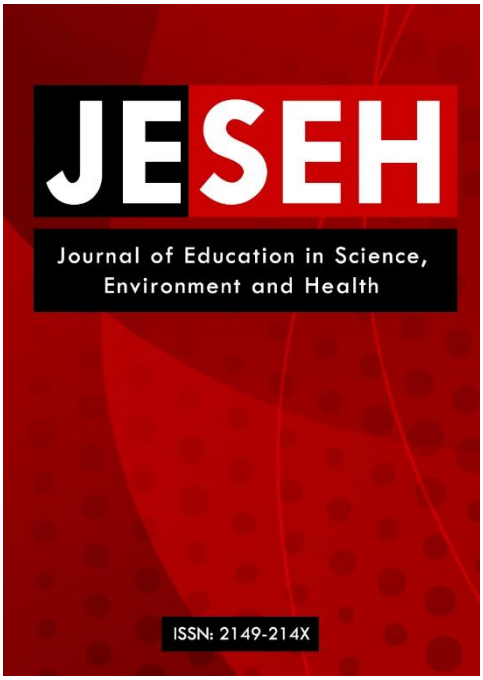

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Senem Erdogan-Yilmaz, Harun Celik
Kırıkkale University

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Senem Erdogan-Yilmaz, Harun Celik

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Abstract

This study examined the relationship between science teachers' effective science teaching levels and their entrepreneurship education levels. A descriptive, correlational survey design was employed. The sample consisted of 94 science teachers working in middle schools in Kırıkkale province during the 2023–2024 academic year. Data were collected using the *Effective Science Teaching Scale* and the *Entrepreneurship Scale for University Students*. Descriptive statistics, independent samples t-tests, one-way ANOVA with LSD post hoc comparisons, and Pearson correlation analysis were conducted. The findings indicated that science teachers demonstrated high levels of both effective science teaching and entrepreneurship education. Significant differences were found in effective science teaching according to professional seniority and gender. Additionally, entrepreneurship education levels differed significantly by educational background and gender. Correlation analysis revealed a statistically significant and positive relationship between effective science teaching and entrepreneurship education levels.

Introduction

Rapid developments in science and technology have substantially transformed the role of teachers, who constitute one of the core components of educational systems. This transformation has increased expectations regarding teachers' professional qualifications, pedagogical competencies, and their ability to adapt to emerging educational demands. In science education, where scientific literacy and innovation-oriented thinking are increasingly emphasized, the quality of science teachers has become particularly critical. Teachers' personal characteristics, professional competencies, and levels of effective science teaching play a decisive role in achieving curricular objectives and ensuring meaningful learning experiences (Öztürk, 2021). Previous research has extensively examined effective science teaching among pre-service and in-service science teachers (Hudson et al., 2005; Lewis et al., 2019, 2020; Mamba & Putsoa, 2018; Öztürk, 2021; Rahman Talukder et al., 2021; Yavuz, 2020). These studies highlight that effective teaching requires the strategic use of diverse instructional approaches, pedagogical flexibility, and the ability to create student-centered learning environments. Accordingly, both teachers' professional qualifications and their instructional preferences are considered fundamental determinants of effective science instruction (Cücük et al., 2018).

In parallel with global educational transformations, entrepreneurship education has gained increasing attention as an essential component of 21st-century skills. Entrepreneurship education aims to equip individuals with innovative thinking, problem-solving abilities, initiative-taking behaviors, and value-creation competencies (San-Martín et al., 2021). Within this framework, teachers are not only transmitters of knowledge but also facilitators of entrepreneurial mindsets. Therefore, teachers' entrepreneurial competencies are regarded as critical in fostering entrepreneurial skills among students. Existing studies have investigated entrepreneurship levels among pre-service and in-service science teachers (Akbulut, 2019; Bolaji, 2012; Çavdar et al., 2018; Deveci, 2018; Köken & Çelik, 2021; Leffler, 2020; San-Martín et al., 2022; Sarı et al, 2022).

Research conducted in Turkiye indicates that science activities, experiments, and inquiry-based practices contribute positively to the development of entrepreneurial characteristics (Çelik et al, 2015). Furthermore, instructional approaches such as STEM education (Deveci, 2018; Yamak et al., 2019), cooperative learning (Peltonen, 2015), project-based learning (Tarhan & Gülmez, 2021), and technopark visits (Bayram & Çelik, 2022) have been reported to support entrepreneurial skill development. These findings suggest that instructional practices in science education may intersect conceptually with entrepreneurship-related competencies.

From a theoretical perspective, entrepreneurial competencies such as creativity, proactivity, and opportunity recognition are conceptually aligned with the demands of effective science teaching, which requires instructional

innovation, adaptability, and the integration of real-world problems into classroom practice. Effective science teaching, particularly within inquiry-oriented and constructivist frameworks, involves experimentation with diverse strategies and the creation of authentic problem-based learning environments (Peltonen, 2015; San-Martín et al., 2021). Within Bandura's (1997) social cognitive framework, teachers' professional behaviors are shaped by their self-efficacy beliefs—that is, their confidence in their ability to organize and execute actions required to manage instructional challenges. Teachers with stronger efficacy beliefs are more likely to adopt innovative practices and student-centered approaches. Because entrepreneurial orientation similarly involves acting under uncertainty and initiating change, it may strengthen instructional self-efficacy and thereby support the implementation of effective science teaching practices.

Despite the growing body of research on effective science teaching and entrepreneurship education as separate domains, no study has directly examined the relationship between science teachers' effective science teaching levels and their entrepreneurship education levels. Considering the increasing emphasis on innovation, creativity, and entrepreneurial thinking in contemporary education systems, understanding the potential association between these two constructs appears particularly important. Therefore, this study aims to examine the relationship between science teachers' effective science teaching and their entrepreneurship education levels. By addressing two critical dimensions of contemporary science education simultaneously, this study seeks to contribute to the literature by providing empirical evidence on whether entrepreneurship-related competencies are associated with effective science teaching practices.

Based on the literature, numerous studies have examined instructional approaches, teaching methods, and entrepreneurship education in science education contexts among both pre-service and in-service teachers. However, no study has directly investigated science teachers' effective science teaching levels in relation to their entrepreneurship education levels. The absence of research integrating these two increasingly prominent dimensions highlights a significant gap in the literature. Accordingly, this study aims to examine the relationship between science teachers' effective science teaching and entrepreneurship education levels. By simultaneously addressing two critical components of contemporary science education, this research seeks to provide empirical evidence regarding their potential association. Understanding this relationship may contribute to improving instructional practices, informing teacher development initiatives, and supporting evidence-based educational policy decisions. The study addresses the following research questions (Q_s):

Q_1. What are science teachers' levels of effective science teaching?
Q_2. Do science teachers' effective science teaching levels differ according to gender, professional seniority, and educational background?
Q_3. What are science teachers' levels of entrepreneurship education?
Q_4. Do science teachers' entrepreneurship education levels differ according to gender, professional seniority, and educational background?
Q_5. Is there a significant relationship between science teachers' effective science teaching and entrepreneurship education levels?

Method

Study Design

This study employed a quantitative, cross-sectional correlational design. Correlational research aims to determine the presence and degree of relationships between two or more variables without manipulating them (Creswell & Creswell, 2018; Fraenkel et al., 2012). In line with the overall purpose of the study and the research questions, this design was considered appropriate for examining the relationship between science teachers' effective science teaching levels and their entrepreneurship education levels, as well as the strength of this association.

Study Sample

A convenience sampling method was employed to determine the study sample. Convenience sampling involves selecting participants who are readily accessible to the researcher and is commonly used in educational research when constraints related to time, cost, and accessibility are present (Creswell & Creswell, 2018; Etikan et al., 2016). The sample consisted of 94 science teachers working in public middle schools in Kırıkkale province during the 2023–2024 academic year. Of the participants, 58 (61.7%) were female and 36 (38.3%) were male. The

distribution of teachers according to gender, professional seniority, and educational background is presented in Table 1.

Table 1. Frequency and percentage distributions of the sample

Variable	Category	f	%
Gender	Female	58	61.7
	Male	36	38.3
Teaching experience (years)	6–10 years	13	13.8
	11–15 years	34	36.2
	16–20 years	28	29.8
	21 years and above	19	20.2
Educational level	Bachelor's degree	70	74.5
	Master's degree	24	25.5
Total		94	100

Data Collection Tools

The data collection instruments used in this study consisted of three sections. The first section included a *Personal Information Form* composed of three items designed to obtain demographic information about the participants, including gender, professional seniority, and educational background. These variables were examined in relation to the main study variables.

The second section included the *Effective Science Teaching Scale*, originally developed by Hudson, Skamp, and Brooks (2005) and adapted into Turkish by Yavuz (2020). The scale consists of 29 items rated on a five-point Likert scale and comprises four subdimensions: Personal Development, Self-Confidence, Pedagogical Skills, and Curriculum Knowledge. Total scores range from 29 to 145, with higher scores indicating higher levels of effective science teaching. The original study reported a Cronbach's alpha coefficient of .96, while the internal consistency coefficient calculated for the present study was $\alpha = .95$.

The third section included the *Entrepreneurship Scale for University Students*, developed by Yılmaz and Sünbül (2009). Although originally designed to measure entrepreneurship levels among university students, the scale has been widely used across different educational levels and professional groups. The instrument consists of 36 items rated on a five-point Likert scale and is structured as a single-factor scale. Total scores range from 36 to 180, with higher scores indicating higher levels of entrepreneurship. Based on total scores, entrepreneurship levels are categorized as very low (36–64), low (65–92), moderate (93–123), high (124–151), and very high (152–180). The original study reported a Cronbach's alpha coefficient of .90, and the reliability coefficient for the present study was calculated as $\alpha = .95$.

Data Analysis

The data collected in the study were entered into a computer environment and analyzed using IBM SPSS Statistics (Version 25.0). Prior to conducting the analyses, the normality assumption was examined by evaluating skewness and kurtosis values. Since the skewness and kurtosis coefficients ranged between −2 and +2, the data were considered to meet the assumption of normal distribution (George & Mallery, 2010). Accordingly, parametric statistical techniques were employed in line with established statistical procedures (Büyüköztürk, Çokluk, & Köklü, 2020). Descriptive statistics (frequency, mean, and standard deviation) were calculated to summarize the data. Independent samples t-tests and one-way analysis of variance (ANOVA) were conducted to examine group differences. Post hoc comparisons were performed using the LSD test. Pearson's correlation coefficient was used to determine the strength and direction of the relationship between the variables.

Findings

Findings Related to the First Sub-Problem (Q_1)

The findings regarding science teachers' levels of effective science teaching are presented in Table 2.

Table 2. Science teachers' levels of *Effective Science Teaching*

Subscale	N	Min.	Max.	x̄	Number of Items	SD	SE
Personal Development	94	43.00	60.00	54.30	12	4.41	0.45
Self-Confidence	94	27.00	40.00	35.40	8	3.40	0.35
Pedagogical Skills	94	18.00	30.00	26.00	6	2.56	0.26
Curriculum Knowledge	94	11.00	15.00	13.73	3	1.30	0.13
Total	94	105.00	145.00	129.43	29	10.67	1.19

As presented in Table 2, the mean total score of science teachers on the *Effective Science Teaching Scale* was 129.43. The observed scores ranged from 105.00 to 145.00. The minimum and maximum possible scores for each subdimension are also provided in the table. Regarding subdimensions, the mean scores for Personal Development, Pedagogical Skills, and Self-Confidence were relatively lower compared to the Curriculum Knowledge subdimension.

Findings Related to the Second Sub-Problem (Q_2)

The findings regarding science teachers' effective science teaching levels according to gender and educational background were analyzed using independent samples t-tests, while differences based on professional seniority were examined using one-way analysis of variance (ANOVA). The results are presented in Tables 3, 4, and 5

Table 3. An independent-samples t-test was conducted to examine whether *Effective Science Teaching Scale* scores differed by gender.

						t-test		
Subscale (SE)	Gender	N	x̄	SD		t	df	p
Personal Development	Female	58	55.09	4.31	.57			
	Male	36	53.03	4.33	.72	2.25	92	.02
Self-Confidence	Female	58	35.91	3.45	.45			
	Male	36	34.56	3.19	.53	1.91	92	.06
Pedagogical Skills	Female	58	26.34	2.74	.36			
	Male	36	25.44	2.16	.35	1.67	92	.09
Curriculum Knowledge	Female	58	13.72	1.37	.18			
	Male	36	13.75	1.20	.20	-.093	92	.93
Total	Female	58	131.07	10.98	1.44			
	Male	36	126.78	9.63	1.60	1.93	92	.06

As shown in Table 3, a statistically significant difference was found between male and female teachers in the Personal Development subdimension of the *Effective Science Teaching Scale*, in favor of female teachers ($p < .05$).

Table 4. An independent-samples t-test was conducted to examine whether *Effective Science Teaching Scale* scores differed according to educational level.

Subscale	Educational Level	N	x̄	SD	SE	t-test		
						t	df	p
Personal Development	Bachelor's degree	70	53.91	4.52	.54	-1.45	92	.15
	Master's degree	24	55.42	3.97	.81			
Self-Confidence	Bachelor's degree	70	35.36	3.16	.38	-.18	92	.86
	Master's degree	24	35.50	4.10	.84			
Pedagogical Skills	Bachelor's degree	70	25.77	2.63	.31	-1.49	92	.14
	Master's degree	24	26.67	2.26	.46			
Curriculum Knowledge	Bachelor's degree	70	13.63	1.30	.16	-1.34	92	.18
	Master's degree	24	14.04	1.30	.27			
Total		70	128.67	10.64	1.27	-1.18	92	.24
		24	131.63	10.55	2.15			

As shown in Table 4, no statistically significant difference was found in science teachers' effective science teaching levels according to educational background ($p > .05$).

Table 5. A one-way ANOVA was performed to compare the total and subscale scores of the *Effective Science Teaching Scale* across different levels of teaching experience

Subscale	Teaching experience (years)	N	x̄	SD	Source	SS	df	MS	F	p
Personal Development	6-10	13	53.46	4.45	Between Groups	188.95	3	62.98	3.49	.02
	11-15	34	55.44	3.52						
	16-20	28	52.39	5.06	Within Groups	1620.71	90	18.01		
	21 and above	19	55.63	3.98						
	Total	94	54.30	4.41	Total	1809.66	93			
Self-Confidence	6-10	13	35.23	2.74	Between Groups	75.69	3	25.23	2.27	.09
	11-15	34	35.85	3.46						
	16-20	28	34.14	3.58	Within Groups	1000.74	90	11.12		
	21 and above	19	36.53	3.18						
	Total	94	35.39	3.40	Total	1076.44	93			
Pedagogical Skills	6-10	13	25.69	2.21	Between Groups	51.93	3	17.31	2.79	.05
	11-15	34	26.59	2.08						
	16-20	28	24.96	3.28	Within Groups	558.07	90	6.20		
	21 and above	19	26.68	1.92						
	Total	94	26.00	2.56	Total	610.00	93			
Curriculum Knowledge	6-11	13	13.46	1.45	Between Groups	4.72	3	1.57	.92	.43
	11-15	34	13.65	1.41						
	16-20	28	13.68	1.33	Within Groups	153.63	90	1.71		
	21 and above	19	14.16	90						
	Total	94	13.73	1.30	Total	158.35	93			
Total	6-10	13	127.85	9.77	Between Groups	930.71	3	310.24	2.91	.04
	11-15	34	131.53	9.78						
	16-20	28	125.18	11.85	Within Groups	9596.27	90	106.63		
	21 and above	19	133.00	9.13						
	Total	94	129.43	10.64	Total	10526.98	93			

As presented in Table 5, effective science teaching levels differed significantly according to professional seniority ($p < .05$). To determine which groups differed from each other, post hoc comparisons were conducted. Since the assumption of homogeneity of variances was satisfied for both the total scale score and its subdimensions, the Least Significant Difference (LSD) test was employed (see Table 6).

Table 6. LSD post hoc test results for *Effective Science Teaching Scale* scores by teaching experience

Teaching experience (years) (i)	Teaching experience (years) (j)	Mean Difference (i-j)	SE	p
6-10	11-15	-3.68	3.37	.28
	16-20	2.67	3.47	.44
	21 and above	-5.16	3.72	.17
11-15	6-10	3.68	3.37	.28
	16-20	6.35*	2.64	.02
	21 and above	-1.47	2.96	.62
16-20	6-10	-2.67	3.47	.44
	11-15	-6.35*	2.64	.02
	21 and above	-7.82*	3.07	.01
21 and above	6-10	5.15	3.72	.17
	11-15	1.47	2.96	.62
	16-20	7.82*	3.07	.01

Findings Related to the Third Sub-Problem (Q_3)

As shown in Table 6, teachers with 21 years or more of professional seniority scored significantly higher on both the total scale and its subdimensions compared to those with 16–20 years of experience ($p < .05$). Similarly, teachers with 11–15 years of seniority also demonstrated significantly higher scores than those with 16–20 years

of experience ($p < .05$). Additionally, no participants in the study had 1–5 years of professional seniority. Table 7. presents the findings related to science teachers' effective science teaching levels.

Table 7. Science teachers' levels of entrepreneurship education

	N	Min.	Max.	x̄	SD	SE
Entrepreneurship education	94	92.00	178.00	140.86	15.54	1.60

As presented in Table 7, the mean score obtained from the *Entrepreneurship Scale* was 140.86. Based on the scale's classification criteria, scores between 124 and 151 indicate a high level of entrepreneurship; therefore, the participating teachers demonstrated a high level of entrepreneurship.
The observed scores ranged from 92.00 to 178.00.

Findings Related to the Fourth Research Problem (Q_4)

The entrepreneurship education levels of science teachers were analyzed using independent samples t-tests for gender and educational background variables and one-way ANOVA for professional seniority. The results are presented in Tables 8, 9, and 10.

Table 8. An independent-samples t-test was conducted to examine whether *Entrepreneurship Scale* scores differed by gender.

	Gender	N	x̄	SD	SE	t-test		
						t	df	p
Entrepreneurship education	Female	58	143.33	16.09	2.11	1.98	92	.05
	Male	36	136.89	13.93	2.32			

As shown in Table 8, entrepreneurship education levels differed significantly by gender, with female teachers scoring higher than male teachers ($p \leq .05$).

Table 9. An independent-samples t-test was conducted to examine whether *Entrepreneurship Scale* scores differed according to educational level.

	Education level	N	x̄	SD	SE	t-test		
						t	df	p
Entrepreneurship education	Bachelor's degree	70	138.00	15.76	1.88	-2.83	92	.006
	Master's degree	24	148.33	12.38	2.53			

As presented in Table 9, entrepreneurship education levels differed significantly according to educational background, with teachers holding postgraduate degrees scoring higher than those with undergraduate degrees ($p < .05$).

Table 10. A one-way analysis of variance (ANOVA) was conducted to examine whether *Entrepreneurship Scale* scores differed according to teaching experience.

	Teaching experience (years)	N	x̄	SD	Source	SS	df	MS	F	p
Entrepreneurship education	6-10	13	140.23	20.89	Between	182.47	3	60.82		
	11-15	34	142.53	15.22	Groups				.246	.86
	16-20	28	139.14	16.61	Within	22288.73	90	247.65		
	21 and above	19	140.84	10.42	Groups					
	Total	94	140.86	15.54	Total	22471.20	93			

As presented in Table 10, entrepreneurship education levels did not differ significantly according to professional seniority ($p > .05$).

Findings Related to the Fifth Research Problem (Q_5)

Because the normality assumption was satisfied, Pearson's product–moment correlation coefficient was calculated to determine the strength and direction of the relationship between effective science teaching and entrepreneurship education levels. The findings are presented in Table 11.

Table 11. The relationship between science teachers' levels of effective science teaching and their levels of entrepreneurship education

Scale		Entrepreneurship education	Effective Science Teaching
Entrepreneurship education	r	1	.63
	p		.00
	N	94	94
Effective Science Teaching	r	.63	1
	p	.00*	
	N	94	94

*Correlation is significant at the .05 level (2-tailed).

As presented in Table 11, a positive and statistically significant correlation was found between scores on the *Effective Science Teaching Scale* and the *Entrepreneurship Scale* ($p < .05$). The correlation analysis revealed a strong, positive, and statistically significant relationship between the total scores of the *Effective Science Teaching Scale* and the *Entrepreneurship Scale* ($r = .63$, $p < .05$). In addition, the results of Pearson's product–moment correlation analysis examining the relationships between the subdimensions of the *Effective Science Teaching Scale* and entrepreneurship education scores are presented in Table 12.

Table 12. Pearson product–moment correlation analysis

Scale	N	Personal Development	Self-Confidence	Pedagogical Skills	Curriculum Knowledge
Entrepreneurship Scale	94	r= .56	r= .57	r= .62	r= .54

p <. 05

As presented in Table 12, a moderate, positive correlation was found between entrepreneurship education scores and the Personal Development ($r = .56$, $p < .05$), Self-Confidence ($r = .57$, $p < .05$), and Curriculum Knowledge ($r = .54$, $p < .05$) subdimensions of the *Effective Science Teaching Scale*. A strong, positive correlation was observed between entrepreneurship education and the Pedagogical Skills subdimension ($r = .62$, $p < .05$).

Results and Discussion

In this study, science teachers were found to demonstrate high levels of effective science teaching. Similar findings are consistent with the results of studies conducted by Yavuz (2020) with classroom and science teachers and Öztürk (2021) with science teachers, which also reported high levels of effective science teaching. Research on entrepreneurship education emphasizes the role of pedagogical frameworks that balance disciplinary, professional, and entrepreneurial purposes to effectively contextualize teaching practices within specific domains, such as science education (Ramsgaard & Blenker, 2022). Therefore, in implementing effective science teaching, teachers' content knowledge and pedagogical competencies play a decisive role, as they enable the planning and enactment of meaningful learning experiences. Additionally, the effective use of technology-supported digital learning environments has emerged as a key factor in enhancing the quality of science instruction (Song & Sparks, 2019). In Pierro's (2019) study, it was indicated that teachers' personal characteristics and their prior science learning experiences influence their science teaching practices.

In the present study, science teachers' competency levels in the Personal Development, Pedagogical Skills, and Self-Confidence subdimensions were found to be lower compared to their competency level in the Curriculum Knowledge subdimension. Teachers demonstrated relatively higher competency in Curriculum Knowledge than in the other subdimensions of the scale. Similar findings in the literature indicate that science teachers' knowledge of effective teaching strategies and their implementation can vary across different teaching domains (Aydın Sesli & Akpolat, 2024; Mamba & Putsoa, 2018). In addition, research on pedagogical content knowledge suggests that effective science teaching requires the integration of subject matter knowledge and pedagogical understanding to make scientific concepts comprehensible to learners (Kind, 2009). Recent research also indicates that teachers' pedagogical content knowledge and instructional practices are important determinants of effective science teaching and student outcomes.

No statistically significant differences were observed between the total score and the Self-Confidence, Pedagogical Skills, and Curriculum Knowledge subdimension scores of the *Effective Science Teaching Scale* and the gender variable. However, female teachers demonstrated a statistically significant difference in the Personal Development subdimension of effective science teaching compared to male teachers. Comparable findings in the literature report gender-based differences in related teacher characteristics: Güler and Bilici (2016) found that secondary school teachers' science teaching attitudes varied by gender; Demirkol, Kartal, and Taşdemir (2022) identified gender differences in attitudes toward STEM activities among science teachers; and Turan and Çelik (2024) documented gender-related differences in science teachers' information and technology literacy. These results align with previous research suggesting that female teachers may exhibit higher levels of certain instructional and professional attributes. It has been suggested that such differences may relate to female teachers' greater effectiveness in employing instructional strategies (as indicated in some studies reporting higher interpersonal relation and planning competencies in female educators) and their relative strengths in communication, collaboration, and professional development engagement.

No significant difference was found between gender and the total scores of the Effective Science Teaching Scale, as well as the sub-dimensions of Self-Confidence, Pedagogical Skills, and Curriculum Knowledge. However, female teachers demonstrated a statistically significant difference in favor of the Personal Development sub-dimension. Güler and Bilici (2016) reported significant differences in favor of female teachers regarding secondary school teachers' Technological Pedagogical Content Knowledge (TPACK) levels. Similarly, Demirkol, Kartal, and Taşdemir (2022) found that female science teachers exhibited more positive attitudes toward STEM activities, while Turan and Çelik (2024) revealed significant differences in favor of female teachers in terms of information and technology literacy. The findings obtained in the present study are consistent with the existing literature and indicate a significant effect in favor of female teachers. This situation may be associated with female teachers' more effective use of instructional strategies (Karakış, Gürcan, & Demirtaş, 2009) and their greater competence in communication, collaboration, and professional development (Aktağ & Walter, 2005).

No significant differences were found between the total score and the Self-Confidence, Pedagogical Skills, and Curriculum Knowledge subdimension scores of the *Effective Science Teaching Scale* and the gender variable. However, female teachers exhibited a statistically significant difference in the Personal Development subdimension of effective science teaching beliefs. Güler and Bilici (2016) reported significant gender differences in Technology Pedagogical Content Knowledge levels among secondary school teachers; Demirkol, Kartal, and Taşdemir (2022) found significant gender differences in science teachers' attitudes toward STEM activities; and Turan and Çelik (2024) identified significant gender differences in science teachers' information and technology literacy, all in favor of female teachers. These findings are consistent with the current results and suggest a significant effect in favor of female teachers. This situation is thought to be related to female teachers' more effective use of instructional strategies (Karakış, Gürcan & Demirtaş, 2009) and their greater competence in communication, collaboration, and professional development (Aktağ & Walter, 2005). These findings align with the current results and suggest that gender-related differences may emerge in certain dimensions of effective teaching, such as personal development, even when no differences are observed in other instructional subdimensions.

The results indicated that educational level did not have a statistically significant effect on science teachers' effective science teaching levels. This finding is consistent with the results reported by Öztürk (2021), who also found no significant differences in effective science teaching based on educational level. Similarly, Biçer, Uzoğlu, and Bozdoğan (2019) concluded that science teachers' views on STEM did not vary significantly according to their educational level. These findings suggest that higher academic qualifications alone may not necessarily translate into differences in instructional effectiveness or teaching-related beliefs. Rather, factors such as teaching experience, professional development engagement, and contextual variables may play a more decisive role in shaping effective science teaching practices.

Significant differences were found in science teachers' effective science teaching levels based on professional seniority. Teachers with 21 years or more of experience and those with 11–15 years of experience scored significantly higher than teachers with 16–20 years of experience, indicating a non-linear relationship between seniority and effective science teaching. Previous research conducted in Türkiye suggests that teachers with 11–20 years of experience tend to use a greater variety of instructional materials in the teaching–learning process (Lal & Sarı, 2015), while teachers with more than 20 years of experience may reach higher levels of career satisfaction that positively influence their instructional practices (Öztürk, 2021). From a social cognitive perspective, these findings can be interpreted through Bandura's (1997) concept of *mastery experiences*, which represent the most influential source of self-efficacy beliefs. As teachers accumulate successful instructional experiences over time, their perceived competence and instructional confidence may strengthen; however, such development does not

necessarily follow a strictly linear pattern. Fluctuations across seniority groups may therefore reflect variations in accumulated mastery experiences, career stage transitions, and contextual factors such as job satisfaction and organizational climate rather than experience alone determining teaching effectiveness.

The results revealed that science teachers demonstrated entrepreneurship education levels corresponding to the "High Entrepreneurship" category. This finding is consistent with previous research conducted with both preservice and in-service teachers, which similarly reported high levels of entrepreneurial tendencies among educators (Armut & Kılınç, 2018; Aydoğmuş, 2019; Demir, Karataş & Metin, 2021; Gördes, 2023). Studies specifically focusing on science education have likewise indicated elevated entrepreneurship levels among preservice science teachers (Akbulut, 2019; Öztürk, 2021; Öztürk, Önder & Güven Yıldırım, 2019) and in-service science teachers (Deveci, 2018; Köken & Çelik, 2021). Moreover, research suggests that participation in entrepreneurial activities is closely linked to entrepreneurship education (Çelik & Pektaş, 2022). In line with the present findings, this relationship implies that higher levels of entrepreneurial disposition among teachers may foster more effective engagement with entrepreneurship education, thereby contributing positively to instructional practices and educational outcomes.

A statistically significant difference was found in teachers' entrepreneurship education levels in favor of female teachers. This finding aligns with previous research reporting higher entrepreneurial tendencies among female preservice teachers (Ateş, 2018; Lee, 2021; Selanik Ay, Duban & Aydoğdu, 2024). Similarly, Ekşioğlu (2021) found that female science teachers demonstrated significantly higher levels in the use of 21st-century teaching skills, which are closely associated with innovation, adaptability, and proactive engagement in instructional contexts. The observed gender difference may also be interpreted in light of socio-emotional and motivational competencies. Research suggests that emotional awareness, self-regulation, intrinsic motivation, adaptability to change, empathy, and advanced social skills may contribute to individuals' entrepreneurial dispositions (Tican, 2020). These characteristics could partially explain why female teachers in the present study exhibited higher levels of entrepreneurship education.

The findings indicated that science teachers' entrepreneurship education levels did not differ significantly according to professional seniority. This result aligns with previous research reporting no significant relationship between teaching experience and entrepreneurial tendencies among teachers (Demir, Karataş & Metin, 2021; Köken & Çelik, 2021). These findings suggest that entrepreneurial disposition may be influenced more by personal and professional development factors than by years of experience alone. In contrast, a statistically significant difference was observed with respect to educational level, favoring teachers who had completed postgraduate education. Baran (2014) found that science teachers engaged in postgraduate studies tend to be more open to innovations in their field, while Biçer, Uzoğlu, and Bozdoğan (2018) reported higher professional competency levels among science teachers with postgraduate qualifications. Taken together, these findings indicate that advanced academic engagement may enhance teachers' entrepreneurial orientation, possibly by fostering critical thinking, innovation awareness, and openness to change.

A strong, positive, and statistically significant correlation was found between science teachers' effective science teaching levels and their entrepreneurship education levels. This finding suggests that higher entrepreneurial orientation is associated with greater instructional effectiveness in science education. From a social cognitive perspective, this relationship may be explained through Bandura's (1997) self-efficacy theory. Teachers with stronger self-efficacy beliefs are more likely to take initiative, adopt innovative strategies, and persist in challenging instructional situations—characteristics that also define entrepreneurial orientation. Therefore, effective science teaching and entrepreneurship education may share a common psychological foundation grounded in elevated self-efficacy beliefs. Consistent with this interpretation, previous studies indicate that teachers' entrepreneurial tendencies are related to self-confidence, professional interest, and domain expertise (Ülgen Aydınlık, 2015), and that inquiry-based practices, STEM-oriented interventions, and entrepreneurship-integrated instructional models positively influence entrepreneurial levels (Bayram & Çelik, 2023; Çelik et al, 2015; Deveci, 2018). Together, these findings suggest that entrepreneurship education and effective science teaching may mutually reinforce one another.

Recommendations

Based on the findings of the study, the following recommendations are proposed:

1. It was found that science teachers scored higher in the Curriculum Knowledge subdimension compared to the Personal Development, Pedagogical Skills, and Self-Confidence subdimensions. In order to

promote high-quality science instruction, in-service training programs focusing on personal development, pedagogical competencies, and self-confidence may be organized to support teachers in these areas.
2. Examining teachers' levels of effective science teaching and entrepreneurship education can help identify their strengths and areas for improvement, thereby informing the development of educational policies and instructional practices.
3. Although numerous studies exist on effective science teaching and entrepreneurship education separately, research addressing these two constructs together remains limited. Therefore, the findings of the present study are considered to contribute to the field of science education by integrating these two dimensions.
4. While the present study relied on scale-based quantitative data, future research may incorporate classroom observations and qualitative data to provide deeper insights into teachers' instructional practices and entrepreneurial orientations.
5. Future studies may expand the current research by including additional variables to examine which factors predict teachers' effective science teaching and entrepreneurship education levels.

Scientific Ethics Declaration

* The authors declare that the scientific ethical and legal responsibility of this article published in JESEH journal belongs to the authors

* Ethical approval for this research was approved by the Scientific Research and Ethics Committee of Kırıkkale University with the decision dated February 21, 2024 (No: E.234670).

Conflict of Interest

* The authors declare that they have no conflicts of interest

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Author(s) Information

Senem Erdogan-Yilmaz
Kırıkkale University, Institute of Science
Kırıkkale, Türkiye
Contact e-mail: senemerdoganyilmaz@gmail.com
ORCID iD: https://orcid.org/0009-0009-5060-9643

Harun Celik
Kırıkkale University, Faculty of Education,
Kırıkkale, Türkiye
ORCID iD: https://orcid.org/0000-0002-3096-8624