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TEACHING PRACTICES THAT FOSTER ENTREPRENEURIAL SKILLS AMONG SCIENCE TEACHERS: AN EVALUATIVE STUDY IN THE SAUDI CONTEXT

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ABSTRACT

This study aimed to investigate the level of teaching practices that foster entrepreneurial skills among science teachers in Saudi Arabia. A descriptive quantitative design was adopted, utilizing a validated 48-item scale distributed across eight dimensions: teaching practices that promote creative thinking and innovation, planning and project management skills, problem-solving and decision-making skills, marketing and communication skills, leadership and teamwork skills, strategic thinking skills, research and development skills, and sustainability and social responsibility skills. The sample consisted of 201 science teachers enrolled in graduate programs at King Khalid University. The study's results demonstrate a generally high level of teaching practices that foster entrepreneurial skills ($M = 2.44, 81.18\%$). Leadership and teamwork emerged as the strongest areas, whereas marketing and communication skills were comparatively weaker. Statistically significant differences were identified in favor of teachers enrolled in master's programs ($p < .011$). Moreover, self-reported technology proficiency showed a strong positive correlation with entrepreneurial teaching practices ($p < .001$). No significant differences were observed across gender, age, or school level. Based on these findings, the study recommends embedding entrepreneurship education within science teacher preparation programs. It further emphasizes the need to strengthen teaching practices that cultivate marketing, communication, and strategic thinking through targeted professional training, expand technology-based pedagogies to support innovation and project-based learning, encourage collaborative and leadership-oriented teaching approaches, and build partnerships between schools and the private sector to sustain entrepreneurial education.

KEYWORDS: Teaching Practices, Science Teachers, Saudi Arabia

1. INTRODUCTION

In today's global context, education systems are tasked not only with transmitting disciplinary knowledge but also with equipping learners with skills that foster innovation, initiative, and value creation. This imperative is particularly salient in Saudi Arabia, where Vision 2030 emphasizes the cultivation of entrepreneurial capacities and the transition toward a knowledge-based economy. Consequently, science education in Saudi secondary schools must extend beyond the mastery of physics or biology to serve as a platform for developing entrepreneurial competencies. Science teachers occupy a pivotal role in balancing these dual aims: ensuring rigorous disciplinary learning while embedding practices that nurture entrepreneurial skills. This study evaluates how science teachers in Saudi Arabia implement teaching practices that foster entrepreneurial skills, with the objective of identifying both strengths and areas for improvement in current pedagogical approaches.

Entrepreneurial teaching practices refer to instructional strategies intentionally designed to cultivate students' capacities for initiative, opportunity recognition, creative problem-solving, collaboration, resilience, and reflective innovation (Hadley, 2025). Such practices typically involve open-ended tasks connected to real-world opportunities and iterative processes that allow students to prototype, test, reflect, and refine their work. In science classrooms, this may take the form of investigating phenomena, developing prototype solutions, analyzing market or societal implications, and revising approaches based on feedback. Effective implementation requires teachers to adopt facilitator-coach roles, integrate cross-disciplinary connections (e.g., science with business or sustainability), and design tasks that emphasize agency, autonomy, and stakeholder engagement (Hadley, 2025; Abbes, 2024). In this way, teaching practices become vehicles for entrepreneurial skill development rather than solely conduits for disciplinary content.

The rationale for embedding entrepreneurial skills in education is supported by pedagogical, economic, environmental, societal, legal, and international considerations. Pedagogically, entrepreneurial competencies align with constructivist and sociocultural theories of learning, which emphasize knowledge construction through active engagement, collaboration, and reflection. By designing tasks that require iteration, failure, reflection, and refinement, teachers cultivate resilience and metacognitive awareness—core entrepreneurial dispositions (Hadley, 2025). In science education, this shift reframes instruction from asking “What is the law?” to prompting “How might you apply this law to address

a novel real-world problem, and what adjustments would you make if your approach proves ineffective?”

Economically, nations increasingly recognize innovation and entrepreneurship as essential drivers of long-term growth and diversification. Saudi Arabia's Vision 2030 underscores the need to transition toward a knowledge-based economy and empower youth as creators rather than mere consumers of technology and business (Abbes, 2024). Embedding entrepreneurial skills within science education thus represents a strategic reform, aligning classroom practices with national economic goals by preparing students not only to understand science but also to apply it in value-creating ventures, start-ups, and socially oriented innovations.

From environmental and societal perspectives, entrepreneurial skills in the science classroom equip learners to address complex sustainability challenges such as climate change, resource depletion, and pollution. Recent studies in Saudi Arabia highlight the role of entrepreneurial education in preparing youth for green innovation and sustainable business practices (Mabkhot *et al.*, 2024). Science teaching that cultivates entrepreneurial mindsets enables students to identify environmental opportunities, develop prototypes—for example, sustainable energy devices—engage stakeholders, and refine their approaches through iterative processes. In doing so, science education becomes directly linked to the development of sustainable citizenship.

At the legal and international level, entrepreneurship education is increasingly embedded within global educational frameworks. Organizations such as the OECD and UNESCO advocate for entrepreneurship competencies as essential components of lifelong learning, global citizenship, and workforce preparation, extending beyond business disciplines to encompass the broader curriculum (Abbes, 2024). Educational reforms in many countries are now aligning curricula and teacher preparation programs with the creation of entrepreneurial ecosystems within schools. This international momentum underscores that teaching practices fostering entrepreneurial skills are not peripheral but central to contemporary education, intersecting pedagogy, policy, economy, and society.

The connection between science education and entrepreneurial skills is both strong and inherent. Science education is fundamentally inquiry-driven, involving questioning, designing investigations, analyzing results, and reflecting on findings. These processes closely parallel entrepreneurial practices such as opportunity recognition, experimentation, prototyping, and reflective evaluation. When students

engage in real-world investigations and design-based tasks—for instance, developing a device to address a local environmental challenge—they practice entrepreneurial thinking: identifying opportunities, formulating hypotheses, testing and refining ideas, and presenting viable solutions (Hadley, 2025). Thus, entrepreneurship pedagogy in science should be regarded not as an “add-on” but as a natural extension of effective science teaching.

Science teachers who integrate entrepreneurial tasks—such as developing prototypes, collaborating with industry partners, pitching ideas, and iterating designs—create environments where scientific literacy and entrepreneurial competence are cultivated simultaneously. This dual development enhances student motivation, deepens conceptual understanding, and better equips learners for the demands of the twenty-first-century workforce (Hadley, 2025; Abbes, 2024). In the Saudi context, examining teaching practices that foster entrepreneurial skills is therefore both timely and necessary.

The importance of developing entrepreneurial teaching practices can be understood at multiple levels. For science teachers, strengthening these practices facilitates a pedagogical shift from traditional, transmission-based instruction to student-centered, innovation-oriented learning environments. Teachers trained in entrepreneurial approaches are better positioned to scaffold inquiry, promote learner autonomy, integrate real-world problem-solving, and support reflective refinement. For students, such practices cultivate creativity, initiative, problem-solving, collaboration, and resilience—attributes that enhance both scientific learning and entrepreneurial readiness. At the institutional level, embedding entrepreneurial teaching practices contributes to curricular relevance, institutional competitiveness, and alignment with national strategic priorities such as Saudi Vision 2030. Within the Saudi educational system more broadly, empowering science teachers to adopt entrepreneurial approaches supports ongoing reform efforts aimed at equipping youth with the competencies required for emerging industries, venture creation, and active participation in innovation ecosystems. Given these multi-level implications, the development and evaluation of entrepreneurial teaching practices among science teachers is both timely and essential.

Over the past five years, empirical research has increasingly explored the relationship between teaching practices and entrepreneurial skill development. Hadley (2025) introduced a comprehensive framework of six key practices—

authentic problem-solving, opportunity recognition, iterative experimentation, learner autonomy, stakeholder engagement, and reflective practice—demonstrating how classrooms across diverse curricular areas, including science, can foster entrepreneurial mindsets. Similarly, Sila Kaya-Capocci, Pabuccu-Akis, and Orhan-Ozteber (2025) investigated the enhancement of high school students’ entrepreneurial skills within STEM education in Turkey through three entrepreneurship-based STEM activities emphasizing problem-solving and self-control. Quantitative findings revealed no significant overall differences, though improvements were noted in subscales related to behavioral planning and emotional control. Qualitative results indicated that students became more proactive in addressing problems and connecting scientific concepts to real-life contexts, underscoring the value of integrating social and green entrepreneurship to enrich STEM learning.

Digón-Arrob et al. (2025) compared the impact of entrepreneurial training in secondary education between students in Spain and the United States. Their findings indicated that entrepreneurship education positively influenced students’ entrepreneurial interest in both contexts, particularly when programs incorporated financial literacy and experiential teaching methods. The authors further emphasized the importance of longitudinal research to examine how school-based learning contributes to students’ future entrepreneurial engagement. In the Saudi context, Abbes (2024) investigated how entrepreneurship education—encompassing content, pedagogy, and environment—shapes students’ entrepreneurial intentions, finding that interactive teaching methods and supportive environments significantly enhance those intentions. Similarly, Aldaaja et al. (2025) demonstrated that university and government support play a critical role in shaping students’ entrepreneurial attitudes and intentions, underscoring the importance of the broader educational ecosystem in fostering entrepreneurial competence. Mabkhot et al. (2024) highlighted the intersection of sustainability and entrepreneurship among Saudi youth, further situating entrepreneurial education within the Kingdom’s evolving educational landscape. While much of this literature is situated in business or higher-education contexts, its extension to science teachers remains limited, revealing a clear gap. The present study addresses this gap by focusing specifically on science teachers in Saudi secondary schools and evaluating how their teaching practices foster entrepreneurial skills.

In summary, teaching practices that cultivate entrepreneurial skills represent an educational

imperative that is pedagogically robust, economically strategic, socially responsive, and internationally aligned. Because science instruction inherently emphasizes inquiry, problem-solving, and investigation, the potential for embedding entrepreneurial skill development is considerable. Given the urgency of Saudi Arabia's Vision 2030 agenda and the relative scarcity of research on science-teacher practices, this study—*Teaching Practices that Foster Entrepreneurial Skills among Science Teachers: An Evaluative Study in the Saudi Context*—is both timely and necessary. It seeks to provide evidence-based insights into how science teachers enact entrepreneurial pedagogies and to inform teacher education, policy, curriculum, and practice.

2. PROBLEM OF THE RESEARCH

In the context of global transitions toward knowledge-based economies and innovation-driven labor markets, education systems are increasingly expected to move beyond the transmission of disciplinary knowledge to actively cultivate entrepreneurial capacities among learners. In Saudi Arabia, under the strategic framework of Vision 2030, there is a strong national emphasis on youth entrepreneurship, innovation, and the transformation of education to align with future workforce demands. Within this agenda, science education at the secondary level holds particular significance: science teachers are expected not only to deliver instruction in physics, chemistry, and biology, but also to adopt pedagogical approaches that foster initiative, creativity, collaboration, and opportunity recognition among students. Despite these expectations, there remains limited evaluative evidence regarding the extent to which Saudi science teachers employ teaching practices designed to nurture entrepreneurial skills—and even less understanding of how such practices are enacted within the distinctive cultural, curricular, and institutional context of Saudi secondary education.

Over the past five years, multiple policy documents and international conference recommendations have underscored the importance of assessing teachers' entrepreneurial teaching practices. For instance, UNESCO's *Global Report on Entrepreneurship Education* (2023) called for systematic evaluation of teaching methodologies that support entrepreneurial competencies across subject domains. Similarly, delegates at the *International Conference on Entrepreneurship Education* (2023) committed to benchmarking teacher practices and integrating metrics that capture entrepreneurial-oriented pedagogy within national education systems. At the national level, Saudi

Arabia's Ministry of Education issued a directive in 2024 promoting "entrepreneurial literacies" in science and vocational curricula, emphasizing the need for regular audits of teacher practices and alignment with entrepreneurial skill frameworks. Collectively, these recommendations highlight a persistent need to evaluate how teaching practices support entrepreneurial skills and reveal a gap in implementation research.

Recent empirical studies confirm that this gap is particularly pronounced in science education. A thematic review by Deveci and Çepni (2017) concluded that although interest in entrepreneurial pedagogy within STEM has grown, evaluation of actual teacher practices remains scarce and unevenly distributed. In Oman, Al Jufaili and Shahat (2023) reported that science teachers perceived a low level of entrepreneurial project integration and expressed a need for further training in entrepreneurial strategies. Castillo and Estremera (2023) examined business-education teachers and demonstrated how instructional methods shaped students' entrepreneurial skills, while noting the absence of comparable evaluative research in science education. Moreover, Gracia-Zomeño *et al.* (2025) identified barriers to teaching entrepreneurial competencies, including lack of clarity and institutional support for teachers attempting to implement entrepreneurial pedagogy. Taken together, these findings underscore that while policy discourse strongly emphasizes entrepreneurial skill development, its translation into science-teacher practice remains underexplored—particularly within the Saudi context.

Field visits to Saudi secondary science classrooms provide further compelling insights. Classroom observations conducted in 2024 revealed that instruction was predominantly lecture-based, with few opportunities for open-ended problem-solving, prototyping, or student-centered entrepreneurial activities. Teachers largely adhered to textbook-driven experiments rather than encouraging students to design solutions, identify opportunities, or reflect on entrepreneurial outcomes. Interviews with science teachers reinforced these findings, with many citing lacks of training, rigid curricula, and time constraints as key barriers to adopting entrepreneurial teaching practices. These observations underscore the urgent need to evaluate the current state of science teaching practices and to assess the extent to which they foster entrepreneurial skills.

In summary, while both international and national educational policies strongly emphasize the integration and continuous evaluation of entrepreneurial pedagogy—and despite growing recognition of

entrepreneurship education as essential for preparing learners in a knowledge-based economy – empirical evidence remains insufficient regarding how Saudi science teachers translate these expectations into classroom practice. The limited research available points to fragmented and inconsistent implementation of pedagogical approaches that nurture entrepreneurial skills within science instruction. This gap highlights the necessity of conducting an in-depth evaluative study to determine the current status of entrepreneurial teaching practices among Saudi science teachers and to generate evidence-based insights that can inform professional development, curriculum design, and educational policy reform.

3. RESEARCH QUESTIONS

This study was guided by the following main and subsidiary research questions:

- 3.1. What is the general level of teaching practices that foster entrepreneurial skills among secondary science teachers in Saudi Arabia?
- 3.2. What is the level of each dimension of entrepreneurial teaching practices, specifically: Creative Thinking and Innovation, Planning and Project Management, Problem-Solving and Decision-Making, Marketing and Communication, Leadership and Teamwork, Strategic Thinking, Research and Development, and Sustainability and Social Responsibility?
- 3.3. Are there statistically significant differences in the level of entrepreneurial teaching practices attributable to selected demographic variables, namely: Gender, Enrolled program, Self-reported technology proficiency, School level taught, and Age?

4. RESEARCH OBJECTIVES

The primary objectives of this study were to:

- 4.1. Determine the general level of teaching practices employed by science teachers to foster entrepreneurial skills among secondary students in Saudi Arabia.
- 4.2. Identify the degree of implementation across the eight dimensions of entrepreneurial teaching practices: Creative Thinking and Innovation, Planning and Project Management, Problem-Solving and Decision-Making, Marketing and Communication, Leadership and Teamwork, Strategic Thinking, Research and Development, and Sustainability and Social Responsibility.
- 4.3. Investigate whether key demographic variables (gender, enrolled program, self-reported technology proficiency, school level taught, and age) significantly influence science

teachers' self-reported entrepreneurial teaching practices.

- 4.4. Provide evidence-based recommendations for integrating and enhancing entrepreneurial education within science teacher preparation and professional development programs in the Saudi context.

5. RESEARCH HYPOTHESES

The study tested the following hypotheses:

- **H1:** The overall level of teaching practices that foster entrepreneurial skills among science teachers in Saudi Arabia is moderate.
- **H2:** There are no statistically significant differences in the mean scores of entrepreneurial teaching practices among science teachers attributable to demographic variables, specifically gender, enrolled program, self-reported technology proficiency, school level taught, and age.

6. RESEARCH IMPORTANCE

This study makes several significant contributions to the fields of education, policy, and professional practice, particularly within the Saudi context.

6.1. Theoretical Significance: The research provides an empirical and quantitative evaluation of teaching practices that foster entrepreneurial skills, thereby enriching the limited body of literature on entrepreneurship education within science curricula in Saudi Arabia. It advances theoretical understanding by offering measurable insights into how entrepreneurial pedagogy is operationalized in science classrooms.

6.2. Practical and Curricular Significance: The findings deliver diagnostic data essential for educational institutions. By identifying current strengths (e.g., leadership and teamwork) and weaknesses (e.g., marketing and communication) in teaching practices, the study informs the design of targeted intervention programs and revisions to science teacher preparation curricula. The results also highlight the urgent need for professional development initiatives that focus on specific entrepreneurial dimensions and the integration of technology-based pedagogies, enabling educational authorities to design effective in-service training programs that address competency gaps.

6.3. Policy Significance: The study provides evidence-based recommendations for policymakers regarding the integration of entrepreneurial competencies into the national

education strategy. By evaluating current practices, the research directly supports the objectives of Saudi Vision 2030, which emphasizes fostering innovation, strengthening the knowledge-based economy, and equipping future generations with essential 21st-century skills.

7. RESEARCH LIMITATIONS

The findings and generalizability of this study are subject to several limitations:

- 7.1. The study was confined to science teachers enrolled in graduate programs at King Khalid University. As such, the results may not be fully representative of all science teachers across Saudi Arabia.
- 7.2. A self-report scale was employed within a descriptive quantitative design. While this approach is valuable for capturing perceptions, it is inherently subject to social desirability bias, whereby participants may over-report favorable practices.
- 7.3. The study focused exclusively on eight dimensions of entrepreneurial teaching practices. Consequently, the findings may not encompass the full range of entrepreneurial skills that could be integrated into science instruction.
- 7.4. Data were collected during the first semester of the 2025/2026 academic year, providing a

snapshot of practices at a single point in time. The results therefore reflect conditions specific to that period and may not account for subsequent policy changes or rapid advancements in technology adoption.

8. RESEARCH METHODOLOGY

This study adopted a descriptive quantitative methodology to address the research questions. Data were collected using a validated 48-item Likert-scale questionnaire designed to measure the extent to which science teachers employ teaching practices that foster entrepreneurial skills. Descriptive statistics (means and standard deviations) were used to determine the overall level of entrepreneurial teaching practices. Inferential statistical tests, including independent samples t-tests and Analysis of Variance (ANOVA), were conducted to examine potential differences across demographic and professional variables.

9. RESEARCH SAMPLE

The research sample comprised 201 male and female science teachers enrolled in graduate programs at the College of Education, King Khalid University, during the first semester of the 2025/2026 academic year. Detailed demographic information of the participants is presented in Table 1, including variables such as gender, age, enrolled program, school level taught, and self-reported technology proficiency.

Table 1: Description of the Demographic Characteristics of the Sample.

Variables	Sub Variables	N	Percentage
Gender	Male	106	52.74%
	Female	95	47.26%
Enrolled Program	Master's	94	46.77%
	Doctorate's	107	53.23%
Self-Reported Technology Usage Level	Moderate	110	54.73%
	High	91	45.27%
School Level Taught	Elementary	58	28.86%
	Intermediate	32	15.92%
	Secondary	48	23.88%
Age	Out of class now	63	31.34%
	Less than 30 years old	40	19.90%
	30-40 years old	75	37.31%
	More than 40 years old	86	42.79%
	Total	201	100%

Table 1 illustrates the demographic profile of the study participants. The distribution by gender was relatively balanced, with males slightly outnumbering females. In terms of academic programs, doctoral students represented a marginal majority compared to master's students. Regarding technology proficiency, more than half of the teachers reported a moderate level of use, while the remainder indicated high proficiency.

When considering the school level taught, the largest proportion of participants were currently not

teaching in classrooms, followed by those at the elementary level, with smaller groups teaching at the secondary and intermediate levels. Age distribution showed that most participants were over 40 years old, while a considerable portion fell within the 30-40 age range, and a smaller group was under 30.

Overall, the demographic characteristics reflect a diverse and well-balanced sample, encompassing variation across gender, academic programs, technology use, teaching levels, and age groups.

10. RESEARCH TOOL

10.1. Description of the Research Tool

An evaluative scale was developed to measure the extent to which science teachers employ teaching practices that foster entrepreneurial skills. The instrument initially comprised 48 items, with six items assigned to each of the eight core dimensions of entrepreneurial pedagogy: Creative Thinking and Innovation, Planning and Project Management, Problem-Solving and Decision-Making, Marketing and Communication, Leadership and Teamwork, Strategic Thinking, Research and Development, and Sustainability and Social Responsibility. These dimensions were derived from a synthesis of recent scholarship highlighting the multifaceted nature of entrepreneurial teaching practices and their essential role in cultivating student competencies (Hadley, 2025; Abbes, 2024; Aldaaja et al., 2025; Zarei, 2020).

Previous studies have demonstrated that entrepreneurial teaching practices can be reliably assessed through structured self-report instruments that capture both cognitive and behavioral aspects of pedagogy (Deveci & Çepni, 2017; Gracia-Zomeño et al., 2025a, 2025b). In line with this evidence, all items were formulated as positively worded self-report statements designed to reflect teachers' engagement in practices

aligned with entrepreneurial skill development. Responses were collected using a three-point Likert scale—Usually (3), Sometimes (2), Rarely (1)—consistent with validated approaches for measuring the frequency and implementation of entrepreneurial teaching behaviors in classroom contexts (Abbes, 2024; Hadley, 2025).

10.2. Psychometric Properties

A. Validity

Face validity was established through expert review. The instrument was evaluated by a panel of 11 specialists with expertise in psychology, educational technology, and curriculum and instruction. The panel unanimously confirmed the clarity, relevance, and comprehensiveness of the items, thereby affirming the instrument's appropriateness for assessing entrepreneurial teaching practices among science teachers.

B. Internal Consistency

Internal consistency was examined following administration of the scale to a sample of 202 science teachers. Pearson correlation coefficients were calculated between each item and both its corresponding dimension total score and the overall scale total score. These results are presented in Table 2.

Table 2: Pearson Correlation Coefficients Between Individual Items and Their Dimension and Overall Scale (N = 201).

Items number	Correlation with its dimension	Correlation with overall Scale	Items number	Correlation with its dimension	Correlation with overall Scale
1	0.599**	0.467**	25	0.838**	0.678**
2	0.671**	0.486**	26	0.836**	0.632**
3	0.755**	0.642**	27	0.816**	0.628**
4	0.746**	0.552**	28	0.836**	0.645**
5	0.802**	0.685**	29	0.852**	0.716**
6	0.681**	0.605**	30	0.841**	0.677**
7	0.808**	0.720**	31	0.803**	0.716**
8	0.738**	0.675**	32	0.836**	0.650**
9	0.708**	0.637**	33	0.888**	0.734**
10	0.801**	0.639**	34	0.798**	0.762**
11	0.841**	0.691**	35	0.904**	0.782**
12	0.808**	0.739**	36	0.845**	0.743**
13	0.764**	0.675**	37	0.858**	0.785**
14	0.793**	0.650**	38	0.838**	0.759**
15	0.801**	0.689**	39	0.880**	0.797**
16	0.831**	0.757**	40	0.851**	0.785**
17	0.828**	0.734**	41	0.838**	0.815**
18	0.747**	0.637**	42	0.833**	0.724**
19	0.800**	0.685**	43	0.833**	0.730**
20	0.834**	0.758**	44	0.845**	0.684**
21	0.841**	0.669**	45	0.852**	0.680**
22	0.870**	0.744**	46	0.826**	0.657**
23	0.848**	0.764**	47	0.848**	0.723**
24	0.799**	0.775**	48	0.823**	0.623**

** Correlation is significant at the 0.01 level (2-tailed).

The results presented in Table 2 demonstrate the strong internal consistency and reliability of the 48-item scale. Pearson correlation coefficients between individual items and their corresponding dimension total scores ranged from 0.599 to 0.904, while correlations with the overall scale total score ranged from 0.467 to 0.815. All coefficients were statistically significant at the 0.01 level ($p < 0.01$). These findings indicate that each item is highly homogeneous with its respective dimension and contributes meaningfully to the measurement of the overall construct of entrepreneurial teaching practices. The consistently high, positive correlations across all items confirm the instrument's internal validity and reliability,

suggesting that the scale is robust for its intended purpose and does not require item deletion.

C. Inter-Dimension Correlations

To further examine the construct validity of the instrument, Table 3 presents the Pearson correlation coefficients among the eight dimensions of entrepreneurial teaching practices, as well as their correlations with the overall scale total score. This analysis provides insight into the degree of interrelatedness among the dimensions and the extent to which each dimension contributes to the overall construct.

Table 3: Pearson Correlation Coefficients Among the Eight Dimensions of Entrepreneurial Teaching Practices, As Well As Their Correlations with the Overall Scale Total Score (N = 201).

Dimensions	Dimension1	Dimension2	Dimension3	Dimension4	Dimension5	Dimension6	Dimension7	Dimension8	Overall scale
Dimension1	1	0.747**	0.666**	0.697**	0.542**	0.665**	0.693**	0.563**	0.808**
Dimension2	0.747**	1	0.735**	0.788**	0.593**	0.752**	0.719**	0.587**	0.868**
Dimension3	0.666**	0.735**	1	0.713**	0.722**	0.634**	0.776**	0.722**	0.869**
Dimension4	0.697**	0.788**	0.713**	1	0.573**	0.784**	0.770**	0.603**	0.879**
Dimension5	0.542**	0.593**	0.722**	0.573**	1	0.581**	0.717**	0.723**	0.793**
Dimension6	0.665**	0.752**	0.634**	0.784**	0.581**	1	0.779**	0.617**	0.863**
Dimension7	0.693**	0.719**	0.776**	0.770**	0.717**	0.779**	1	0.767**	0.916**
Dimension8	0.563**	0.587**	0.722**	0.603**	0.723**	0.617**	0.767**	1	0.816**
Overall scale	0.808**	0.868**	0.869**	0.879**	0.793**	0.863**	0.916**	0.816**	1

** Correlation is significant at the 0.01 level (2-tailed).

Table 3 provides strong evidence of the structural integrity and construct validity of the entrepreneurial teaching practices scale. All inter-dimension correlations were positive, statistically significant at the $p < 0.01$ level, and ranged from 0.542 to 0.788. These robust correlations indicate that the eight dimensions are not independent but rather interrelated components of a single, overarching construct – entrepreneurial teaching practices.

Moreover, the correlations between each dimension and the overall scale score were exceptionally high, ranging from 0.793 to 0.916. This strong positive association confirms that each dimension makes a substantial contribution to the

measurement of the overall construct, with Dimension 7 demonstrating the highest shared variance (0.916). Collectively, these findings affirm that the multi-dimensional structure of the scale is both reliable and valid for its intended purpose.

D. Reliability

The reliability of the scale was assessed using two complementary methods: Cronbach's Alpha (α) and the Guttman Split-Half coefficient. The results, presented in Table 4, further confirm the internal consistency and robustness of the instrument.

Table 4: Cronbach's Alpha (A) And the Guttman Split-Half Coefficient of the Scale (N = 201).

Dimensions	No. of items	Cronbach's Alpha (α)	Guttman split-half coefficients
1. Creative Thinking and Innovation Teaching Practices	6	0.801	0.764
2. Planning and Project Management Teaching Practices	6	0.875	0.815
3. Problem-Solving and Decision-Making Teaching Practices	6	0.883	0.870
4. Marketing and Communication Teaching Practices	6	0.911	0.913
5. Leadership and Teamwork Teaching Practices	6	0.914	0.923
6. Strategic Thinking Teaching Practices	6	0.920	0.917
7. Research and Development Teaching Practices	6	0.922	0.893
8. Sustainability and Social Responsibility Teaching Practices	6	0.915	0.899
9. Overall Entrepreneurial Teaching Practices	48	0.977	0.924

Table 4 reports the reliability coefficients of the scale and its eight dimensions, estimated using Cronbach's Alpha (α) and the Guttman split-half

method. The findings demonstrate that all dimensions exhibited high internal consistency, with Cronbach's Alpha values ranging from 0.801 to 0.922 and Guttman

split-half coefficients ranging from 0.764 to 0.923. These values exceed the widely accepted threshold of 0.70 (Nunnally & Bernstein, 1994; Gliem & Gliem, 2003; Tavakol & Dennick, 2011), confirming that the items within each dimension reliably measure the intended construct.

The strongest internal consistency was observed for Teaching Practices that Promote Research and Development Skills ($\alpha = 0.922$), followed closely by Strategic Thinking Skills ($\alpha = 0.920$) and Sustainability and Social Responsibility Skills ($\alpha = 0.915$). Importantly, the overall scale demonstrated excellent reliability ($\alpha = 0.977$; Guttman = 0.924), indicating that the instrument as a whole is highly consistent and dependable for assessing entrepreneurial teaching

practices among science teachers.

11. RESEARCH RESULTS

1. What is the general level of teaching practices that foster entrepreneurial skills among secondary science teachers in Saudi Arabia?

To answer this research question, descriptive statistical analyses were conducted, including the calculation of arithmetic means, standard deviations, and percentages based on participants' responses to each item of the scale. Table 5 summarizes the findings, presenting both the overall level of teaching practices that foster entrepreneurial skills among science teachers in the study sample, as well as the results for each of the eight individual dimensions.

Table 5: Descriptive Statistics for the Overall Level of Entrepreneurial Teaching Practices and Their Eight Dimensions (N=201).

No	Dimensions	Mean	SD	Percentage	Level	Rank
1	Creative Thinking and Innovation Teaching Practices	2.439	0.446	81.29%	High	5
2	Planning And Project Management Teaching Practices	2.386	0.537	79.52%	High	6
3	Problem-Solving And Decision-Making Teaching Practices	2.534	0.498	84.47%	High	3
4	Marketing And Communication Teaching Practices	2.247	0.644	74.90%	Moderate	8
5	Leadership And Teamwork Teaching Practices	2.635	0.508	87.84%	High	1
6	Strategic Thinking Teaching Practices	2.250	0.636	75.01%	Moderate	7
7	Research And Development Teaching Practices	2.443	0.596	81.43%	High	4
8	Sustainability And Social Responsibility Teaching Practices	2.551	0.543	85.02%	High	2
	Overall Entrepreneurial Teaching Practices	2.436	0.471	81.18%	High	

Table 5 shows that the overall level of teaching practices fostering entrepreneurial skills among science teachers was high ($M = 2.436$, 81.18%). This finding indicates that, in general, teachers in the sample employ pedagogical strategies supportive of developing entrepreneurial competencies in their students. The relatively low standard deviation ($SD = 0.471$) further suggests a moderate level of agreement among respondents regarding the frequency of these practices. A closer examination of the eight dimensions reveals clear areas of strength alongside dimensions requiring targeted improvement. The highest levels of implementation were observed in Leadership and Teamwork ($M = 2.635$, 87.84%) and Sustainability and Social Responsibility ($M = 2.551$, 85.02%), reflecting teachers' strong emphasis on collaboration, leadership roles, and awareness of societal and environmental impact within science instruction.

By contrast, two dimensions were rated at a moderate level, highlighting critical gaps. Marketing and Communication ($M = 2.247$, 74.90%) ranked lowest, suggesting limited integration of practices related to presenting project value, communication skills, and market awareness. Similarly, Strategic Thinking ($M = 2.250$, 75.01%) ranked seventh, pointing to insufficient emphasis on long-term planning, foresight, and risk analysis.

The remaining five dimensions—including Creative Thinking, Problem-Solving, and Research and Development—were all assessed at a high level of implementation. Taken together, these results underscore the importance of targeted professional development initiatives aimed at strengthening teachers' practices in the communicative and strategic dimensions of entrepreneurship, thereby ensuring a more balanced integration of entrepreneurial skills across science education.

2. What is the level of each dimension of entrepreneurial teaching practices, specifically: Creative Thinking and Innovation, Planning and Project Management, Problem-Solving and Decision-Making, Marketing and Communication, Leadership and Teamwork, Strategic Thinking, Research and Development, and Sustainability and Social Responsibility?

To examine this research question, descriptive statistical analyses were conducted, including the calculation of arithmetic means, standard deviations, and percentages based on participants' responses to each item of the scale.

▪ Results For Dimension 1: Creative Thinking and Innovation

Table 6: Descriptive Statistics for Creative Thinking and Innovation Teaching Practices Among Science Teachers (N = 201).

No.	Dimensions	Mean	SD	Percentage	Level	Rank
1	I encourage students to use scientific knowledge to develop new solutions or products.	2.746	0.490	91.54%	High	1
2	I design instructional activities that stimulate students to think outside the box when applying science in entrepreneurial fields.	2.512	0.521	83.75%	High	3
3	I teach students how to formulate innovative ideas based on users' or market needs.	2.443	0.623	81.43%	High	4
4	I encourage students to develop, test, and refine prototypes.	2.030	0.799	67.66%	Moderate	6
5	I conduct activities that help students identify entrepreneurial opportunities in the market or community.	2.289	0.697	76.29%	Moderate	5
6	I teach students how to analyze scientific phenomena and ideas logically and critically.	2.612	0.599	87.06%	High	2
	Overall Creative Thinking and Innovation Teaching Practices	2.439	0.446	81.29%	High	

Table 6 presents the descriptive statistics for the first dimension of the scale, Creative Thinking and Innovation Teaching Practices, which achieved an overall high level (M = 2.439, 81.29%). This result indicates that science teachers place strong emphasis on methods that cultivate creative thinking and encourage innovative approaches among their students. A closer analysis of the individual items within this dimension reveals both areas of strength and notable gaps. The highest-rated practice was encouraging students to apply scientific knowledge to develop new solutions or products (M = 2.746, 91.54%), reflecting a clear focus on applied science and tangible outputs. Similarly, practices related to logical and critical analysis of scientific phenomena (M = 2.612, 87.06%) and designing activities that stimulate unconventional thinking (M = 2.512, 83.75%) were also implemented at a high level. Collectively, these findings suggest that teachers are

effective in fostering scientific analysis and general creative application.

However, the results also highlight weaker areas in practical, market-oriented innovation. The lowest-rated item was encouraging students to develop, test, and refine prototypes (M = 2.030, 67.66%), which reached only a moderate level. Likewise, conducting activities that help students identify entrepreneurial opportunities in the market or community (M = 2.289, 76.29%) was also assessed at a moderate level. While teachers excel in promoting knowledge application, these lower scores reveal a gap in implementing hands-on, iterative development and in linking scientific ideas directly to market needs and opportunities. This suggests a critical area for targeted pedagogical enhancement.

▪ Results for Dimension 2: Planning and Project Management

Table 7: Descriptive Statistics for the Second Dimension of the Scale, Planning and Project Management Teaching Practices, Based on the Responses of Science Teachers (N = 201).

No.	Dimensions	Mean	SD	Percentage	Level	Rank
1	I encourage students to prepare business plans that include project goals and implementation steps.	2.388	0.685	79.60%	High	3
2	I guide students in managing their time effectively and setting clear task priorities within project work.	2.677	0.583	89.22%	High	1
3	I encourage students to utilize scientific and material resources efficiently to maximize the quality and outcomes of their projects.	2.617	0.581	87.23%	High	2
4	I design instructional activities that help students prepare project budgets and attract funding.	2.159	0.751	71.97%	Moderate	5
5	I teach students how to develop marketing strategies for their projects.	2.100	0.762	69.98%	Moderate	6
6	I encourage students to evaluate and continuously improve their project performance.	2.373	0.725	79.10%	High	4
	Overall planning and project management teaching practices	2.386	0.537	79.52%	High	

Table 7 presents the descriptive statistics for the dimension of Planning and Project Management Teaching Practices, which reached an overall high level (M = 2.386, 79.52%). This result indicates that science teachers generally emphasize the integration of skills necessary for organizing and executing projects effectively within their instructional practices. The relatively low standard deviation (SD = 0.537) further reflects a consistent application of these practices across the sample.

A closer look at the individual items within this dimension reveals strong performance in internal management skills, contrasted with notable weaknesses in financial and marketing aspects. The highest-rated practice was teaching students how to manage time and set task priorities (M = 2.677, 89.22%), underscoring the importance teachers place on time management and organizational skills. This was followed by encouraging students to use scientific and material resources efficiently (M = 2.617, 87.23%),

highlighting effective resource utilization. Practices related to preparing business plans and promoting continuous project improvement also achieved a high level of implementation.

By contrast, the financial and commercial components emerged as critical gaps. Two items were rated at only a moderate level: designing activities that help students prepare project budgets and attract funding ($M = 2.159$, 71.97%) and teaching students how to develop marketing strategies for their projects ($M = 2.100$, 69.98%). These lower scores point to a clear

deficiency in preparing students for the economic realities of project execution, particularly in securing funding and developing market outreach. Despite strong foundations in time and resource management, these gaps suggest an urgent need for professional development initiatives focused on strengthening teachers' capacity to integrate financial and marketing dimensions into project-based learning.

▪ Results For Dimension 3: Problem-Solving and Decision-Making

Table 8: Descriptive Statistics for the Third Dimension of the Scale, Problem-Solving and Decision-Making Teaching Practices, Based on the Responses of Science Teachers (N = 201).

No.	Dimensions	Mean	SD	Percentage	Level	Rank
1	I encourage students to use scientific knowledge to propose innovative solutions to real-world problems.	2.647	0.574	88.23%	High	1
2	I teach students how to analyze data and information to make informed decisions.	2.418	0.674	80.60%	High	6
3	I design activities that help students develop alternative approaches to deal with challenges and obstacles.	2.527	0.625	84.25%	High	3
4	I encourage students to assess risks and devise response plans.	2.478	0.679	82.59%	High	5
5	I teach students how to use scientific tools to solve complex problems.	2.522	0.617	84.08%	High	4
6	I design instructional activities that enhance students' critical thinking skills.	2.612	0.590	87.06%	High	2
	Overall Problem-Solving and Decision-Making Teaching Practices	2.534	0.498	84.47%	High	

Table 8 presents the descriptive statistics for Problem-Solving and Decision-Making Teaching Practices, which reached an overall high level ($M = 2.534$, 84.47%). This result demonstrates that science teachers consistently adopt pedagogical strategies designed to equip students with the skills needed to analyze challenges and develop informed solutions. As the third highest-scoring dimension in the scale, it underscores the central role of problem-solving and decision-making in contemporary science instruction. A closer examination of the individual items reveals a strong and relatively consistent application across all aspects, with particular emphasis on applied and critical thinking. The highest-rated practice was encouraging students to use scientific knowledge to propose innovative solutions to real-world problems ($M = 2.647$, 88.23%), highlighting a clear focus on practical application and societal relevance. This was followed by designing instructional activities that enhance

students' critical thinking skills ($M = 2.612$, 87.06%), confirming teachers' commitment to fostering analytical thinking.

All six items within this dimension were rated at a high level. The lowest, though still strong, was teaching students how to analyze data and information to make informed decisions ($M = 2.418$, 80.60%). Other practices, such as designing activities that encourage alternative approaches to challenges and guiding students to assess risks and develop response plans, also achieved high mean scores. Collectively, these results suggest that problem-solving and decision-making are firmly embedded in science teachers' instructional repertoire, providing students with a solid foundation of analytical skills essential for future entrepreneurial endeavors.

▪ Results For Dimension 4: Marketing and Communication

Table 9: Descriptive Statistics for the Fourth Dimension of the Scale, Marketing and Communication Teaching Practices, Based on the Responses of Science Teachers (N = 201).

No.	Dimensions	Mean	SD	Percentage	Level	Rank
1	I teach students how to promote products or services using innovative marketing approaches.	2.129	0.783	70.98%	Moderate	5
2	I encourage students to deliver clear and persuasive presentations about their ideas and projects.	2.383	0.747	79.44%	High	1
3	I conduct activities that help students build professional networks with experts and entrepreneurs.	2.114	0.795	70.48%	Moderate	6
4	I teach students how to use social media platforms for effective marketing.	2.234	0.794	74.46%	Moderate	4
5	I encourage students to prepare reports and presentations that demonstrate project progress.	2.259	0.795	75.29%	Moderate	3
6	I design instructional activities that enhance students' persuasion skills.	2.363	0.730	78.77%	High	2
	Overall Marketing and Communication Teaching Practices	2.247	0.644	74.90%	Moderate	

Table 9 presents the descriptive statistics for Marketing and Communication Teaching Practices, which were assessed at an overall moderate level ($M = 2.247$, 74.90%). Notably, this dimension ranked lowest among all eight dimensions of the entrepreneurial teaching scale, highlighting a significant gap in the pedagogical practices of science teachers. The relatively high standard deviation ($SD = 0.644$) further indicates greater variability in the application of these practices compared to other dimensions.

A closer examination of the individual items confirms that Marketing and Communication remains an underdeveloped area, particularly in relation to external engagement. While two items achieved a high level of implementation, the remaining four were rated only at a moderate level. The highest-scoring practice was encouraging students to deliver clear and persuasive presentations of their ideas and projects ($M = 2.383$, 79.44%), followed by designing activities that strengthen students' persuasion skills ($M = 2.363$, 78.77%). These results suggest that teachers are

relatively more successful in fostering internal presentation and advocacy skills.

By contrast, practices linked to external market engagement were the weakest. The lowest-rated item was conducting activities that help students build professional networks with experts and entrepreneurs ($M = 2.114$, 70.48%), followed closely by teaching students how to promote products or services using innovative marketing approaches ($M = 2.129$, 70.98%). Similarly, teaching students to use social media platforms for effective marketing was also rated at a moderate level. Collectively, these findings underscore that while teachers are able to cultivate basic presentation skills, there is a clear deficiency in practices that connect students to the external environment—such as networking, real-world promotional strategies, and digital marketing tools—which are essential for entrepreneurial success.

▪ *Results For Dimension 5: Leadership and Teamwork*

Table 10: Descriptive Statistics for the Fifth Dimension of the Scale, Leadership and Teamwork Teaching Practices, Based on the Responses of Science Teachers (N = 201).

No.	Dimensions	Mean	SD	Percentage	Level	Rank
1	I encourage students to lead teams effectively and distribute tasks fairly.	2.627	0.629	87.56%	High	4
2	I teach students how to collaborate with teammates to achieve shared goals.	2.682	0.607	89.39%	High	1
3	I design activities that enhance communication and conflict-resolution skills within teams.	2.607	0.608	86.90%	High	5
4	I encourage students to motivate team members to achieve optimal results.	2.672	0.585	89.05%	High	3
5	I teach students how to assess team performance and provide constructive feedback.	2.547	0.647	84.91%	High	6
6	I conduct instructional activities that foster team spirit and collaboration among students.	2.677	0.566	89.22%	High	2
	Overall Leadership and Teamwork Teaching Practices	2.635	0.508	87.84%	High	

Table 10 presents the descriptive statistics for Leadership and Teamwork Teaching Practices, which achieved an overall high level ($M = 2.635$, 87.84%). This result is particularly noteworthy, as this dimension ranked highest among all eight entrepreneurial teaching dimensions, indicating that science teachers are especially effective in embedding collaborative and leadership skills within their pedagogy. The relatively low standard deviation ($SD = 0.508$) further reflects strong consistency and consensus in the application of these practices across the sample.

A closer analysis of the individual items highlights the exceptional strength of this dimension, with all six practices rated at a high level. The highest-scoring items emphasized foundational cooperative skills, such as teaching students how to collaborate with teammates to achieve shared goals ($M = 2.682$, 89.39%) and conducting activities that foster team spirit and collaboration ($M = 2.677$, 89.22%). Similarly, encouraging students to motivate

team members ($M = 2.672$, 89.05%) also received a very high mean score.

Even the lowest-ranked item—teaching students how to assess team performance and provide constructive feedback ($M = 2.547$, 84.91%)—remained at a high level. Other practices, including those related to effective team leadership and conflict resolution, also scored strongly. The consistently high results across all items confirm that science teachers provide a solid foundation in collaborative dynamics, team motivation, and distributed leadership, making this dimension a clear strength within current entrepreneurial teaching practices.

▪ *Results For Dimension 6: Strategic Thinking*

Table 11 presents the descriptive statistics for Strategic Thinking Teaching Practices, which were assessed at an overall moderate level ($M = 2.250$, 75.01%). This outcome reinforces the previously identified gap, as this dimension ranked seventh among the eight entrepreneurial teaching practices.

The moderate level of implementation suggests that teachers are only partially successful in embedding

long-term foresight, market analysis, and strategic planning within their science instruction.

Table 11: Descriptive Statistics for the Sixth Dimension of the Scale, Strategic Thinking Teaching Practices, Based on the Responses of Science Teachers (N = 201).

No.	Dimensions	Mean	SD	Percentage	Level	Rank
1	I encourage students to set long-term goals for their projects.	2.473	0.693	82.42%	High	1
2	I teach students how to analyze markets and identify potential clients.	2.095	0.791	69.82%	Moderate	6
3	I design activities that help students develop risk management strategies.	2.149	0.767	71.64%	Moderate	5
4	I encourage students to study competitors and identify strengths and weaknesses.	2.308	0.738	76.95%	Moderate	1
5	I teach students how to develop strategic plans to achieve sustainable growth.	2.194	0.753	73.13%	Moderate	4
6	I conduct instructional activities that enhance students' strategic planning skills.	2.284	0.764	76.12%	Moderate	2
	Overall Strategic Thinking Teaching Practices	2.250	0.636	75.01%	Moderate	

An item-level analysis reveals a clear disparity between basic project goal-setting and more advanced, market-oriented strategic competencies. The only practice rated at a high level was encouraging students to set long-term goals for their projects (M = 2.473, 82.42%), indicating that teachers effectively promote a basic vision for project continuity. In contrast, the remaining five items were rated at a moderate level, reflecting notable weaknesses in advanced strategic skills.

The lowest scores were observed in practices related to external market navigation. Teaching students how to analyze markets and identify potential clients (M = 2.095, 69.82%) ranked last, followed closely by designing activities that help

students develop risk management strategies (M = 2.149, 71.64%). Similarly, encouraging students to study competitors and identify strengths and weaknesses was also moderately implemented. These findings suggest that while science teachers encourage students to consider the future of their projects, they fall short in equipping them with the essential skills needed to navigate competitive and uncertain external environments—particularly in market analysis, competitor assessment, and proactive risk management.

▪ Results For Dimension 7: Research and Development

Table 12: Descriptive Statistics for the Seventh Dimension of the Scale, Research and Development Teaching Practices, Based on the Responses of Science Teachers (N = 201).

No.	Dimensions	Mean	SD	Percentage	Level	Rank
1	I encourage students to design and conduct scientific experiments to support their projects.	2.448	0.727	81.59%	High	3
2	I teach students how to analyze data and draw conclusions to strengthen their ideas.	2.323	0.742	77.45%	Moderate	6
3	I design activities that help students improve their products based on feedback.	2.418	0.696	80.60%	High	5
4	I encourage students to follow scientific and technological advancements to refine their ideas.	2.488	0.657	82.92%	High	2
5	I teach students how to document their project steps and results scientifically.	2.433	0.726	81.09%	High	4
6	I design instructional activities that promote students' scientific research skills.	2.547	0.663	84.91%	High	1
	Overall Research and Development Teaching Practices	2.443	0.596	81.43%	High	

Table 12 presents the descriptive statistics for Research and Development Teaching Practices, which attained an overall high level (M = 2.443, 81.43%). This result indicates that science teachers effectively integrate foundational research skills into their instruction—skills that are essential for systematic inquiry and iterative improvement, both of which are central to entrepreneurial activity. Notably, this dimension ranked fourth overall among the eight teaching practices. An item-level analysis shows a generally consistent high level of implementation across most practices, reflecting strong integration of scientific methodology. The highest-rated practice was designing instructional activities that promote students' scientific research skills (M = 2.547, 84.91%), followed by encouraging

students to keep pace with scientific and technological advancements to refine their ideas (M = 2.488, 82.92%). These results highlight teachers' commitment to fostering scientific investigation and continuous knowledge updating. Additionally, practices such as encouraging students to design and conduct scientific experiments and teaching them to document project steps and outcomes also scored highly, confirming the robustness of methodological training.

However, the analysis revealed a relative weakness in one critical area: teaching students how to analyze data and draw conclusions to strengthen their ideas (M = 2.323, 77.45%), which was rated at a moderate level and ranked lowest within the dimension. While teachers strongly emphasize

research design and experimentation, these findings suggest comparatively less focus on the analytical stage—extracting insights from data to inform strategic project decisions. This indicates that while inputs such as experimentation and documentation are well established, greater emphasis on data

analysis and inferential reasoning is needed to enhance the rigor and entrepreneurial relevance of student projects.

▪ Results For Dimension 8: Sustainability and Social Responsibility

Table 13. Descriptive Statistics for the Eighth Dimension of the Scale, Sustainability and Social Responsibility Teaching Practices, Based on the Responses of Science Teachers (N = 201).

No.	Dimensions	Mean	SD	Percentage	Level	Rank
1	I encourage students to design projects that emphasize the preservation and sustainable use of natural resources.	2.552	0.655	85.07%	High	4
2	I teach students how to develop scientific solutions that serve the community and improve quality of life.	2.542	0.632	84.74%	High	5
3	I design activities that foster commitment to ethical and scientific values in students' projects.	2.577	0.652	85.90%	High	3
4	I encourage students to minimize waste and optimize the use of available resources.	2.622	0.645	87.40%	High	1
5	I teach students how to design environmentally and economically sustainable projects.	2.398	0.686	79.93%	High	6
6	I conduct instructional activities that enhance students' awareness of social responsibility.	2.612	0.615	87.06%	High	2
	Overall Sustainability and Social Responsibility Teaching Practices	2.551	0.543	85.02%	High	

Table 13 presents the descriptive statistics for Sustainability and Social Responsibility Teaching Practices, which attained an overall high level ($M = 2.551, 85.02\%$). This result is particularly noteworthy, as this dimension ranked second overall among the eight entrepreneurial teaching practices, confirming that science teachers place strong emphasis on embedding ethical, environmental, and social considerations into their pedagogy. The relatively low standard deviation ($SD = 0.543$) further indicates a consistent and uniform commitment to these practices across the sample. An item-level analysis highlights the exceptional strength of this dimension, with all six practices rated at a high level of implementation. The highest-scoring practices focused on resource efficiency and ethical conduct. Specifically, encouraging students to minimize waste and optimize the use of available resources ($M = 2.622, 87.40\%$) ranked first, followed closely by conducting instructional activities that enhance students' awareness of social responsibility ($M = 2.612, 87.06\%$). Similarly, designing activities that foster commitment to ethical and scientific values also achieved a very high mean score. These findings underscore the effectiveness of science teachers in promoting environmental stewardship and ethical awareness.

The lowest-ranked item, though still at a high level, was teaching students how to design environmentally and economically sustainable projects ($M = 2.398, 79.93\%$). While preservation and waste reduction are strongly emphasized, this relatively lower score suggests a reduced focus on formal economic and environmental design principles necessary for comprehensive project sustainability. Nevertheless, the consistently high

scores across all items confirm that science teachers successfully integrate societal and ecological responsibilities into their entrepreneurial teaching practices.

3. Are there statistically significant differences in the level of entrepreneurial teaching practices attributable to selected demographic variables, namely: Gender, Enrolled program, Self-reported technology proficiency, School level taught, and Age?

To address this question, independent samples *t*-tests were employed to examine the influence of gender, academic qualification (enrolled program), and self-reported technology proficiency. Furthermore, one-way ANOVA was conducted to test differences across the school level taught and age groups.

Table 14 presents the results of the independent samples *t*-test conducted to examine the influence of gender on the level of entrepreneurial teaching practices and their eight dimensions. The findings generally suggest that gender does not constitute a statistically significant factor affecting the overall application of these practices.

Specifically, the results show that for the Overall Entrepreneurial Teaching Practices scale, the difference between male ($M = 114.67$) and female ($M = 119.40$) teachers was not statistically significant ($t = -1.486, \text{Sig.} = 0.139$). This indicates that male and female science teachers report similar general levels of implementing pedagogical practices that foster entrepreneurial skills.

The dimension-by-dimension analysis largely corroborates the overall findings, as seven of the eight dimensions revealed no statistically significant differences based on gender, with significance values

consistently exceeding the conventional threshold of $\alpha = 0.05$. For example, no significant differences were observed in Creative Thinking (Sig. = 0.915),

Planning and Project Management (Sig. = 0.217), or Strategic Thinking (Sig. = 0.432).

Table 14: Independent Samples T-Test Results for Differences in the Level of Entrepreneurial Teaching Practices and Their Dimensions Across Gender.

Dimensions	variables	N	M	SD	df	t	Sig. (2-tailed)
Creative Thinking and Innovation Teaching Practices	Male	106	14.65	2.41	199	0.107	0.915
	Female	95	14.61	2.96			
Planning and Project Management Teaching Practices	Male	106	14.05	3.02	199	-1.239	0.217
	Female	95	14.61	3.42			
Problem-Solving and Decision-Making Teaching Practices	Male	106	14.87	2.87	199	-1.691	0.092
	Female	95	15.58	3.10			
Marketing and Communication Teaching Practices	Male	106	13.25	3.77	199	-0.919	0.359
	Female	95	13.75	3.98			
Leadership and Teamwork Teaching Practices	Male	106	15.34	3.15	199	-2.344	0.020
	Female	95	16.34	2.85			
Strategic Thinking Teaching Practices	Male	106	13.30	3.45	199	-0.787	0.432
	Female	95	13.73	4.19			
Research and Development Teaching Practices	Male	106	14.28	3.53	199	-1.571	0.118
	Female	95	15.07	3.60			
Sustainability and Social Responsibility Teaching Practices	Male	106	14.93	3.15	199	-1.708	0.089
	Female	95	15.72	3.34			
Overall Entrepreneurial Teaching Practices	Male	106	114.67	21.37	199	-1.486	0.139
	Female	95	119.40	23.76			

However, a statistically significant difference was observed only in the Leadership and Teamwork Teaching Practices dimension ($t = -2.344$, Sig. = 0.020). This difference was in favor of female teachers ($M = 16.34$) compared to male teachers ($M = 15.34$), suggesting that female science teachers report integrating leadership and collaboration skills into

their teaching more frequently than their male counterparts. Despite this isolated difference, the pervasive absence of significant gender-based differences across the overall scale and the majority of its dimensions leads to the acceptance of the null hypothesis regarding gender's lack of influence on entrepreneurial teaching practices.

Table 15: Independent Samples T-Test Results for Differences in the Level of Entrepreneurial Teaching Practices and Their Dimensions Across Enrolled Program.

Dimensions	variables	N	M	SD	df	t	Sig. (2-tailed)
Creative Thinking and Innovation Teaching Practices	Master's	94	14.89	2.48	199	1.302	0.194
	Doctorate's	107	14.40	2.83			
Planning and Project Management Teaching Practices	Master's	94	14.74	2.99	199	1.788	0.075
	Doctorate's	107	13.93	3.38			
Problem-Solving and Decision-Making Teaching Practices	Master's	94	15.49	3.13	199	1.270	0.206
	Doctorate's	107	14.95	2.85			
Marketing and Communication Teaching Practices	Master's	94	14.12	3.57	199	2.201	0.029
	Doctorate's	107	12.93	4.05			
Leadership and Teamwork Teaching Practices	Master's	94	16.35	2.72	199	2.384	0.018
	Doctorate's	107	15.34	3.24			
Strategic Thinking Teaching Practices	Master's	94	14.36	3.61	199	3.056	0.003
	Doctorate's	107	12.75	3.84			
Research and Development Teaching Practices	Master's	94	15.37	3.13	199	2.701	0.008
	Doctorate's	107	14.03	3.83			
Sustainability and Social Responsibility Teaching Practices	Master's	94	15.86	2.96	199	2.302	0.022
	Doctorate's	107	14.81	3.43			
Overall Entrepreneurial Teaching Practices	Master's	94	121.19	20.69	199	2.555	0.011
	Doctorate's	107	113.14	23.61			

A statistically significant difference was identified for the overall Entrepreneurial Teaching Practices scale ($t = 2.555$, Sig. = 0.011). This difference favored teachers enrolled in the master's program ($M =$

121.19) compared to those in the doctoral program ($M = 113.14$). These results suggest that teachers pursuing a master's degree report employing entrepreneurial teaching practices significantly more

frequently than their doctoral counterparts.

The dimension-by-dimension analysis further reinforces this overall trend. Five of the eight dimensions demonstrated statistically significant differences (Sig. < 0.05) based on academic program, with all differences consistently favoring the master's group. Significant differences were observed in Strategic Thinking (Sig. = 0.003), Research and Development (Sig. = 0.008), Leadership and Teamwork (Sig. = 0.018), Sustainability and Social Responsibility (Sig. = 0.022), and Marketing and Communication (Sig. = 0.029). The higher mean scores reported by the master's group across these dimensions indicate stronger engagement in complex areas such as strategic foresight, research integration, and external communication.

The remaining three dimensions – Creative

Thinking (Sig. = 0.194), Planning and Project Management (Sig. = 0.075), and Problem-Solving (Sig. = 0.206) – did not show statistically significant differences. However, it is noteworthy that the mean scores in these dimensions also consistently favored the master's group.

Taken together, the comprehensive pattern indicates that teachers pursuing master's degrees are more actively engaged in entrepreneurial teaching practices, particularly in higher-order skills such as strategic planning, research application, and market communication, compared to their doctoral counterparts. This disparity may reflect differences in curriculum emphasis or the distinct stages of professional development associated with the two academic programs.

Table 16: Independent Samples T-Test Results Examining Differences in Entrepreneurial Teaching Practices and Their Dimensions Based on Self-Reported Technology Proficiency.

Dimensions	variables	N	M	SD	df	t	Sig. (2-tailed)
Creative Thinking and Innovation Teaching Practices	Moderate	110	14.12	2.65	199	-3.053	0.003
	High	91	15.25	2.58		-3.061	0.003
Planning and Project Management Teaching Practices	Moderate	110	13.78	3.10	199	-2.608	0.010
	High	91	14.96	3.27		-2.596	0.010
Problem-Solving and Decision-Making Teaching Practices	Moderate	110	14.61	2.85	199	-3.170	0.002
	High	91	15.92	3.01		-3.154	0.002
Marketing and Communication Teaching Practices	Moderate	110	12.90	3.73	199	-2.376	0.018
	High	91	14.19	3.94		-2.363	0.019
Leadership and Teamwork Teaching Practices	Moderate	110	15.35	3.13	199	-2.363	0.019
	High	91	16.36	2.87		-2.382	0.018
Strategic Thinking Teaching Practices	Moderate	110	12.91	3.90	199	-2.456	0.015
	High	91	14.22	3.60		-2.475	0.014
Research and Development Teaching Practices	Moderate	110	13.92	3.62	199	-3.298	0.001
	High	91	15.55	3.33		-3.324	0.001
Sustainability and Social Responsibility Teaching Practices	Moderate	110	14.71	3.30	199	-2.898	0.004
	High	91	16.02	3.07		-2.917	0.004
Overall Entrepreneurial Teaching Practices	Moderate	110	112.30	22.38	199	-3.252	0.001
	High	91	122.47	21.71			

Table 16 presents the results of the independent samples t-test assessing the impact of self-reported technology proficiency (Moderate vs. High) on the level of entrepreneurial teaching practices. The findings demonstrate that technology proficiency is a highly significant determinant in the application of these practices.

A statistically significant difference was observed for the overall Entrepreneurial Teaching Practices scale ($t = -3.252$, Sig. = 0.001), with teachers reporting high technology proficiency ($M = 122.47$) scoring substantially higher than those reporting moderate proficiency ($M = 112.30$). This result underscores that greater self-assessed technological competence is strongly associated with more frequent implementation of entrepreneurial teaching methods.

The dimension-by-dimension analysis further confirms the pervasive influence of technology proficiency, as all eight dimensions revealed statistically significant differences (Sig. < 0.05), consistently favoring the high-proficiency group. The most pronounced differences were found in Research and Development (Sig. = 0.001), Problem-Solving (Sig. = 0.002), and Creative Thinking (Sig. = 0.003), highlighting the critical role of technology in supporting analytical, iterative, and innovative aspects of entrepreneurial pedagogy.

Additional significant differences were also identified in Sustainability and Social Responsibility (Sig. = 0.004), Planning and Project Management (Sig. = 0.010), Strategic Thinking (Sig. = 0.015), Marketing and Communication (Sig. = 0.018), and Leadership and Teamwork (Sig. = 0.019). Collectively, these

results provide compelling evidence that higher technology proficiency enhances teachers' ability to integrate entrepreneurial practices across all dimensions of science instruction. The universal nature of these differences across all dimensions

strongly suggests that technology is not merely an auxiliary tool, but rather an integrative factor that underpins and enables the effective implementation of the entire spectrum of entrepreneurial teaching practices in the classroom.

Table 17: One-Way Analysis of Variance (ANOVA) Results for Differences in the Level of Entrepreneurial Teaching Practices and Their Dimensions Across School Level Taught.

Dimensions	Source of Variance	Sum of Squares	df	Mean Square	F	Sig.
Creative Thinking and Innovation Teaching Practices	Between Groups	7.23	3	2.41	0.333	0.802
	Within Groups	1425.53	197	7.24		
	Total	1432.76	200			
Planning and Project Management Teaching Practices	Between Groups	48.81	3	16.27	1.580	0.195
	Within Groups	2028.45	197	10.30		
	Total	2077.25	200			
Problem-Solving and Decision-Making Teaching Practices	Between Groups	11.40	3	3.80	0.421	0.738
	Within Groups	1777.23	197	9.02		
	Total	1788.64	200			
Marketing and Communication Teaching Practices	Between Groups	66.03	3	22.01	1.483	0.220
	Within Groups	2924.16	197	14.84		
	Total	2990.19	200			
Leadership and Teamwork Teaching Practices	Between Groups	11.00	3	3.67	0.392	0.759
	Within Groups	1843.82	197	9.36		
	Total	1854.82	200			
Strategic Thinking Teaching Practices	Between Groups	41.51	3	13.84	0.951	0.417
	Within Groups	2866.74	197	14.55		
	Total	2908.25	200			
Research and Development Teaching Practices	Between Groups	24.80	3	8.27	0.643	0.588
	Within Groups	2532.51	197	12.86		
	Total	2557.31	200			
Sustainability and Social Responsibility Teaching Practices	Between Groups	7.50	3	2.50	0.233	0.873
	Within Groups	2112.99	197	10.73		
	Total	2120.49	200			
Overall Entrepreneurial Teaching Practices	Between Groups	1109.08	3	369.69	0.721	0.541
	Within Groups	101020.13	197	512.79		
	Total	102129.20	200			

Table 17 presents the results of the One-Way Analysis of Variance (ANOVA) conducted to determine whether the level of entrepreneurial teaching practices varies significantly based on the school level taught by the science teachers. The analysis comprehensively indicates that the school level taught is not a statistically significant factor influencing the implementation of these practices.

Specifically, the results for the Overall Entrepreneurial Teaching Practices scale show that the difference between the mean scores across the different school levels is not statistically significant ($F = 0.721$, $Sig. = 0.541$). Since the significance value far exceeds the conventional alpha level of 0.05, the null hypothesis of no difference across school levels must be accepted for the overall scale.

The dimension-by-dimension analysis consistently confirms the overall finding, as none of the eight individual dimensions showed a statistically significant difference across the school levels taught. All significance values ($Sig.$) across all

dimensions were substantially greater than 0.05 (e.g., Creative Thinking: $Sig. = 0.802$; Planning and Project Management: $Sig. = 0.195$; Marketing and Communication: $Sig. = 0.220$). This robust lack of significant differences implies that science teachers, regardless of whether they teach at the primary, intermediate, or secondary level, report applying the entrepreneurial teaching practices at comparable frequencies. The consistency of these non-significant results suggests that the integration of entrepreneurial skills into science pedagogy is likely driven by factors other than the specific educational stage of the students.

Table 18 presents the results of the One-Way Analysis of Variance (ANOVA) conducted to investigate whether the level of entrepreneurial teaching practices varies significantly across the age groups of the science teachers. The analysis definitively shows that age is not a statistically significant predictor of the implementation of these practices.

Specifically, the results for the Overall Entrepreneurial Teaching Practices scale show that the difference between the mean scores across the different age groups is not statistically significant ($F = 0.774$, $\text{Sig.} = 0.463$). Since this significance value is

far greater than the 0.05 threshold, there is no statistical evidence to reject the null hypothesis, indicating that age does not influence the overall self-reported frequency of entrepreneurial teaching.

Table 18: One-Way Analysis of Variance (ANOVA) Results for Differences in the Level of Entrepreneurial Teaching Practices and Their Dimensions Across Age.

Dimensions	Source of Variance	Sum of Squares	df	Mean Square	F	Sig.
Creative Thinking and Innovation Teaching Practices	Between Groups	8.11	2	4.05	0.563	0.570
	Within Groups	1424.65	198	7.20		
	Total	1432.76	200			
Planning and Project Management Teaching Practices	Between Groups	25.43	2	12.72	1.227	0.295
	Within Groups	2051.82	198	10.36		
	Total	2077.25	200			
Problem-Solving and Decision-Making Teaching Practices	Between Groups	4.54	2	2.27	0.252	0.777
	Within Groups	1784.09	198	9.01		
	Total	1788.64	200			
Marketing and Communication Teaching Practices	Between Groups	32.23	2	16.12	1.079	0.342
	Within Groups	2957.96	198	14.94		
	Total	2990.19	200			
Leadership and Teamwork Teaching Practices	Between Groups	17.39	2	8.70	0.937	0.393
	Within Groups	1837.42	198	9.28		
	Total	1854.82	200			
Strategic Thinking Teaching Practices	Between Groups	49.78	2	24.89	1.724	0.181
	Within Groups	2858.47	198	14.44		
	Total	2908.25	200			
Research and Development Teaching Practices	Between Groups	16.41	2	8.20	0.639	0.529
	Within Groups	2540.91	198	12.83		
	Total	2557.31	200			
Sustainability and Social Responsibility Teaching Practices	Between Groups	13.63	2	6.81	0.640	0.528
	Within Groups	2106.86	198	10.64		
	Total	2120.49	200			
Overall Entrepreneurial Teaching Practices	Between Groups	792.08	2	396.04	0.774	0.463
	Within Groups	101337.12	198	511.80		
	Total	102129.20	200			

The dimension-by-dimension analysis consistently reinforces the overall finding, as none of the eight dimensions revealed statistically significant differences across the various age groups. All significance values were well above the conventional threshold of 0.05 (e.g., Problem-Solving: $\text{Sig.} = 0.777$; Creative Thinking: $\text{Sig.} = 0.570$; Strategic Thinking: $\text{Sig.} = 0.181$).

This absence of significant differences across all dimensions indicates a high degree of uniformity in the application of entrepreneurial pedagogy, regardless of teachers' stage in their professional careers. Moreover, the consistency of these results across both age and school level (as noted in the previous analysis) suggests that the adoption of entrepreneurial teaching practices is shaped more by systemic factors—such as professional training opportunities and access to technology—than by demographic characteristics.

12. DISCUSSION

The overall high level of entrepreneurial teaching

practices reported in this study ($M = 2.436$; 81.18%) indicates that Saudi science teachers are progressively adopting inquiry-driven, project-based, and socially responsive pedagogies. These approaches align with contemporary perspectives on entrepreneurship education, which conceptualize it as a transversal competency framework rather than a narrowly business-oriented subject. This finding is consistent with global research emphasizing that science classrooms function as unique ecosystems for cultivating entrepreneurial mindsets through inquiry, experimentation, and evidence-based reasoning—contexts that inherently foster innovation and value creation (Davis, Chiang, & English, 2025). The relatively low variation in responses further suggests a systemic diffusion of these practices across the teaching profession, reflecting the institutionalization of entrepreneurship and digital competencies within national teacher standards and continuous professional development frameworks, as highlighted in UNESCO's (2023) Global Education Monitoring Report.

Among the eight assessed dimensions, Leadership and Teamwork ($M = 2.635$; 87.84%) and Sustainability and Social Responsibility ($M = 2.551$; 85.02%) emerged as the strongest domains. These results demonstrate that Saudi science teachers are particularly effective in embedding collaborative, ethical, and sustainability-oriented goals into instructional practice. Such emphasis resonates with the integration of sustainability and innovation in STEM education policy under Vision 2030 (Al-Barakat et al., 2025; Okonkwo, Toromade, & Ajayi, 2024; Maashi, Kewalramani & Alabdulkareem, 2022; Eltanahy, Forawi, & Mansour, 2020). It also aligns with international findings that highlight teamwork and social value orientation as strong predictors of students' entrepreneurial intention and civic engagement (Abbes, 2024; Leiva-Lugo et al., 2024). The growing inclusion of sustainability themes within science instruction reflects a paradigm shift toward Sustainable Entrepreneurial Education (SEE), where environmental stewardship, ethical responsibility, and innovation coexist as mutually reinforcing aims (Rosário & Raimundo, 2023; Abdelwahed, 2022; Kayal, 2024; Zarei, 2020; Al-Mulla, 2018). This pattern illustrates that teachers are beginning to link scientific problem-solving with socially and environmentally responsible innovation—an essential competency for a sustainability-driven economy.

In contrast, the dimensions of Marketing and Communication ($M = 2.247$; 74.90%) and Strategic Thinking ($M = 2.250$; 75.01%) recorded comparatively lower mean scores. These findings mirror a globally observed pedagogical gap: while teachers are generally confident in fostering creativity and experimentation, they are less experienced in facilitating authentic market-facing learning such as opportunity recognition, stakeholder engagement, or cost-benefit analysis (Pathan et al., 2023; Gracia-Zomeño et al., 2025a, 2025b). Similar challenges have been reported in Saudi schools, where entrepreneurship education often falls short of linking creativity to practical commercialization or community impact (Elvi Rahmi et al., 2025; Badghish et al., 2023). This shortfall is frequently associated with limited professional preparation, as teacher education programs tend to underemphasize the business, marketing, and communication dimensions of entrepreneurship within science instruction (Ouragini & Lakhal, 2024; Vicente-Ramos, Idone-Cordova, & Mendoza-Farro, 2024).

Consequently, these findings highlight an urgent need for professional development initiatives that immerse teachers in market simulation, design validation, and digital marketing practices. Such

interventions are essential to bridge the gap between creativity and applied innovation, ensuring that entrepreneurial education in science classrooms fully equips students with both the inventive and market-oriented skills required for success in a knowledge-based economy.

One of the most noteworthy findings of this study is the strong positive correlation between teachers' digital competence and their overall entrepreneurial teaching scores. Teachers with advanced digital literacy consistently demonstrated higher proficiency across all entrepreneurial dimensions, underscoring the role of technology integration as a foundational enabler of entrepreneurship pedagogy. This result aligns with prior evidence showing that digital fluency enhances teachers' ability to facilitate authentic entrepreneurship learning through tools such as digital prototyping, market research platforms, and online collaboration networks (Eskici & Çayak, 2023; Liu, Wang, & Chen, 2023; Leiva-Lugo et al., 2024; Al-Modafar, 2025; ISTE, 2023). Within the Saudi context, this relationship resonates with the national digital transformation agenda, suggesting that sustained investment in educational technology infrastructure and teacher digital upskilling can generate a multiplier effect on innovation-oriented teaching and learning.

Leadership-oriented teaching practices also emerged as a critical driver of entrepreneurial skill development. This finding corroborates Gracia-Zomeño's (2025c) conclusion that collaborative and autonomy-supportive instruction strengthens learners' self-efficacy, initiative, and willingness to take calculated risks—competencies that are central to cultivating an entrepreneurial mindset in science education. The results suggest that Saudi science teachers are increasingly fostering a socially conscious form of entrepreneurship, where leadership, sustainability, and ethical responsibility intersect to shape students' innovation capacity and civic orientation.

The analysis further revealed significant differences by academic qualification, with master's-level teachers reporting higher entrepreneurial teaching scores than their doctoral-level counterparts. This pattern may reflect the practice-oriented nature of master's programs, which emphasize applied pedagogy, instructional design, and classroom innovation, whereas doctoral programs often prioritize theoretical research. Similar observations in international contexts (Tu & Akhter, 2022; EtOH, 2025) highlight the need for teacher preparation programs—particularly at the doctoral level—to incorporate explicit modules on entrepreneurial pedagogy,

experiential practicums, and digital innovation labs to ensure that advanced academic training translates effectively into classroom practice.

Interestingly, no significant differences were found by age or school level taught, suggesting that entrepreneurial teaching practices have diffused relatively uniformly across demographic and institutional boundaries. This horizontal coherence likely reflects systemic factors—such as centralized professional development schemes, standardized competency frameworks, and policy alignment under Vision 2030—rather than individual variation (Al-Barakat *et al.*, 2025; OECD, n.d.). Similar consistency has been reported in OECD studies, where strong policy coordination and teacher collaboration mechanisms contribute to cross-level alignment in the adoption of innovative pedagogies.

Overall, the findings present a balanced yet developmental picture. Saudi science teachers have successfully integrated the humanistic and sustainability-oriented dimensions of entrepreneurship—particularly leadership, teamwork, and social responsibility—but continue to underperform in the strategic and market-oriented domains. Moving toward a fully realized model of entrepreneurial science education will require targeted interventions that consolidate existing strengths while addressing implementation gaps. Such interventions may include the development of assessment rubrics for leadership and sustainability outcomes, the creation of structured modules linking scientific inquiry to market validation (e.g., digital market labs or industry mentorship programs), and the expansion of partnerships between schools and innovation ecosystems. These recommendations align with international evidence that school-industry collaborations, scaffolded teacher training, and technology-mediated learning environments enhance teaching fidelity and improve student entrepreneurial outcomes (Vicente-Ramos *et al.*, 2024; Abbes, 2024; Leiva-Lugo *et al.*, 2024).

Collectively, this discussion underscores that Saudi Arabia's science education system is transitioning toward a holistic model of entrepreneurial pedagogy—one that integrates creativity, leadership, sustainability, digital competence, and strategic foresight as foundational pillars of 21st-century scientific literacy.

13. CONCLUSIONS

This study provides strong evidence that science teachers in Saudi Arabia are progressively adopting teaching practices that foster entrepreneurial competencies across multiple pedagogical

dimensions. The findings reveal a generally high level of implementation in areas such as leadership, teamwork, sustainability, problem-solving, and research-oriented inquiry. These domains demonstrate clear alignment with contemporary paradigms in science education and the strategic objectives of Saudi Vision 2030, which emphasize innovation, entrepreneurship, and the transition toward a knowledge-based economy.

A key conclusion is that Saudi science teachers are increasingly capable of integrating creativity, innovation, and inquiry-based learning into classroom practice. Nonetheless, implementation remains uneven, largely due to limited curricular guidance and the absence of structured pedagogical models specifically designed for entrepreneurial learning in science.

The study identifies two dimensions requiring reinforcement: marketing and communication practices and strategic thinking skills. Weaknesses in these areas may limit students' ability to transform scientific inquiry into scalable, market-relevant innovations. Strengthening teachers' capacity to cultivate communication, persuasion, and strategic foresight is therefore essential to bridge the gap between theoretical creativity and practical application.

Leadership-oriented teaching practices emerged as a critical driver of entrepreneurial skill development. Teachers who adopt collaborative and autonomy-supportive approaches tend to enhance learners' self-efficacy, initiative, and willingness to take calculated risks—competencies that are fundamental to nurturing an entrepreneurial mindset in science education. However, entrepreneurship is still often perceived as supplementary rather than integral to science teaching, underscoring the need for targeted professional development and curriculum reform.

Another important conclusion relates to the integration of sustainability and social responsibility into science instruction. The growing emphasis on these themes reflects a paradigm shift toward sustainable and responsible innovation, where environmental stewardship and creativity coexist as mutually reinforcing aims.

The study also highlights the significant role of teachers' digital competence. Educators with advanced technological skills are better positioned to design project-based, collaborative, and research-oriented activities that strengthen entrepreneurial learning outcomes.

Finally, the results show that practice-oriented professional preparation—particularly among master's-level teachers—is positively associated with

higher implementation of entrepreneurial pedagogy. Embedding experiential and technology-integrated components in teacher education programs appears crucial to ensuring that theoretical knowledge translates into innovative classroom practice.

Collectively, these conclusions suggest that Saudi science teachers are moving toward a more entrepreneurial orientation in their teaching. Sustained progress, however, will depend on systemic support, including curriculum redesign, institutional incentives, and capacity-building frameworks that empower teachers to act as catalysts of innovation, sustainability, and economic transformation within science education.

14. RECOMMENDATIONS

Building on the findings of this study, several actionable recommendations are proposed to strengthen the integration of entrepreneurial pedagogy within science education in Saudi Arabia. These recommendations address systemic, institutional, and classroom levels to ensure sustainable and scalable transformation.

14.1. Curriculum Design and Pedagogical

Integration: Entrepreneurship should be explicitly and progressively embedded within science curricula across all educational stages. Integration must move beyond abstract discussions of innovation toward structured, sequenced modules that link scientific inquiry with market validation, strategic planning, and sustainability tasks. Assessment frameworks should evaluate both scientific rigor and entrepreneurial viability, including feasibility, stakeholder engagement, and social impact.

14.2. Professional Development and Teacher

Capacity-Building: Professional development programs should be redesigned into practice-oriented, market-facing modules that combine theory with authentic entrepreneurial applications. These programs should include scaffolded lesson designs on customer discovery, budgeting, and promotional strategies, supported by digital tools for market analysis and prototyping. Collaborations with local incubators and

innovation centers can further enhance teacher–industry exchange.

14.3. Digital Competence as a Systemic Lever for

Innovation: Teacher digital competence should be prioritized as a cross-cutting enabler of entrepreneurial education. Policymakers should institutionalize adequate funding for educational technology, digital assessment tools, and dedicated professional learning time to foster innovation and experimentation.

14.4. Higher Education and Teacher Preparation

Pathways: Teacher education institutions and postgraduate programs should incorporate applied components such as teaching practicums, entrepreneurship pedagogy modules, and digital innovation labs. These elements can help reduce the implementation gap observed between teachers with different academic qualifications.

14.5. Policy and Institutional Support for

Entrepreneurial Ecosystems: Educational authorities should align teacher evaluation, incentives, and promotion systems with the adoption of entrepreneurial teaching practices. Schools and universities should establish partnerships with entrepreneurs, startups, and innovation hubs to provide authentic learning experiences through projects, competitions, and mentorship programs.

14.6. Sustainability and Responsible

Innovation: Entrepreneurship education should be aligned with the Sustainable Development Goals (SDGs) to cultivate environmentally and socially responsible innovators. Embedding sustainability-focused modules within science and entrepreneurship curricula can promote eco-innovation, systems thinking, and ethical responsibility.

14.7. Research and Continuous Evaluation:

Future research should employ mixed-method and longitudinal designs to validate self-reported data, observe classroom practices, and track long-term student outcomes such as entrepreneurial intention, innovation persistence, and sustainability literacy.

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