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A Quantitative Study on The Scientific Literacy Skills of Prospective Biology Teachers

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Abstract: Scientific literacy skills are very important skills in life, not only related to academic aspects, but also in real life. Therefore, science literacy skills become a goal in 21st century education. This study aims to investigate the level of scientific literacy skills of biology prospective teacher, and to find out whether there are significant differences in scientific literacy skills of biology prospective teacher based on semester. In this study, there were 69 prospective biology teachers as voluntary respondents, consisting of 17 (2nd semester), 25 (4th semester), and 27 (6th semester). The Test of Scientific Literacy Skills (ToSLS) is an instrument used to measure scientific literacy skills. Furthermore, the data were analyzed descriptively and multivariatly using SPSS 22 at the 5% significance level. Based on the results of the analysis, it can be concluded that our participants' scientific literacy skills were not significantly different. In general, our participants' scientific literacy skills were low in the aspect understanding of element research design, creating graphs, solving problems using quantitative skills, and justify inferences, predictions, and conclusions based on quantitative data, and semesters have no significant effect on scientific literacy skills. Then, the recommendations for the results of this study are described briefly in the conclusion section.

Keywords: Scientific literacy sills; ToSLS; Prospective biology teachers

Introduction

Education in the 21st century aims to prepare students to become a global society (Mun et al., 2015). The educational process should emphasize the mastery of scientific literacy skills in students (Altun-Yalçln et al., 2011; Gormally et al., 2012; Han-Tosunoglu & Ozer, 2022; Karışan & Zeidler, 2016; Özdem et al., 2010; Ozden, 2020; Soobard & Rannikmäe, 2011; S. Wu et al., 2018), because scientific literacy is not only a supporting factor for success in the 21st century and an era knowledge based economy (Adnan et al., 2021; Boh Podgornik et al., 2017; Suwono et al., 2017), but also includes responsibility and cultural aspects (Allison & Goldston, 2018).

In simple terms, scientific literacy is defined as reading and writing skills (Olatoye, 2010), or we can define scientific literacy as knowledge and understanding of scientific processes (Altun-Yalçln et al., 2011; Boh Podgornik et al., 2017). However, this definition is very simple. We know that these scientific processes are the basis for knowledge building and solving problems. Thus, the current definition of scientific literacy refers to the application of scientific knowledge, identifying questions, compiling reasoning and conclusions based on data to understand natural phenomena (Cook et al., 2011).

In addition, scientific literacy is related to the problem-solving process and everyday life (Aina et al., 2020). In the development and application of knowledge, problem solving and decision making requires ethics and scientific methodologies, understanding of scientific concepts, and the impact of technological developments (Özdem et al., 2010). This is very much needed to realize a global society as part of the responsibility and socio-cultural aspects (Allison & Goldston, 2018).

From the description above, we can understand how important scientific literacy is, not only in academic

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aspects, but also in everyday life, and even in global life. Therefore, scientific literacy is one of the areas of study in research, both on a local and international scale. Several studies on scientific literacy show that students' scientific literacy skills are low, such as students in Estonia (Soobard & Rannikmäe, 2011). Likewise, students in the Philippines showing low scientific literacy skills (Fancubila Farillon, 2022). United States of America students' have a low score in scientific literacy (McPhearson et al., 2008). PISA results show that the scientific literacy of students in Turkey is still low (Özdem et al., 2010).

Studies on scientific literacy are not only carried out at the student level but also at the university level. Al-Momani (2016) and Obi (2019) show that students' scientific literacy skills are also still low. The results of a comparative study between the scientific literacy of Indonesian and Thai prospective teachers show that prospective Indonesian teachers have a lower level of scientific literacy than Thai students (El Islami & Nuangchalerm, 2020). Suppose we use aspects of scientific literacy developed by Gormally et al. (2012), as shown in Table 1, to explain the results of the study regarding scientific literacy, both for students and students. In that case, we can state that the results of the study are unclear, which aspects are low (or weak) and high (strong). Meanwhile, we did not get clear information about the scientific literacy skills of prospective teachers at the Mandalika University of Education. Perhaps, this is influenced by the research theme at the Mandalika University of Education, which focuses more on 21st-century skills, especially critical thinking skills.

Paying the importance of scientific literacy skills and the results of research on scientific literacy skills, as well as the emphasis on research themes at the Mandalika University of Education, we believe that scientific literacy and critical thinking go hand in hand. Or, if not together, scientific literacy skills are a prerequisite for critical thinking skills because scientific literacy is closely related to various aspects, so it is called the basic construct of scientific knowledge and practice (Aina et al., 2020). With scientific literacy skills, students can understand, analyze, and evaluate various information (Porter et al., 2010), solve problems, both in personal and global contexts, collaborate and communicate with others, skilled to use various available sources, able to defend opinions when faced with different of thoughts (Mun et al., 2015). Therefore, this research was conducted with the aim of identifying the level of scientific literacy skills of prospective biology teachers. We can use the results of this research later as a springboard for developing teaching programs which not only aim to help them (prospective biology teachers) have good scientific literacy skills but also help them to improve other skills, such as critical thinking and problem-solving skills. The research questions to be answered in this study include, *first*; what the level of science literacy skills of prospective biology teachers? *Second*; whether there is an effect of semester differences on the level of science literacy skills of prospective biology teachers?

Method

This research was conducted at the Mandalika University of Education using a quantitative survey. A total of 69 biology prospective teacher as voluntary respondents in this study, consist of 17 (2nd semester), 25 (4th semester), and 27 (6th semester). To measure and/or investigate the scientific literacy skills of prospective biology teachers, we use the Test of Scientific Literacy Skills (ToSLS) instrument developed by Gormally et al. (2012) as many 28 items in the multiple choice form, consisting of identify a valid scientific arguments (3 items), evaluate the validity of source (5 items), evaluating the use and misuse of scientific information (3 items), understanding the elements of research design and its impact on scientific research findings (4 items), create the table, graph, or picture to represent research finding (1 item), read and interpreting the table, figure, and/or graph (4 items), solving-problems using quantitative skills (including probability and statistics) (3 items), understand and interpret basic statistics (3 items), and the last is justify of inferences, predictions, and conclusions based on quantitative data (2 items).

The data that has been obtained were analyzed descriptively, and to find out whether there is an effect of semester differences on scientific literacy skills, the data were analyzed multivariately using SPSS 24 for windows at a significance level of 5%. Before carrying out a multivariate analysis, the covariance matrix equality requirements must first be met (seen from the significance value of the Box'M test) and sample homogeneity (seen from the significance of each aspect using the Levene test).

Result and Discussion

There are 9 components of scientific literacy skills in measuring using the instrument developed by Gormally et al. (2012), namely identifying a valid scientific argument, evaluating the validity of sources, evaluating the use and misuse of scientific information, understanding the elements of research designs and how they impact to scientific findings/conclusions, presenting data in the form of table, graph, or picture, reading and interpret graphical representations of data, solve problems using quantitative skills (including probability and statistics), understand and interpret basic statistics, and justification inferences, predictions, and conclusions based on quantitative data.

Table 1. The average of each component of scientific literacy skills by semester

Components of scientific literacy skills	2nd Semester		4th Semester		6th Semester	
	Mean	SD	Mean	SD	Mean	SD
Identifying a valid scientific argument.	1.12	0.96	1.00	0.76	0.93	0.78
Evaluating the validity of sources.	1.88	1.41	1.60	1.12	1.26	0.86
Evaluating the use and misuse of scientific information.	0.88	0.78	0.68	0.63	0.96	0.76
Understanding the elements of research designs and how they impact to scientific findings/conclusions.	0.41	0.80	0.80	0.71	0.89	0.75
Create the table or graph.	0.29	0.27	0.28	0.46	0.26	0.45
Reading and interpret graphical representations of data.	0.82	0.73	0.96	0.84	1.19	0.96
Solve problems using quantitative skills (including probability and statistics).	0.59	0.71	0.72	0.68	0.81	0.83
Understand and interpret basic statistics.	0.71	0.69	1.04	0.73	0.89	0.80
Justify inferences, predictions, and conclusions based on quantitative data.	0.41	0.51	0.44	0.65	0.37	0.69

Table 2 shows the similarity of the population matrix covariance. From the results of this analysis, it is stated that the covariance matrix of the population is stated to be the same. Then, Table 3 shows the results of the sample homogeneity analysis that the sample is homogeneous in every aspect of scientific literacy skills. The two requirements of multivariate analysis have been met, where the results of the multivariate analysis can be seen in Table 4, and further analysis (Tukey HSD) can be seen in Table 5. Both results of this analysis (Tables 4 and 5) show that the semester has no effect on our participants' scientific literacy skills. Or in other words, our participants have the same scientific literacy skills.

Table 2. Box'M test of equality of civariance matrices[a]

Box's M	121.437
F	1.066
df1	90
df2	8633.257
Sig.	0.316

Tests the null hypothesis that the observed covariance matrices of the dependent variables are equal across groups.
a. Design: Intercept + Semesters

Table 3. Levene test result

Components of Scientific Literacy	F	df1	df2	Sig.
Identify a valid scientific argument	0.804	2	66	0.452
Evaluate the validity of sources	1.800	2	66	0.173
Evaluate the use and misuse of scientific information	0.184	2	66	0.833
Understand elements of research	0.080	2	66	0.923
Create graphical representations of data	1.435	2	66	0.246
Read and interpret graphical representations of data	0.299	2	66	0.743
Solve problems using quantitative skills	1.199	2	66	0.308
Understand and interpret basic statistics	0.095	2	66	0.910
Justify inferences, predictions, and conclusions based on quantitative data	0.343	2	66	0.711

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.
a. Design: Intercept + Semester

Table 4. Results of multivariate analysis

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	.909	64.558[b]	9.000	58.000	0.000	0.909
	Wilks' Lambda	.091	64.558[b]	9.000	58.000	0.000	0.909
	Hotelling's Trace	10.018	64.558[b]	9.000	58.000	0.000	0.909
	Roy's Largest Root	10.018	64.558[b]	9.000	58.000	0.000	0.909
Semesters	Pillai's Trace	0.251	0.942	18.000	118.000	0.531	0.126
	Wilks' Lambda	0.759	.951[b]	18.000	116.000	0.520	0.129
	Hotelling's Trace	0.303	0.960	18.000	114.000	0.511	0.132
	Roy's Largest Root	0.247	1.618[c]	9.000	59.000	0.131	0.198

a. Design: Intercept + Semessters
b. Exact statistic
c. The statistic is an upper bound on F that yields a lower bound on the significance level.

Table 5. Results of post hoc analysis (Tukey HSD)

Components of scientific literacy skills	(I) Semesters	(J) Semesters	Mean difference (I-J)	Sig
Identify a valid scientific argument	2nd Semester	4th Semester	0.12	0.89
		6th Semester	0.19	0.73
	4th Semester	2nd Semester	-0.12	0.89
		6th Semester	0.07	0.94
	6th Semester	2nd Semester	-0.19	0.73
		4th Semester	-0.07	0.94
Evaluate the validity of sources	2nd Semester	4th Semester	0.28	0.67
		6th Semester	0.62	0.94
	4th Semester	2nd Semester	-0.28	0.67
		6th Semester	0.34	0.51
	6th Semester	2nd Semester	-0.62	0.94
		4th Semester	-0.34	0.51
Evaluate the use and misuse of scientific information	2nd Semester	4th Semester	0.20	0.65
		6th Semester	-0.08	0.93
	4th Semester	2nd Semester	-0.20	0.65
		6th Semester	-0.28	0.34
	6th Semester	2nd Semester	0.08	0.93
		4th Semester	0.28	0.34
Understanding elements of research	2nd Semester	4th Semester	-0.39	0.23
		6th Semester	-0.48	0.11
	4th Semester	2nd Semester	0.39	0.23
		6th Semester	-0.09	0.90
	6th Semester	2nd Semester	0.48	0.11
		4th Semester	0.09	0.90
Create graphical representations of data	2nd Semester	4th Semester	-0.16	0.45
		6th Semester	-0.14	0.53
	4th Semester	2nd Semester	0.16	0.45
		6th Semester	0.02	0.98
	6th Semester	2nd Semester	0.14	0.53
		4th Semester	-0.02	0.98
Read and interpret graphical representations of data	2nd Semester	4th Semester	-0.14	0.87
		6th Semester	-0.36	0.37
	4th Semester	2nd Semester	0.14	0.87
		6th Semester	-0.23	0.62
	6th Semester	2nd Semester	0.36	0.37
		4th Semester	0.23	0.62
Solve problems using quantitative skills	2nd Semester	4th Semester	-0.13	0.84
		6th Semester	-0.23	0.59
	4th Semester	2nd Semester	0.13	0.84
		6th Semester	-0.09	0.89
	6th Semester	2nd Semester	0.23	0.59
		4th Semester	0.09	0.89
Understand and interpret basic statistics	2nd Semester	4th Semester	-0.33	0.34
		6th Semester	-0.18	0.71
	4th Semester	2nd Semester	0.33	0.34
		6th Semester	0.15	0.75
	6th Semester	2nd Semester	0.18	0.71
		4th Semester	-0.15	0.75
Justify inferences, predictions, and conclusions based on quantitative data	2nd Semester	4th Semester	-0.03	0.99
		6th Semester	0.04	0.97
	4th Semester	2nd Semester	0.03	0.99
		6th Semester	0.07	0.92
	6th Semester	2nd Semester	0.03	0.99
		4th Semester	-0.07	0.92

From the results of the analysis shown in Table 4 and 5, the scientific literacy skills of our participants were similar. This indicates that our participants' scientific literacy skills are at the same level. These results are similar to the findings of Segarra et al. (2018) that student grades do not show a significant difference in TOSLS performance. On the other hand, these results contrast to the findings of Özdem et al. (2010) that there are differences in the scientific literacy skills of students in grades 6, 7 and 8. Likewise with the findings of Al-

Momani (2016) show that there are significant differences in the level of students' scientific literacy skills based on the academic year. Altun-Yalçln et al. (2011) also found that there was a significant difference in the level of science literacy skills of prospective science education teacher students based on the level of study.

If we pay attention to the results of the descriptive analysis (Table 1), the scientific literacy skills of both participants from semesters 2 to 6 are weak in the aspects of creating the table or graph, justify inferences, predictions, and conclusions based on quantitative data. In addition, our participants from semester 2 were also weak in the aspect of understanding the elements of research designs and how they impact scientific findings or conclusions, and solving problems using quantitative skills (including probability and statistics).

In addition, from the results of the descriptive analysis, it can be stated that, in general, our participants have the skills or ability to identify valid arguments. Or in other words, our participants understand the essential characteristics of a valid argument. Although it must be admitted that there were weaknesses in several aspects, especially for our participants from 2nd semester who were weak in the aspects of creating the table or graph, justify inferences, predictions, and conclusions based on quantitative data, understanding the elements of research designs and how they impact to scientific Findings or conclusions, and solving problems using quantitative skills (including probability and statistics).

These results put pressure on improving the scientific literacy skills of the 2nd semester participants. However, it is okay if the scientific literacy skills of the 4th and 6th semester participants must also be improved, especially in the aspect of evaluating the use and misuse of scientific information (4th semester).

The inquiry learning method or model is one of the models that can be used to improve science literacy skills. Nwagbo (2006) and Mutmainah et al. (2019) shows that inquiry learning is a learning method or model that affects scientific literacy skills. In addition, lecturers can also use socio-scientific issues (SSI) as a learning approach to help prospective biology teachers to improve their scientific literacy skills (Solli, 2021; Wu & Tsai, 2011, 2011). SSI is a learning approach related to life issues, such as political, economic, and ethical issues (Vasconcelos et al., 2018). So, SSI is also referred to as a way to contextualize these life issues in learning to build and improve scientific literacy skills (Kinslow et al., 2019). SSI as a learning approach is not only related to scientific literacy but also critical thinking and ethical-based decision making (El Arbid & Tairab, 2020).

Conclusion

The results of this study can be concluded that our participants' scientific literacy skills were not significantly different. Our participants from 2nd semester are weak in the aspects of creating the table or graph, justify inferences, predictions, and conclusions based on quantitative data, understanding the elements of research designs and how they impact to scientific findings or conclusions, and solving problems using quantitative skills (including probability and statistics). Our partisans from 4th semester were weak in the aspect of creating the table or graph, evaluating the use and misuse of scientific information, and justifying inferences, predictions, and conclusions based on quantitative data. Meanwhile, our participants from 6th semester were weak in the aspect of creating the table or graph, justify inferences, predictions, and conclusions based on quantitative data.

As we know, lecturers as the primary role in promoting scientific literacy (Altun-Yalçln et al., 2011; Chatila & Sweid, 2018), should make more efforts to improve the lack or weakness of prospective biology teachers' scientific literacy skills (Özdem et al., 2010). It can be understood that when the literacy skills of prospective biology teachers increase, they will have a good knowledge and understanding of science itself and the nature of science.

In an effort to improve the scientific literacy skills of prospective biology teachers, there are several learning methods or models that can be used, such as the inquiry learning model. Scientific literacy skills are very important skills in the 21st century because they are integrated with people's lives, and SSI is one approach that can be used to improve the scientific literacy skills of prospective biology teachers. Not only as an effort to solve the lack of scientific literacy skills level but also as an effort to prepare them to become global citizens (Vasconcelos et al., 2018).

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