financial resources. By providing actionable insights, the research supports educators and policymakers in designing STEM curricula that align with global sustainability objectives, enhancing the efficacy and impact of educational interventions.

Together, these contributions underscore the study's role in advancing both the theoretical understanding and practical application of STEM education in the context of the SDGs, fostering informed and sustainable educational practices.

Population and Sampling

The study population consisted of educators affiliated with the Ministry of Education in the Kingdom of Saudi Arabia for the academic year 2024–2025. The sample was purposefully selected from the population and comprised a total of 173 educators, including 86 males and

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87 females. The sample included 127 teachers and 46 educational supervisors as illustrated in Table 3.

Table 3: Sample Distribution

Gender	Current Position		Total
	Teacher	Supervisor	
Male	61	25	**86**
Female	66	21	**87**
Total	**127**	**46**	**173**

Study Instrument

A questionnaire was developed by researchers based on the Sustainable Development Goals (SDGs) in education to identify educators' perspectives using a Likert scale. The items were aligned with the SDGs and divided into three dimensions:

- **First dimension:** Goals that can be achieved through implementing them as projects in teaching based on the STEM approach. This dimension included nine SDGs.
- **Second dimension:** Goals that can be achieved through teaching practices based on the STEM approach. This dimension included four SDGs.
- **Third dimension:** Goals that can be achieved as long-term outcomes of teaching based on the STEM approach. This dimension included four SDGs.

Validation and Reliability of the Research Instrument

The validity and reliability of the research instrument were rigorously established through a systematic process. The instrument was reviewed by nine experts from Saudi University, specializing in curricula, teaching methodologies, and measurement and evaluation. Based on their expert feedback, the researchers revised, reformulated, and eliminated certain items to enhance the instrument’s clarity and relevance.

To further ensure validity and reliability, a pilot study was conducted with a sample of 23 teachers and supervisors. The responses and feedback collected during this phase informed additional refinements to the final instrument. Data analysis was performed using SPSS version 26. To assess the instrument’s validity, the discriminant coefficient (corrected item-total correlation) was calculated, and items with a discriminant coefficient below 0.20 were excluded to maintain the instrument’s psychometric integrity.

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Indicators and Coefficients of Construct Validity

The reliability of the instrument was evaluated using McDonald's omega and composite reliability (CR), widely recognized metrics for assessing the internal consistency of observational tools. As presented in Table 2, McDonald's omega values ranged from 0.887 to 0.936, and CR values ranged from 0.889 to 0.939. Both metrics surpassed the recommended threshold of 0.7 (Aboud & AlAli, 2025), indicating strong internal consistency.

Additionally, the average variance extracted (AVE) was calculated to assess convergent validity, with values ranging from 0.587 to 0.629, all exceeding the 50% benchmark. This confirms the instrument's ability to capture the intended constructs effectively. For discriminant validity, the square root of the AVE for each construct was compared to the corresponding minimum loading factor, as shown in the final column of Table 4. In all cases, the square root of the AVE exceeded the minimum loading factor, satisfying the criteria for discriminant validity.

Table 4 Indicators and coefficients of construct validity

Constructs	Items	McDonald's ω	CR	AVE	$\sqrt{AVE}$
First dimension	9	0.901	0.903	0.608	0.779
Second dimension	4	0.936	0.939	0.629	0.793
Third dimension	4	0.887	0.889	0.587	0.766

Study Results

To address the research questions, a set of statistical methods appropriate to each question was employed.

To answer the first question, which states: *"To what extent is STEM-based instruction capable of achieving the Sustainable Development Goals in education from the perspective of educators?"*

A **one-sample t-test** was used, with the test level set at the **median of the Likert scale (3)** as the benchmark value. The results are presented in **Table 5** as follows:

Table 5. Results on the Extent to Which the STEM Approach Can Achieve the Sustainable Development Goals

	Goal	Mean	Standard Deviation	t-value	Sig.
1	End poverty in all its forms everywhere	3.51	1.421	4.932	0.000

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2	End hunger, achieve food security and improved nutrition	3.43	1.314	3.416	0.001
3	Ensure healthy lives and promote well-being for all at all ages	3.59	1.163	6.563	0.000
4	Ensure availability and sustainable management of water and sanitation for all	3.79	1.162	8.831	0.000
5	Ensure access to affordable, reliable, sustainable and modern energy for all	3.89	1.127	10.417	0.000
6	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	4.11	1.098	13.361	0.000
7	Make cities and human settlements inclusive, safe, resilient, and sustainable	4.06	1.092	12.273	0.000
8	Ensure sustainable consumption and production patterns	3.91	1.052	11.758	0.000
9	Take urgent action to combat climate change and its impacts	3.78	1.114	9.743	0.000
10	Conserve and sustainably use the oceans, seas, and marine resources	3.90	1.117	10.793	0.000
11	Protect, restore, and promote sustainable use of terrestrial ecosystems (e.g., forests, desertification, biodiversity loss)	3.99	1.141	12.238	0.000
12	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	4.41	0.973	17.617	0.000
13	Achieve gender equality and empower all women and girls	4.13	1.093	14.356	.000
14	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all	4.14	0.956	15.471	0.000
15	Reduce inequality within and among countries	3.89	1.069	11.258	0.000

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16	Promote peaceful and inclusive societies for sustainable development	3.91	1.091	11.453	0.000
17	Strengthen the means of implementation and revitalize the global partnership for sustainable development	4.06	1.046	12.912	0.000

The results indicate that the means for all goals are higher than the benchmark level 3 and are statistically significant at the 0.01 level. This suggests that teaching based on the STEM approach is capable of achieving all the sustainable development goals related to learning, according to the educators' perspectives.

To answer the second research question, which states: *"What are the priority goals to be adopted in teaching according to the STEM approach?"* Arithmetic means were used to assess educators' views on the extent to which STEM-based teaching can achieve each goal. Table 6 below presents the ranking of the sustainable development goals from highest to lowest priority based on the mean scores.

Table 6. Ranking of Sustainable Development Goals According to the Extent to Which STEM-Based Teaching Can Achieve Them.

Priority Rank	**Survey Order**	**Goal**	**Mean Score**
1	12	Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	4.41
2	14	Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all	4.14
3	13	Achieve gender equality and empower all women and girls	4.13
4	6	Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation	4.11
5	17	Strengthen the means of implementation and revitalize the global partnership for sustainable development	4.06
6	7	Make cities and human settlements inclusive, safe, resilient, and sustainable	4.06
7	11	Protect, restore, and promote sustainable use of terrestrial ecosystems (forests, desertification, biodiversity loss)	3.99

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8	5	Ensure access to affordable, reliable, sustainable, and modern energy for all	3.89
9	16	Promote peaceful and inclusive societies for sustainable development	3.91
10	8	Ensure sustainable consumption and production patterns	3.91
11	10	Conserve and sustainably use the oceans, seas, and marine resources for sustainable development	3.90
12	15	Reduce inequality within and among countries	3.89
13	4	Ensure availability and sustainable management of water and sanitation for all	3.79
14	9	Take urgent action to combat climate change and its impacts	3.78
15	3	Ensure healthy lives and promote well-being for all at all ages	3.59
16	1	End poverty in all its forms everywhere	3.51
17	2	End hunger, achieve food security and improved nutrition	3.43

The table above shows that the highest priority is given to the goal *"Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all,"* with a mean score of 4.41, while the lowest priority is given to the goal *"End hunger,"* with a mean score of 3.43.

To answer the third research question, which states: *Are there statistically significant differences between the mean perspectives of supervisors and teachers regarding the extent to which STEM-based instruction can achieve sustainable development goals?*

An independent samples **t-test** was conducted to examine the differences in perspectives between supervisors and teachers. The results indicated that there was **a statistically significant difference** in the goal *"Achieve gender equality and empower all women and girls"* in favor of **teachers**, at a significance level less than **0.05**. The **t-value** was **2.1** with a **standard deviation of 0.182**.

For all other goals, there were **no statistically significant differences** between the mean perspectives of supervisors and teachers, as shown in **Table 7** below:

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Table 7. Differences Between Teachers' and Supervisors' Perspectives on the Extent to Which STEM-Based Instruction Achieves Sustainable Development Goals

Goal	Group	Mean	Std. Deviation	t-value	Sig. (p)
End poverty in all its forms everywhere	Teacher	3.47	0.227	-0.278	0.775
	Supervisor	3.53	—	—	—
End hunger	Teacher	3.33	0.224	-0.035	0.972
	Supervisor	3.33	—	—	—
Ensure healthy lives and promote well-being for all	Teacher	3.75	0.198	1.786	0.076
	Supervisor	3.40	—	—	—
Ensure availability and sustainable management of water and sanitation	Teacher	3.88	0.197	0.636	0.525
	Supervisor	3.76	—	—	—
Ensure access to affordable, reliable, sustainable energy	Teacher	3.99	0.191	0.539	0.591
	Supervisor	3.89	—	—	—
Build resilient infrastructure and promote sustainable industrialization	Teacher	4.09	0.186	0.111	0.912
	Supervisor	4.07	—	—	—
Make cities inclusive, safe, resilient, and sustainable	Teacher	4.02	0.186	0.487	0.627
	Supervisor	3.93	—	—	—
Ensure sustainable consumption and production patterns	Teacher	3.98	0.181	0.851	0.396
	Supervisor	3.82	—	—	—
Take urgent action to combat climate change	Teacher	3.81	0.193	-0.066	0.948
	Supervisor	3.82	—	—	—
Conserve oceans, seas, and marine resources	Teacher	3.90	0.193	-0.263	0.793
	Supervisor	3.96	—	—	—
Protect and promote sustainable terrestrial ecosystems	Teacher	3.96	0.198	-0.313	0.755
	Supervisor	4.02	—	—	—
	Teacher	4.31	0.161	-0.148	0.882

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Ensure inclusive and equitable quality education	Supervisor	4.33	—	—	—
Achieve gender equality and empower women and girls	Teacher	4.18	0.182	2.100	0.037
	Supervisor	3.80	—	—	—
Promote inclusive and sustainable economic growth and decent work	Teacher	4.15	0.163	0.927	0.355
	Supervisor	4.00	—	—	—
Reduce inequality within and among countries	Teacher	3.88	0.183	0.200	0.842
	Supervisor	3.84	—	—	—
Promote peaceful and inclusive societies	Teacher	4.01	0.187	0.872	0.384
	Supervisor	3.84	—	—	—
Strengthening means of implementation and partnerships	Teacher	4.10	0.178	0.036	0.972
	Supervisor	4.09	—	—	—

To answer the fourth research question, which states: Are there statistically significant differences in the mean perspective based on gender regarding the extent to which STEM-based teaching can achieve the goals of sustainable development in education?"

An **independent samples t-test** was conducted to examine differences in the mean perspectives based on **gender**. The results indicated that there was a **statistically significant difference** in perceptions regarding the extent to which STEM-based teaching can contribute to achieving the sustainable development goal: **"Eradicate poverty in all its forms everywhere,"**
in favor of **males**, at a significance level of **0.01**. The **t-value** was **2.471** with a **standard deviation** of **0.196**.

However, **no statistically significant differences** were found between males and females in their views concerning the remaining sustainable development goals, as shown in the following table:

Table 8. Differences in Perspectives Based on Gender

Goal	Gender	Mean	Standard Deviation	t-value	Sig.
	Male	3.73	0.196	2.471	0.014

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Eradicate poverty in all its forms everywhere	Female	3.24			
End hunger in all its forms	Male	3.52	0.195	1.936	0.055
	Female	3.14			
Ensure healthy lives and promote well-being for all at all ages	Male	3.72	0.176	0.642	0.522
	Female	3.60			
Ensure availability and sustainable management of water and sanitation for all	Male	4.00	0.172	1.756	0.081
	Female	3.70			
Ensure access to affordable, reliable, sustainable, and modern energy for all	Male	4.05	0.168	0.970	0.333
	Female	3.88			
Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation	Male	4.09	0.164	0.148	0.882
	Female	4.07			
Make cities and human settlements inclusive, safe, resilient, and sustainable	Male	4.04	0.164	0.428	0.669
	Female	3.97			
Ensure sustainable consumption and production patterns	Male	3.95	0.160	0.215	0.830
	Female	3.92			
Take urgent action to combat climate change and its impacts	Male	3.81	0.170	-0.013	0.990
	Female	3.81			
Conserve and sustainably use the oceans, seas, and marine resources	Male	4.01	0.169	1.099	0.273
	Female	3.83			
Protect, restore, and promote sustainable use of terrestrial ecosystems (forests, desertification, biodiversity loss)	Male	4.09	0.174	1.346	0.180
	Female	3.86			
Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all	Male	4.29	0.142	-0.304	0.761
	Female	4.34			
Achieve gender equality and empower all women and girls	Male	3.94	0.161	-1.736	0.084
	Female	4.22			

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Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all	Male	4.09	0.144	-0.235	0.814
	Female	4.13			
Reduce inequality within and among countries	Male	3.86	0.161	-0.155	0.877
	Female	3.88			
Promote peaceful and inclusive societies for sustainable development	Male	3.98	0.165	0.139	0.890
	Female	3.95			
Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development	Male	4.08	0.157	-0.142	0.887
	Female	4.10			

Discussion of Results

Overall, the findings align with the educational literature related to STEM-based instruction on one hand, and with the literature concerning sustainable development and its learning goals on the other. They also correspond with previous studies conducted within this framework. The result of the study's main question—regarding the extent to which STEM-based instruction can achieve the Sustainable Development Goals (SDGs) for learning—indicates that this approach is capable of contributing to the achievement of all seventeen goals. This outcome reflects the advantages and benefits of STEM education as previously highlighted in the educational literature reviewed in the current study, such as its ability to foster creative and systemic thinking, deepen understanding, and contribute to solving current and future problems, as well as improving and developing the environment. These are the very aspirations of the SDGs for learning.

The findings of this study offer a nuanced understanding of how STEM-based teaching aligns with the Sustainable Development Goals (SDGs), while also highlighting critical gaps and opportunities for refinement. Below is a synthesis of the results, their implications, and recommendations for practice and policy.

1. STEM's Alignment with SDGs: Strengths and Gaps

- **Strong Alignment with Technical and Environmental SDGs**:

STEM education excels in addressing SDGs tied to problem-solving, innovation, and environmental sustainability (e.g., Goals 6, 7, 11–15). Its emphasis on real-world applications—such as designing water conservation systems or renewable energy solutions—

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directly supports these goals. This aligns with literature emphasizing STEM's role in fostering systemic thinking and environmental stewardship (Vasquez et al., 2019).

- **SDG 4 (Quality Education) as a Foundation**:

Educators prioritized SDG 4, recognizing STEM's capacity to improve learning environments, teacher competencies, and student skills (e.g., critical thinking, collaboration). This mirrors the UN's stance that education is the "enabler" of all other SDGs. Studies in Saudi Arabia (Aldahmash et al., 2019) corroborate this, linking STEM to teacher development and student readiness for future challenges.

- **Weak Links to Social SDGs (Goals 1, 2, and 5)**:

STEM's limited focus on Goals 1 (No Poverty) and 2 (Zero Hunger) underscores its technical orientation, which often sidelines socioeconomic and humanitarian dimensions. Similarly, while STEM indirectly supports SDG 5 (Gender Equality) through inclusive education, its primary focus on skills like engineering may not explicitly address systemic gender disparities.

Transition toward **STREAMS** (integrating Reading, Arts, and Social Studies) to address sociocultural contexts and human-centered challenges (Vasquez et al., 2019). For example: Use literature and social studies to explore poverty/hunger's root causes. Incorporate arts to design inclusive solutions for marginalized communities.

2. Gender and Role-Based Differences in Perceptions

- **SDG 5 (Gender Equality)**:

Teachers—particularly females—rated STEM's impact on SDG 5 higher than supervisors. This may reflect female educators' firsthand experience with gender barriers in STEM fields, as well as Saudi Arabia's Vision 2030 efforts to empower women in education and workforce participation.

- **SDG 1 (No Poverty)**:

Male participants perceived STEM's relevance to poverty alleviation more strongly than females. This could stem from gendered societal roles (e.g., males' greater exposure to economic policymaking) or differing interpretations of poverty as a technical vs. systemic issue.

Implications: **Gender-Sensitive Training**: Address unconscious biases in STEM curricula and highlight female role models in technical fields. **Collaborative Policymaking**: Engage both teachers and supervisors in SDG-aligned curriculum design to bridge perception gaps.

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3. The Case for a Holistic STREAMS Approach

The study reinforces calls to expand STEM into **STREAMS** to better address social SDGs:

- **Reading/Literacy**: Analyze poverty narratives (e.g., SDG 1) through literature.
- **Arts**: Design community-driven solutions for hunger (SDG 2) using creative methods.
- **Social Studies**: Explore systemic inequities (e.g., gender, class) hindering SDG progress.

This shift aligns with global trends advocating interdisciplinary, culturally responsive education (Jikha, 2016; Jabr & Al-Zoubi, 2018). For instance, a STREAMS project in agriculture could combine:

- **Science/Engineering**: Develop drought-resistant crops.
- **Social Studies**: Examine land ownership policies affecting small farmers.
- **Arts**: Create campaigns to reduce food waste.

Conclusion

While STEM-based teaching is a powerful tool for advancing many SDGs, its narrow technical focus risks overlooking critical social dimensions. By adopting a **STREAMS framework**, educators can create more inclusive, contextually relevant learning experiences that address all 17 SDGs. Policymakers must also prioritize gender equity and collaboration between teachers and supervisors to ensure cohesive, impactful implementation.

Recommendations

To enhance the efficacy of STEM-based teaching in advancing the United Nations' Sustainable Development Goals (SDGs) and addressing identified gaps, the following recommendations are proposed:

1. **Integration of STEM and Transition to STREAMS for Holistic SDG Alignment** To address both social and technical SDGs, the adoption of the STREAMS framework (Science, Technology, Reading, Engineering, Arts, Mathematics, Social Studies) is recommended. This approach can effectively target SDGs such as Goal 1 (No Poverty), Goal 2 (Zero Hunger), and Goal 5 (Gender Equality) by incorporating social studies to analyze systemic poverty, leveraging arts for community-driven hunger solutions, and promoting literacy to explore gender equity narratives. Pilot STREAMS projects should be implemented in Saudi schools, aligning with Vision 2030's focus on cultural and social transformation. Concurrently, the traditional STEM framework should be retained for technical and environmental SDGs (Goals 6, 7, and 11–15), with initiatives like cross-school STEM challenges (e.g., designing solar-powered irrigation systems) to foster innovation.

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2. **Redesign of Curriculum and Learning Environments**

Curricula should explicitly embed SDG targets within STEM lesson plans, such as linking climate action projects to SDG 13 or developing interdisciplinary modules combining biology and engineering to address water scarcity. Teacher capacity must be strengthened through professional development programs focused on SDG-aligned pedagogies, including STREAMS integration, and supported by mentorship networks bridging STEM and humanities educators. Additionally, equitable resource allocation is critical to ensure that rural and underserved schools have access to STEM laboratories, digital tools, and SDG-focused instructional materials.

3. **Promotion of Gender Equity in STEM Education**

To address gender disparities, awareness campaigns should highlight female role models in STEM fields, such as Saudi women in renewable energy or artificial intelligence, while offering scholarships and internships to encourage girls' participation in STEM careers. Teachers should receive training on gender-sensitive pedagogies to mitigate unconscious biases and develop STEM projects that explicitly address gender equality, such as designing applications to enhance women's access to healthcare.

4. **Strengthening Collaboration Among Stakeholders**

Policymakers and educators should establish committees to align national STEM strategies with SDG targets, fostering partnerships between Saudi Arabia's STEM centers and non-governmental organizations for SDG-focused initiatives. Schools should collaborate with communities by organizing STEM fairs to showcase student solutions to local challenges, such as waste reduction prototypes. Industry partnerships with entities like NEOM and Saudi Aramco can provide funding for SDG-driven STEM projects, enhancing their scalability and impact.

Limitations

The study's findings are subject to certain limitations that warrant consideration. The research primarily relied on the perspectives of educators within a specific context, which may limit the generalizability of the results to other educational systems or regions. Additionally, the study focused on the STEM approach with limited exploration of the STREAMS framework, potentially overlooking the broader interdisciplinary contributions to SDG achievement. The sample size and scope of the pilot study for the research instrument may also constrain the robustness of the findings, necessitating further validation across diverse settings.

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Future Research Directions

To build on the current findings, future research should explore the following areas:

1. **Impact of STREAMS on Social SDGs**: Investigating how the integration of arts and social studies into STEM influences students' understanding of poverty (SDG 1) and hunger (SDG 2) could provide insights into the efficacy of the STREAMS framework.

2. **Gender Dynamics in STEM-SDG Integration**: A longitudinal analysis of female participation in STEM programs and its correlation with progress on SDG 5 (Gender Equality) could illuminate strategies to enhance gender equity.

3. **21st-Century Skills as Mediators for SDG Achievement**: Examining how skills such as critical thinking and collaboration, developed through STEM projects, translate to real-world SDG outcomes could strengthen the case for STEM-based education.

4. **Cross-Cultural Comparisons**: Comparing Saudi Arabia's STEM-SDG alignment with decentralized educational systems, such as those in the United States or European Union, could identify best practices for global application.

5. **Policy Implementation Barriers**: Exploring challenges in scaling STREAMS curricula across diverse Saudi educational institutions could inform strategies to overcome logistical and systemic obstacles.

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