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INTERACTION AMONG THREE FUNDAMENTAL SKILLS: REFLECTIONS OF COGNITIVE AND AFFECTIVE STRUCTURES ON PRE-SERVICE SCIENCE TEACHERS*

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Abstract

In the contemporary educational landscape, science education has evolved from mere knowledge transmission into a multidimensional process encompassing higher-order thinking, cognitive readiness, and practical application. This shift necessitates that pre-service teachers are not only professionally competent but also capable of designing educational content tailored to their target audience. This study investigates the correlation between computational thinking skills, attitudes toward laboratory practices, and the readiness levels of pre-service science teachers. The study sample included 200 pre-service science teachers pursuing higher education at a state university in Izmir for the 2023-2024 academic year. The data were analyzed using Pearson correlation. The findings reveal positive, significant, and moderate-to-strong correlations between all three variables. Furthermore, fourth-year students demonstrated significantly higher laboratory readiness than third-year students, reflecting an increased responsibility for self-regulated learning as they approach graduation. These results suggest that cognitive tools like computational thinking are deeply intertwined with attitudes and self-directed learning, emphasizing the need for teacher education curricula to adopt a holistic approach that considers these interactions.

Keywords: attitude, computational thinking, laboratory, pre-service science teacher, readiness

INTRODUCTION

Skill development in contemporary education is best understood not as a series of isolated processes, but as a multifaceted and interconnected whole. In science education particularly, a high-quality laboratory process integrates cognitive, psychomotor, and affective components simultaneously. Revealing the relationships among these components demonstrates that education must be designed as an integrated process of holistic development, rather than a mere transfer of information.

Recent developments in science and technology have transformed science teaching from a process limited only to knowledge transmission into a multidimensional structure that shapes individuals' ways of thinking, approaches toward learning, and scientific process skills. In an increasingly digitized world, science education must not only focus on traditional laboratory techniques but also equip individuals with the ability to structure these processes within an algorithmic and systematic framework. Contemporary educational models aim to develop individuals' abilities not only to acquire knowledge passively but to analyze, interpret, and transform this knowledge into practice; to

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strengthen their attitudes toward learning; and to manage their own learning processes effectively (Bransford, Brown, & Cocking, 2000; Voogt & Roblin, 2012; YÖK, 2018; Zimmerman, 2002).

In the Turkish teacher education context, laboratory applications are emphasized as critical instruments for improving pre-service science teachers' professional and cognitive competencies (Şahin & Şaşmaz Ören, 2022). Particularly in practice-based fields such as science education, this transformation requires students to develop higher-order cognitive skills, exhibit more positive attitudes toward learning, and assume more independent roles in their learning processes (Bybee, 2013; Osborne & Dillon, 2008). Moreover, developing these skills at an early stage strengthens students' scientific process skills and lays the foundation for their future professional competence.

In this context, three critical constructs that pre-service science teachers—who are regarded as a very critical component for understanding the quality of contemporary science teaching and who represent the educators of the future—must acquire during their undergraduate education come to the forefront: Computational Thinking Skills (CTS) as a cognitive tool; Attitude Toward Laboratory Skills as an affective tendency related to laboratory applications; and Readiness for Self-Directed Learning (SDL) in the Laboratory, which reflects the self-management capacity within the learning process (Saeid & Eslaminejad, 2017; Wing, 2006).

In science education, pre-service teachers participate in various laboratory courses from their first year through their final year of undergraduate studies, such as biology, chemistry, and physics laboratories. Consequently, investigating the interaction between skills is vital for enhancing the laboratory competencies of these pre-service teachers. Internalizing these laboratory skills during their undergraduate education directly influences the quality of guidance they will provide to their future students in their professional lives. A pre-service teacher who deeply understands skill interactions will be better equipped to accurately analyze their students' learning difficulties—determining, for instance, whether a challenge stems from a lack of technical skills or low readiness—and develop appropriate intervention strategies.

Within the science education context, CT is considered an essential cognitive tool that supports students' ability to analyze scientific problems, organize experimental data, and develop solution strategies. The information processing skills acquired by pre-service teachers will help them teach their future students a more systematic approach to scientific research, problem-solving, and information processing (Barr, Harrison, & Conery, 2011). Recent studies have shown that such skills constitute one of the eight fundamental scientific research practices, and the focus is increasingly shifting toward integrating technology-based virtual simulations into the analysis of real-world data and experimental processes (Cheng, 2025).

In science education, laboratory work is an unavoidable component that combines abstract concepts with concrete experiences (Hofstein & Lunetta, 2004). Attitude toward laboratory skills refers to the student's positive or negative affective orientation toward being in the laboratory environment, conducting experiments, and engaging in the process of obtaining knowledge. A positive attitude directly affects an individual's motivation, self-efficacy, and level of active participation in the laboratory environment, thereby enhancing learning outcomes and the development of scientific process skills (Hofstein, & Lunetta, 2004).

Having positive attitudes and being able to process knowledge are not sufficient on their own. Students must also be able to organize their own learning processes independently. In this regard, SDL is conceptualized as an individual's capacity to act independently in the learning process, set goals, manage resources, and self-regulate learning processes (Guglielmino, 1977; Saeid & Eslaminejad, 2017). Particularly in free and practice-oriented environments such as laboratories, this readiness forms the foundation of pre-service teachers' capacity to work independently, take responsibility, and autonomously solve problems encountered in experimental processes (Strat, Henriksen, & Jegstad, 2024).

When these three variables are considered together, an integrated structure emerges: the cognitive dimension (CT), the affective dimension (laboratory attitude), and the self-regulatory dimension (SDL readiness). As a cognitive tool, CT functions as a mechanism for reducing cognitive load in complex experimental settings; by systematically organizing scientific data, CT enables students to manage their learning processes more effectively, thereby fostering more positive attitudes and higher self-directed readiness (Kurbanoglu, & Akim, 2010). In turn, positive laboratory attitudes motivate voluntary and intrinsically driven participation, enabling individuals to manage their learning process more successfully and improving its overall quality (Saeid & Eslaminejad, 2017). Examining the interaction among these three dimensions therefore provides a comprehensive lens for analyzing the professional development of pre-service teachers, underscoring the necessity of a holistic approach in science education.

From another perspective, understanding the interactions between skills is crucial for developing high-quality curricula. Curriculum development should consider all aspects of the process. Therefore, a thorough understanding of the interactions between skills helps in creating high-quality content. This is because the relationships between skills are not always positive. Skills with negative relationships exist in the literature, and this relationship is very critical when writing a curriculum. Content written to develop one skill may hinder the development of another. The "Expertise Reversal Effect" phenomenon within Cognitive Load Theory can be given as an example of this. As demonstrated by Sweller, Ayres, and Kalyuga (2011), advanced skills and mental schemas acquired in one area can conflict with introductory instructional supports or different application skills, potentially hindering performance rather than enhancing it. This implies that the development of one competency can have a negative correlation with another.

Therefore, instructional designers must meticulously analyze the skill dimensions when developing educational content. Modern science education aims for students to achieve "cognitive flexibility" to solve complex problems in dynamic and variable laboratory environments, rather than simply acquiring static knowledge. Understanding these interactions allows us to identify how a student activates one skill while using another, or which skills might conflict to create a cognitive difficulty.

A study of the literature finds research that looks at the connections between academic achievement and CT (Weintrop et al., 2016), learning outcomes and laboratory attitude (Hofstein, & Lunetta, 2004), or academic achievement and self-directed learning (Yurdal & Toraman, 2023). For example, in the study of Sarı, Ulusoy, and Pektaş (2025), it was revealed that the instructional process conducted in flipped classroom-based science laboratories significantly improved students' computational thinking skills and attitudes toward laboratory work, and that there was a bilateral interaction between these two variables.

Although the roles of critical competencies such as CT skills, attitudes toward laboratory skills, and SDL in science laboratories have been examined separately in the literature (Hofstein & Lunetta, 2004; Wing, 2006), no study has been identified in the context of pre-service science teachers that simultaneously and holistically examines these cognitive, affective, and self-regulatory dimensions and statistically reveals the complex relational structure among them. Unless the interplay between these cognitive, affective, and self-regulatory structures is clearly understood, laboratory education may remain limited to technical skill acquisition rather than providing a holistic framework for professional competence.

The purpose of this research is to improve the current literature by examining the interplay between these three constructs and their roles in the professional development of pre-service teachers. Through this approach, the findings obtained will not only reveal a theoretical relationship but also potentially provide curriculum designers in science teacher education programs with evidence-based and practical suggestions for integrating CT, laboratory attitude, and responsibility for self-directed learning. Thus, the study aims to make a paradigm-shifting contribution to strategies for developing teacher competencies in science education. In this context of these theoretical foundations, it is hypothesized that computational thinking skills serve as a significant predictor for both laboratory attitudes and self-directed learning readiness, forming an integrated structure for teacher development.

The study examines answers to the following questions in order to accomplish this purpose:

- Is there a substantial association between the computational thinking skills of pre-service science teachers and their views towards laboratory skills?
- How do CT skills relate to the laboratory-based SDL of pre-service science teachers?
- Do pre-service science teachers' laboratory-related attitudes significantly predict or align with their SDL?
- To what degree does grade level affect the self-directed learning of pre-service science teachers in laboratory classrooms?

METHOD

Study Methodology

This study primarily aims to elucidate the intricate interrelationships between the specified competencies. In this context, a correlational survey model, a quantitative research method, was used. It was chosen to investigate and examine the complex relationships between pre-service teachers' computational thinking skills, attitudes towards the laboratory, and readiness skills. In line with the theoretical foundations established by Karasar (2012), the correlational model is fundamentally used to measure the relationships between two or more variables, allowing researchers to make statistically grounded inferences about these naturally occurring phenomena without any experimental intervention.

Participants and Sampling

The study sample consisted of 200 pre-service science teachers enrolled in the Science Education Undergraduate Program at a state university in Izmir. While this sample size is statistically adequate for the correlational analyses performed, it is important to note that the participants were drawn from a single institutional context. This choice was made to ensure a homogeneous educational background and consistent exposure to the same laboratory curriculum; however, it may limit the direct generalizability of the findings to different geographical or institutional settings.

The gender distribution of the sample (144 females, 56 males) reflects the typical demographic trend in science education departments in Turkey. Although exploring gender differences was not a primary research question of this study, preliminary analyses indicated no statistically significant differences between male and female participants regarding their computational thinking skills or laboratory attitudes. Therefore, gender was not included as a primary variable in the subsequent predictive models.

Data Collection Instruments

Computational Thinking (CT) Skills Scale

To assess the extent of pre-service teachers' CT skills in the sample, the validated "Computational Thinking Skills Scale" (Üzümcü, 2023), which addresses this skill more comprehensively, was used. The general structure of the scale consists of a single factor. Therefore, it aims to measure CT levels comprehensively. It was established as a Likert-type scale with five points. The scale is through "Strongly Disagree" to "Strongly Agree." The scale consists of 28 items, and it does not contain any negative items. The Cronbach Alpha internal reliability coefficient was determined as a consequence of the analyses published by Üzümcü (2023).98.This rate shows that it has a high reliability and can be used in research.

Attitudes Toward Laboratory Skills Scale

The "Attitude Scale Towards Laboratory Skills," developed and confirmed by Alkan (2012), was used for evaluating the sample's pre-service teachers' attitudes toward laboratory skills. There are four sub-factors and twenty-five elements on the scale. Additionally, a Likert scale with a score of five is used to define the measure.

The scale's sub-factors have the following Cronbach's Alpha internal consistency coefficients:

- Recognition of materials and chemicals (Cronbach's Alpha = .91),
- Considering feedback (Cronbach's Alpha = .77),
- Communication in the laboratory (Cronbach's Alpha = .80),
- Feeling prepared (Cronbach's Alpha = .64).

The overall internal consistency for the entire scale was reported as .91, confirming that the tool is a reliable measure for capturing the diverse facets of laboratory-related attitudes in teacher education.

Self-Directed Learning Readiness (SDL) in Laboratory Scale

The "Self-Learning Readiness Scale in the Laboratory," developed and verified by Alkan (2012), was used to examine the sample's pre-service teachers' level of readiness for self-learning in the lab. There are five sub-factors and thirty-two elements on the scale. Additionally, the measure is formatted on a 5-point Likert scale. The scale's sub-factors have the following Cronbach's Alpha internal consistency coefficients:

- Self-directed learning desire (Cronbach's Alpha = .91),
- Self-directed learning anxiety (Cronbach's Alpha = .84),
- Self-management in laboratory learning (Cronbach's Alpha = .84),
- Self-confidence in laboratory learning (Cronbach's Alpha = .75),
- Preparedness for self-directed learning (Cronbach's Alpha = .74).

With an overall Cronbach's Alpha coefficient of .91, this scale offers a highly dependable framework for evaluating how ready pre-service teachers are to take ownership of their learning processes in practical scientific environments.

Reliability Analysis of Data Collection Instruments

In order to determine the internal consistency of the tools for measurement utilized in this study, Cronbach's Alpha coefficients have been determined. The primary rationale for conducting these analyses was that two of the data collection instruments employed within the scope of the study were developed in 2012. Due to the time elapsed since the initial development of these scales, reliability analyses were repeated to ensure current statistical stability. Within this framework, grade level, since the final data collection instrument was recently developed before the commencement of this study, its reliability was re-evaluated by the researcher to examine the current status of the scales. Moreover, although the final data collection instrument was recently developed, the reliability analyses were repeated by the researcher to ensure contextual reliability and to verify the internal consistency of the instrument within the specific study sample. The obtained values are presented in Table 1.

Table 1. The scales' Cronbach's alpha reliability coefficients

Scale	Number of Items	Cronbach's Alpha (α)
Computational Thinking Skills Scale (CT)	28	.98
Attitudes Toward Laboratory Skills Scale	25	.91
Self-Directed Learning Readiness in Laboratory Scale (SDL)	32	.91

Upon examining Table 1, it is observed that all scales used in the research possess Cronbach's Alpha values above .90. It could be determined that the internal consistency of the data used in this study is exceptionally good, considering that values of .70 and higher are considered acceptable in the statistical literature. The margin of error is quite low. In particular, the Computational Thinking scale possesses a high value of .98, which demonstrates that the measured cognitive structure yields highly stable and consistent results across the sample.

Data Analysis and Statistical Procedures

Quantitative data obtained within the scope of the study were analyzed using a comprehensive and widely preferred statistical software package program in the literature for systematic evaluation. Basic descriptive statistics were performed before correlation analyses. Then, in order to select appropriate correlation analyses, the basic assumptions of parametric statistics were checked against the data. In this example, a variety of parameters were considered to verify that the data distribution was normal. The researchers specifically looked at the data distribution's normality, skewness, and kurtosis coefficients. As a result of the findings obtained from the analysis of the data, it was determined that the scores of all variables were within acceptable ranges, i.e., within the baseline values found in the literature (e.g., skewness and kurtosis values between -1.5 and +1.5). Therefore, the data were examined by performing analyses consistent with the normal distribution model.

Based on the findings, it was assumed that parametric statistical techniques were appropriate for subsequent analyses. The following steps were applied in the data analysis phase:

- Descriptive Statistics: To obtain general information regarding participants' computational thinking abilities, attitudes toward the lab, and readiness levels, mean scores, standard deviations, and frequency distributions were computed.
- Pearson Correlation Analysis: The frequency, direction, and significance of correlations between the three main study variables were determined using this technique.
- Multiple Regression Analysis: This was used to determine if attitudes on laboratory skills were significantly predicted by CT.
- Independent Samples t-Test: This test was used to determine whether grade level differences existed in the SDL.

The reliability of the results observed within the framework of scientific educational research was ensured by setting all statistical significance levels at the $p<.05$ standard.

This study involves ethical obligations. Therefore, the researcher applied to the Dokuz Eylül University Social and Human Sciences Scientific Research and Publication Ethics Committee and received approval to conduct the study. Following a rigorous review of the study procedures and participant protection, official approval was granted on January 3, 2025 (Decision Number: 118). All research activities were conducted in strict accordance with the ethical rules established by the committee to ensure participant confidentiality and informed consent (voluntary consent forms were obtained from participants, and detailed information about the process was provided).

RESULTS

This section of the study presents a systematic explanation of the findings obtained from quantitative data analysis. The findings are structured to directly address the main objectives and research questions of the study; specifically, they focus on the relationship between the three core skills examined in the study and pre-service science teachers.

Descriptive Statistics: Current Status of Pre-service Teachers

The study presents descriptive statistical data on the distribution of scores, arithmetic means, and standard deviations related to the three core skills studied by pre-service teachers. Table 2 shows a summary of the results obtained.

Table 2. The study variables' descriptive statistics

Variable	n	Minimum	Maximum	Mean ($\bar{X}$)	Std. Deviation (SD)
Computational Thinking (CT)	200	1.00	5.00	3.92	.41
Laboratory Attitude	200	1.00	5.00	3.77	.46
Self-Directed Readiness (SDL)	200	1.00	5.00	3.68	.44

Mean score of CT: 3.92 (SD = .41)
Mean score of attitudes toward laboratory skills: 3.77 (SD = .46)
Mean score of SDL in the laboratory: 3.68 (SD = .44)

When the data obtained within the scope of descriptive statistics are examined, it shows that pre-service teachers generally have high levels of computational thinking skills, positive attitudes towards laboratory skills, and good levels of readiness. Consequently, these results indicate that pre-service teachers generally possess "good" and "high" skill levels in all three areas. To better interpret the average scores, the scale ranges were calculated using the formula $\frac{(n-1)}{3}$, where 'n' represents the maximum scale value. The researcher therefore defined the following score ranges: 1.00–2.33 for the "Low" level, 2.34–3.66 for the "Medium" level, and 3.67–5.00 for the "High" level.

- High-level skills revealed as a result of the analyses: The highest average score in the study was obtained in the CT dimension ($\bar{X}$ = 3.92). This shows that the candidates are quite proficient in cognitive processes such as problem-solving, algorithmic thinking, and data analysis. Consequently, a positive mean score for attitude towards the laboratory ($\bar{X}$ = 3.77) indicates that candidates have a high level of interest and motivation towards laboratory practices.
- Intermediate skills revealed by the analyses: Compared to other variables, the lowest mean score was observed in the dimension of Readiness for Self-Learning in the Laboratory ($\bar{X}$ = 3.68). This finding suggests that even though pre-service teachers are cognitively and emotionally ready, they may still need guidance in independently managing their own learning processes and taking individual responsibility in a laboratory setting.

Relationships Among Variables: Correlation Analysis

This document presents the findings of analyses examining the relationships between pre-service teachers' computational thinking skills, attitudes towards laboratory work, and SDL. A comprehensive overview of the associations identified through the Pearson correlation analysis is detailed in Table 3 below.

Table 3. Coefficients of correlation between variables

Variables	**1**	**2**	**3**
1. Computational Thinking (CT)	1		
2. Attitudes Toward Laboratory Skills	.519**	1	
3. Self-Directed Learning Readiness in the Laboratory (SDL)	.451**	.506**	1

*Note: **$p < .01$*

When looking at Table 3:

- Attitudes regarding laboratory skills and CT are positively and significantly correlated (r = .519, p <.01).
- Additionally, CT and laboratory SDL are positively and significantly correlated (r = .451, p <.01).
- Moreover, attitudes on laboratory skills and SDL are positively and significantly correlated (r = .506, p <.01).

These results show a moderate and substantial relationship between the three primary variables that the study examined.

The moderate and statistically significant correlations (r > .45, p < .01) among all three variables suggest a synergistic interaction between the cognitive, affective, and self-regulatory dimensions of laboratory education. Specifically, the strongest relationship observed—between CT and laboratory attitudes (r= .519) indicates that as pre-service teachers' proficiency in algorithmic and systematic thinking increases, their emotional and professional orientation toward laboratory environments also strengthens. Hence, the consistent positive correlations between self-directed learning readiness and both cognitive (CT) and affective (Attitude) components suggest that autonomy in the laboratory is not an isolated trait; rather, it is deeply intertwined with analytical competence and positive motivation. These findings highlight that a holistic improvement in science teacher education requires a simultaneous focus on these interconnected constructs, as a gain in one domain likely acts as a catalyst for the others.

Predictive Role of Computational Thinking on Attitudes: Regression Analysis

Using multiple regression analysis, the predictive power of computational thinking skills on pre-service teachers' attitudes toward laboratory skills was examined. This statistical method aimed to determine the extent to which independent variables significantly contribute to the variance in attitudes towards laboratory skills. Comprehensive statistical outputs, including beta coefficients and significance levels, are systematically presented in Table 4.

Table 4. Regression analysis of computational thinking predicting attitudes toward laboratory skills

Variable	B	Std. Error	β	*t*	*p*
Constant	1.452	.305		4.76	.000
Computational Thinking (CT)	.519	.061	.519	8.51	.000

According to the regression analysis results:

- CT significantly predicts attitudes toward laboratory skills ($F_{(1, 198)} = 72.48$, $p < .001$), and the model explains 27% of the variance ($R^2 = .27$).
- This shows that CT accounts for 27% of the variance in attitudes toward laboratory skills.
- According to the standardized coefficient, CT has a positive and strong effect on attitudes toward laboratory skills ($\beta = .519$, $p < .001$).

Regression analysis reveals that computational thinking (CT) skills are a significant predictor of attitudes toward laboratory skills, explaining 27.0% of the total variance ($R^2 = .270$; $p < .001$). This finding is particularly noteworthy because it demonstrates that CT is not merely a cognitive processing tool limited to computer science but also holds a significant place in science education. Specifically, the results show that as pre-service teachers improve their algorithmic thinking and systematic problem-solving abilities, they exhibit higher self-confidence and more positive attitudes toward complex laboratory practices. This highlights a critical intersection: CT acts as a bridge that transforms cognitive systematicity into emotional engagement in experimental settings. Therefore, integrating CT into teacher education programs can be considered a strategic approach to enhance not only technical competence but also a long-term positive orientation toward science teaching based on laboratory practices.

While the Pearson correlation analysis reveals moderate and statistically significant associations among the variables, it is important to note that these correlations describe the strength and direction of relationships and do not inherently imply a direct causal link.

Self-Directed Learning Readiness by Grade Level: Independent Samples t-Test

Table 5 presents the findings from a t-test conducted to assess the effect of grade level on readiness levels for self-directed learning in laboratory applications. The table highlights the observed t-values and p-values, providing a comprehensive analysis of the comparison between groups.

Table 5. Independent samples t-test results for grade level and self-directed learning readiness

Grade Level	N	Mean ($\bar{X}$)	SD	*t*	*p*
3rd Grade	50	3.65	0.45	-2.205	.029
4th Grade	50	3.85	0.42		

Based on the findings of the independent samples t-test:

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- Third- and fourth-year students differ significantly in their preparedness for self-directed learning ($t(198) = -2.205$, $p < .05$).
- Fourth-year students have significantly higher levels of SDL than third-year students.
- This result shows that pre-service teachers take more responsibility for independent learning and become more capable of working independently as their education progresses.

The statistically significant difference ($p = .029$) ($\bar{X} = 3.85$) in favor of fourth-year pre-service teachers indicates that SDL is a developmental construct that matures throughout the teacher education curriculum. This upward trend suggests that pre-service teachers undergo a process of professional maturation as they progress towards the final stage of their undergraduate education, transitioning from guided learning to independent learning. The higher levels of readiness at the fourth-year level likely stem from greater exposure to more complex laboratory settings and independent research projects, which require a higher level of self-regulation and individual responsibility. This finding underscores the importance of a structured curriculum; as students gain more experience, they can become significantly more adept at managing their own learning environments and taking initiative by working independently in laboratory settings. This transition is vital for their future careers, as independent laboratory management is a fundamental competency for effective science teaching.

Moreover, based on the findings of the independent samples t-test, third- and fourth-year students differ significantly in their preparedness for self-directed learning ($t(198) = -2.205$, $p<.05$). Fourth-year students ($M = 3.85$, $SD = 0.42$) demonstrated significantly higher levels of SDL readiness than third-year students ($M = 3.65$, $SD = 0.45$), with a medium effect size observed (Cohen's $d = 0.46$). This result indicates that the observed difference is not only statistically significant but also possesses practical relevance in the context of teacher development.

DISCUSSION, CONCLUSION, and SUGGESTIONS

Descriptive statistics obtained within the scope of the study show that pre-service teachers generally possess high levels of computational thinking skills, positive attitudes towards laboratory work, and good levels of readiness. Specifically, the higher average score for CT ($\bar{X} = 3.92$) compared to other variables indicates that pre-service teachers are stronger in problem-solving, algorithmic thinking, and analytical skills compared to other skills. The positive average score for attitudes towards laboratory skills ($\bar{X} = 3.77$) shows that candidates have a high level of interest and motivation towards laboratory application processes. However, the slightly lower average score for SDL in the laboratory compared to other skills ($\bar{X} = 3.68$) indicates that guidance is still needed in individual learning processes. These findings reveal that while pre-service teachers generally adopt the cognitive, affective, and individual learning competencies required by contemporary science education, supporting their skills in their own learning processes remains substantial.

The study's findings revealed strong correlations between pre-service teachers' computational thinking skills, attitudes, and readiness levels. The finding that information processing skills predict attitudes in the laboratory environment demonstrates that positive laboratory experiences are based not only on possessing information but also on the ability to process that information. Information processing skills, a critical skill in STEM education, encompass processes such as problem-solving, algorithmic thinking, and data analysis, and these processes directly influence individuals' approaches to laboratory practices. Similarly, this study observed that as computational thinking skills increased, attitudes towards the laboratory became more positive. This outcome is in accordance with previous studies (Sari, Ulusoy, & Pektaş, 2025).

Furthermore, the fact that pre-service teachers' readiness for self-learning in a laboratory setting differs significantly according to grade level reveals that they develop individual responsibility and learning strategies throughout the training process. This situation emphasizes that teaching should not only focus on transferring information but also support students' learning motivation and intrinsic

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learning processes. In line with these findings, it was concluded that teacher education should not only aim to enhance cognitive skills but also support attitudes and promote readiness for individual learning. Especially in hands-on environments such as science laboratories, such multidimensional approaches are expected to contribute directly to the professional competence of pre-service teachers.

The findings of this study support the fundamental research questions and the starting point of the study. By demonstrating significant relationships between the three key variables, these results confirm the expected conceptual framework and thus provide a strong basis for discussing these findings in light of the current literature in science education.

The three skills examined in this study and their relationship can be described in detail in the laboratory setting as follows: A student who comes prepared by researching the experiments beforehand understands the theoretical framework and application steps better, which facilitates independent work. As a result, the student processes information more efficiently and begins to question the information obtained during the experiment; this process is defined as a computational thinking skill. In these processes, the ability to work independently develops self-confidence and a positive attitude towards the laboratory. These observations are supported by the analyses and findings of this study. As seen in the example above, the teaching content should be structured to consider and support student preparation and pre-laboratory preparation. Creating a holistic assessment framework encompassing pre-laboratory, in-laboratory, and post-laboratory phases is essential for quality science education. It is not possible to fully interpret attitudinal changes during the experiment without evaluating the level of self-confidence and theoretical knowledge a student brings to the laboratory. In this context, assessment should become a process monitoring mechanism that allows for the identification of specific phases (preparation, information processing, or attitude) where the student struggles.

The main findings of this study reveal a statistically significant and positive correlation between computational thinking (CT) skills and attitudes toward laboratory skills. This finding demonstrates that the influence of CT extends beyond mere algorithmic processing or technical problem-solving; it fundamentally shapes emotional tendencies toward hands-on learning environments. This result largely aligns with the perspectives of Lye and Koh (2014) and Shute et al. (2017), who suggest that CT plays a key role in enhancing learning motivation and improving strategic approaches to complex tasks. Consequently, it can be argued that individuals with advanced CT proficiency approach laboratory settings with increased cognitive confidence and a systematic process, thus developing more productive and positive attitudes during experimental practices.

Another comparison analyzed shows a positive relationship between computational thinking (CT) skills and SDL. This finding highlights that the ability to process information not only influences external cognitive outputs but also affects one's own learning process, supporting the internal processes necessary for regulating and efficiently managing the learning process. According to Zimmerman (2002), in self-regulated learning theory, computational thinking skills provide the necessary strategic framework for goal-oriented behavior. In this context, it is believed that pre-service teachers with strong CT skills can create and manage a higher degree of independent study because they can break down complex learning tasks into manageable components; this is a fundamental requirement for SDL preparation in academic settings.

The results revealed a significant positive relationship between attitude toward the laboratory and SDL preparation. This suggests that a positive emotional orientation toward the laboratory functions as a motivational antecedent for independent learning. Pre-service teachers are more likely to participate more actively in experimental procedures and demonstrate a greater readiness to work independently when they have a positive perspective about laboratory skills. The groundbreaking study of Hofstein and Lunetta (2004), who emphasized the importance of laboratory-based environments for the development of both individual capacity for learning and scientific process skills, supports this conclusion. Overall, there are significant parallels between the results of this study and the remainder of existing literature.

The study also revealed statistically significant differences in SDL in a laboratory setting across different grade levels. Specifically, fourth-year teacher candidates had significantly higher readiness levels compared to third-year candidates, indicating that the progression of the educational process encouraged teacher candidates to take on more responsibility and work independently. This finding is consistent with Candy's (1991) theory of self-directed learning, which argues that the level of independence of teacher candidates naturally increases with the accumulation of various learning experiences and the long-term development of self-regulation skills. The significantly higher readiness levels of fourth-year teacher candidates compared to third-year candidates demonstrate that the training they receive during the teacher education process enhances their self-regulation capacity. The developmental change in teacher candidates' readiness observed in this study aligns with the perspective that structured laboratory environments provide essential feedback and guidance and support the transition from theoretical knowledge to practical scientific reasoning (Şahin & Şaşmaz Ören, 2022). This developmental shift demonstrates that as pre-service teachers engage in diverse learning experiences and develop through academic challenges, they gradually transition from passive recipients of information to those who take greater responsibility for their own learning. This increase in the level of independent study reflects the successful internalization of professional competencies, with pre-service teachers moving beyond acquiring technical skills towards a holistic framework of self-directed scientific inquiry. Ultimately, this development enables independent work and helps them navigate the complex and ever-evolving professional lives of their future careers.

While the data obtained in this study are generally consistent with the existing literature, some results or relationships between skills differ. For example, the correlation between computational thinking (CT) skills and readiness for self-directed learning (SDL) in the laboratory was weaker than other obtained relationships. This finding may point to a gap in pedagogical integration where pre-service teachers cannot fully synthesize their cognitive competencies with practical self-management strategies. This finding means that current educational frameworks do not effectively facilitate the transfer of learning responsibility to students.

In conclusion, the results indicate that cognitive and emotional frameworks work together as complementary elements in the professional development of pre-service teachers. Developing CT skills plays a fundamental role in fostering positive laboratory-related attitudes, which in turn enhances the student's capacity for effective learning management. Consequently, it is imperative that teacher education programs move beyond traditional knowledge transfer. They must adopt a holistic approach that simultaneously fosters higher-order thinking skills, positive attitudes, and sustainable learning motivation to prepare future educators for the complexities of modern scientific research. In other words, assessments should go beyond simply measuring the final part of learning—the results—and the assessment process should be considered as a whole. Particular attention should be paid to individuals' pre-lesson preparation, which is often overlooked. Assessment criteria should be examined, taking into account the student's pre-lesson preparation. Including pre-laboratory conditions in the assessment criteria provides "preventive feedback" before the experiment begins. For example, if a student is poorly prepared, giving them a low grade at the end of the experiment will not facilitate improvement. Rather, a process-oriented assessment design allows for a safer transition to the information processing stage by identifying such deficiencies early. Approach practically realizes the dynamic where skills support one another, fostering the positive correlations highlighted in this study.

The findings of this study offer several strategic recommendations for the design of science teacher education curricula. First, given that computational thinking (CT) is a significant predictor of laboratory attitudes, teacher training should move beyond teaching CT as a standalone coding skill. Instead, it should be integrated into laboratory courses through algorithmic problem-solving and data modeling activities. Second, the development of self-directed learning (SDL) readiness should be explicitly scaffolded throughout the four-year program. Since senior students showed higher readiness, early-stage students (1st and 2nd years) could benefit from more structured laboratory environments, gradually transitioning to open-ended, inquiry-based investigations to foster independence. Finally, policy makers should encourage the use of virtual laboratories and simulations as bridge tools to reduce anxiety and build positive attitudes before students engage in complex physical laboratory experiments.

Recommendations

The study's conclusions showed that pre-service science teachers ‘computational thinking skills, attitudes toward laboratory work, and SDL were significantly and positively related. The results show that laboratory environments should support not only experimental knowledge but also thinking skills and individual learning responsibility. High levels of CT positively affect individuals’ attitudes toward laboratory processes. Similarly, readiness that enables active participation in learning is strongly associated with both attitudes and thinking skills. This highlights that laboratory environments should be designed not only as instructional spaces but also as cognitive development environments.

The results demonstrate the importance of developing laboratory-based instructional strategies for pre-service teachers, increasing activities that support CT, and implementing practices that foster students’ responsibility for their own learning. The following recommendations for strategy are brought forward to support a multifaceted improvement of pre-service science teachers' cognitive, affective, and motivational development based on the empirical data compiled in this study:

1. **Curriculum Integration**
   - Practical course content that reinforces algorithmic thinking, data analysis, and modeling skills should be designed.
2. **Attitude Development Workshops**
   - Workshops focusing on “laboratory readiness” should be conducted before and during laboratory activities to support participants’ motivation and self-efficacy.
3. **Guidance Supporting Self-Regulation**
   - Pre-service teachers can define objectives and analyze their progress at every level, from experiment design to reporting, by using a digital learning journal.
4. **Progressive Competency Development**
   - A “scaffolding mode” approach can be accepted to gradually increase responsibility and independence as grade level increases—for instance, frequent feedback and guidance in the 1st–2nd years and more flexible experiment designs in the 3rd–4th years.
5. **Enhancement of Assessment Processes**
   - Mixed quantitative–qualitative assessment tools (self-reflection reports, video analyses) that measure attitudes and readiness toward laboratory skills should be developed and implemented regularly.

Limitations and Directions for Future Research

Despite its contributions, this study has several limitations that should be acknowledged. First, the data were collected from a single institutional context in Turkey, which may limit the generalizability of the findings to different cultural or educational systems. Future research should involve multi-center studies with larger, more diverse samples to validate these relationships. Second, this study relied on self-report scales to measure CT, SDL, and attitudes. While these scales are validated, they are subject to social desirability bias; future studies could incorporate performance-based assessments or longitudinal observations in actual laboratory settings. Third, the cross-sectional design of the study captures a snapshot of pre-service teachers’ skills at one point in time. Longitudinal designs are needed to observe how the interaction between cognitive and affective structures evolves as students transition from undergraduate education to professional teaching careers.

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Ethics and Conflict of Interest

All ethical rules were observed at each stage of the research. The authors declare that he acted in accordance with ethical rules in all processes of the research. The authors declare that they do not have any conflict of interest with other persons, institutions or organizations.

Data Availability

The data that support the findings of this study are available on request from the author.

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REFERENCES

Alkan, F. (2012). *Kendi kendine öğrenmenin kimya laboratuvarında öğrenci başarısına, öğrenme hazırbulunuşluğuna, laboratuvar becerilerine yönelik tutumuna ve endişesine etkisi* [Effect of self-directed learning on the students' success, learning readiness, attitudes towards laboratory skills and anxiety in chemistry laboratory]. [Unpublished Master's thesis]. Hacettepe University.

Barr, D., Harrison, J., & Conery, L. (2011). Computational thinking: A digital age skill for everyone. *International Society for Technology in Education, 38*, 20-23. https://eric.ed.gov/?id=EJ918910

Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). *How people learn: Brain, mind, experience, and school*. Washington DC: National Academy Press.

Bybee, R. W. (2013). *The Case for STEM education: Challenges and opportunities.* National Science Teachers Association.

Candy, P. (1991). *Self-direction for lifelong learning: A comprehensive guide to theory and practice.* San Francisco, CA: Jossey-Bass Publishers.

Cheng, X. (2025). Significance and challenges of scientific inquiry in science education. *Science Insights Education Frontiers, 28*(2), 4529–4631. https://doi.org/10.15354/sief.25.co471

Guglielmino, L. M. (1977). *Development of the self-directed learning readiness scale*. Athens: University of Georgia, 64.

Hofstein, A., & Lunetta, V.N. (2004), The laboratory in science education: Foundations for the twenty-first century. *Sci. Ed., 88*. 28-54. https://doi.org/10.1002/sce.10106

Karasar, N. (2012). *Bilimsel araştırma yöntemi: Kavramlar, ilkeler, teknikler* (23rd ed.). Nobel Yayın Dağıtım.

Kurbanoglu, N., & Akin, A. (2010). The relationships between university students' chemistry laboratory anxiety, attitudes, and self-efficacy beliefs. *Australian Journal of Teacher Education, 35*(8), 48-59. https://doi.org/10.14221/ajte.2010v35n8.4

Lye, S. Y., & Koh, J. H. L. (2014). Review on teaching and learning of computational thinking through programming: What is next for K-12? *Computers in Human Behavior, 41*, 51-61. https://doi.org/10.1016/j.chb.2014.09.012

Osborne, J. F., & Dillon, J. (2008). *Science education in Europe.* London: Nuffield Foundation.

Saeid, N., & Eslaminejad, T. (2017). Relationship between students' self-directed learning readiness, academic self-efficacy, and achievement motivation. *International Education Studies, 10*(1), 225–232. http://dx.doi.org/10.5539/ies.v10n1p225

Sari, U., Ulusoy, A., & Pektaş, H.M. (2025) Computational thinking in science laboratories based on the flipped classroom model: Computational thinking, Laboratory Entrepreneurial and Attitude. *J Sci Educ Technol, 34*, 1334–1358. https://doi.org/10.1007/s10956-024-10192-y

Şahin, F., & Şasmaz Ören, F. (2022). Laboratory as an ınstrument in improving the scientific reasoning skills of pre-service science teachers with different cognitive styles. *Science Insights Education Frontiers, 13*(2), 1875–1897. https://doi.org/10.15354/sief.22.or072

Shute, V., Sun, C., & Asbell-Clarke, J. (2017). Demystifying computational thinking. *Educational Research Review, 22*, 142-158. https://doi.org/10.1016/j.edurev.2017.09.003

Strat, T. T. S., Henriksen, E. K., & Jegstad, K. M. (2024). Inquiry-based science education in science teacher education: a systematic review. *Studies in Science Education, 60*(2), 191-249. https://doi.org/10.1080/03057267.2023.2207148

Sweller, J., Ayres, P., & Kalyuga, S. (2011). *The expertise reversal effect. In Cognitive load theory* (pp. 155-170). New York, NY: Springer New York. https://doi.org/10.1007/978-1-4419-8126-4_12

Üzümcü, Ö. (2023). Computational thinking scale: the predictive role of metacognition in the context of higher order thinking skills. *Journal for the Education of Gifted Young Scientists, 11*(3), 423-437. https://doi.org/10.17478/jegys.1355722

Voogt, J., & Roblin, N. P. (2012). A comparative analysis of international frameworks for 21st century competences: Implications for national curriculum policies. *Journal of Curriculum Studies, 44*, 299-321. https://doi.org/10.1080/00220272.2012.668938

Voogt, J., Fisser, P., Good, J., Mishra, P., & Yadav, A. (2015). Computational thinking in compulsory education: Towards an agenda for research and practice. *Education and information technologies, 20*(4), 715-728. https://doi.org/10.1007/s10639-015-9412-6

Weintrop, D., Beheshti, E., Horn, M., Orton, K., Jona, K., Trouille, L., & Wilensky, U. (2016). Defining computational thinking for mathematics and science classrooms. *Journal of Science Education and Technology, 25*(1), 127-147. https://doi.org/10.1007/s10956-015-9581-5

Wing, J. M. (2006) Computational thinking. *Communications of the ACM, 49*, 33-35. https://doi.org/10.1145/1118178.1118215

Yurdal, M. O., & Toraman, Ç. (2023). Self-directed learning, academic achievement and motivation: A meta-analytical study. *Alberta Journal of Educational Research, 69*(2), 1–21. https://doi.org/10.55016/ojs/ajer.v69i2.75098

Yükseköğretim Kurulu (YÖK). (2018). *Yeni Öğretmen Yetiştirme Lisans Programları*. YÖK Yayınları.

Zimmerman, B. J. (2002). Becoming a self-regulated learner: An overview. *Theory Into Practice, 41*(2), 64–70. https://doi.org/10.1207/s15430421tip4102_2