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Investigation of Pre-Service Teachers' Statistical Literacy Levels

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ABSTRACT

Statistical literacy is one of the most important actors in the information age. There has been an increase in the importance of education. Therefore, teachers' mastery of statistical concepts is necessary for quality education. The present study aims to examine the statistical literacy levels of pre-service elementary mathematics teachers. The study is a quantitative research with ex post facto design. The sample consists of 530 pre-service teachers in two universities. "Statistical Literacy Scale" was used for data collection. For the validity analysis of the scale, a first level confirmatory factor analysis was carried out and the Cronbach alpha coefficient was calculated for reliability. The data were analyzed using independent samples t-test and one-way ANOVA. The statistical literacy levels of pre-service teachers increase with the statistics and probability courses they take during their undergraduate education. It was also concluded that there was a significant difference between the students who took the courses and those who did not. It is recommended to conduct new studies for curriculum development and educational policies by revealing the factors affecting the development of statistical literacy.

Keywords: Statistics literacy, pre-service teachers, statistics and probability, mathematics

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Introduction

Education has a vital role in the development of societies (Balı & Dönmez, 2018). Therefore, teachers' competencies and skills are a determining factor in the effectiveness of education (Wu et al., 2022). Statistical literacy (SL) is gaining more importance in education. In addition, SL has become an indispensable requirement in today's information age. It is also important that teachers will use both in their professional development and teaching (Sharma, 2017). Therefore, determining and improving the SL levels of pre-service teachers (PST) is important in improving the quality of education. The studies conducted in this direction have a significant place in the literature. The present study examines the SL levels of PST and the gap in this field.

Literature Review

In today's information age, individuals need literacy skills for personal development and social participation. Literacy requires mastery in various areas of knowledge. Within the education system, teachers must have literacy in various fields to ensure that future generations grow up as individuals who can make informed decisions (Mhlongo et al., 2023). In this context, SL is becoming increasingly important at all levels of education.

Literacy is one of the most basic needs of modern societies. Beyond the ability to read and write texts, literacy now refers to the ability to critically evaluate and use information effectively. Today, the ability to access and interpret information accurately plays a critical role in determining individuals' personal and professional development (Pilgrim & Martinez, 2013). Literate individuals can solve problems more effectively, make more informed decisions and contribute to society. Literacy supports individuals' lifelong learning and is an essential requirement for general well-being. Therefore, individuals need to acquire literacy skills. This can be realized through education.

Literacy is needed in many different areas of society. For example, it manifests in various fields such as finance, media and digital technologies, information management, and mathematics. Financial literacy is concerned with the ability to manage finances (Goyal & Kumar, 2021). Digital literacy, which is indispensable today, includes the ability to interact with digital tools and understand media content (Kaya et al., 2024; Nicholson, 2017). Information literacy is related to the skills of accessing, sharing, evaluating, and using information (Walsh, 2011). Mathematical literacy requires performing basic mathematical operations and recognizing symbols and terms (Holenstein et al., 2021). Different types of literacy promote individuals' involvement in social life and enhance their overall well-being. One of the types of literacy is SL. It is essential in today's data-driven world. It basically involves understanding and interpreting statistical data (Sharma, 2017). Many situations and events encountered both in professional life and in the public domain are based on data. For example, statistical methods are used to evaluate the effectiveness of constructive policies, measure the performance of employees, and evaluate education. Therefore, to make rational and efficient decisions, it is necessary to make inferences by mastering the data obtained. SL is necessary and essential for everyone involved in social life. Moreover, SL is needed to calculate probabilities when shopping individually or when planning a career. SL is also becoming increasingly important today due to its use in many areas of social life. It involves understanding and using statistics' basic concepts and language (Garfield, 2011). SL also includes being able to recognize and interpret different representations of data. Moreover, its scope is not limited to these but goes beyond the basic skills. SL includes the ability to interpret and critique

real-world data, such as graphs presented in the media on climate change. It also develops the ability to understand and evaluate, and cultural contexts of data's social, environmental, and cultural contexts. Thus, it strengthens individuals' statistical thinking skills, enabling them to solve real-life problems more effectively. There are many different models related to SL in the literature as it concerns society in general. Gal (2002) proposed a SL model that includes knowledge and attitude or disposition components and emphasized the importance of making inferences after understanding and interpretation. For this, mathematics, statistics, and literacy skills are employed, and dispositions are effective in this process. Watson and Callingham (2003) constructed the structure of SL in a hierarchical way. This structure is from personal and informal views (the lowest) to the stage that has grounds and requires critical thinking (the highest). Sharma et al. (2011) presented a four-stage framework for diagnosing students' thinking. The aim of this framework, which is similar to the Watson and Callingham (2003) model, is to provide teachers with a tool that can be used to construct and assess students' SL constructs. Finally, the GAISE framework defined three statistical stages (levels A, B, and C) through which students' progress to develop their statistical understanding in order to determine the level of development of K-12 students (Carver et al., 2016). In these models and frameworks, SL levels were determined according to individuals' knowledge. In addition, the importance of the components of SL was emphasized. SL has an essential place in education, especially in the case of Sharma et al. (2011) and Carver et al. (2016), who focus on students' statistical skills.

SL aims to develop individuals' statistical thinking skills. Therefore, teachers and PST must help students develop their SL skills. In this way, educational practices become more effective, students' statistical thinking skills increase and their academic achievement and social contributions are strengthened (Darling-Hammond et al., 2020). Therefore, for teachers, SL is of critical importance in education. Teachers need to have SL enabling students to think and make inferences based on data. SL empowers teachers to make informed and effective decisions not only in their own field but also in education. It also allows teachers to monitor student achievement, evaluate educational programs, and develop strategies that are appropriate to student needs (Ridgway et al., 2011). Moreover, SL is becoming increasingly important in education because today's decision-making processes require making inferences from data. Teachers are responsible for equipping their students with the skills that they will need in society. Therefore, teachers must continuously improve their SL competencies and apply these skills effectively in and out of the classroom (Ben-Zvi & Makar, 2013). In order to strengthen teachers' knowledge and skills in SL, it is important that they successfully complete the teacher training program and follow the best practices in this field. Also, teacher training programs must emphasize the importance of SL (Guven et al., 2021). In this way, future generations can be better educated and more successful in a data-driven world. Moreover, school administrators and educational institutions must also provide appropriate environments to support teachers' SL skills and offer professional development opportunities in this area.

In summary, developing and promoting SL should become a key priority of education systems. This increases success in individuals' personal and professional lives and contributes to society's general well-being. Furthermore, statistical skills are needed in daily life. Therefore, statistics is an essential integral part of education and training. Statistics also goes beyond the transfer of mathematical knowledge. It encompasses an understanding of statistical concepts and their applications. Mathematics teachers play an important role in developing individuals' SL (Callingham & Watson, 2017). However, teachers experience difficulties because they struggle with statistical content or lack confidence in teaching statistics (Marshman & Dunn, 2024).

Therefore, knowledge and experience in undergraduate education are required for PST of mathematics. Within the scope of probability and statistics courses, basic concepts of probability, probability types, probability function, sampling, data organization and analysis, sampling distribution and estimation, and confidence intervals are included. Topics related to probability and statistics are included in all levels of education from primary school to undergraduate level. PSTs are expected to be statistically literate individuals to teach in their future professional lives.

Research conducted to evaluate the SL levels of PST is considered an important step toward increasing the effectiveness of education. Statistics is developing and, therefore, the focus of numerous research. Many studies are focusing on SL (Badenes-Ribera et al., 2018; De Vetten et al., 2023; Zieffler et al., 2018). In the literature, various tools and methods for measuring PST's SL skills have been examined, and research on the effect of these skills on PST's professional performance has been discussed. In addition, studies on the importance of SL training of PST and the effectiveness of these trainings have a prominent place in the literature. Ozmen and Baki (2019) examined the secondary school mathematics curriculum in the context of SL and revealed that SL is shaped around statistical process components and indicators. Cakmak and Durmus (2015) stated that secondary school students had difficulty learning probability concepts. Regarding this result, it is known that PST has difficulties in providing appropriate feedback based on student mistakes. They also have difficulty solving problems that require going beyond procedures and comparing measures of central tendency (Kazunga et al., 2023). Guven et al. (2021) stated that the SL levels of PST are generally low, which affects the competencies. PST who had and had not taken mathematics courses in their undergraduate education responded similarly to the SL questions. There was no significant difference between them (Forgasz et al., 2024). (Schreiter et al., 2024) reported that PST had low conceptual knowledge in the basic areas of statistics. PST understand statistical data and present them in different representations, but they are inadequate in interpreting and making inferences (De Vetten et al., 2023; Nahdi et al., 2021). In addition, there is a greater focus on the procedural aspects of statistics with significant differences in their knowledge levels. Aydin et al. (2019), who examined the self-efficacy and attitudes of PST toward the statistics course, reported that their self-efficacy beliefs and attitudes toward the statistics course were high and moderate, respectively.

The theoretical framework and empirical studies reveal the importance of SL. Recent studies on PST's SL have focused on variables such as attitude and competence. PST's SL levels are expected to increase with the statistics and probability courses they take during their undergraduate education. The present study aims to investigate the relationship between statistics and probability courses on PST's SL level. The research questions are:

1. Is there a relationship between statistics and probability courses and the SL levels of pre-service elementary mathematics teachers?
2. Is there a significant difference in the SL levels of pre-service elementary school mathematics teachers according to grade level?

Method

Research Design

The present study utilized a descriptive survey, which is one of the quantitative research approaches (Şata, 2020). The model is preferred to explore the relationship between changing conditions and subsequent behaviors after the pre-existing conditions and situations are defined.

Sample

The study's population consists of PSTs studying in an elementary mathematics teaching program in Turkey. The sample consists of 530 PSTs (67.7% female) selected by convenient sampling method. Table 1 shows the demographic variables of the participants.

Table 1. Distribution of participants according to demographic variables

Variables	Categories	N	%
Gender	Female	359	67.7
	Male	171	32.3
Grade	1st grade	122	23.0
	2nd grade	161	30.4
	3rd grade	130	24.5
	4th grade	117	22.1
Take a statistics and probability course*	1	253	47.7
	2	277	52.3
	Total	530	100.0

**1: PST who have taken statistics and probability courses*
2: PST who have not taken statistics and probability courses

Of the sample who continue their education in 2 different universities, 23.0% of them are at the 1st-grade level, 30.4% are at the 2nd-grade level, 24.5% are at the 3rd-grade level, and 22.1% are at the 4th grade level. In addition, the percentage of participants who took and did not take statistics and probability courses is almost equal to each other. The fact that the participants were selected from different universities in Turkey and from different grade levels contributes to the generalizability of the study.

Data Collection

The data for this study was collected through an online survey using Google Forms. All participants took part in the study voluntarily and were informed of the purpose and procedures. Responses were assured of confidentiality.

Data Collection Tools

SL Scale (SLS)

SLS, developed by Sahin (2012), consisting of 17 items, was designed to measure the SL levels of PST. Items (e.g., "There are 30 numbers. The standard deviation of these numbers is found to be zero. Which of the following can you be sure of?") are scored one-point for questions with four options and 0.5 points for questions with two options. The score obtained from the SLS varies between 0 and 16. High scores mean that PST's levels of SL have increased, while low scores mean that their levels of SL have decreased. In the present study, the Cronbach α coefficient calculated for the whole scale was. 601, while the McDonald ω coefficient was determined to be .933. CFA was performed for the validity of the measurements obtained from the measurement

tool, and the fit values were χ^2 /df = 297.82/118 = 2.523, CFI = .981, NNFI = .980, NFI = .965, RMSEA (%90 CI) = .054 (.040 - .050), SRMR = .060.

Data Analysis

Descriptive statistics of the measurements, Cronbach alpha coefficients for the reliability of the measurements, and confirmatory factor analysis were performed to provide evidence for the validity of the measurements. One-way ANOVA was conducted to determine the change in SL levels of PST according to their taking statistics and probability courses. In addition, Levene's test was used to determine whether the variance was equally distributed before the variance analysis. SPSS and LISREL software packages were used for data analysis. In data analysis, the .05 level was taken into consideration for statistical significance.

Ethic

The study was conducted with the permission of Ağrı İbrahim Çeçen University Scientific Research Ethics Committee dated 24.03.2022 and numbered 84.

Results

Descriptive statistics calculated for the measurements obtained from the measurement tools are presented in Table 2.

Table 2. Descriptive statistics of measurements

Variable	Variable level	Skewness		Kurtosis	
		Value	Std. Error	Value	Std. Error
Take a statistics and probability course	1	-0.217	0.153	-0.243	0.305
	2	-0.223	0.146	-0.095	0.292
Grade	1	-0.145	0.219	0.040	0.435
	2	-0.331	0.191	-0.124	0.380
	3	-0.240	0.212	-0.191	0.422
	4	0.147	0.224	-0.382	0.444

Table 2 shows that the skewness and kurtosis values of the measurements according to both the status of taking statistics and probability course and the grade level are within the range of ± 2.00. Accordingly, it was determined that the measurements had a normal distribution (Shiel & Cartwright, 2015).

The confirmatory factor analysis of the SLS was made and the results are presented in Figure 1.

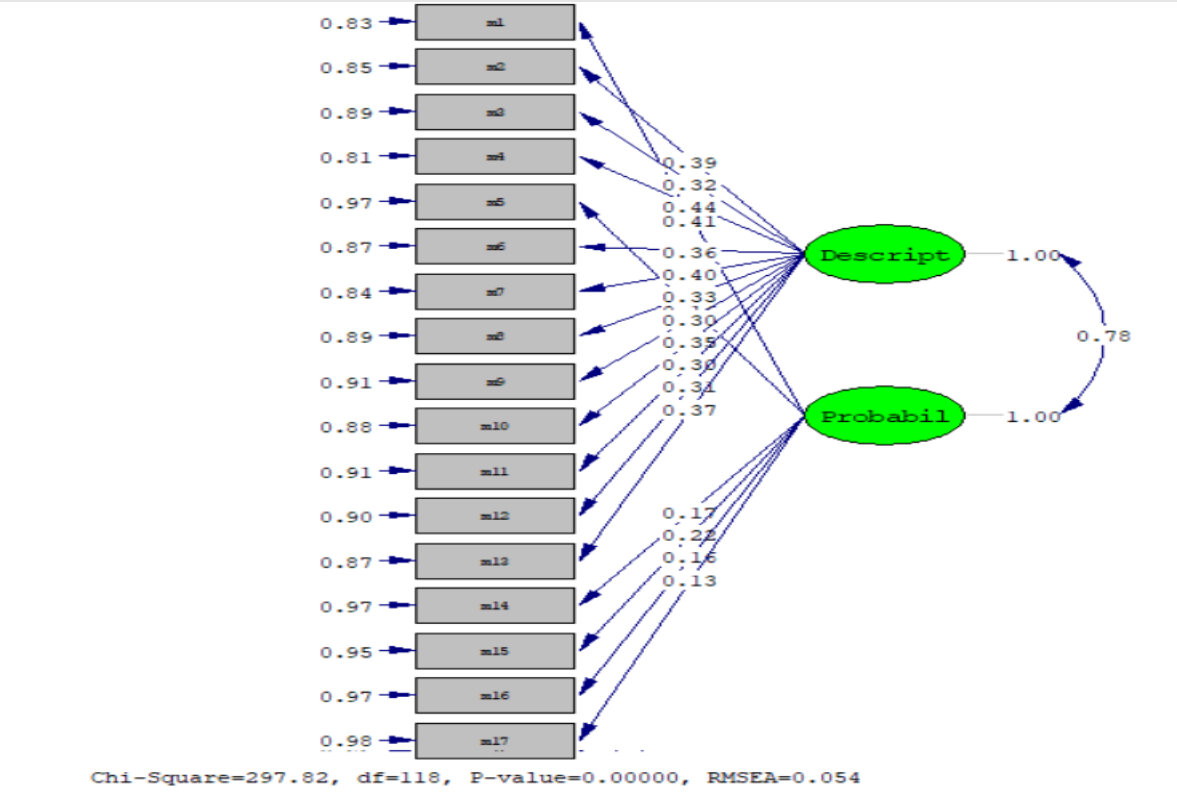

Figure 1. Measurement model defined for SLS first-level CFA results

Figure 1 shows that the factor structure of the scale was confirmed by confirmatory factor analysis. When Figure 1 is examined, it is seen that the factor loadings of some items are low. The analysis included these items because the model-data fit had a high fit value. No items were removed because there was sufficient evidence for construct validity. The results of the analysis conducted to determine the SL levels of PST according to their course-taking status are presented in Table 3.

Table 3. SL levels of PST

Variables	Categories	n	$\bar{x}$	SD
Take a statistics and probability course	1	253	9.84	3.082
	2	277	7.96	2.537
	Total	530	8.86	2.961

Table 3 shows that PSTs who did not take the statistics and probability course ($\bar{x}$ =7.96) had lower SL scores than those who did ($\bar{x}$ =9.84). The results of the independent samples t-test analysis to test the significance of this difference are presented in Table 4.

Table 4. Independent sample t-test analysis results related to taking statistics and probability course

Variables	Categories	n	$\bar{x}$	SD	df	t	*p*
Take a statistics and probability course	1	253	9.84	3.082	489.328	7.699	.000
	2	277	7.96	2.537			
	Total	530	8.86	2.961			

Levene test (F): 10.332; p= .001

Table 4 shows that the variances of the scores obtained by the groups who took and did not take statistics and probability courses were not homogeneous [F=10.332; p = .001, (p > .05)]. The results of the independent samples t-test when the variances are not homogeneous show that the mean scores of the groups who took and did not take statistics and probability courses differed significantly [t (489.328)= 7.699; p=0.000, (p < .05)]. According to the calculated eta-square value (η^2 = .099), it may propose that taking statistics and probability course has a moderate effect on the differentiation between PST's SL levels. The results of the analysis conducted to determine the SL levels of PST according to their grade levels are presented in Table 5.

Table 5. SL levels of PST at grade levels

Variables	Categories	n	$\bar{x}$	SD
Grade	1st grade	122	7.86	2.642
	2nd grade	161	7.95	2.507
	3rd grade	130	10.25	3.051
	4th grade	117	9.60	2.960
	Total	530	8.86	2.961

Table 5 shows that PST at the 1st ($\bar{x}$ =7.86) and 2nd ($\bar{x}$ =7.95) levels had lower SL scores than PST at the 3rd ($\bar{x}$ =10.25) and 4th ($\bar{x}$ =9.60) levels. One-way ANOVA results to test the significance of the difference are presented in Table 6.

Table 6. One-way ANOVA results according to the grade levels of PST

Variables	Categories	n	$\bar{x}$	Source of Variance	Sum of Squares	df	Sum of Squares	F	p	Difference (scheffe)
Grade	1st grade	122	7.86	between groups	571.41	3	190.470	24.63	0.000	1-3
	2nd grade	161	7.95							1-4
	3rd grade	130	10.25	within groups	4066.97	526	7.732			2-3
	4th grade	117	9.60							2-4
	Total	530	8.86		4638.38	529				

Levene test (F): 2.548; p= .055

Table 6 shows that the variances of SLS scores of PST at all grade levels are homogeneous (F=2.548; p > .05). One-way ANOVA results show that the mean scores of PST at all grade levels differed significantly ($F_{(3-526)}$=24.63; p < .05). Scheffe test showed that the significant difference was between 1-3, 1-4, 2-3, 2-4 grade levels. According to the calculated eta-square value (η^2= .118), it can be said that the grade level has a moderate effect on the differentiation between PST's SL levels.

Discussion

This study examined the relationship between statistics and probability courses and the SL level of PST. The findings provide insights into the SL levels of PST about their course-taking status and grade level. The results are interpreted in terms of both theoretical and empirical support. The results show that SL differs according to grade level and course-taking status. In other words, statistics and probability courses are related to SL. This result is consistent with the findings in the literature that emphasize the importance of statistics and probability courses in SL and skill development (Guven et al., 2021). The statistics and probability knowledge levels of PST who have taken statistics and probability courses are higher than those who have not. Therefore, integrating these courses into teacher education programs can be an effective strategy to strengthen the basic skills of pre-service teachers. Basic concepts and skills in statistics and probability courses affect the SL levels of PST. This training requires practice, a goal-oriented approach, and learning. This coincides with the conceptual understanding emphasized by GAISE (Carver et al., 2016). Therefore, PST can more effectively cope with the challenges they will encounter in their future professional lives. The results are similar across different grade levels. For example, the statistics and probability knowledge levels of 3rd and 4th grade PST are higher than the 1st and 2nd grade teacher candidates. This progress can be attributed to exposure to and interest in more statistical concepts over time. Upper-grade levels provide students with the opportunity to encounter and apply statistical concepts in a variety of contexts.

The importance of SL today is increasing as data-based decision-making and solving complex problems become basic skills. Teachers can promote SL by developing students' conceptual understanding and statistical thinking skills in this context. As previous research emphasizes, knowledge and practice are important in developing SL (Badenes-Ribera et al., 2018; Darling-Hammond et al., 2020). As pre-service teachers master statistical concepts and apply them in different contexts, they may increase their SL levels. Therefore, to improve the SL of PSTs, besides theoretical knowledge, opportunities to encounter concrete examples and apply them in real life should be provided. This approach can help them to increase their literacy levels. In this context, it should be remembered that this hands-on approach in education can more effectively develop PSTs' statistical thinking skills and provide effective teaching.

Conclusion and Implication

This research shows that statistics and probability courses taken at the undergraduate level are related to SL levels of PST. Findings reveal that these courses play a critical role in developing PST's statistical thinking skills and that these skills further increase at higher grade levels. The importance of this study emphasizes that statistics and probability courses should be included more in the context of teacher education programs. Statistics and probability education can enable PST to make data-based mathematics teaching decisions and transfer statistical thinking skills to students. More focus on these areas by teacher education programs can increase the professional competencies of future teachers. Additionally, this finding demonstrates how statistics and probability courses not only improve the SL levels of PST, but also how teacher education programs can contribute to developing these skills. The study results emphasize the importance of reconsidering teacher education programs to increase the potential of PST to increase their SL levels and be more successful in teaching mathematics. In this context, relevant stakeholders need to shape education policies by considering these results. Changes made in this direction may contribute to future teachers' ability to provide mathematics education more effectively.

Limitations and Suggestions

This study has several limitations. The data collected in this study are based on the participants' statements and are limited by the scope of the measurement tool. The gender distribution in the sample is unbalanced, with a higher representation of women (67.7%) compared to men (32.3%). This skewed distribution could potentially reveal gender-related biases and limit the generalizability of the results to a wider population. The results of the analyses show that statistics and probability courses are related to PST's SL. Therefore, longitudinal and experimental studies are needed to analyze the relationship in more detail. In addition, researchers can conduct studies to examine PST's attitudes toward statistics and probability courses. Teacher education programs can include more activities to increase PST's conceptual understanding of statistics and probability courses. It is also suggested to conduct new studies for curriculum development and educational policies by revealing the factors affecting the development of SL skills. Comparative studies related to statistical literacy can be conducted by including university students from different undergraduate programs in the sample.

Conflicts of Interest

The authors declare no competing interests.

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Ethics

All procedures were conducted in accordance with the ethical standards of the institutional and/or national research committee. The study was conducted with the permission of Ağrı İbrahim Çeçen University Scientific Research Ethics Committee dated 24.03.2022 and numbered 84.

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