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Original article

Relationship Between Competence for Learning Science and Learner Autonomy: A Study on Pre-Service Teachers

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Abstract

This study examined the relationship between pre-service teachers' science learning competence and learner autonomy and whether these constructs differed by teacher education program and grade level. Using a correlational survey design, data were collected from 341 pre-service teachers enrolled in preschool, primary, and science education programs. The Competence Scale for Learning Science and the Learner Autonomy Scale were used for data collection. Data were analyzed using one-way ANOVA and Pearson correlation analysis. Science learning competence differed significantly by teacher education program and grade level, with preschool education pre-service teachers reporting higher scores than primary and science education pre-service teachers. Learner autonomy also differed across programs and grade levels. Preschool education pre-service teachers reported higher overall learner autonomy than science education pre-service teachers, while third- and fourth-year pre-service teachers scored higher than second-year pre-service teachers. Science learning competence was weakly and negatively related to learner autonomy. The findings suggest that science learning competence and learner autonomy are related but distinct aspects of pre-service teachers' learning.

Keywords: Competence for Learning Science, Learner Autonomy, Pre-service Teachers.

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INTRODUCTION

Contemporary approaches to education increasingly emphasize students' active participation in and responsibility for their own learning. Rapid advancements in science, technology, and access to information have also heightened the importance of individuals' ability to adapt to new knowledge, manage their own learning, and continue learning throughout their lives (Alkan & Arslan, 2019; Yaşar & Atay, 2023). These expectations are particularly important for science education, where learning involves not only acquiring scientific knowledge but also asking questions, conducting research, interpreting evidence, communicating ideas, and taking responsibility for the learning process (Yaşar & Atay, 2023). Accordingly, developing the competencies necessary for learning science and supporting students' capacity to manage their own learning represent important and potentially complementary goals of teacher education (Smith, 2003). Researchers have conducted studies aimed at determining pre-service teachers' science learning competencies (Chang et al., 2011; Ural & Yolagiden, 2021) and learner autonomy (Okumuş Dağdeler, 2018; Sofracı, 2016). However, examining the relationship between these two in the context of various variables will assist researchers in identifying key considerations in the teacher education process.

Science Learning Competencies

Science education requires students to actively participate in scientific inquiry and to effectively communicate their ideas and findings. Rather than merely acquiring scientific facts, students are expected to formulate questions, gather and analyze evidence, draw conclusions, and communicate their reasoning. In this context, science education encompasses a set of competencies that enable students to actively participate in the processes through which scientific knowledge is generated and communicated (Chang et al., 2011; Özdemir et al., 2022; Yaşar & Atay, 2023).

Chang et al. (2011) conceptualized science learning competencies through two interrelated dimensions: scientific inquiry and communication. Scientific inquiry encompasses competencies such as asking questions and formulating hypotheses, planning research, conducting experiments, collecting data, and analyzing and interpreting evidence. Communication includes elements such as expressing and evaluating ideas, interacting with others, discussing different perspectives, and conveying scientific explanations. Together, these dimensions reflect students' active participation in both the research and communication processes of science learning. Developing these competencies is particularly important in teacher education. Pre-service teachers are expected not only to possess the competencies necessary for their own effective participation in science learning, but also to create learning environments in which their future students can engage in inquiry, reasoning, communication, and active participation in science (Smith, 2003). However, effective participation in science learning may also involve students' capacity to take responsibility for and manage their own learning. This necessitates addressing learner autonomy as another relevant concept.

Learner Autonomy

Learner autonomy is generally defined as students' capacity to take responsibility for their own learning (Holec, 1981, 1991). Autonomous learners take an active role in setting learning goals, selecting appropriate strategies and resources, monitoring their progress, and evaluating learning outcomes (Alkan & Arslan, 2019; Yaşar & Atay, 2023). Thus, autonomy extends beyond working independently and involves taking responsibility for different aspects of the learning process. This capacity is increasingly important as changing knowledge and technologies require learners to identify their learning needs, adapt to new demands, and continue learning beyond formal education. Learner autonomy is therefore closely associated with lifelong learning, particularly in professions that require continuous professional development (Smith, 2003).

Learner autonomy is particularly relevant to preservice teachers because it has both personal and professional dimensions. During teacher preparation, preservice teachers are expected to assume greater responsibility for their own learning and develop habits that support continued professional learning. As future teachers, they also need to create learning environments in which students can make decisions, monitor their learning, and gradually assume greater responsibility for the learning process (Smith, 2003). Developing autonomy during teacher preparation may therefore contribute not only to preservice teachers' own learning but also to their ability to support autonomy in their future classrooms.

Learner autonomy is closely linked to student-centered learning environments where students have opportunities to make decisions, reflect on their learning, assess their progress, and gradually take on greater responsibility. In such environments, the teacher's role does not disappear. Instead, it shifts toward facilitating and supporting an increase in students' responsibility for their own learning. Accordingly, examining learner autonomy in teacher education can provide insight into how well future teachers are prepared not only to manage their own learning but also to support more autonomous forms of learning in their future professional practice.

Research on learner autonomy has largely focused on language education, with relatively limited attention to other disciplinary contexts (Taş, 2016). Studies involving pre-service teachers have also examined whether autonomy varies according to educational characteristics such as the teacher education program and grade level. For example, Alkan and Arslan (2019) reported differences in autonomous learning based on the curriculum, but not on grade level. More recently, Phan et al. (2024) demonstrated that pre-service teachers in different programs and grade levels perceived their teacher education experiences as providing only partial preparation for developing autonomy and emphasized the importance of opportunities that enable future teachers to take greater responsibility for their own learning.

Science Learning Competence and Learner Autonomy

Science learning competence and learner autonomy share a common focus on active student participation and responsibility for learning. However, their potential connections extend beyond this general similarity. Autonomous learning requires students to make decisions, select appropriate strategies and resources, monitor their progress, and evaluate their learning outcomes (Alkan & Arslan, 2019; Yaşar & Atay, 2023). Similarly, science education requires students to make decisions throughout their inquiry, search for and evaluate information, gather and interpret evidence, communicate explanations, and revise their ideas considering the evidence (Chang et al., 2011). Thus, both frameworks position students as active participants in knowledge construction rather than passive recipients of information.

Scientific inquiry requires students to formulate questions, determine ways to investigate these questions, gather and evaluate evidence, and draw conclusions. Scientific communication, on the other hand, requires students to articulate their reasoning, interact with others, evaluate alternative perspectives, and assess scientific explanations. These processes, to a certain extent, require responsibility, decision-making, and active engagement with one's own learning (Yaşar & Atay, 2023). Learner autonomy similarly involves taking responsibility for learning, making decisions related to the learning process, selecting appropriate strategies, and monitoring one's own progress (Holec, 1981; Reinders, 2010). This conceptual overlap provides a basis for expecting a relationship between science learning competence and learner autonomy. This relationship may be particularly significant in teacher education. Pre-service teachers, who are prepared to facilitate inquiry-based and student-centered science learning, are themselves learners who must engage with scientific knowledge, ask questions, communicate ideas, and manage their own learning (Smith, 2003; Yaşar & Atay, 2023). Understanding the relationship between science learning competencies and learner autonomy can provide insights into preparing future teachers who are capable of both learning science effectively and supporting their students' active and autonomous learning.

Despite these conceptual links, previous studies have largely examined science learning competence (Chang et al., 2011; Ural & Yolagiden, 2021) and learner autonomy (Okumuş Dağdeler, 2018; Sofracı, 2016) separately. Consequently, the relationship between science learning competence and learner autonomy among pre-service teachers has been relatively under-researched. Therefore, examining these structures together can contribute to a more integrated understanding of how pre-service teachers actively and responsibly engage in science learning.

Teacher Education Program and Grade Level

Teacher education program and grade level provide two relevant contexts for examining science learning competence and learner autonomy. The three programs included in this study—science education, primary education, and preschool education—prepare teachers who contribute to children's

science learning at different educational levels. Science teachers receive specialized preparation for science instruction, whereas primary and preschool teachers address science within broader educational responsibilities. These differences may result in varying experiences with science content, scientific inquiry, and science teaching during teacher preparation. Comparing preservice teachers across these programs may therefore provide insight into differences in science learning competence and learner autonomy.

Grade level offers an additional educational perspective. It is thought that pre-service teachers may differ across various stages of teacher education in terms of their exposure to discipline-specific courses, pedagogical preparation, science teaching experiences, and opportunities to take responsibility for their own learning (Alkan & Arslan, 2019; Smith, 2003). Previous research also indicates that educational experience and the stage of preparation may be related to learner autonomy and learning-related competencies (Alkan & Arslan, 2019). Therefore, examining grade-level differences may provide further insight into science learning competence and learner autonomy at different stages of teacher preparation. However, given the cross-sectional nature of the present study, these differences are interpreted as differences between groups at different grade levels rather than as evidence of individual development over time.

Purpose of the Study

The primary objective of this study was to examine the relationship between pre-service teachers' science learning competence and learner autonomy. The secondary objective was to determine whether science learning competence and learner autonomy vary according to teacher education program and grade level. By examining these constructs together among pre-service teachers preparing for teaching responsibilities in the sciences, this study aims to contribute to the understanding of the relationship between competence in science learning and autonomous learning in teacher education. The following research questions guided the study:

1. Do pre-service teachers' science learning competencies differ according to the teacher education program and grade level?

2. Do pre-service teachers' learner autonomy vary according to the teacher education program and grade level?

3. Is there a significant relationship between pre-service teachers' science learning competencies and learner autonomy, as well as their respective dimensions?

METHODS

Research Design

This study employed a correlational survey design, a quantitative research approach. The correlational survey model is the preferred model for identifying relationships involving at least two variables or within a given context (Karasar, 1998). The variables used in this study are science learning competencies and learner autonomy. Additionally, the relationships between these variables and the teacher education program and grade level of the pre-service teachers were examined.

Participants

The study sample consisted of pre-service science, primary school, and preschool teachers studying in a province located in the southern part of the Marmara Region. A total of 341 pre-service teachers participated in the study through convenience sampling. The purpose of selecting this method was to allow the researcher to non-randomly determine the sample to be drawn from the population. This method was preferred because it allows for the fastest, easiest, and most economical collection of data from the population (Yıldırım & Şimşek, 2018). It aims to create a sample by selecting individuals who will teach science and who are easily accessible. For this reason, the sample was drawn from pre-service science teachers, pre-service primary school teachers, and pre-service preschool education teachers. The pre-service teachers participated in the study on a voluntary basis. The demographic information of the study group is presented in Table 1.

Table 1. Demographic information

Variable		***f***	***%***
Grade Level	First year	122	36
	Second year	61	18
	Third year	83	24
	Fourth year	75	22
Teacher education program	Preschool Education	99	29
	Primary Education	77	23
	Science Education	165	48
Total		341	100

Data Collection Tools

Three different tools were used to collect data. The first is a personal information form. It includes questions regarding the pre-service teachers' subject area and grade level.

The second data collection tool is the "Competence Scale for Learning Science (CSLS)." It was developed by Chang et al. (2011). The scale was adapted into Turkish by Şenler (2014). The scale consists of two subdimensions *Scientific Inquiry* and *Communication* and a total of 29 items. The scientific inquiry dimension has four subdimensions: formulating questions and hypotheses, planning,

conducting experiments and collecting data, and analyzing and interpreting data; the communication dimension has four subdimensions: expressing ideas, evaluating, interacting, and negotiating. The scale is a 5-point Likert-type scale, scored as follows: 5 = Strongly Agree, 4 = Agree, 3 = Undecided, 2 = Disagree, and 1 = Strongly Disagree. In this study, Cronbach's Alpha coefficients were calculated as .95 for the entire CSLS, .91 for the scientific inquiry subscale, and .93 for the communication subscale.

The third data collection tool is the "Learner Autonomy Scale (LAS)," developed by Macaskill and Taylor (2010). The scale was adapted into Turkish by Alkan and Arslan (2019). The scale consists of two subscales *Study Habits* and *Independence of Learning* and a total of 12 items. It is a 5-point Likert-type scale scored as 1 (not at all like me) to 5 (very like me). Higher scores on the scale indicate a greater degree of autonomy, a positive attitude toward learning, and independence. Cronbach's Alpha coefficient for the entire scale was calculated as .74, which is considered an acceptable value (Taber, 2018).

Data Analysis

Normality tests were applied to the scales to determine which analyses should be performed first on the data obtained from the study. The results of the normality analyses are presented in Table 2.

Table 2. Results of the normality analysis of the scales

Scale	***n***	***M***	***SD***	***SE***	**Skewness**	**Kurtosis**
Learner Autonomy Scale (LAS)	341	3.72	0.38	0.02	0.213	-0.672
Competence Scale for Learning Science (CSLS)	341	2.14	0.68	0.03	3.488	0.571

According to Table 2, the arithmetic mean of the LAS scores is 3.72, with a standard deviation of 0.38. The arithmetic mean (*M*) of the CSLS scores is 2.14, with a standard deviation of 0.68. Based on the LAS and CSLS variables, a normal distribution was observed, and parametric tests were applied. Kim (2013) states that in study groups larger than 300, an absolute skewness value greater than 2 and an absolute kurtosis value greater than 7 can be used as indicators to identify significant deviations from normality. In this study, ANOVA and correlation, two quantitative research techniques, were used. The correlation technique is used to identify and interpret the relationship between two or more variables. One-Way ANOVA is used to determine whether the difference between the means of two or more independent samples is statistically significant (Büyüköztürk, 2020).

RESULTS

Competence for Learning Science

The results of the one-way ANOVA analysis of CSLS among pre-service teachers by teacher education programs are presented in Table 3.

Table 3. Results of the One-Way ANOVA analysis of CSLS among pre-service teachers by teacher education program

Variable	Teacher Education Program	*n*	*M*	*SD*	*F*(2, 338)	*p*	η²	Significant Differences
CSLS (Total)	Preschool Education	99	2.38	0.91	9.37	< .001	.053	Preschool-Primary; Preschool-Science
	Primary Education	77	2.00	0.49				
	Science Education	165	2.05	0.56				
	Total	**341**	**2.14**	**0.68**				
Scientific Inquiry	Preschool Education	99	2.42	0.92	9.84	< .001	.055	Preschool-Primary; Preschool-Science
	Primary Education	77	2.03	0.52				
	Science Education	165	2.07	0.58				
	Total	**341**	**2.17**	**0.71**				
Communication	Preschool Education	99	2.34	0.92	7.76	.001	.044	Preschool-Primary; Preschool-Science
	Primary Education	77	1.97	0.52				
	Science Education	165	2.03	0.60				
	Total	**341**	**2.11**	**0.71**				

Note. M = mean; *SD* = standard deviation; η² = eta squared. Significant pairwise differences were determined using Tukey's HSD post hoc test.

A one-way ANOVA was conducted to examine whether pre-service teachers' science learning competence differed across teacher education programs. As shown in Table 3, a statistically significant difference was found in overall science learning competence across programs, $F(2, 338) = 9.37$, $p < .001$, $\eta^2 = .053$. Tukey HSD post hoc comparisons indicated that pre-service teachers in the preschool education program ($M = 2.38$, $SD = 0.91$) scored significantly higher than those in the primary education ($M = 2.00$, $SD = 0.49$) and science education programs ($M = 2.05$, $SD = 0.56$). No significant difference was found between the primary and science education groups.

A similar pattern was observed for both dimensions of science learning competence. Significant program differences were found for scientific inquiry, $F(2, 338) = 9.84$, $p < .001$, $\eta^2 = .055$, and communication, $F(2, 338) = 7.76$, $p = .001$, $\eta^2 = .044$. Post hoc comparisons showed that pre-service preschool teachers had significantly higher scores than both pre-service primary and science teachers on both dimensions, whereas the primary and science education groups did not differ significantly from each other. Overall, the findings indicate that teacher education program was associated with small but statistically significant differences in science learning competence and both of its dimensions, with preschool education students consistently reporting higher scores.

The results of the one-way ANOVA analysis of CSLS among pre-service teachers by grade levels are presented in Table 4.

Table 4. One-Way ANOVA results for science learning competence by grade level

Variable	Grade Level	*n*	*M*	*SD*	*F*(3,337)	*p*	η²	Significant Differences
CSLS (Total)	First year	122	2.01	0.46	5.39	.001	.046	2 > 1; 4 > 1; 4 > 3
	Second year	61	2.30	0.65				
	Third year	83	2.02	0.50				
	Fourth year	75	2.33	1.04				
	Total	**341**	**2.14**	**0.68**				
Scientific Inquiry	First year	122	2.07	0.47	4.18	.006	.036	4 > 1; 4 > 3
	Second year	61	2.31	0.66				
	Third year	83	2.04	0.57				
	Fourth year	75	2.34	1.06				
	Total	**341**	**2.17**	**0.71**				
Communication	First year	122	1.96	0.51	6.00	.001	.051	2 > 1; 4 > 1; 4 > 3
	Second year	61	2.28	0.68				
	Third year	83	2.01	0.51				
	Fourth year	75	2.31	1.05				
	Total	**341**	**2.11**	**0.71**				

Note. M = mean; SD = standard deviation; η² = eta squared. Significant pairwise differences were determined using Tukey's HSD post hoc test. 1 = first year; 2 = second year; 3 = third year; 4 = fourth year.

A one-way ANOVA showed that pre-service teachers' overall science learning competence differed significantly across grade levels, $F(3, 337) = 5.39$, $p = .001$, $\eta^2 = .046$. Post hoc comparisons indicated that second-year students ($M = 2.30$, $SD = 0.65$) scored significantly higher than first-year students ($M = 2.01$, $SD = 0.46$). Fourth-year students ($M = 2.33$, $SD = 1.04$) also scored significantly higher than both first-year ($M = 2.01$, $SD = 0.46$) and third-year students ($M = 2.02$, $SD = 0.50$).

Significant grade-level differences were also found for scientific inquiry, $F(3, 337) = 4.18$, $p = .006$, $\eta^2 = .036$, and communication, $F(3, 337) = 6.00$, $p = .001$, $\eta^2 = .051$. For scientific inquiry, fourth-year students scored significantly higher than first- and third-year students. For communication, second-year students scored significantly higher than first-year students, while fourth-year students scored significantly higher than both first- and third-year students. Overall, grade-level differences were small, accounting for approximately 3.6%–5.1% of the variance in science learning competence and its dimensions.

Learner Autonomy

Table 5 presents the findings regarding pre-service teachers' learner autonomy and its dimensions according to teacher education program.

Tablo 5. One-Way ANOVA results for learner autonomy by teacher education program

Variable	Teacher Education Program	*n*	*M*	*SD*	*F*(2, 338)	*p*	η²	Significant Differences
LAS (Total)	Preschool Education	99	3.80	0.36	4.09	.018	.024	Preschool > Science
	Primary Education	77	3.74	0.40				
	Science Education	165	3.67	0.40				
	Total	**341**	**3.72**	**0.39**				
Study Habits	Preschool Education	99	3.69	0.45	4.02	.019	.023	Preschool > Science
	Primary Education	77	3.72	0.45				
	Science Education	165	3.56	0.48				
	Total	**341**	**3.63**	**0.47**				
Independence of Learning	Preschool Education	99	3.88	0.48	2.76	.065	.016	-
	Primary Education	77	3.76	0.53				
	Science Education	165	3.74	0.48				
	Total	**341**	**3.79**	**0.50**				

Note. M = mean; *SD* = standard deviation; η² = eta squared. Significant pairwise differences were determined using Tukey's HSD post hoc test.

A one-way ANOVA revealed a statistically significant difference in learner autonomy across teacher education programs, $F(2, 338) = 4.09$, $p = .018$, $\eta^2 = .024$. Tukey HSD post hoc comparisons indicated that pre-service teachers in preschool education ($M = 3.80$, $SD = 0.36$) reported significantly higher learner autonomy than those in science education ($M = 3.67$, $SD = 0.40$). A significant program difference was also found for study habits, $F(2, 338) = 4.02$, $p = .019$, $\eta^2 = .023$, with pre-service teachers in primary education ($M = 3.72$, $SD = 0.45$) scoring significantly higher than those in science education ($M = 3.56$, $SD = 0.48$). In contrast, Independence of Learning did not differ significantly across teacher education programs, $F(2, 338) = 2.76$, $p = .065$, $\eta^2 = .016$. Overall, teacher education program was associated with small differences in learner autonomy and study habits, while no statistically significant program difference was found in Independence of Learning.

The findings regarding whether pre-service teachers' learner autonomy and its dimensions differed across grade levels are presented in Table 6.

Table 6. One-Way ANOVA results for learner autonomy by grade level

Variable	Grade Level	*n*	*M*	*SD*	*F*(3, 337)	*p*	η²	Significant Differences
LAS (Total)	First year	122	3.71	0.35	3.56	.015	.031	3 > 2; 4 > 2
	Second year	61	3.59	0.40				
	Third year	83	3.76	0.43				
	Fourth year	75	3.80	0.37				
	Total	**341**	**3.72**	**0.39**				
Study Habits	First year	122	3.68	0.47	1.18	.317	.010	-

	Second year	61	3.55	0.49				
	Third year	83	3.65	0.44				
	Fourth year	75	3.62	0.47				
	Total	**341**	**3.63**	**0.47**				
Independence of Learning	First year	122	3.74	0.45	5.07	.002	.043	3 > 2; 4 > 1; 4 > 2
	Second year	61	3.63	0.50				
	Third year	83	3.85	0.55				
	Fourth year	75	3.93	0.46				
	Total	**341**	**3.79**	**0.50**				

Note. M = mean; SD = standard deviation; η^2 = eta squared. Significant pairwise differences were determined using Tukey's HSD post hoc test. 1 = first year; 2 = second year; 3 = third year; 4 = fourth year.

A one-way ANOVA revealed a statistically significant difference in overall learner autonomy across grade levels, $F(3, 337) = 3.56$, $p = .015$, $\eta^2 = .031$. Post hoc comparisons indicated that third-year ($M = 3.76$, $SD = 0.43$) and fourth-year pre-service teachers ($M = 3.80$, $SD = 0.37$) reported significantly higher learner autonomy than second-year pre-service teachers ($M = 3.59$, $SD = 0.40$). No other significant differences were observed.

Regarding the dimensions of learner autonomy, no statistically significant difference was found in study habits across grade levels, $F(3, 337) = 1.18$, $p = .317$, $\eta^2 = .010$. In contrast, Independence of Learning differed significantly across grade levels, $F(3, 337) = 5.07$, $p = .002$, $\eta^2 = .043$. Post hoc comparisons showed that third-year pre-service teachers ($M = 3.85$, $SD = 0.55$) had significantly higher Independence of Learning scores than second-year pre-service teachers ($M = 3.63$, $SD = 0.50$). Fourth-year pre-service teachers ($M = 3.93$, $SD = 0.46$) also scored significantly higher than both first-year ($M = 3.74$, $SD = 0.45$) and second-year pre-service teachers. Overall, grade level was associated with small differences in learner autonomy and Independence of Learning, whereas study habits did not vary significantly across grade levels.

Relationship Between Science Learning Competence and Learner Autonomy

Pearson correlation analysis was conducted to examine the relationships between pre-service teachers' science learning competence, learner autonomy, and their respective dimensions. The results are presented in Table 7.

Table 7. Correlations between pre-service teachers' science learning competence and learner autonomy

Variable	1	2	3	4	5	6
1. Science Learning Competence	-					
2. Scientific Inquiry	.964**	-				
3. Communication	.969**	.867**	-			
4. Learner Autonomy	−.256**	−.249**	−.246**	-		
5. Study Habits	−.204**	−.206**	−.188**	.700**	-	
6. Independence of Learning	−.209**	−.198**	−.205**	.877**	.271**	-

Note. $N = 341$. Values are Pearson correlation coefficients. $p < .01$.

As shown in Table 7, science learning competence was significantly and negatively correlated with learner autonomy, $r = -.256$, $p < .01$. Significant negative correlations were also found between science learning competence and study habits ($r = -.204$, $p < .01$) and Independence of Learning ($r = -.209$, $p < .01$). At the dimensional level, scientific inquiry was negatively correlated with study habits ($r = -.206$, $p < .01$) and Independence of Learning ($r = -.198$, $p < .01$). Similarly, communication was negatively correlated with study habits ($r = -.188$, $p < .01$) and Independence of Learning ($r = -.205$, $p < .01$). Overall, the associations between science learning competence and learner autonomy were statistically significant but weak in magnitude.

CONCLUSION and DISCUSSION

The present study examined the relationship between pre-service teachers' science learning competence and learner autonomy and investigated whether these constructs differed according to teacher education program and grade level. Three main findings emerged. First, science learning competence and its dimensions differed according to both teacher education program and grade level. Second, learner autonomy showed differences according to program and grade level, although these differences were not consistent across its dimensions. Third, and most importantly, science learning competence was negatively associated with learner autonomy and both of its dimensions. Although these relationships were statistically significant, their magnitude was weak. These findings provide a differentiated picture of how science-related learning competencies and autonomy coexist among pre-service teachers.

Science Learning Competence Across Teacher Education Programs and Grade Levels

Science learning competence differed significantly across teacher education programs. Pre-service teachers in preschool education reported higher overall science learning competence than those in both primary and science education. The same pattern was observed for scientific inquiry and communication. Although the effect sizes were small, the consistency of the differences across the total scale and both dimensions suggests that teacher education program is relevant to how pre-service teachers perceive their competence in learning science.

At first glance, the higher scores of preschool education students may appear unexpected, particularly because science education students receive more specialized preparation in science content and science teaching. However, science learning competence encompasses more than disciplinary science knowledge. Scientific inquiry and communication involve questioning, investigating, exchanging ideas, and communicating explanations (Chang et al., 2011). Greater exposure to disciplinary content, therefore, may not necessarily be accompanied by higher perceived competence in science-related learning. Beudels et al. (2021) found that the relationship between pre-service teachers' content knowledge and academic self-concept varied across subject areas, suggesting that differences in disciplinary exposure may not always be reflected in perceptions of competence.

The higher scores of preschool education students may also be considered in relation to the characteristics of their teacher preparation experiences. Preschool teacher education typically emphasizes learner-centered, exploratory, interactive, and activity-based learning experiences (Catalano, 2025; Diamond, 2015; Demirci, 2020; Özbay Karlıdağ, 2022). Such experiences may provide opportunities to develop skills related to questioning, exploration, interaction, and communication, which overlap with the dimensions of science learning competence. However, the present study did not examine participants' specific course experiences or instructional practices. This explanation should therefore be considered as one possible interpretation of the program differences rather than a direct conclusion from the findings.

Science learning competence also differed across grade levels, although the results did not show a consistent increase from the first to the fourth year. Second-year pre-service teachers had higher overall science learning competence than first-year students, whereas fourth-year students scored higher than both first- and third-year students. A similar pattern emerged for the two dimensions. Fourth-year students had higher scientific inquiry scores than first- and third-year students. For communication, second-year students scored higher than first-year students, while fourth-year students scored higher than both first- and third-year students.

Previous studies have reported varying patterns in science learning competencies across different grade levels. Kremer et al. (2014) found that pre-service teachers' scientific inquiry skills improved as they progressed through their teacher training, while Özden and Yenice (2022) reported that third-year science pre-service teachers had higher science learning and inquiry skills than students at other grade levels. Findings regarding communication skills are similarly mixed: Saracaloğlu et al. (2009) reported higher communication skills among first-year pre-service teachers, while Tümkaya (2011) found higher levels in fourth-year students. Overall, these findings indicate that grade-level differences in science learning competencies do not follow a consistent pattern across studies.

Rather than reflecting a simple progression associated with year of study, differences between grade levels may reflect variations in the nature and timing of disciplinary, pedagogical, and practice-oriented experiences across teacher education programs (Orakcı, 2021). The relatively higher scores of fourth-year students may also be related to the academic and professional experiences accumulated during teacher preparation. Yalmacı and Aydın (2014) noted that senior pre-service teachers devote greater attention to professional examinations and profession-related subject matter. This increased focus on professional preparation may partly account for the higher science learning competence observed among fourth-year students.

This interpretation should be treated with caution, however. The present study did not directly examine participants' course experiences, professional examination preparation, or other factors that might explain differences between grade levels. Moreover, the higher scores of second-year students

relative to first-year students, together with the lower scores observed among third-year students in some comparisons, show that science learning competence does not simply increase with each year of teacher education. Given the cross-sectional design of the study, these findings represent differences among students at different grade levels rather than developmental changes over time.

Learner Autonomy Across Teacher Education Programs and Grade Levels

Learner autonomy also differed according to teacher education program, although the pattern varied across its dimensions. Preschool education students reported higher overall learner autonomy than science education students, while primary education students reported higher study habits scores than science education students. No significant program difference was found for Independence of Learning. The small effect sizes suggest that teacher education program accounts for only a limited proportion of the variation in learner autonomy.

These findings are consistent with the view that learner autonomy may vary across teacher education contexts rather than functioning as a uniform characteristic of pre-service teachers (Alkan & Arslan, 2019; Badak & Şenel, 2022). Differences in program structure, instructional practices, learning tasks, assessment practices, and opportunities for students to make decisions about their learning may contribute to variation in autonomy (Smith, 2003; Yaşar & Atay, 2023). Previous research has similarly indicated program-related differences in autonomous learning among pre-service teachers (Alkan & Arslan, 2019). The present findings extend this observation by showing that such differences may not occur equally across all dimensions of autonomy.

The absence of a significant program difference in Independence of Learning is particularly informative. Whereas study habits may be more closely associated with how students organize and approach their academic work, Independence of Learning reflects their capacity to take greater responsibility for and act more independently in the learning process (Alkan & Arslan, 2019). The findings therefore suggest that differences among teacher education programs may be more evident in particular learning practices than in pre-service teachers' broader independence as learners.

Grade level was also associated with learner autonomy. Third- and fourth-year students reported higher overall learner autonomy than second-year students. However, this difference was not observed for study habits. Instead, grade-level differences were particularly evident in Independence of Learning: third-year students scored higher than second-year students, and fourth-year students scored higher than both first- and second-year students.

This pattern may suggest that Independence of Learning is the aspect of autonomy most closely associated with students' stage of teacher preparation. As pre-service teachers advance through their programs, they are generally exposed to more complex disciplinary and pedagogical tasks and, particularly in later years, to teaching practice and greater professional responsibility (Smith, 2003). Such experiences may provide more opportunities to make decisions, solve problems independently,

and assume responsibility for professional learning. This interpretation is also compatible with the view that autonomy is important not only for students' current learning but also for teachers' continuing professional and lifelong learning (Badak & Şenel, 2022; Yaşar & Atay, 2023).

Nevertheless, the findings again do not demonstrate a uniform developmental progression. Second-year students had the lowest overall learner autonomy, and study habits did not differ significantly across grade levels. Grade-level differences should therefore be interpreted as variation among cohorts at different stages of teacher preparation rather than evidence that learner autonomy automatically develops with each year of university education.

Relationship Between Science Learning Competence and Learner Autonomy

Science learning competence was negatively related to learner autonomy, with similar relationships observed across their dimensions. However, these relationships were weak, indicating only limited overlap between the two constructs. This result was somewhat unexpected. Science learning competence and learner autonomy have several features in common. Scientific inquiry involves asking questions, making decisions, evaluating evidence, and taking an active role in constructing knowledge. Learner autonomy similarly requires learners to take responsibility for their learning, make decisions, select appropriate strategies, and monitor their progress (Chang et al., 2011; Holec, 1981; Reinders, 2010). Considering these common features, the relationship between the two might have been expected to be positive. The results of this study did not support this expectation.

The way the two constructs are defined may help explain this result. In the present study, science learning competence refers to scientific inquiry and communication, while learner autonomy includes study habits and Independence of Learning. These constructs are related to active learning, but they emphasize different aspects of it. Scientific inquiry often requires discussion, interaction with others, consideration of alternative explanations, and collaborative construction of knowledge. Independence of Learning, on the other hand, places greater emphasis on learners' responsibility for managing their own learning (Alkan & Arslan, 2019; Smith, 2003; Yaşar & Atay, 2023). Therefore, greater independence in learning may not necessarily be accompanied by stronger perceived competence in inquiry and communication.

The weak correlations also need to be considered when interpreting this finding. Although the relationships were statistically significant, their magnitude indicates limited overlap between science learning competence and learner autonomy. It would therefore be inappropriate to conclude that greater learner autonomy is associated with poorer science learning competence in a broader sense. The results instead indicate that the two constructs capture different aspects of pre-service teachers' learning, despite some conceptual similarities.

This finding may have implications for teacher education. Supporting learner autonomy alone may not be enough to develop the inquiry and communication competencies involved in science

learning. Conversely, engaging pre-service teachers in scientific inquiry does not necessarily mean that they will develop greater responsibility for managing their own learning. Both may need to be supported within teacher education through experiences that combine inquiry and communication with opportunities to make decisions, monitor learning, and evaluate one's own progress (Aming'a et al., 2026).

Further research is needed to understand the negative relationship found in this study. Variables such as self-regulation, epistemic beliefs, previous inquiry experiences, and the nature of instructional practices may help explain why the two constructs were weakly and negatively related. Longitudinal studies could also examine whether this relationship changes over the course of teacher education, while qualitative research could provide a clearer picture of how pre-service teachers themselves understand independence and responsibility in science learning.

Implications

The findings suggest that science learning competence and learner autonomy should not be treated as interchangeable outcomes of student-centered teacher education. Although both emphasize active learner participation, they appear to represent distinct aspects of learning. Teacher education programs may therefore benefit from creating learning environments in which pre-service teachers are explicitly supported in both domains. Inquiry-based tasks can provide opportunities to formulate questions, evaluate evidence, and communicate scientific reasoning, while autonomy supportive practices can allow pre-service teachers to make meaningful choices, monitor their progress, evaluate their learning, and assume greater responsibility for learning.

The differences observed across teacher education programs also suggest that opportunities for developing these competencies may not be distributed uniformly across programs. In particular, the comparatively lower scores of science education students on both science learning competence and learner autonomy warrant further examination. These findings should not be interpreted as evidence of deficiencies in a particular program, but they raise questions about how different teacher education curricula provide opportunities for inquiry, communication, decision making, and learner responsibility. Examining specific course structures and instructional experiences may help identify practices that support these competencies across teacher education programs.

Limitations and Future Research

The cross-sectional design does not allow differences across grade levels to be interpreted as developmental changes. Future longitudinal studies could follow the same group of preservice teachers from the first to the fourth year of their teacher education to examine changes in science learning competence and learner autonomy over time. The participants were also drawn from a single university, which limits the generalizability of the findings. Future studies involving preservice teachers from

different universities could provide a broader understanding of whether similar patterns are observed across teacher education contexts.

Both science learning competence and learner autonomy were measured using self-report instruments. The findings therefore represent pre-service teachers' perceptions rather than direct evidence of their performance. Future research could combine self-report measures with performance-based tasks, observations, or interviews. In addition, the correlational design does not allow causal conclusions to be drawn from the negative relationship between science learning competence and learner autonomy. This relationship should be interpreted as an association between the two constructs rather than evidence that one affects the other. Further research could examine variables that may help explain this relationship and how it changes during teacher education.

Additional Declaration

Author Contributions

The theoretical framework of the study was created by the second author, the data collection and analysis process was carried out by the first author, the article was written jointly by both authors, and the final version was approved together. The contribution rates are first author (60%) and second author (40%).

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Responsible Artificial Intelligence Statement

In this study, artificial intelligence tools ChatGPT (OpenAI) and Grammarly AI were used in language editing, data analysis and literature review stages. The artificial intelligence tool was used to correct language errors, to check the data analysis made by the author, and to provide the colophon information of current related resources in the literature review. We declare that we, as the authors, take full responsibility for the problems that may arise from the content produced by artificial intelligence.

Conflicts of Interest

The authors declare that there are no conflicts of interest related to the publication of this study.

Ethics Approval

The study received ethical approval from the Ethics Committee of Çanakkale Onsekiz Mart University on October 20, 2022 (Approval No: 2022-YÖNP-0773).

Note

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