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The Relationship between Competency in Interpreting Data and Evidence Scientifically and the Academic Performance of Students in Biological and Physical Science Streams

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ABSTRACT

Despite the fact that appropriate decision-making is an essential ability in dealing with almost every circumstance in life, most people lack the competency in interpreting data and evidence scientifically, which is an important step in decision-making, resulting in negative consequences for individuals and society as a whole. Even though this is one of PISA's three scientific literacy competencies, it is unclear if advanced-level science streams' students in Sri Lanka have an adequate level of this competency. Therefore, this research investigated the relationship between the competency in interpreting data and evidence scientifically and the academic performance of students in the biological and physical science streams. The study was based on three specific objectives: identifying the importance of the competency in interpreting data and evidence scientifically for students in GCE (A/L), measuring the competency in interpreting data and evidence scientifically of students in biological and physical sciences, and investigating the relationship between their academic achievement and the competency in interpreting data and evidence scientifically. A descriptive one-shot cross-sectional survey was conducted using a quantitative research approach on 121, 13th grade students pursuing biological and physical science streams in six schools in Kandy Zone in Sinhala-medium. The sample was selected by a non-randomized convenience sampling method, and data was collected using a self-constructed test of competency in interpreting data and evidence scientifically, with a reliability coefficient of 0.672. Students' first and second term marks were used to assess their academic performance. Data was analyzed using MS Excel and SPSS software, and correlation and regression analyses were performed. Both students of biological sciences ($r = 0.719$, $n = 62$, $p = 0.000$) and physical sciences ($r = 0.783$, $n = 59$, $p = 0.000$) exhibited a positive correlation between the competency of interpreting data and evidence scientifically and academic performance. Furthermore, for every point improvement in the competency in interpreting data and evidence scientifically, the academic performance score of biological and physical science students increased by 0.567 and 0.6609, respectively. Since the competency of interpreting data and evidence scientifically is necessary for student achievement, A/L science section teachers should adopt student centered instructional strategies and encourage active student engagement to enhance the competency of interpreting data and evidence scientifically.

Keywords: Interpreting data and evidence, Academic performance, Scientific literacy

INTRODUCTION

The modern world presents new difficulties and situations for its inhabitants, demanding the development of persons capable of dealing with them. Individuals' education, formal or informal, has the greatest impact on this. The greatest responsibility for adapting a country's inhabitants to changing global problems and conditions rests mostly on formal educational institutions, mainly schools. Education in a country aims to

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue II February 2024

provide residents with the knowledge, skills, and attitudes required to live in a complex, worldwide society.

Due to the examination-centric nature of Sri Lanka's educational system, learning and teaching are usually employed to practice writing test answers rather than achieving primary goals of education. This is why students fail to achieve advanced degrees of learning skills. Although this impacts every subject in school at various levels, it has a significant influence on a more practical subject such as science. This is particularly frequent among GCE (A/L) science students. Although every resident of the country should be scientifically literate, the Sri Lankan school system appears to be uninterested in this. The question is whether students in the Advanced Level Science stream, which is the final stage of school science education, have achieved the scientific literacy competencies required for daily life, as well as academic performance, as measured by their marks. Despite the fact that applying knowledge through critical analysis increases high-level cognitive skills (Zoller, 1993), lower-order thinking continues to take precedence over classroom inquiry that leads to public examinations (National Education Commission, 2014).

Learning science strives to build skills and creativity based on scientific knowledge applicable to everyday life and problem-solving decisions (Holbrook, J and Rannikmae, M, 2009). In the twenty-first century, it is vital to create people with scientific knowledge and an understanding of current technology concerns (Turiman, P. et al., 2012). Scientific literacy refers to the ability to use evidence and data to evaluate science information and the quality of arguments presented by scientists and the media (NRC, 1996). The Program for International Student Assessment (PISA) science framework of OECD emphasized the importance of scientific literacy when dealing with science-related problems (OECD, 2003, 2019), as well as three scientific literacy competencies: explaining phenomena scientifically, evaluating and designing scientific inquiry, and interpreting data and evidence scientifically (OECD, 2019).

Among these competencies, analyzing data and developing evidence-based conclusions are critical for making risk-based decisions. The process of scientifically interpreting facts and evidence include analyzing and evaluating data, claims, and arguments in a number of forms before making acceptable conclusions based on science (OECD, 2019). Several attempts have been made to assess students' competency in interpreting data and evidence scientifically, such as using a written instrument (Jeong, H., Songer, N.B., and Lee, S.Y., 2007), PISA-like tests (Saengmek, 2019), and assessment documents (Kurniasih, W., Wulan, A.R., and Nuraeni, E., 2022). Guidelines (OECD, 2019) and assessment frameworks for multidimensional scientific competencies have also been established for this purpose (Intasoi, S., Junpeng, P., Tang, K., Keow, N., Ketchatturat, J., Zhang, Y, & Wilson, M, 2020). However, a scientific competence assessment framework is extremely pertinent to the difficulties since it may give criteria for judging the development of students' learning. (Millar, 2006)

Even if teachers are not aware of scientific literacy, they employ the PISA Framework 2015 competences during the learning process (Hardinata, A. and Putri, R. 2019). However, more clear instructions are necessary to improve students' data collection and interpretation competencies (Jeong, H., Songer, N.B., & Lee, S.Y., 2007). Trends in International Mathematics and Science Study (TIMSS) is also concerned with strengthening scientific skills in students from 64 member nations (Mullis, I.V.S. et al., 2020). Apart from national cognitive achievement tests in science conducted by The National Education Research and Evaluation Center (NEREC) at the University of Colombo (Aturupane H. et al., 2011, National Education Research and Evaluation Center, 2017), Sri Lanka, as a non-member of any of these organizations, focuses on increasing academic achievement through root learning rather than strengthening scientific literacy skills.

In this context, this study aimed to identify the relationship between competency in interpreting data and evidence scientifically and the academic performance of students in biological and physical science streams under three specific objectives: to identify the importance of the competency in interpreting data and evidence scientifically for students in GCE (A/L); measure the competency in interpreting data and evidence scientifically of students in biological and physical sciences streams; and investigate the relationship

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue II February 2024

between academic performance and the competency in interpreting data and evidence scientifically.

MATERIALS AND METHODS

Under the quantitative research approach, this study used descriptive, one-shot cross-sectional survey analysis. All 13th grade students in the Advanced Level Biological and Physical Science streams at Kandy Zone schools in 2023 who were enrolled in Sinhala-medium classes were the target group. Using the non-randomized convenience sampling method, 121 Sinhala-medium students from six (3 girls' and 3 boys') schools were chosen as the study sample; of them, 62 were from the biological science stream and 59 from the physical science stream. There were 33 boys and 26 girls in the physical sciences stream, and 29 boys and 33 girls in the biological sciences stream (Figure 1).

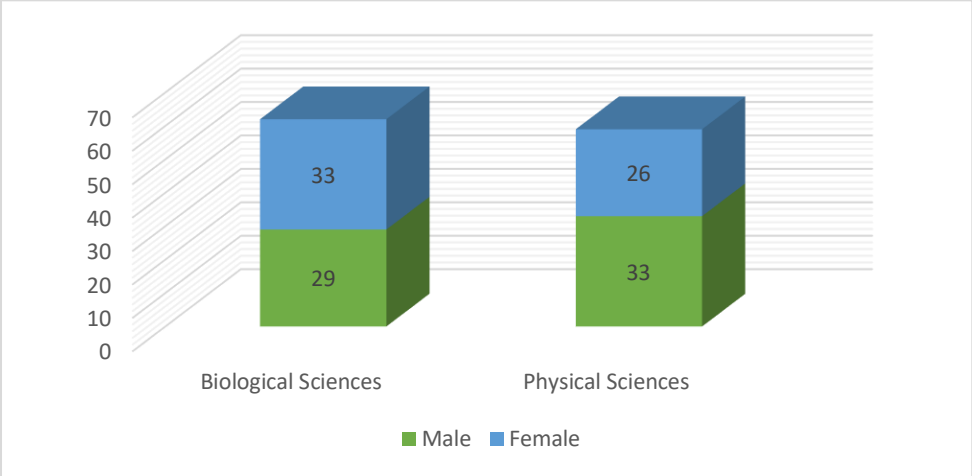

Figure 1: Demography of the sample

The study used two instruments to collect data: student term test mark sheets and a self-constructed test of competency in interpreting data and evidence scientifically with a reliability coefficient of 0.672. It looked at the relationship between academic performance (a dependent variable) and competency in interpreting data and evidence scientifically (an independent variable). The students' academic performance was assessed using the mean scores of their first and second term marks in the three main subjects for each stream. To develop a test for assessing competency in interpreting data and evidence scientifically, it was necessary to identify the key terminology used in education policy papers and reviews. Taking into account the OECD-PISA's description of scientific literacy and the sample questions provided, the instrument was self-constructed with ten questions based on Sri Lanka's 10th-11th grade science curriculum and 12th grade science subject stream curriculum while maintaining reliability and validity. The test comprised of questions with short answers that the students had to answer independently.

Constructed test of competency in interpreting data and evidence scientifically completed pilot testing and was further revised. Following research ethics, the instrument was applied to the sample, data was gathered, and serial numbers were allocated for the completed instruments, which then were organized into data sets. When evaluating students' responses to the test of competency in interpreting data and evidence scientifically, scores were assigned according to the table below (table 1). The overall score for each student had been calculated and expressed as a percentage, as was each student's academic performance.

Table 1: Scoring system for students' answers

Type of answer	**Marks allocated**
1- No Answer	0

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue II February 2024

2- wrong answer	0
3- Incomplete answer	1
4- correct answer	2

The obtained data was entered into an MS Excel spreadsheet, and the data were analyzed using SPSS software. Descriptive statistical analysis methods, including means and standard deviations, as well as parametric statistical analysis methods, were used for quantitative data analysis. Correlation testing was used for hypothesis testing, and regression analysis was used to test the relationship between variables. A p-value of <0.05 indicated statistical significance for the changes. The correlation analysis was conducted using the following null hypotheses to investigate the relationship between competency in interpreting data and evidence scientifically and academic achievement of students in biological and physical science streams.

For biological science stream:

- There is no correlation between the academic performance and competency in interpreting data and evidence scientifically of the students of the Biological Science stream.

For physical science stream:

- There is no correlation between the academic performance and competency in interpreting data and evidence scientifically of the students of the Physical Science stream

RESULTS

Despite the fact that scientific competency is better measured using a multidimensional model than a unidimensional model (Intasoi, S., Junpeng, P., Tang, K., Keow, N., Ketchatturat, J., Zhang, Y., & Wilson, M., 2020), this study used a self-constructed test to assess students' competency in interpreting data and evidence scientifically, which was created in a unidimensional model because it aims to measure one of the scientific competencies. The acquired data were analyzed using both descriptive and parametric statistics.

Levels of competency in interpreting data and evidence scientifically

With a standard deviation of 17.06, the mean score of students in the biological sciences stream for competency in interpreting data and evidence scientifically was 56.85. Table 2 displays the lowest and highest levels of proficiency that these students reported, which were 30 and 100, respectively. The physical sciences stream students scored lowest (20) and highest (100), respectively, with a mean score of 56.44 and a standard deviation of 19.7 in terms of competency in interpreting data and evidence scientifically. In the biological sciences stream, the lowest and greatest marks for student performance were 26.17 and 86.50, respectively, with a mean score of 52.52 and a standard deviation of 13.46. The physical sciences stream had minimum and maximum marks for student performance of 20.33 and 86.83, respectively, with a mean score of 50.11 and a standard deviation of 16.59.

Table 2: Descriptive statistics of the sample

Subject stream		N	Minimum	Maximum	Mean	Std. Deviation
Biological Sciences	Competency in interpreting data and evidence scientifically	62	30	100	56.85	17.064
	Academic performance	62	26.17	86.50	52.5188	13.46344
	Valid N (listwise)	62				

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue II February 2024

Physical Sciences	Competency in interpreting data and evidence scientifically	59	20	100	56.44	19.697
	Academic performance	59	20.33	86.83	50.1130	16.59119
	Valid N (listwise)	59				

Figure 2 shows that 9.7% of students in the biological sciences stream and 11.9% of students in the physical sciences stream have good competency in interpreting data and evidence scientifically, while 3.2% and 3.4% of students in the biological sciences and physical sciences streams have very good competency in interpreting data and evidence scientifically, respectively. Meanwhile, 9.7% of students in the biological sciences stream and 10.2% of students in the physical sciences stream have sufficient competency in interpreting data and evidence scientifically, while 46.8% and 44.1% of students in the biological sciences and physical sciences streams, respectively, require assistance in interpreting data and evidence scientifically. The interpretation of competency in interpreting data and evidence scientifically is based on Purwanto's category, as mentioned by (Hardinata, A., Putri, R.E. and Permanasari, A., 2019. (table 3).

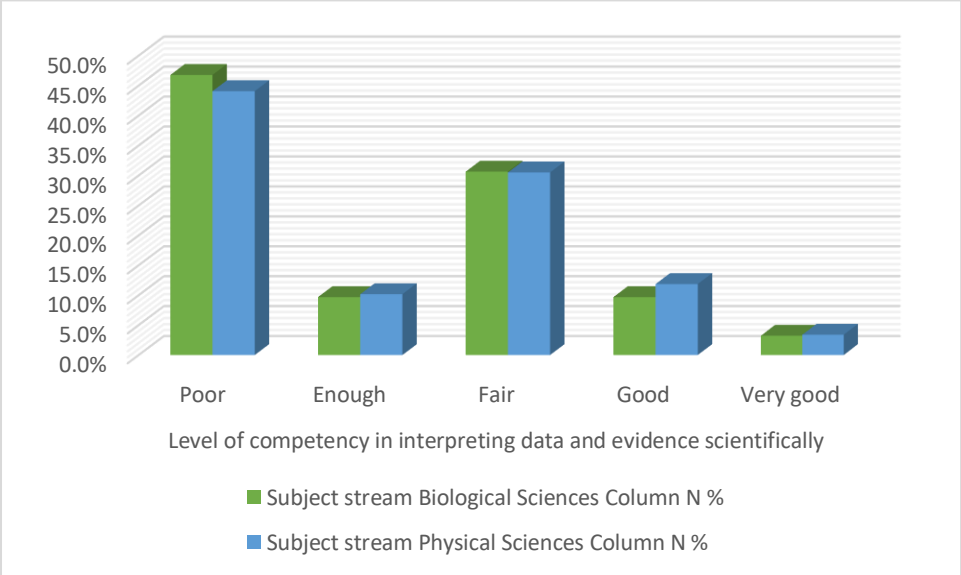

Figure 2: Level of competency in interpreting data and evidence scientifically

Table 3: The category of level of competency in interpreting data and evidence scientifically

Percentage	**Category**
86-100	Very good
76-85	Good
60-75	Fair
55-59	Enough
54>	Poor

Relationship between competency in interpreting data and evidence scientifically and the academic performance

According to correlation analysis in Table 4, The significant level in both streams is less than 0.05, so the calculation-related significant level of 0.000 rejected the null hypothesis. The findings indicate that there is a significant positive correlation ($r = 0.719$, $n = 62$, $p = 0.000$) between students' academic performance and their competency in interpreting data and evidence scientifically in the biological sciences stream. Likewise,

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue II February 2024

a positive correlation has been observed between students' academic performance in the physical sciences stream and their competency in interpreting data and evidence scientifically (r = 0.783, n = 59, p = 0.000). These findings suggest that students' academic performance in both streams is positively impacted by their competency in interpreting data and evidence scientifically.

Table 4: correlation analysis

Subject stream			level of competency in interpreting data and evidence scientifically	Academic performance
Biological Sciences	Competency in interpreting data and evidence scientifically	Pearson Correlation	1	.719**
		Sig. (2-tailed)		.000
		N	62	62
	Academic performance	Pearson Correlation	.719**	1
		Sig. (2-tailed)	.000	
		N	62	62
Physical Sciences	Competency in interpreting data and evidence scientifically	Pearson Correlation	1	.783**
		Sig. (2-tailed)		.000
		N	59	59
	Academic performance	Pearson Correlation	.783**	1
		Sig. (2-tailed)	.000	
		N	59	59

**. Correlation is significant at the 0.01 level (2-tailed).

Based to the model summary of linear regression analysis shown in table 5, 50.9 percent of the variation in the academic performance scores of students following the biological science stream is due to competency in interpreting data and evidence scientifically, with the remaining 49.1 percent due to other unchecked or uncontrolled variables. Similarly, 60.7 percent of the variation in students' academic performance scores in the physical science stream is due to competency in interpreting data and evidence scientifically, with the remaining 39.3 percent caused by other unexamined factors or uncontrolled variables.

Table 5: Model summary of linear regression analysis

Subject stream	Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
Biological Sciences	1	.719[a]	.517	.509	9.43230
Physical Sciences	1	.783[a]	.614	.607	10.40370
a. Predictors: (Constant), Competency in interpreting data and evidence scientifically					

Linear regression also reports a p value of less than 0.05 in terms of biological sciences and physical science streams, indicating that the ability to competency of interpreting data and evidence scientifically has a

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue II February 2024

significant impact on the variation in academic performance scores for biological sciences and physical science streams. (Table 6)

Table 6: ANOVA in linear regression analysis

Subject stream	Model		Sum of Squares	df	Mean Square	F	Sig.
Biological Sciences	1	Regression	5719.025	1	5719.025	64.282	.000[b]
		Residual	5338.092	60	88.968		
		Total	11057.117	61			
Physical Sciences	1	Regression	9796.016	1	9796.016	90.505	.000[b]
		Residual	6169.509	57	108.237		
		Total	15965.524	58			
a. Dependent Variable: Academic performance							
b. Predictors: (Constant), Competency in interpreting data and evidence scientifically							

The estimated maximum academic performance score for students in the biological science stream in the absence of competency in interpreting data and evidence scientifically is 20.26. following table 7 demonstrates that every point gain in the ability to assess facts and evidence scientifically increases academic achievement by 0.57. Furthermore, for the physical sciences stream, the estimate indicates that the maximum performance score available to students if there is no competency in interpreting data and evidence scientifically is 12.87, implying that for every point increase in the competency of interpreting data and evidence scientifically, the academic performance mark increases by 0.66.

Table 7: linear regression analysis coefficients

Subject stream	Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
			B	Std. Error	Beta			Lower Bound	Upper Bound
Biological Sciences	1	(Constant)	20.257	4.198		4.825	.000	11.859	28.655
		Competency in interpreting data and evidence scientifically	.567	.071	.719	8.018	.000	.426	.709
Physical Sciences	1	(Constant)	12.874	4.142		3.108	.003	4.579	21.168
		Competency in interpreting data and evidence scientifically	.6609	.069	.783	9.513	.000	.521	.799
a. Dependent Variable: Academic performance									

According to the scatter plots below (figure 3 and 4), there is a moderately strong positive linear relationship between competency in interpreting data and evidence scientifically and academic performance in students from both streams. The relationship can be expressed in the biological sciences stream by $y = 20.26 + 0.57x$, and in the physical sciences stream by $y = 12.87 + 0.66x$.

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue II February 2024

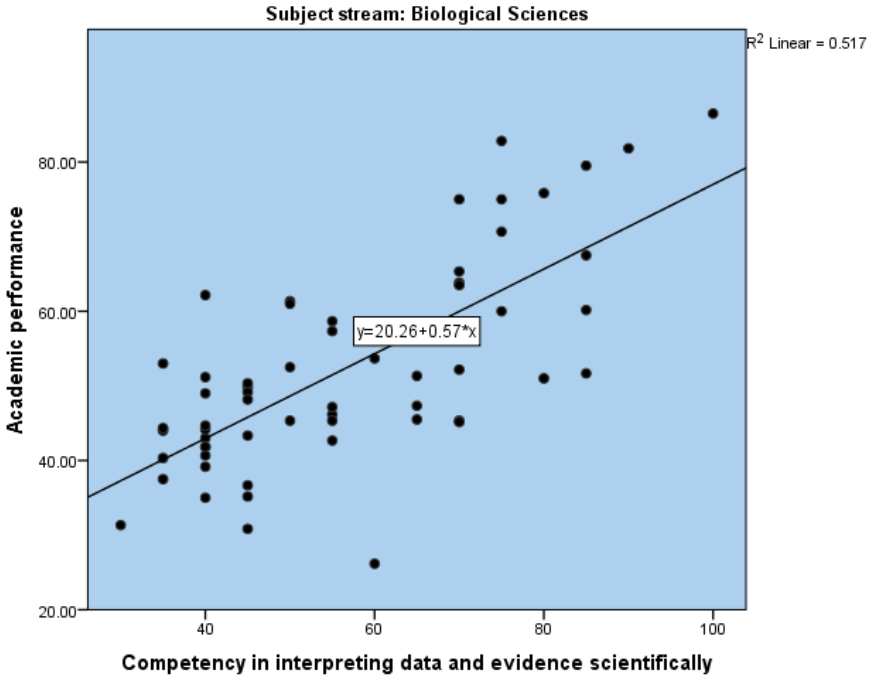

Figure 3: The relationship between competency in interpreting data and evidence scientifically and academic performance of students in biological sciences stream

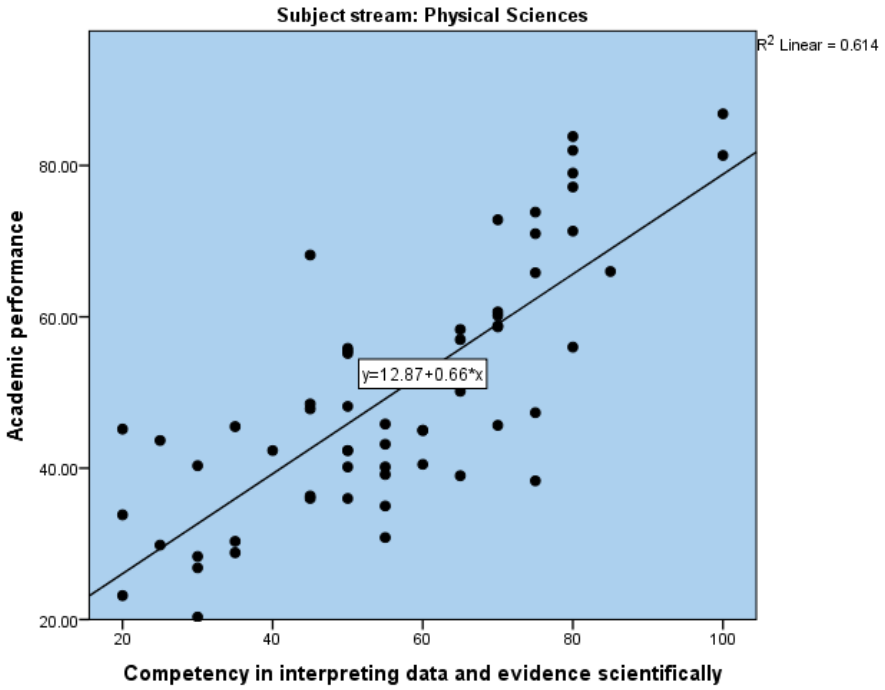

Figure 4: The relationship between competency in interpreting data and evidence scientifically and academic performance of students in physical sciences stream

DISCUSSION

The study aimed to investigate the association between the competency in interpreting data and evidence scientifically and students' academic performance. The reported mean score for competency in interpreting

ISSN No. 2321-2705 | DOI: 10.51244/IJRSI |Volume XI Issue II February 2024

data and evidence scientifically in students in biological and physical science streams were 56.85 and 56.44 respectively, which was in enough level according to Purwanto's categories. These results consistent with the study by Hardinata et al. (2019), which found a mean of 58 percent, the lowest mean attained by students across three scientific competences, and differ from the results observed by Shofatun et al. (2021), which resulted in an average of 72.2 in the same competency. This disparity might be due to Shofatun and the team employing different learning methods.

When focused on improving student learning outcomes, science education should emphasize the development of scientific literacy (Jufrida, J., Basuki, F.R., Kurniawan, W., Pangestu, M.D. and Fitaloka, O., 2019). Because test scores were the most prevalent means to evaluate learning outcomes, it is vital to examine the relationship between scientific literacy skills and academic accomplishment. Despite the fact that this study finds no discernible difference in the mean of the two streams' competency in interpreting data and evidence scientifically, there is a notable difference in the standard deviation. When examining the sample's academic performance, there is considerable variation in both the mean and standard deviation. This may cause by teachers focusing more on giving notes and test questions (Bandara, 2014) and students' adaptation to these teaching approaches varies.

In this study, students in both streams showed a positive correlation between their academic performance and their competency in interpreting data and evidence scientifically. These findings are consistent with those of Oboma (2019) and Aderonmu and Adolphus (2021), who discovered a significant relationship between scientific literacy and academic performance in chemistry and physics respectively.

This study found that the association between competency in interpreting data and evidence scientifically and students' academic performance may state as $y = 20.26 + 0.57x$ in the biological sciences stream and $y = 12.87 + 0.66x$ in the physical sciences stream. This means that if we assess a student's ability to interpret data and evidence scientifically, we can use the above formulas to predict their academic performance because x represents the student's competency in interpreting data and evidence scientifically and y represents the student's academic performance. According to data from Sri Lanka's examination department, 16.72 percent and 19.43 percent of biology and physics students who participated in the GCE(A/L) examination 2021 failed all three subjects, respectively. The formulas generated in this study may be used to assess the risk of failure and take the required steps to overcome those failure.

CONCLUSION

This study reveals that there is a positive relationship between competency in interpreting data and evidence scientifically and the academic performance of learners in both biological and physical sciences streams. Thus, it is important to emphasize that teaching approaches must be more student-centered in order to acquire scientific literacy competencies. According to study results, even though overall level of the achievement of competency in interpreting data and evidence scientifically in both streams are in enough range, approximately 45 percent of students in each subject stream are in the poor category. This is a major concern affecting science education in Sri Lanka, and educators need investigate on it further and take action to address it.

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