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Science Literacy and Science Learning Skills as Predictive Factors of Preservice Teachers' Self-Efficacious Beliefs in Teaching Science

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This study aims to investigate the effects of science literacy level, science learning skills, grade, gender, and academic success on the self-efficacy perceptions of preservice primary school teachers in teaching science. In the research using the relational survey model, a sample of 241 preservice primary school teachers was studied. The "Science Teaching Self-Efficacy Belief Scale", "Science Learning Skills Scale" and "Basic Science Literacy Test" were used for data collecting. Parametric tests were applied using SPSS for data analysis. Gender and grade level did not significantly affect the positive self-efficacy dimension and overall science teaching self-efficacy beliefs, but there was a notable difference between groups in the negative self-efficacy dimension. Academic achievement increases self-efficacy beliefs and science learning skills. However, scientific literacy did not differ significantly according to gender, grade level or academic achievement. Also, science learning skills showed no significant differences based on gender or grade level according to total scores and sub-dimensions too. The science teaching self-efficacy and science learning skills are moderately related, while both show weaker correlate to science literacy. Together, science learning skills, basic science literacy, grade level, and academic success accounted for 51% of the variance in self-efficacy perceptions of preservice primary school teachers in teaching science. The research suggests that developing preservice teachers' scientific literacy and science learning skills, and supporting their academic success, is crucial for effective science teaching. The development of these three variables together can be supported with science content knowledge and courses and practices in science teaching.

Introduction

Recent advances in artificial intelligence and technology have once again highlighted the importance of science education for national development. With science education from a young age, scientific and technological advancements may be sustained. The expectations and needs of society, students, and the relevant discipline determine the goals of the education programs (Demirel, 2007). Factors such as educational content and level suitability, learning environment, student motivation, pedagogical approaches, materials, use of technology, social and cultural context, measurement and evaluation system, and teacher characteristics are effective on the quality of the education provided. The quality of education has been examined through classifications such as student characteristics, teaching processes, school resources,

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characteristics of parents, and home environment (Bacolod & Tobias, 2006; Climaco, 1995). School-based factors include teacher qualifications and competencies, materials, technology, and internet use (Yıldırım, 2012). Teacher competencies can be considered as an important element in achieving the goal of education. The term "teacher competencies" refers to all of the traits or attributes that a teacher ought to possess, including knowledge, abilities, attitudes, values, and actions. Research has shown that there are relationships between teacher efficacy and teaching practices (Tschannen-Moran, Hoy, & Hoy, 1998), behaviours and attitudes (Dembo & Gibson, 1985; Mulholland & Wallace, 1996), student achievement (Tosun, 2000), and learning outcomes (Bandura, 1982; Tschannen-Moran, et.al., 1998).

Self-efficacy, which is based on Social Cognitive Theory and was first conceptualized by Bandura (1977), is a judgment about one's ability to perform actions that one believes will lead to desired results. Bandura (1986) states that teachers' direct experiences, indirect experiences, verbal persuasion, and psychological states are effective in science teaching self-efficacy beliefs. It can be predicted that the teacher's self-belief and knowledge should also be sufficient for effective science teaching. However, there are different views about the effect of the teacher's science field knowledge on science teaching self-efficacy beliefs. While science teachers with high self-efficacy beliefs are more successful by using inquiry-based, student-centred teaching in their classes (Watters & Ginns, 2000), those with low self-efficacy use teacher-centred teaching through books and materials that cause students to think in limited ways to understand science (Appleton & Kindt, 2002; Ramey-Gassert & Shroyer, 1992). Having a high sense of self-efficacy facilitates the more efficient use of professional knowledge and abilities.

Teacher education is crucial for developing self-efficacy in science teaching. Limited content knowledge reduces teachers' confidence and self-efficacy (Rice & Roychoudhury, 2003; Wu & Chang, 2006). Studies highlight that both the amount and depth of science content learned during pre-service education are key to strengthening self-efficacy (Appleton, 2006; Hechter, 2011; Jarrett, 1999). Thus, the link between science topic comprehension and science teaching self-efficacy is significant. When teachers are properly trained in both content and pedagogy, they develop higher levels of scientific literacy and knowledge, which in turn enhance self-efficacy (Akıllı & Kutur, 2023; Al Sultan, Henson, & Fadde, 2018).

Science education is an academic and applied discipline that deals with the teaching, learning, and assessment of science content, scientific process skills, and the nature of science (McComas, 2014). Scientific literacy, broadly defined as understanding, applying, and critically engaging with science in daily life and social contexts (DeBoer, 2000; Miller, 1983; NRC, 1996), is a central goal of science education worldwide (MoNE, 2024). It is shaped by factors such as curricula, teaching methods, basic literacy skills, socio-cultural participation, and individual beliefs (Laugksch, 2000; Menon & Sadler, 2016; Phillips & Norris, 2003; Rannikmâe, & Holbrook, 2007; Valladares, 2021). Importantly, research shows a direct relationship between scientific literacy and self-efficacy in science teaching (Fadde, Sultan & Henson, 2018; Menon & Sadler, 2016). A key component of scientific literacy is the development of scientific process skills. Inquiry- and research-based science education—where students form hypotheses, conduct experiments, make observations, and draw conclusions—fosters both scientific literacy and science learning skills (Husna, Halim, Evendi, Syukri, Nur, Elisa, & Khaldun, 2022). Strengthening these skills enhances students' academic achievement and equips them to solve real-life problems (Husna et al., 2022; Tenreiro-Vieira & Vieira, 2016).

Science learning skills involve students’ understanding, application, and scientific thinking, including problem-solving, argumentation, and inquiry (Aydoğdu, 2014). These are supported by scientific process skills, categorized as basic (e.g., observation, measurement, classification) and integrated (e.g., hypothesis making, experimenting, interpreting data) (Harlen, 1999; Gizaw & Sota, 2023). Applied and mental strategies, student-centred teaching methods, inquiry-based approaches, the use of information and communication technologies, and engineering-focused STEM integration activities can improve students' scientific process skills (Idris, Talib & Razali, 2022).

When the studies on scientific literacy and science learning skills are examined, the studies in which the sample was pre-service teachers (Al Sultan, Henson & Lickteig., 2021; Aydede, 2022; Chin, 2005; Çavaş, Özdem, Çavas, Çakıroglu, & Ertepınar, 2013; Nurhayati, Sopandi & Riandi, 2023; Sarini, Widodo, Sutoyo, & Suardana, 2024; Tekin, Aslan & Yağız, 2016; Ural & Yolagiden, 2021), and in-service teachers (Göktepe, Eroğlu Doğan & Doğan, 2022; Walag, Fajardo, Bacarrisas & Guimary, 2022) stand out. Studies on science learning skills have been conducted primarily with pre-service teachers and have focused on the scientific process skills of pre-service teachers. Examining the holistic relationship between science learning skills and scientific literacy is important for teacher education. Science teaching self-efficacy belief has been studied extensively with pre-service science teachers (Kutluca & Aydın, 2016) and primary school teacher candidates (Cantrel, Young & Moore, 2003; Menon & Sadler, 2016). The variables affecting scientific literacy and science learning skills are mostly discussed in terms of teacher characteristics. Determining the relationship between self-efficacy belief for science teaching and scientific literacy, and science learning skills, and their effects on each other is critical for the effectiveness of science education. Especially primary school teachers and preservice teachers see themselves as inadequate in science courses. Pre-service teachers who feel inadequate in teaching science may avoid conducting experiments, and his/her students' science success and interest will be negatively affected. Therefore, since providing effective science education to primary pre-service teachers will be reflected in future science education, it is important to examine the relationship between science-related self-efficacy, learning skills, and literacy. The literature contains numerous studies on scientific literacy and science learning skills, and there is also separate research on self-efficacy. However, the combined consideration of these three concepts is limited. Most studies link self-efficacy solely to content knowledge or pedagogical knowledge, while research directly examining the impact of scientific literacy and learning skills on self-efficacy is scarce. Examining this relationship will demonstrate how the development of pre-service teachers' science process skills and scientific literacy impacts their self-efficacy, thus contributing to aligning teacher preparation programs with 21st-century skills and science education goals. It can be beneficial for teacher training universities to understand the elements influencing pre-service primary school teachers' (PPST) opinions about the effectiveness of scientific instruction and how these ideas evolve over time so that they can modify their curricula accordingly. This study aims to investigate the extend to which the science teaching self-efficacy belief of PPST predicts their science literacy and science learning skills. The research problem is "What is the relationship between PPST science teaching self-efficacy belief, scientific literacy, and science learning skills?" and the sub-problems are as follows:

- How are the PPST science teaching self-efficacy, science learning skills, and basic science literacy levels in total and sub-dimensions?
- How do PPST science teaching self-efficacy, science learning skills, and basic science literacy levels change overall and subdimensions by grade level, gender, and academic success?

- To what extent do science learning skills, basic science literacy, grade level, and academic success predict PPST science teaching self-efficacy?

Method

Research Model

The relational survey model was employed in the research. Determining the relationship between variables in their current condition is the goal of the relational survey model (Fraenkel, Wallen, & Hyun, 2012). The relational survey model avoids any separate interventions on participants' current situations and allows for simultaneous analyses of multiple variables. This model was implemented because it enables a holistic and systematic assessment of the relationships between self-efficacy for science teaching, scientific literacy, and science learning skills.

Research Group

The population consists of students studying in the primary school teaching program at a university's Faculty of Education at the end of the fall semester of the 2022-2023 academic year, and the sample consists of 241 students who could be reached. The number of students in each grade was obtained from the faculty's student affairs unit, and enough students were reached to constitute 75% of the relevant grade. Thus, the sample was considered representative of the population. The sample distribution is given in Table 1.

Table 1. Demographic Composition of the Research Sample by Academic Level, Gender, and Academic Performance

		1		2		3		4		Total	
		n	%	n	%	n	%	n	%	N	%
Gender	Woman	25	14.2	43	24.4	51	29.0	57	32.4	176	73.0
	Male	13	20.0	26	40.0	9	13.8	17	26.2	65	27.0
	Total	38	34.2	69	64.4	60	42.8	74	58.6	241	100
Academic Success Average	2.00-2.50	6	15.8	2	2.9	3	5	3	4.1	14	5.8
	2.51-3.00	16	42.1	26	38	20	33.3	30	40.5	91	37.7
	3.01-3.50	16	42.0	39	56.5	35	58.3	40	54.1	129	53.5
	3.51-4.00	0	0	2	2.9	2	3.3	1	1.4	5	2.9
	Total	38	100	69	100	60	100	74	100	241	100

A total of 241 pre-service primary school teachers participated in the research, including 38 first-year, 69 second-year, 60 third-year, and 74 fourth-year students. When the distribution is examined, it can be said that there are 176 female, and 65 male students and according to the students' statements, more than half of their grade point averages are between 3.0 and 3.5.

Data Collection Tools

"Science Teaching Self-Efficacy Belief Scale" (STSEB)

The STSEB scale developed by Gözüm and Güneş (2018) was used due to its suitability for the level of preservice teachers and the scope of the research. The scale, which has a five-point likert structure, consists of 46 items and includes two dimensions called positive self-efficacy (28 items) and negative self-efficacy (18 items). Negative self-efficacy items are analysed by reverse coding. The two-factor structure explains 41.025% of the variance. The "Cronbach's alpha reliability coefficient" of STSEB was determined as .946, and the sub-dimensions were determined as .933 and .920, respectively. In this study, reliabilities were determined as .957 for the positive self-efficacy belief sub-dimension, .970 for the negative self-efficacy belief sub-dimension, and .972 for the entire scale.

"Science Learning Skills Scale" (SLS)

The original scale developed by Chang, Chen, Guo, Cheng, Lin and Jen (2011) was adapted to Turkish by Şenler (2014). Since the scales adapted to Turkish increase the cultural and linguistic accuracy of the measurement (Aybek & Toraman, 2022), this scale, which was deemed appropriate for the level of the prospective teachers, was used. The original scale has two sub-factors, titled "scientific inquiry" and "communication", each with four dimensions. In the scientific inquiry sub-factor, students' views on scientific process skills are determined (Example item: I can use experimental materials to collect data). In the communication sub-factor, views on effective communication in science-related processes are determined (Example: I can evaluate questions from a different perspective).The scientific inquiry sub-factor, "generating questions and hypotheses, planning, conducting experiments and collecting data, analysing data, interpreting and concluding," sub-dimensions (14 items); the communication sub-factor "expressing, evaluating, interacting, negotiating" sub-dimensions (15 items) includes a total of 29 items and has a five-point Likert structure. The fit indices obtained as a result of confirmatory factor analysis were found to be $\chi2/sd = 4.55$, NNFI = .96, CFI = .96, RMSEA = .08, PGFI = .68, PNFI = .82. When compared with reference values in the literature, it was determined that the factor structure of the Turkish adaptation of the scale was identical to the factor structure of the original scale (Şenler, 2014). The "Cronbach's alpha reliability coefficients" of the scale were determined as .88 for the "scientific inquiry dimension" (sub-dimensions .64- .68- .79- .74, respectively), .89 for the "communication dimension" (sub-dimensions .73- .74- .69- .79, respectively), and 0.93 for entire scale. In this study, reliability was calculated as .973 for all scales (SLS), .954 for the scientific inquiry dimension (.805- .882- .859- .886 in sub-dimensions), and .953 for the communication dimension (.902- .895- .837- .895 in sub-dimensions).

"Basic Science Literacy Test" (BSL)

The original version of the test, adapted into Turkish by Duruk (2012), was developed by Laugksch and Spargo (1996). Considering that the primary school teacher candidates had not taken science courses in high school and had received basic science education at university, the test adapted by Duruk (2012) was deemed appropriate, because it had been used in previous studies with teacher candidates. A validity and reliability study of the BSL test was conducted with high school students, and item difficulty and discrimination indices and KR-20 values were examined. The final version of the test consisted of 49 items, including subtests on the nature of science, science content knowledge, and science-technology-society. The test is answered by choosing from the options "true, false and I don't know" for the given statements. The "Scientific Content Knowledge" sub-dimension includes 6 items in Earth and Space Sciences, 11 items in Life Sciences, 6 items in Physics and Chemistry, and 10 items in Health

Sciences (Example: A gene is a specialized part of a DNA molecule consisting of one or more segments). The "Science-Technology-Society" sub-dimension includes 7 items (Example: Engineering activities affect the daily life of human society more immediately and more directly than scientific research), and the "Nature of Science" sub-dimension includes 9 items (Example: Scientists may emphasize different aspects of scientific findings in their studies due to their past experiences, personal beliefs and value judgments). In the adaptation study, Duruk (2012) calculated the reliability KR-20 value as .82. In this study, the KR-20 value was determined as .80.

Data Collection and Analysis

Before collecting the research data, permission was obtained from the “Social Sciences Ethics Committee”. An online form was created that included demographic information about the participants and the three data collection tools mentioned above. The researcher went to the classrooms, shared the survey form link with the pre-service teachers, had them fill out the form, and checked it. Participants were informed about the purpose of the research, voluntary participation and confidentiality, and that their data would not be shared with third parties. Convenience sample selection was made. Data collection was completed in a month. Then, the online forms were analysed with the help of Excel and SPSS programs. Descriptive analysis of the total scale scores was performed to examine the normal distribution using skewness and kurtosis values. Skewness and kurtosis values were found to be - .529 and .505 for STSEB; -.678 and .145 for SLS; and -1.569 and 3.361 for BSL. Kim (2013) and Hair, Black, Babin, and Anderson (2010) state that for samples larger than 300, an absolute skewness value greater than 2 or an absolute kurtosis (unique) value greater than 7 can be used as reference values to determine non-normality. Based on this, the data were assumed to be normally distributed, and parametric tests were applied. The first sub-problem was analysed using descriptive statistics. Group differences (gender, academic average, and grade) for the second sub-problem were analysed using independent samples t-tests and one-way ANOVA with Bonferroni corrections. The third sub-problem, concerning variable relationships and effects, was examined using Pearson correlation analysis and regression analysis.

Results

The total STSEB score of pre-service primary school teachers (PPST) was 181.65, with a mean of 110.34 in the positive self-efficacy sub-dimension and 71.30 in the negative self-efficacy sub-dimension. The results of the analyses examining differences by grade, gender, and academic success are presented in Table 2.

Table 2. Change in STSEB Scores According to Grade, Gender, And Success

			n	$\bar{X}$	sd	F (t)	df	p
$STSEB_1$	Grade	1	38	107.37	17.16	.698	3	.554
		2	69	109.46	20.34		240	
		3	60	110.95	17.01			
		4	74	112.20	16.31			
	Gender	Woman	176	109.90	15.32	- .631	239	.528
		Male	65	111.54	23.37			
	GPA	a.2.0-2.50	14	92.86	26.45	7.677	2	.000*
		b.2.51-3.00	92	112.11	17.72		238	(between b-a)
		c. Aa>3.00	135	110.96	15.91			(between c-a)
$STSEB_2$	Grade	1	38	73.50	13.66	3.090	3	.028*
		2	69	70.04	18.89		240	
		3	60	75.93	12.84			(3-4)
		4	74	67.59	18.68			
	Gender	Woman	176	73.34	13.85	3.126	239	.002*
		Male	65	65.78	22.59			
	GPA	a.2.0-2.50	14	64.29	16.63	3.683	2	.027*
		b.2.51-3.00	92	68.79	18.80		238	(between c-a)
		c.Aa>3.00	135	73.74	15.24			(between c-b)
$STSEB_{total}$	Grade	1	38	180.87	25.78	1.079	3	.359
		2	69	179.51	26.98		240	
		3	60	186.88	26.86			
		4	74	179.80	25.43			
	Gender	Woman	176	183.24	23.63	1.555	239	.121
		Male	65	177.32	32.29			
	GPA	a.2.0-2.50	14	157.14	40.19	7.390	2	.000*
		b.2.51-3.00	92	180.90	27.02		238	(between b-a)
		c.Aa>3.00	135	184.65	22.68			(between c-a)

GPA: Academic average $STSEB_1$: Positive self-efficacy sub-dimension $STSEB_2$: Negative self-efficacy sub-dimension $STSEB_{total}$: Scale total score *$p< .05$

No significant grade-level difference was found in total STSEB or positive self-efficacy (STSEB1). However, a significant difference emerged in negative self-efficacy (STSEB2) between third- and fourth-year students ($F_{3-240}=3.090$, $p< .05$). By gender, males scored significantly lower in negative self-efficacy ($t_{239}=3.126$, $p< .05$), while no significant differences were observed in positive self-efficacy or the total score. In terms of academic achievement (GPA), students with GPAs of 2.51–3.00 and above 3.00 scored significantly higher in STSEB1 than those with GPAs of 2.00–2.50 ($F_{3-238}=7.677$, $p< .05$). In STSEB2, students with GPAs above 3.00 differed significantly from all other groups ($F_{2-238}=3.683$, $p< .05$). Similarly, total STSEB scores were significantly higher for students with GPAs of 2.51–

3.00 and above 3.00 than for those below 2.50 ($F_{2\text{-}238}$ =7.390, $p < .05$).

The mean SLS score of PPST was 121.54, with 58.79 in scientific inquiry and 62.76 in communication. Results by grade, gender, and academic success are presented in Table 3.

Table 3. Change in SLS Scores According to Grade, Gender, And Success

			n	$\bar{X}$	sd	F(t)	df	p
SLS_1	Grade	1	38	58.26	9.31	.179	3	.911
		2	69	58.45	9.13		238	
		3	60	58.85	8.21			
		4	74	59.34	8.50			
	Gender	Woman	176	58.93	8.15	.408	239	.683
		Male	65	58.42	10.11			
	GPA	a.2.0-2.50	14	53.00	12.46	3.372	2	.036*
		b.2.51-3.00	92	59.26	8.39		238	(between b-a)
		c.Aa>3.00	135	59.07	8.30			(between c-a)
SLS_2	Grade	1	38	61.47	11.03	.423	3	.737
		2	69	62.52	9.91		238	
		3	60	63.72	8.27			
		4	74	62.85	10.23			
	Gender	Woman	176	62.89	9.08	.342	239	.733
		Male	65	62.40	11.55			
	GPA	a.2.0-2.50	14	56.93	12.96	2.672	2	.071
		b.2.51-3.00	92	63.13	9.78		238	
		c. Aa>3.00	135	63.10	9.30			
SLS_{Total}	Grade	1	38	119.74	19.87	.250	3	.861
		2	69	120.97	18.50		237	
		3	60	122.56	15.76			
		4	74	122.19	17.89			
	Gender	Woman	176	121.82	16.51	.387	239	.699
		Male	65	120.82	21.06			
	GPA	a.2.0-2.50	14	109.93	25.25	3.224	2	.042*
		b.2.51-3.00	92	122.39	17.21		238	(between b-a)
		c.Aa>3.00	135	122.17	17.04			(between c-a)

GPA: Academic average SLS_1 : Scientific inquiry sub-dimension SLS_2 : Communication sub-dimenson SLS_{Total} : Scale total score *$p< .05$

SLS scores did not differ significantly by grade or gender. However, significant differences were found by GPA. In the scientific inquiry sub-dimension (SLS_1), students with GPAs above 2.50 scored significantly higher than those with GPAs between 2.00–2.50 ($F_{2\text{-}238}$=3.372, $p< .05$). No significant differences were found in the communication sub-dimension (SLS_2), although students with higher GPAs tended to score better. For the total SLS score, students with GPAs above 2.50 again outperformed those with lower GPAs ($F_{2\text{-}238}$=3.224, p< .05).

The BSL of the PPST was found to be $\bar{X}$=32.91 in total, scientific content (BSL_1)sub-dimension 23.06 (earth and space sciences $\bar{X}$=4.27; life sciences $\bar{X}$=8.02; physics and chemistry $\bar{X}$=3.64; health sciences $\bar{X}$=7.14), nature of science (BSL_2) sub-dimension $\bar{X}$=5.56, and science-technology-society (BSL_3) sub-dimension $\bar{X}$=4.29. It was analyzed according to grade, gender and academic success average; Table 4 presents the results.

Table 4. Change in BSL Level Scores According to Class, Gender and Success

			n	$\bar{X}$	*sd*	F(t)	df	p
BSL 1	Grade	1	38	21.97	6.79	1.973	3	.119
		2	69	23.98	3.50		237	
		3	60	23.20	3.46			
		4	74	22.65	4.48			
	Gender	Woman	176	23.23	3.95	.940	239	.348
		Male	65	22.61	5.70			
	GPA	a.2.0-2.50	14	22.00	5.32	.525	2	.587
		b.2.51-3.00	92	23.30	3.58		238	
		c.Aa>3.00	135	23.00	4.91			
BSL 2	Grade	1	38	5.55	2.28	1.681	3	.172
		2	69	5.86	1.62		237	
		3	60	5.70	1.86			
		4	74	5.18	1.94			
	Gender	Woman	176	5.52	1.86	- .578	239	.564
		Male	65	5.68	2.01			
	GPA	a.2.0-2.50	14	5.07	2.23	2.601	2	.076
		b.2.51-3.00	92	5.90	1.83		238	
		c. Aa>3.00	135	5.38	1.89			
BSL 3	Grade	1	38	4.18	1.52	.674	3	.569
		2	69	4.48	1.17		237	
		3	60	4.27	1.52			
		4	74	4.18	1.38			
	Gender	Woman	176	4.26	1.30	- .461	239	.645
		Male	65	4.35	1.58			
	GPA	a.2.0-2.50	14	4.14	1.88	.083	2	.920
		b.2.51-3.00	92	4.28	1.24		238	
		c.Aa>3.00	135	4.30	1.42			
BSL_t	Grade	1	38	31.71	9.38	1.953	3	.122
		2	69	34.32	5.07		237	

	3	60	33.17	6.02			
	4	74	32.00	6.67			
Gender	Woman	176	33.01	5.92	.371	239	.711
	Male	65	32.65	8.40			
GPA	a.2.0-2.50	14	31.21	8.55	.912	2	.403
	b.2.51-3.00	92	33.51	5.47		238	
	c.Aa>3.00	135	32.91	7.17			

GPA: Academic average BSL_1 : Scientific content sub-dimension
BSL_2 : Nature of science sub-dimension BSL_3: STS sub-dimension BSL_{total} : Total score

BSL levels of PPST showed no significant differences in sub-dimensions or total scores across any variables. In scientific content sub-dimension (BSL_1), second graders, females, and those with GPAs of 2.51–3.00 had the highest means, but differences were not significant. In nature of science sub-dimension (BSL_2), higher means were observed for second graders, males, and GPAs of 2.51–3.00, with no significant differences. In science-technology-society sub-dimension (BSL_3), the highest means were again for second graders, males, and GPAs of 2.51–3.00, with no significant differences. For the total score, second graders, females, and GPAs of 2.51–3.00 scored highest, but differences remained non-significant.

Correlation analysis revealed a moderate positive relationship between STSEB and SLS ($r= .658$, $p < .001$), a weak positive relationship between STSEB and BSL ($r= .246$, $p < .001$), and a weak positive relationship between SLS and BSL ($r= .203$, $p < .001$).

Multiple regression analysis examined the extent to which STSEB was predicted by SLS, BSL, grade, and academic success. The results are presented in Table 5.

Table 5. Regression Analysis Results

Variable	B	Standard Error	β	t	p	Binary r	Partial R
Constant	38.502	10,198		3.776	.000		
SLS	0.987	.068	.668	14.431	.000	.697	.685
BSL	2.600	1.235	.097	2.105	.036	.212	.136
grade	-0.828	1.123	- .034	- .737	.462	.010	- .048
success	5.671	1.884	.138	3.010	.003	.202	.192

$R= .717$ $R^2 = .514$ $F_{4\text{-}236} = 62.386$ $p= .000$

$$STSEB= 38.502 + .987SLS + 2.60BSL - .828Grade + 5.671Success$$

The model was significant ($R = .717$, $R^2 = .514$, $F_{4\text{-}236} = 62.386$, $p < .001$), indicating that these variables together explained 51% of the variance in STSEB.

When the standardized regression coefficients (β) are examined, the order of importance of the determined variables on science teaching self-efficacy belief is science learning skills, academic success, and basic science literacy level. It is evident from the t-test results about the significance of the regression coefficients that the grade level has no discernible impact on the belief in the usefulness of science instruction. The equation produced from the regression analysis is as follows: Science Teaching Self-Efficacy Belief= 38.502 + .987(Science Learning Skill) + 2.60(Basic Science Literacy) - .828Grade + 5.671Success. These values indicate that a one-unit increase in pre-service teachers' SLS scores will result in a .987-unit increase in STSEB scores; a one-unit increase in BSL scores will result in a 2.60-unit increase in STSEB scores; and a one-unit increase in achievement will result in a 5.671-unit increase in STSEB scores. Academic achievement may be considered to have the highest impact here.

Discussion, Conclusion, and Suggestions

This study examined pre-service primary school teachers' (PPST) science teaching self-efficacy beliefs, science learning skills, and scientific literacy levels. The mean STSEB score (above 181.25) was consistent with previous research (Aydede, 2022; Kahraman, Yılmaz, Bayrak & Güneş, 2014). Although no significant grade-level differences were found in total STSEB or in positive self-efficacy, a difference emerged in negative self-efficacy between third- and fourth-year students. These variations may be linked to curriculum structure. First-year students had low self-efficacy, likely due to limited exposure to science courses. These variations may be linked to curriculum structure. First-year students had low self-efficacy, likely due to limited exposure to science courses. Fourth-year students, having completed science teaching and practicum courses, generally exhibited higher self-efficacy—a pattern supported by literature linking such courses to improved confidence (Bayraktar, 2011; Morrell & Carroll, 2003; Watter & Ginns, 1995). However, at the time of data collection (end of fall semester), fourth-year students' STSEB was lower than that of third-year students, possibly due to the long gap since their last science method course. Recent changes in teacher education (e.g., reduce of mandatory science courses after 2018) may further contribute to inconsistent self-efficacy development across grades. Offering sustained and structured science teaching courses over multiple terms could help maintain and strengthen pre-service teachers' self-efficacy

No significant gender-based differences were found in PPSTs' overall science teaching self-efficacy beliefs (STSEB) and positive self-efficacy sub-dimension, although but the difference in favor of female participants in negative self-efficacy beliefs was significant. This finding aligns with several studies in the literature (e.g., Çetin, 2008; Kutluca & Aydın, 2016). However, a significant difference in STSEB was identified based on academic average. Students with higher grade point averages reported stronger self-efficacy, suggesting a positive relationship between academic performance and confidence in teaching science—a correlation supported by Fettahlıoğlu, Güven, Aka, Çıbık, and Aydoğru (2011), though not universally confirmed (e.g., Amponsah, Adu-Gyamfi, Awoniyi & Commey-Mintah, 2024). High levels of self-efficacy regarding science teaching among preservice teachers will be a determinant in their future classroom practices, such as designing experiments in science lessons, guiding students toward science, research, and inquiry. Considering that students encounter science classes in third and fourth grades in primary school, especially primary school teachers need to be active in making science appealing, drawing interest in science-related topics, and guiding children toward science-related careers. This can only be achieved if they possess a high level of confidence in science teaching self-efficacy.

The mean science learning skills (SLS) score of pre-service primary school teachers (PPST) was above the scale average, consistent with previous studies (Aydede, 2022; Ural & Yolagiden, 2021). No significant overall difference was found in SLS by grade level, but fourth-year students scored higher in inquiry skills, while third-year students scored higher in communication skills and total SLS. Inquiry skills and communication skills are competencies targeted for students to acquire during science courses. It can be inferred that senior students, having completed science courses in the primary school teaching curriculum and undertaken teaching practice, possess stronger inquiry skills; while third-year students, who are more immersed in teaching courses, exhibit stronger communication skills compared to others. Inquiry learning skills can be influenced by many factors such as learning styles, teaching methods, materials, collaboration, and guidance. Involving pre-service teachers in a learning environment where they are cognitively and socially active supports the development of cognitive skills and contributes to the development of inquiry skills (Kuter, 2013).

Analysis by gender revealed that while female participants had higher mean scores on the overall Science Learning Skills (SLS) scale and its sub-dimensions, these differences were not statistically significant. In terms of academic achievement, a significant difference was found. Participants with high (GPA > 3.50) and medium (GPA 2.51–3.50) grade point averages scored significantly higher on the overall SLS, and the inquiry skills sub-dimension (SLS1) compared to those with low academic achievement (GPA ≤ 2.50). However, no significant difference was observed in the communication skills sub-dimension (SLS2). This finding is consistent with previous research (Chandola & Tiwari, 2024; Dolapçıoğlu & Subaşı, 2022). These results suggest that students with higher academic performance exhibit stronger inquiry and communication skills. Inquiry skills, which are closely linked to critical thinking, problem-solving, creativity, and intrinsic motivation, appear to contribute positively to academic success. Moreover, students with well-developed scientific process skills and science literacy—core components of inquiry—demonstrate greater proficiency in solving problems and mastering scientific content.

The average scientific literacy (BSL) score of preservice primary school teachers (PPST) was 32.91, which is above the average score attainable on the test. In the literature, the science literacy levels of preservice teachers have been rated across a wide range, from good (Al Sultan et al., 2021; Chin, 2005; Fadde et al., 2018) to moderate (Nurhayati et al., 2023) or low (Sarini et al., 2024). These differences may stem from the measurement tools used and the sample. When the scores from the scientific content knowledge section (BSL_1) of the test were examined, the lowest average was found in physics-chemistry questions (3.64 points out of 6). While scores in other disciplines were well above average, this result highlights a significant inadequacy in preservice teachers' physics and chemistry content knowledge. This finding is consistent with other studies (Catalano, Asselta, & Durkin, 2019; Walag et al., 2022).

Physics and chemistry topics are challenging to teach and learn due to their abstract concepts, difficulty in visualization, reliance on mathematical formulas, and the differences between scientific and everyday language (Suprapto, 2020). Teachers with insufficient content knowledge tend to provide superficial instruction on these topics. A teacher's content knowledge directly influences their self-efficacy beliefs and teaching methods. Research shows that teachers perceive their self-efficacy to be highest in biology and lowest in physics (Al Sultan et al., 2018). In conclusion, scientific literacy encompasses not only content knowledge but also an awareness of the nature of science and the relationship between science, technology, and society. Improving this literacy helps boost preservice teachers' self-efficacy in science instruction and enables them to design more student-centred activities in their future careers.

No significant difference was found in scientific literacy (BSL) levels across grade levels. However, notable patterns emerged in the averages: Second-year students had the highest overall and sub-dimension scores. First-year students scored the lowest in scientific content knowledge (BSL1) and overall BSL. Fourth-year students scored the lowest in the nature of science sub-dimension (BSL2). First and fourth-year students had low scores in the science-technology-society sub-dimension (BSL3). The second-year students' strong performance in scientific content is likely attributable to their recent completion of foundational science and science laboratory courses. Conversely, first-year students, entering the program with a general university entrance score, began with insufficient science knowledge. The low nature of science (BSL2) scores among senior students align with previous findings that preservice teachers often hold inadequate perceptions of the nature of science, despite increases in self-efficacy in their final year (Çavaş et al., 2013; Lederman, 1992).

In the research, no significant difference in BSL levels was found based on gender. The literature reports announce mixed findings on gender, with some studies favouring women (e.g. Çavaş et al., 2013), the other men (e.g. Chin, 2005), and some findings bear no significant difference (e.g. Tekin et al., 2016). This suggests that within a standardized curriculum, gender is not a primary determinant of science literacy. When examined by academic achievement, while not statistically significant, a trend was observed: students with the lowest GPAs had lower BSL averages, whereas those with higher GPAs (above 3.00) scored highest in the science-technology-society sub-dimension (BSL3). This indicates a positive relationship between general academic success and science literacy comprehension, supporting the finding that scientific literacy increases with academic achievement (Tekin et al., 2016).

Science learning skills, basic science literacy level, grade, and academic success together explain 51% of the variance in PPST' STSEB scores. While the effect of grade was not significant in the regression analysis, the effect of academic success was found to be significant. The enhancement of preservice teachers' general academic success, science literacy, questioning, and communication skills also improves their beliefs in the efficacy of science education.

This study was conducted with preservice teachers at a single university in the Black Sea region, and its findings may be influenced by variations in teacher training programs across institutions. The results indicate that preservice teachers' self-efficacy in science teaching is closely linked to their academic achievement, science literacy, and science learning skills. To develop confident and effective science teachers, both content knowledge and self-efficacy must be strengthened concurrently. It is recommended that physics, chemistry, biology, and science laboratory courses—previously reduced or removed from the curriculum—be reintroduced and aligned with the primary school science curriculum.

Providing ample practical experience and mentorship in science teaching methods and teaching practice courses is essential, as hands-on application is a critical source of self-efficacy. Furthermore, science teaching courses should explicitly incorporate the nature of science, science-life connections, problem-solving, and inquiry-based approaches to indirectly enhance scientific literacy, learning skills, and teaching self-efficacy. Ultimately, cultivating passionate, curious, and confident science teachers will positively impact future generations by inspiring student interest in science and contributing to a more scientifically literate society.

Declarations

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Ethics Committee Approval: This research was conducted with the permission obtained by the Amasya University Scientific Research and Publication Ethics Social and Human Sciences Board's decision dated 08/04/2022 and numbered E-6532808.

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Informed Consent: Preservice teachers were informed about the purpose and scope of the study, that data collection was based on voluntary participation, and that the data provided would be used only for the relevant research purpose. It was stated that information would be collected anonymously, and before administering the online form, the necessary environment was prepared, and completion of the online surveys was verified.

***Data availability**:* The data collected and analysed in the study can be obtained from the corresponding author upon request.

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