

Examining Prospective Teachers' Scientific Literacy and STEM Efficacy Beliefs

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Abstract: *The research study focuses on prospective teachers' scientific literacy and STEM efficacy beliefs. 105 prospective teachers from 2 universities participated in this research. For examining scientific literacy of participants, two components of science literacy (scientist and nature of science) were defined. A questionnaire, "science literacy scale" developed by the researchers and applied to participants first. Later, for the second component of scientific literacy, scientist and where and how he/she works, participants were asked to draw pictures. Finally, for STEM efficacy beliefs, "Prospective Teachers' Self-Efficacy Scale towards Science-Technology-Engineering-Mathematics" was applied. Data collected through scales were statistically analyzed and participants' drawings about scientists and their work environment were scanned to be filed in computer. Drawings were open coded first and with the grouping of codes, themes were identified. Statistical analysis of science literacy scale and themes emerged from qualitative analysis were evaluated together to understand scientific literacy levels of the participants. In conclusion, prospective teachers have an average level of scientific literacy and neither gender nor department attended has significant change. Also, prospective teachers have slightly more than average STEM efficacy beliefs and neither gender nor department attended has significant change.*

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Introduction

IN THE LAST 20 years, scientific literacy has developed conceptually, and the two notions, namely social participation, and emancipation, have an influence in this development. Social participation and emancipation mean a strong engagement in science and its components. This engagement resulted in a new definition of scientific literacy and this definition brings a transition between the transmissive nature of education to transformative one (Valladares, 2021). The world goes through many challenges like wars, climate change, mass migration and pandemics, and all these challenges alter the education systems of the countries. The last pandemic Covid 19 might be an example of these challenges. Although Covid 19 effected education negatively to some extent, it also caused an improvement in education. More specifically, in hard times like pandemic, to be able to deal with the uncertainty and complexity of the world, people need to find new ways, paradigms and practices to reshape what they know to understand and solve what they faced. This may happen not with the transmission of scientific knowledge but transforming it into what is needed. After Covid19, one of the big challenges throughout the world is to determine what is scientific knowledge and what is misinformation. Therefore, this became a global challenge. To understand the difference between them and to catch the misinformation, scientific literacy needed to be covered in all curricula. Although scientific literacy is addressed by many researchers, this concept is not fully clarified. It is a concept known by everyone, but to clarify the definition, some re-searchers have persistently tried to create an alternative concept so that people can understand it more easily. There are several resources for definition of scientific literacy, and they are derived from two different roots. The first view of scientific literacy is rooted in the product and process components of science and based on transmissive education. This view focuses on learning the nature of science, namely, science content and processes. Science education focuses on reading and writing scientific texts. On the other hand, the second view is rooted in social situations with scientific components which an individual may face as a citizen and focuses on understanding the usefulness of scientific knowledge in life and society (Valladares, 2021). Therefore, in this view, science education settles on not its practice of reading and writing but on the use of scientific content and critical thinking components of science. In this research study, data collection tool reflects the transmissive view.

Students who have low understanding of nature of science may know the theories in science but may not be able to apply science concepts to their everyday life (Lestari et al., 2021). They may also have some misconceptions about how science is produced. This lack of knowledge about the nature of science and not being able to apply it to everyday life, i.e.

lack of problem-solving skills as an important everyday life skill, may end up with low self-efficacy for the individual. Additionally, rapid changes of technological and organizational structures require young people to develop new skills and understanding to let them know how to link information across multiple disciplines (Connor, Karmokar & Whittington, 2015). When all this information analyzed, one can very well understand why we still need to develop scientific literacy and knowledge about the nature of science of individuals.

STEM Efficacy Beliefs and Its Importance

“Self-efficacy beliefs are based on four primary sources of information: mastery experience, vicarious experience, social persuasion and physiological reaction.” (Rittmayer & Beier, 2008).

Before explaining each self-efficacy belief, it is necessary to briefly explain how gender differences among individuals affect self-efficacy and, in turn, STEM success. Individuals' self-efficacy beliefs are a determining factor in STEM education. For this reason, it can be used as a precursor to increase students' performance in STEM education. Among middle school students, it is seen that girls' science and mathematics achievement is higher than boys'. However, when we look at higher education and high school, it is seen that boys surpass girls in physics, chemistry, biology, mathematics and even engineering. For this reason, determining self-efficacy beliefs is considered important to increase the success of girls in tasks and performances in STEM education (Rittmayer & Beier, 2008; Escobar, Majewski, Qazi & Rawajfih, 2022).

Individuals' mastery experiences in their self-efficacy beliefs can be developed by providing students with active learning opportunities, by continuing to perform tasks that are small but become more difficult over time, in other words, by revealing the struggling side of students. When this context is examined, the strategies mentioned that support student learning also provide feedback to the student's mastery experience. Vicarious experience allows students to observe each other's tasks. A student who sees a friend design a tool or machine may believe that he or she can design a similar or different machine. In general, vicarious experience encourages students to be role models for each other in STEM education (Rittmayer & Beier, 2008).

According to Demirbağ, Arıkan and Muğaloğlu (2020), individuals' self-efficacy beliefs in the STEM field are of great importance in their academic success and career choice. Individuals' self-efficacy beliefs in this area come to the fore especially when they want to choose a profession related to the STEM field.

Scientific Literacy

Scientific literacy emerges as a concept that is effective in individuals' decision-making mechanisms around a scientific issue or that can make individuals accept scientific claims. Unfortunately, in the 21st century, scientific literacy is the only source of scientists against scientific misunderstandings on social media (Osborne & Allchin, 2024). In general, scientific literacy is in the ensuing three aspects: learning science and technology, doing science and technology, and learning about science and technology. Also, there are two visions in scientific literacy: Vision I, which concentrates mainly on learning about scientific content and scientific processes for later utilization, and Vision II, which engages on understanding the versatility of scientific knowledge in life and society by beginning science learning from consequential contexts (Sjöström & Eilks, 2018).

Research Problem, Focus and Questions

Every country needs scientifically literate workers with developed deep problem-solving skills. Although scientific literacy has been the subject of academic re-search for a long period of time, newly arranged 21st century literacies and required job skills enforce researchers to revisit the subject. Some research studies conclude that pandemic and distance education have positive impact on students' scientific literacy, if integrated with STEM pedagogy in a blended way (Lestari et al., 2021). These kinds of positive results encourage educational researchers to investigate prospective teachers' levels of scientific literacy and their efficacy beliefs with respect to the STEM approach to teaching. Based on the positive effects of integrating STEM pedagogy into scientific literacy, this study underlines the importance of knowing what STEM is and how individuals perceive their self-efficacy about STEM and its role in their scientific literacy.

This research examines the answers to the following questions:

1. What is the scientific literacy level of prospective teachers?
2. Is the scientific literacy level changing with gender and department attended?
3. What are the STEM efficacy beliefs of prospective teachers?
4. Is STEM efficacy belief changing with gender and department attended?
5. Is there any relation between prospective teachers' scientific literacy and STEM efficacy beliefs?

Methods

General Background

This research was designed as descriptive correlational research to examine the relationship between two variables, scientific literacy and STEM efficacy beliefs of prospective teachers. According to Creswell, descriptive correlational research design is used to investigate the degree of relation between two or more variables or sets of scores and it does not make any claim about cause and effect (Creswell, 2012).

Sample

A total of 105 volunteer prospective teachers from 2 universities participated in this research. Forty-eight of them were prospective elementary science teachers whereas 57 percent were prospective early childhood teachers. Participants were attending instructional methods courses in science in their universities and the researchers are the instructors of these courses. None of the participants had a course on the nature of science.

Instrument and Procedures

For examining scientific literacy of participants, two components of science literacy (scientist and nature of science) were defined. A questionnaire, "science literacy scale", asking questions about the nature of science (including scientific knowledge and its characteristics, science process skills and how science is produced), developed by the researchers and applied to participants first. The scale consisted of 13 True/False items about scientific knowledge and its characteristics, science process skills and how science is produced. Later, for the second component of scientific literacy, more specifically, scientists and where and how he/she works, participants were asked to draw pictures. Finally, for STEM efficacy beliefs, "Prospective Teachers' Self-Efficacy Scale towards Science-Technology-Engineering-Mathematics (PTSSSTEM)" (Gelen et al., 2019) was applied. PTSSSTEM is a likert type scale and has 12 items of which participants will choose from 1- "certainly not agree" to 5- "certainly agree". PTSSSTEM has two subsections, self-efficacy in teaching science and expectations at the end of science teaching.

Data Analysis

Science literacy scale and Prospective Teachers' Self-Efficacy Scale towards Science-Technology-Engineering-Mathematics were quantitatively analyzed with SPSS whereas pictures drawn by participants were qualitatively analyzed with MAXQDA software. Findings are presented below. MAXQDA helps in analyzing data in codes and themes in qualitative and mixed research. MAXQDA does not only analyze documents, but also

Table 1. Reliability Statistics for Scientific Literacy Scale and PTSSSTEM.

Scale	Cronbach- α	N of items
Scientific literacy scale	0.842	13
PTSSSTEM	0.746	12

Table 2. Kolmogorov-Smirnov Test for Scientific Literacy Scale

Scientific literacy scale	Kolmogorov-Smirnov			Shapiro-Wilk		
	statistic	df	Sig.	statistic	df	Sig.
M total	0.167	105	0.00	0.889	105	0.00

images and audio files. After analysis, presenting the data with options called ‘creative coding’ and ‘code clouds’ adds a difference to a professional study (MAXQDA, 2025). In **Table 1**, reliability statistics for scientific literacy scale and PTSSSTEM are shown.

Table 1 shows the reliability coefficients for scientific literacy scale is 0.842 and this shows that the scale is reliable, the reliability coefficient for PTSSSTEM is 0.746 and it is accepted as reliable.

Results

In this section, scale’s reliability results and answers to research questions were presented in two subsections as follows.

What is the scientific literacy level of prospective teachers?

To answer this research question scientific literacy scale results were analyzed first, and participants-generated pictures of scientist and his/her work environment were analyzed second. Analysis of scale started with normality test Kolmogorov-Smirnov ($N > 50$) and it is presented in **Table 2**.

Table 2 shows that scale does not have a normal distribution ($p < 0.05$). Therefore, non-parametric tests are required for analysis. Participants’ mean score is evaluated and it is found as 8.52 with a standard deviation of 3.337. The minimum and maximum scores one can get from the scale are zero and thirteen. Therefore, participants’ mean score implies that their literacy level is on average, in other words they are neither too literate nor too illiterate.

Table 3. Scientific Literacy – Gender and Department

	Gender	N of items	Mean rank	Sig.
M total	Female	88	53.53	0.682
	Male	17	50.26	
	Elementary science	48	32.54	0.000
	Early childhood	57	70.23	

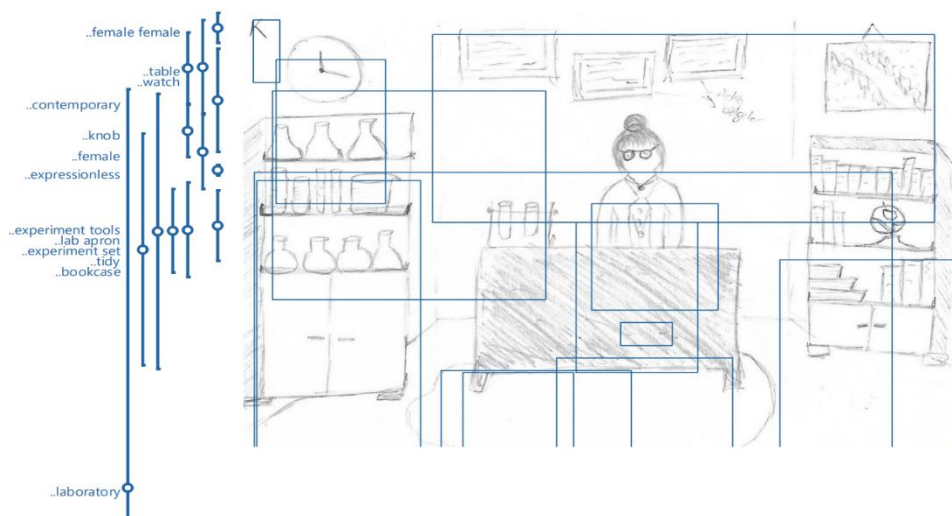


Figure 1. Open Coding Sample.

Is the scientific literacy level changing with gender and department?

Analysis related to this sub question was given in **Table 3**.

Table 3 shows that there is no significant difference between scientific literacy levels due to gender. Although number of male participants is much less than number of female participants, it is interesting that their mean scores are very similar. The prospective early childhood teachers have a higher mean (70.23) than prospective elementary science teachers (32.54) and this difference is statistically significant ($p < 0.05$). Although there is high expectation for prospective science teachers it is not the case.

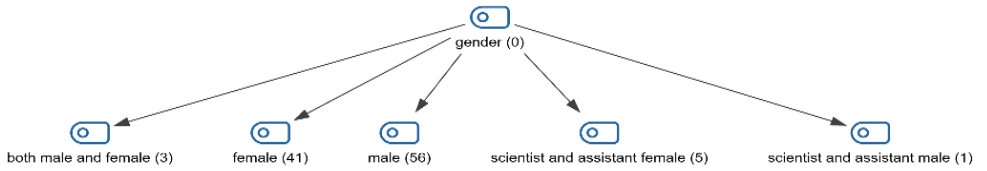


Figure 2. Gender of the Scientists.

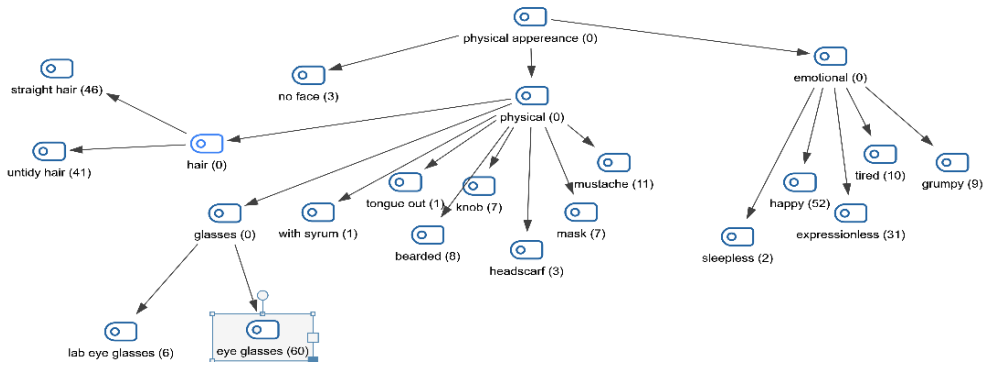


Figure 3. Physical Appearance of the Scientist.

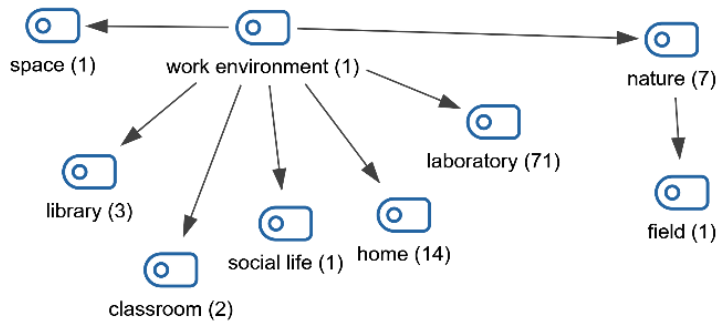


Figure 4. Scientists' Environment.

Table 4. PTSSSTEM Scores.

F total	105	42.02	6.080
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To sum up, prospective teachers who participated in this research study displayed an average scientific literacy level with a significant difference due to departments they attend and no significant difference due to gender.

To have a deeper understanding of how participants perceive scientists and their work environment, pictures generated by participants were open coded with MAXQDA software (**Figure 1**).

Open coding of the pictures ended up with three themes, gender of the scientists, physical appearance of the scientist and scientists' environment. The themes were explained with code maps presented in the following **Figures 2, 3** and **4**.

As one can see from **Figure 2**, eight of the participants drew scientist with an assistant who are female. More than half of the participants (56) perceived scientist as male.

According to **Figure 3**, scientists, mostly wear eye and lab glasses (66), have mostly happy (52) or expressionless (31) face, female scientists have knob (Hadiprayitno et al., 2022) and male scientists have mustache (Er & Acar, 2020) and beard (Kumar & Banerjee, 2018). Based on the coding, participants perceive scientist mostly male with mustache, beard and untidy hair.

Figure 4 displays that participants mostly describe the work environment of scientists as laboratory (71), and home (Latifah et al., 2019). This leads researchers to think that participants accept mostly basic sciences and life sciences as sciences and do not draw social scientists.

What is the STEM efficacy beliefs (PTSSSTEM) of prospective teachers?

Minimum and maximum points one can get from PTSSSTEM changes between 12 and 60.

Table 4 displays mean scores of the participants form the scale. Mean value of research participants is 42.02 and it shows that participants STEM efficacy beliefs are slightly above average.

STEM efficacy belief changing with gender and department attended?

Participants' STEM efficacy beliefs across their genders and department attended are presented in **Table 5** below.

Table 5 implies that there is no significant difference in participants' STEM efficacy beliefs scores due to their genders ($p > 0.05$). Number of males is 20% of the number of females participated in this research study.

Table 5. STEM Efficacy Beliefs Across Genders and Departments.				
	Gender	N	Mean Rank	Sig.
F total	Female	88	52.18	0.530
	Male	17	57.24	
	Elementary science	48	50.95	0.526
	Early childhood	57	54.73	

Table 6. Scientific Literacy and STEM Efficacy Beliefs				
			M total	F total
Spearman's rho	M total	Correlation coefficient	1.000	0.143
		Sig.		0.146
		N	105	105
	F total	Correlation coefficient	0.143	1.000
		Sig.	0.146	
		N	105	105

On the other hand, males have greater mean points than females and this result may lead researchers to think that equal representation may affect the result.

Prospective teachers from elementary science and early childhood departments participated in this research and their STEM efficacy beliefs scores across their departments were displayed in **Table 5** above.

Table 5 implies no significant difference due to departments attended by participants ($p > 0.05$). Departments have similar representations (48 versus 57) and participants from early childhood departments had higher means. STEM is usually and normally related to science subjects. It is a general expectation that the more you are exposed to science subjects the higher STEM efficacy scores you have. This result does not agree with this expectation.

Is there any relation between teachers' scientific literacy and STEM efficacy beliefs?

Knowing something well does not guarantee teaching it well. This research question addresses this issue. Is being scientifically literate ending up with high STEM efficacy beliefs, more specifically, beliefs about teaching STEM subjects? **Table 6** represents science literacy and STEM efficacy beliefs scores in relation to Spearman's rho.

Table 6 shows no significant relationship between participants' scientific literacy levels and their STEM efficacy beliefs ($p > 0.05$). Although both scientific literacy and self-efficacy towards teaching STEM related subjects requires common knowledge like nature of science, this result implies that one's scientific literacy level is not parallel to efficacy beliefs to teach STEM.

Discussion

Turkey is a candidate nation expected to join the European Union for a long time. During this period, education system in Turkey has been changed to align with European standards. In 1990's, Turkey started to reform teacher education through the National Education Development Project. One of the purposes of the project was to improve pre-service teacher education (Tuncer et al., 2009).

Prospective teachers participating in this research study have average levels of scientific literacy and neither gender nor department attended by participants make significant difference in this literacy level. This result is consistent with the latest re-search studies about prospective teachers' scientific literacy levels (Nurhayati, Sopandi & Riandi, 2023) and it is reported that prospective elementary teachers have moderate level of scientific literacy. Similarly, research studies examining science literacy skills across gender report no difference in gender parallel to findings of this research (Hadiprayitno et al., 2022). On the other hand, more detailed research studies (Kumar & Banerjee, 2018) concentrated on functional scientific literacy which includes 3 dimensions, nature of science, science process skills, and use of science understanding in daily life, reports a gender difference in scientific literacy. According to this research study, males have higher points than female participants. Therefore, we may conclude that males are better in transforming what they know in science, both content and skills, into their daily life. Participants' perceived scientist as a male ($n = 56$) with mustache or beard and untidy hairs and working mostly in labs ($n = 71$). This leads researchers to think that participants accept mostly basic sciences and life sciences as science and do not drew social scientists. Literature supports this result. One of the research studies focusing on middle school students' perceptions of science reported their perceptions of scientist as men, happy, wearing lab coats and glasses, working individually in indoor places (Ivgin, Akcay & Kapici, 2021). Another study with the same focus reported secondary school students' perceptions of scientist as hardworking and smart male individuals wearing gown, glasses or protective glasses, tie or bowtie, mustache with a peculiar hairstyle or with no hair (Balcın & Ergun, 2018).

Like scientific literacy levels, participants' STEM efficacy beliefs are slightly above the average and neither gender nor department attended by

participants make significant difference in these beliefs. This is parallel to what literature says (Er & Acar, 2020). Even if prospective teachers have high STEM awareness, their STEM efficacy beliefs are on average. Opposite to gender part of the result, some research studies reported that gender differences, favoring men, have been observed in STEM self-efficacy (Rittmayer & Bayer, 2008). Although it seems males have more self-efficacy and agreed with the goals of STEM education, as well as expressed confidence in their ability to execute them, one of the re-search studies from literature (DeCoito & Myszkal, 2018) underlines that there was a disconnect between their beliefs and implementation in practice.

There is no significant relationship between participants' scientific literacy levels and STEM efficacy beliefs resulted in this research study. Although there are some re-search studies (Latifah et al., 2019) describing a cause and effect relationship between scientific literacy and stem self-efficacy and underlying that self-efficacy has a high relationship, positive and significant to scientific literacy, this research does not end up with a relationship.

Limitations

This research can also be conducted with different research models with larger sample sizes, measuring a wider range of demographic variables.

Conclusion

Prospective teachers:

- have an average level of scientific literacy and neither gender nor department attended has a significant change. This result can be explained as follows: Even though the branches of the students in both departments are different, the importance and existence of science are given equally. In general, while it is expected that the scientific literacy of male students is higher than that of female students, the fact that it is not high is in favor of the girls. This means that the female students in the sample know what science means and how important it is for people as much as the male students.
- perceive scientist as male with mustard, beard and untidy hairs working in labs. This result can be explained as follows: From a young age, all events and facts that children see and follow about science are identified with men. Almost most scientists are men. When we think about it, only Marie Curie comes to mind for students, and as it is known, she was able to explain her scientific studies under her husband's name at the beginning. However, one of most important reasons for this result may be Albert Einstein. Einstein is shown to children as a scientist first and

foremost from kindergarten onwards, and he can hold a place in students' memories with his messy hair and tongue-sticking picture. Similarly, the drawing of beards and moustaches by students may have been seen as one of the most important differences between women and men.

- have slightly more than average STEM efficacy beliefs and neither gender nor department attended has a significant change. The result can be explained as follows: Students in both departments may have been taught STEM-related information and techniques. Students in preschool teaching may have had extra interest in STEM and therefore may have informally acquired more information. The fact that STEM self-efficacy skills did not differ based on gender may be an indication that female students are as interested in STEM as male students. However, the small number of male students in both departments may have been a limitation for the research when analyzing self-efficacy beliefs. The fact that preschool teacher candidates' STEM self-efficacy beliefs are close to those of science teacher candidates is a good result for preschool teachers but an insufficient result for science teachers. Based on this result, it can be suggested that science teacher candidates be provided with more accurate, understandable and applicable activities and lesson plans regarding STEM.
- There is no significant relationship between participants' scientific literacy levels and STEM efficacy beliefs. This result can be explained as follows: "STEM is possible with scientific literacy that will be acquired at an early age." (Yaşar Ekici, Bardak, & Yousef Zadeh, 2018), because of this research, no relationship was found between STEM self-efficacy beliefs and scientific literacy. Although it is seen as an insignificant result, many possibilities can be evaluated for this result; one of these could be that students were given an inaccurate scale. Another possibility could be that students did not answer the scales correctly.

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