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The Effect of Optimizing Digital and Information Literacy in Writing Scientific Articles on Students' Critical Thinking Skills

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ABSTRACT

Writing scientific articles that are integrated with learning biology is still rarely done. On the other hand, students' critical thinking skills need to be developed. One of the efforts is to develop students' thinking skills by writing scientific articles by optimizing digital and information literacy use. Scientific articles are used as student assignments in learning conservation and environmental knowledge through the group investigation learning model. This study aims to determine the effect of writing scientific articles through optimizing digital and information literacy on students' critical thinking skills. The method used in this research is quantitative with a non-experimental explanatory design. Data collection using a questionnaire with a Five Point Likert Scale. There were 43 respondents, of which 100 percent of the completed questionnaire was usable for further analysis. Data analysis in this study used a structural equation model with a partial less square analysis technique (SEM-PLS) using smart-pls 3.2.7 software at a significance level of 5% to predict the hypothesis. Structural Equation Modeling Estimation Shows that Digital Literacy, Information Literacy, and Article Writing Affect Students' Critical Thinking Skills. These findings indicate that writing scientific articles through optimizing digital and information literacy has an effect on students' critical thinking skills. Therefore, writing scientific articles through optimizing digital and information literacy is one method to improve students' critical thinking skills. The implication in the world of education, writing scientific articles through optimizing digital and information literacy can be used as an alternative task for students to improve critical thinking skills.

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1. INTRODUCTION

Writing scientific articles published in journals is the goal of most academic institutes (Omidian, Siyanova-Chanturia, & Biber, 2021). Many world researchers are involved in publishing scientific articles in journals (Ware & Mabe, 2015). Academic skills such as writing scientific articles and students' critical thinking are essential to be empowered in university learning to express new knowledge (Borglin, 2012; Millar, Budgell, & Salager-Meyer, 2020). Writing scientific articles is one of the skills needed by the knowledge community, which is helpful for career advancement and obtaining academic qualifications (Ecarnot, Seronde, Chopard, Schiele, & Meneveau, 2015; van Laar, van Deursen, van Dijk, & de Haan, 2017). Besides that, writing scientific articles can train critical thinking skills (Agustin, 2015). Critical thinking is reflective thinking that focuses on deciding what to believe in doing (Ennis, 2016). Critical thinking can develop when reflection occurs in meaningful experiences (Carter, Creedy, & Sidebotham, 2017). The skill of writing scientific articles allows students to use higher-order thinking skills in answering complex problems.

However, from several studies, students from tertiary institutions do not have the skills required in academic writing or the basic knowledge needed in critical thinking (Borglin, 2012). The academic community, especially students, still experience many difficulties in writing scientific articles (Nagari & Nugraha, 2020). The results of Wahyuni's research (2020) show that some students dislike writing scientific articles, ultimately impacting Indonesia's low number of publications (Al-Amien, Hidayati, & Haryadi, 2022). Students' scientific articles writing skills can be improved by analysing and synthesising phenomena according to their field of knowledge (Agustin, 2015; Gunawan, Triwiyanto, & Kusumaningrum, 2018; Kirom, 2019). Writing scientific articles requires skills to obtain information and must be trained continuously (El–Serag, 2012). Therefore digital literacy and information literacy as 21st-century skills (Shao & Purpur, 2016; Voogt, Erstad, Dede, & Mishra, 2013) must be utilized to write good scientific articles. So far, these skills have not been used optimally among the academic community, especially students. Jang & Kim (2021) explains that digital literacy is a skill to meet information needs. The information obtained is closely related to the need to write. A study by Wen & Walters (2022) shows that technology affects the quality and quantity of writing for students. William & Beam's (2019) review results show that digital technology and web-based learning environments have been used to teach writing.

Digital literacy, in this case, is in the form of skills needed by students when using ICT to 1) use information from various digital sources; 2) manage information; 3) use digital devices to meet information needs; and 4) use cognitive skills to complete tasks (Ala-Mutka, 2011; Jang et al., 2021; Mishra, Wilder, & Mishra, 2017; Phuapan, Viriyavejakul, & Pimdee, 2016; van Laar et al., 2017) on when writing scientific articles. Some research results show that if students have digital literacy skills, it is helpful to retrieve more relevant information, support their academic abilities, have implications for job opportunities, and influence student work (Helsper & Smahel, 2020; Mohammadyari & Singh, 2015; Shariman, Razak, & Noor, 2012; Techataweewan & Prasertsin, 2018). Therefore, it is necessary to increase digital literacy skills in learning (Tejedor, Cervi, Pérez-Escoda, & Jumbo, 2020), especially in writing scientific articles. During a pandemic, all learning activities are carried out online (Dhawan, 2020; Jang et al., 2021). The impact of digital literacy on students' use of information and communication technology in learning has been widely studied, especially during the coronavirus pandemic (Adnan & Anwar, 2020; Almanthari, Maulina, & Bruce, 2020; Kim & Lee, 2021).

Another skill to support writing scientific papers is information literacy. The Association of College and Research Libraries (ACRL) (2015) defines information literacy as a set of abilities for information discovery, understanding how information is produced, and using the information to create knowledge. According to Machin-Mastromatteo (2012), information literacy is an individual's ability to manage data in general. Shao and Purpur (2016) define information literacy as an intellectual ability to develop a student's academic potential. Information literacy involves searching for information on the web and critically analyzing its content (Moreno-Morilla, Guzmán-Simón, & García-Jiménez, 2021). This information literacy is critical for students to succeed academically, including writing scientific articles.

Another Polizzi (2020) study shows that using digital literacy functionally and critically helps students evaluate online content from information sources. Information literacy is related to students' success in learning activities to find information, evaluate and use it effectively, not just receiving it from the teacher (Franklin, Faulkner, Ford-Baxter, & Fu, 2021; Shao & Purpur, 2016). As in writing a scientific article, some information is needed. The importance of information literacy has been proven by several educational institutions that integrate information literacy into learning (Ellis, Johnson, & Rowley, 2017; Franklin et al., 2021).

Several researchers have evaluated learning information literacy through writing scientific articles with critical thinking (Buselic, 2019). Information-literate individuals will have the skills to use information in critical thinking and problem-solving(Bawden, 2001; Grafstein, 2017). Wertz et al. (2013) explained that critical thinking is strongly related to information literacy and writing skills. Critical thinking is a 'metaphorical bridge' between information and action (Carter et al., 2017). Writing can transform information, enhance critical thinking, and make balanced judgments about any information we find and use (Güven, Calpbinici, Kuzgun, & Çelik, 2020; Hollis, 2019).

Therefore it is necessary to research optimising digital and information literacy skills in writing scientific articles to improve students' critical thinking skills. Novetli from this research is in the form of a learning method in the form of giving assignments to write scientific articles by optimizing digital literacy and information literacy skills. As for the problem, how does optimizing Digital Literacy and Information Literacy in Writing Scientific Articles affect the Critical Thinking Ability of Biology Education Students? Furthermore, these problems are described in the form of research questions as follows:

1. RQ1: Does digital literacy affect information literacy?
2. RQ2: Does digital literacy affect writing articles?
3. RQ3: Does information literacy affect writing articles?
5. RQ4: Does information literacy affect students' critical thinking?
5. RQ5: Does writing articles affect students' critical thinking?

The study aimed to determine the impact of digital and information literacy in writing scientific articles on the critical thinking skills of biology education students.

2. METHODS

2.1. Research Design

This research is a non-experimental explanatory design that describes the statistical relationship between two or more variables obtained from each subject or phenomenon (Punch, 2013). Variable Writing Scientific Articles (WA), Digital Literacy (DL), and Information Literacy are used to assess critical thinking skills. In the proposed conceptual research model, the critical thinking skills of biology education students are the dependent variable. There are five hypotheses proposed in this study, namely:

H1. Digital literacy affects students' information literacy skills.
H2. Digital literacy affects students' ability to write scientific articles.
H3. Information literacy affects students' skills in writing scientific articles.
H4. Information literacy affects students' critical thinking skills.
H5. Students' skills in writing scientific articles affect critical thinking skills.
The research model is shown in Figure 1.

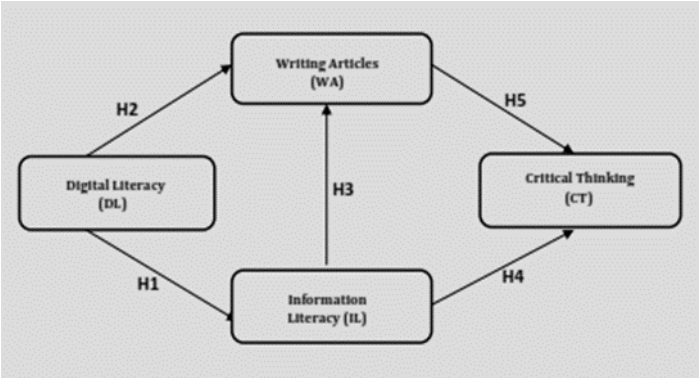

Figure 1. Research Model, Own elaboration based on Jang (2021) and Purnama et al.(2021)

2.2. Variable Measurement

Collecting data through a five-point Likert scale, starting from 1 strongly disagree to 5 strongly agree. Furthermore, biology education students complete online questionnaires via the Google Form application during the final meeting. Scientific articles are student assignments through Group Investigation learning in conservation and environmental knowledge courses. Implementation of research in the odd semester of the 2021/2022 class with 43 respondents. Data on digital literacy, information literacy, writing scientific articles, and critical thinking skills were obtained from questionnaires filled out by students. The questionnaire was adapted from previous research and then developed according to the characteristics of the data needed. Furthermore, the data is recapitulated and analyzed. To measure digital literacy (DI) and information literacy (IL), both use seven indicators from Jang et al. (2021). Meanwhile, to measure article writing skills (WA) and critical thinking skills (CT), each uses seven indicators of the results of their elaboration.

2.3. Data Analysis

The data analysis in this study used the Structural Equation Modeling with Partial Least Square (SEM-PLS) analysis technique using SmartPLS 3.2.7 software at a significance level of 5% to estimate the hypothesis (Rafdinal & Senalasari, 2021). This study follows two main calculations: 1) Measurement Model/Outer Model and 2) Structure Model/Inner Model (Hair, Risher, Sarstedt, & Ringle, 2019; Rafdinal & Senalasari, 2021). Estimating the outer model aims to see the validity and reliability of the indicators of each construct, including composite reliability, convergent validity, and discriminant validity. The assessment of a model meets the reliability criteria based on the Cronbach alpha (ϱA), Composite Reliability (CR), and rho Dijkstra–Henseler (ϱA) values. Convergent validity of a model based on the value of Cross-Loading/Loading and the Average Variance Extracted (AVE). Furthermore, to assess the construct to achieve discriminant validity based on the Fornell-Larcker and Heterotrait-Monotrait Ratio (HTMT) criteria. The structure model (Inner Model) was set based on the Collinearity Issue, evaluated the Path Coefficient, performed the level of R-square (R2), estimated the effect size (f2), and assessed the predictive relevance (Q2) (Hair et al., 2019).

3. FINDINGS AND DISCUSSION

3.1. Measurement Model (Outer model)

The evaluation of the measurement model aims to analyze the validity and reliability of the constructs. Some indicators of the construct (digital literacy and information literacy) are discarded. The first step is to analyze the loading indicators of each construct. The loading value must be greater than 0.708 (Hair et al., 2019). The study results loading all indicators of each construct is more than

0.708. Assess construct reliability (Critical Thinking, Digital Literacy, Information Literacy, and Writing Articles) by calculating: Cronbach alpha, Composite Reliability (CR), and rho Dijkstra–Henseler (ϱA). A construct is reliable if the CR value is more than 0.7 and the Dijkstra–Henseler rho (ϱA) value is more than 0.7 (Hair et al., 2019). The results showed that the importance of Cronbach alpha, Composite Reliability (CR), and rho Dijkstra–Henseler (ϱA) all constructs met the reliability criteria (Table 1). Convergent validity analysis based on the value of cross-loading/loading and Average Variance Extracted (AVE). The significance of each loading was determined using a bootstrap resampling procedure (5,000 subsamples of the original sample size) to obtain the t statistical value (Hair et al., 2019). The results showed that all loadings were obtained significantly with a 99.9% confidence level. AVE must be more than 0.5 (Fornell & Larcker, 1981). The results found that all AVE for each construct was more than 0.5, with a 0.677-0.754. The next step is to assess the discriminant validity of each construct based on the Fornell–Larcker criteria. The square root of each value of the AVE construct must be higher than the correlation construct with other latent variables (Fornell & Larcker, 1981). The results showed that the value of the AVE construct was higher (Table 2). In addition, Discriminant validity was analyzed based on the Heterotrait-Monotrait Ratio (HTMT). This measure determines the ratio between Heterotrait and Monotrait correlations. Discriminant validity is good when the HTMT value is below 0.90 (Henseler, Ringle, & Sarstedt, 2015). Other criteria set the HTMT value below 0.85 (Hair et al., 2019). In this study, the discriminant validity was good because the value obtained was still below the cut-off value (Table 3).

Table 1. Results of Measurement Model (Outer Model)

Construct	No.of Item	Item Loading	Cronsbach' apha	Dijkstra-Henseler's rho (ρ_A)	CR	AVE
Critical Thinking (CT)	7	0.812-0.906	0.946	0.946	0.955	0.754
Digital Literacy (DL)	5	0.790-0.853	0.881	0.886	0.913	0.677
Information Literacy (IL)	4	0.827-0.873	0.869	0.870	0.910	0.717
Writing Articles (WA)	6	0.820-0.877	0.928	0.931	0.943	0.735

Table 2. Discriminant Validity Based On The Fornell–Larcker Criteria

	CT	DL	IL	WA
Critical Thinking (CT)	**0.869**			
Digital Literacy (DL)	0.751	**0.823**		
Information Literacy (IL)	0.805	0.791	**0.847**	
Writing Articles (WA)	0.751	0.785	0.732	**0.857**

Table 3. Discriminant Validity Based On The Heterotrait–Monotrait Ratio (HTMT) criteria.

	CT	DL	IL	WA
Critical Thinking (CT)				
Digital Literacy (DL)	0.819			
Information Literacy (IL)	0.882	0.898		
Writing Articles (WA)	0.797	0857	0.808	

3.2 Structural Model (Inner model)

Initial evaluation shows that the constructs have met the validity and reliability. Collinearity evaluation is based on the variance inflation factor (VIF) value. Ideally, the variance inflation factor (VIF) should be lower than 3 (Hair et al., 2019). The VIF value that meets the criteria is below the specified limit. Thus collinearity is not a problem in this study (Table 4). The next step is estimating the inner model by bootstrapping at 5,000 iterations to evaluate the significance of the Indicators and path coefficients. Before testing the hypothesis, first determine the quality of the model by assessing the structural model predictions based on R2 (coefficient of determination), f2 (effect size), Q2 (cross-validate redundancy), and path coefficients (Hair et al., 2019).

The metric most often used to assess the predictions of structural models is R-square (R2), known as the coefficient of determination. The coefficient of determination aims to predict the accuracy of the model. R2 is also known as the predictive power of the model. R2 ranges from 0 to 1. As a guide, Hair et al. (2019) R2 values are substantial (0.75), moderate (0.50), and weak (0.25) for all endogenous variables. The results showed that R2 for Information Literacy (IL) was 0.626. Thus, 0.626 IL variants explained that digital literacy (DL) was in the moderate category. R2 for Writing Articles (WA) is 0.649. Thus, 0.649 WA variants explained that DL and IL were in the medium category. Likewise, R2 for Critical Thinking is 0.703, which means that 0.703 variant CT explains that IL and WA are in the moderate category. The second metric to assess the predictions of a structural model is to calculate f2 (effect size) for each construct. The f2 criteria include 0.02 (considered small); 0.15 and up to 0.35 (medium); and a value of 0.35 and above (large) (Hair Jr, Howard, & Nitzl, 2020). The results showed that the effect size of Digital Literacy was large on Information Literacy (1,675). In Writing Articles, the effect size of Digital Literacy is medium (0.320), and the effect size of Information literacy is small (0.095). In critical thinking, the effect size of Information Literacy is large (0.473), and the effect size of Writing Articles is medium (0.189). The third metric is Q2 to assess the predictions of the PLS-SEM model. The criteria for interpreting Q2 are: meaningful if the value of Q2 is more than zero; less predictive relevance when the value of Q2 is below 0; medium predictive relevance when the value of Q2 is more than 0.25; and the magnitude predictive relevance when the value of Q2 is more than 0.50 (Hair Jr et al., 2020). The results showed that Q2 for Information Literacy was 0.419, Critical Thinking was 0.504, and Article Writing was 0.464. Thus the PLS-SEM model has significant predictive power because all Q2 values are above zero (Table 4).

Information on the results of hypothesis testing in this study using a significant level of 5% is shown in Table 5 and Figure 2. We confirmed the five proposed hypotheses. Hypothesis testing uses the path coefficient value, which is the value of the direct effect of an exogenous latent variable on endogenous latent variables. The results show that Digital Literacy affects Information Literacy (= 0.791, t = 9.196), Digital Literacy affects Article Writing (= 0.549, t = 3.756), and Information Literacy has a significant effect on Critical Thinking (β = 0.550, t = 4.090) with $p < 0.001$ so that **H1**, **H2**, and **H3** are accepted. Furthermore, Information Literacy affects Writing Articles (= 0.298, t = 1.966), and Writing Articles affects Critical Thinking (= 0.348, t = 2.362) significantly with $p < 0.01$; therefore, **H4** and **H5** are accepted. The findings from this study are that writing scientific articles through optimizing digital and information literacy affects students' critical thinking skills. Obtaining the information needed by students to write scientific articles is influenced by digital literacy and information literacy skills. Other findings from this study are the relationship between digital literacy, information literacy, article writing, and Critical thinking skills. Digital literacy influences information literacy and scientific article writing. Information literacy impacts scientific article writing and students' critical thinking skills. Writing scientific articles influences students' critical thinking

Table 4. Structural Model Evaluation

Relationships	β	*T* value	Confidence-Interval (95%)	Variance explained (R^2)	R^2 adjusted	Predictive relevance (Q^2)	Effect size (f^2)	Confidence interval (95%)	VIF
DL– > IL	0.791	9.196***	[0.591;0.921]	0.626	0.617	0.419	1.675	[0.535;5.567]	1.000
DL– > WA	0.549	3.756***	[0.308;0.899]				0.320	[0.072;0.922]	2.675
IL– > CT	0.550	4.090***	[0.277;0.797]			0.504	0.473	[0.117;1.330]	2.156
IL– > WA	0.298	1.966**	[-0.071;0.528]	0.649	0.631	0.464	0.095	[0.001;0.390]	2.675
WA– > CT	0.348	2.362**	[0.072;0.640]	0.703	0.689		0.189	[0.008;0.945]	2.156

Note (s): n = 5,000 subsample; **p < 0.01; ***p < 0.001; (two-tailed t-test) t(0.05; 4,999) 1.960; t(0.01; 4,999) 2.576; t(0.001; 4,999) 3.291; VIF: Variance Inflation Factor; DL: Digital Literacy; IL: Information Literacy; WA: Writing Article; CT: Critical Thinking.

Tabel 5. Results of Hypotheses Testing

Hypothesis/Relationships	β	*T* value	Confidence interval (95%)	Supported
H1: DL– > IL	0.791	9.196***	[0.591;0.921]	Yes
H2: DL– > WA	0.549	3.756***	[0.308;0.899]	Yes
H3: IL– > CT	0.550	4.090***	[0.277;0.797]	Yes
H4: IL– > WA	0.298	1.966**	[-0.071;0.528]	Yes
H5: WA– > CT	0.348	2.362**	[0.072;0.640]	Yes

Note (s): n = 5,000 subsample; **p < 0.01; ***p < 0.001; (two-tailed t-test) t(0.05; 4,999) 1.960; t(0.01; 4,999) 2.576; t(0.001; 4,999) 3.291; DL: Digital Literacy; IL: Information Literacy; WA: Writing Article; CT: Critical Thinking.

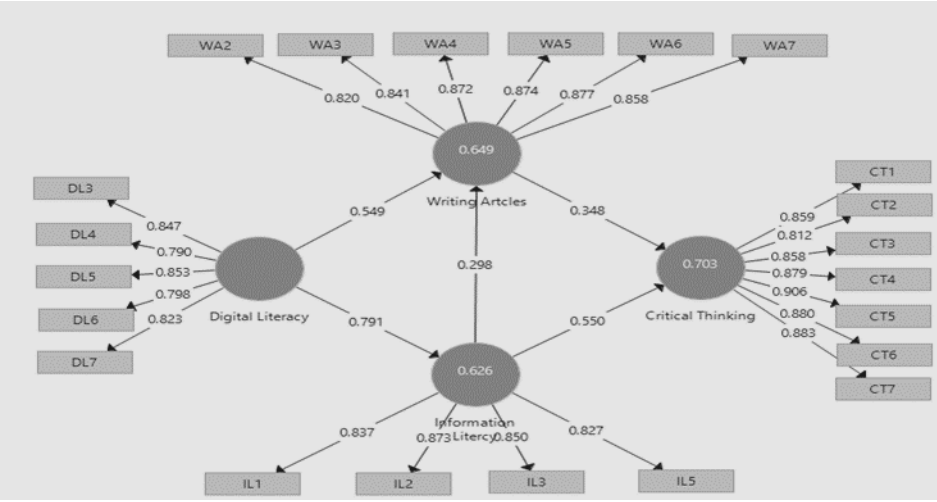

Figure 2: Measurement and structural model estimation.

3.3. Discussion

Based on the structural model (Figure 2), writing scientific articles affects students' critical thinking skills. Proven by the results of hypothesis testing (H5). Writing scientific articles requires critical reflection involving analytical evaluation of perceptions and theories (Bahmani, 2016). These activities will train critical thinking skills. Writing involves a cognitive activity that requires a lot of high-level thinking (Stephenson & Sadler-McKnight, 2016). Meanwhile, exploring and evaluating ideas in writing scientific articles requires critical thinking (Shao & Purpur, 2016). Several studies

have proven that scientific writing activities can train students' critical thinking skills (Arifin, Ilyas, & Sukmawidjaya, 2020; Arter, Wallace, & Shaffer, 2016; Bahmani, 2016; Estrada & Mariam Rahman, 2014; Stanton & Stanton, 2017; Stephenson & Sadler-McKnight, 2016). Referring to the structural model, writing scientific articles is influenced by digital literacy and information literacy (test results of hypotheses H2 and H3). To meet the information needs in writing scientific articles, students use digital technology (software) as digital literacy skills (Jang et al., 2021; Machin-Mastromatteo, 2012; Moreno-Morilla et al., 2021). Students need digital literacy skills to use digital technology to search for information on the internet and interpret digital text information (Wolfe & Flewitt, 2010). The use of digital technology fosters communicative interactions between students and the internet without teachers. In addition, students use information literacy skills to meet information needs (Sujana, 2019). Students with digital literacy skills will use them functionally and critically to evaluate the nature, origin, and sources of information needed (Polizzi, 2020). Thus, it is evident from the Hypothesis test (H1) results that digital literacy affects information literacy.

In this study, students used various digital technologies to write scientific articles as an assignment for a conservation and environment course. Shao and Purpur (2016) explain that digital technology requires digital literacy skills. Thus, writing scientific articles requires digital literacy skills. It is evident from the hypothesis test (H2) that the research results show that digital literacy affects writing scientific articles. In line with the results of Williams & Beam's (2019) review, teaching writing in the digital era requires computers, various digital technologies, applications, and a web-based learning environment. Technology-based writing improves students' writing skills, knowledge, and the use of new literacy. Thus it can be said that digital literacy impacts students' writing abilities.

The results of this study indicate that optimizing the use of digital literacy and information literacy in writing scientific articles is an effective way to improve these skills. This research is in line with Shao & Pupur (2016). Information literacy skills contribute to completing the task of writing scientific articles. In this case, information literacy becomes part of the student experience in learning (Bawden, 2001). Information literacy is finding and evaluating the information needed in writing scientific articles (Wertz et al., 2013). Digital literacy and information literacy are digital competencies that are the main competencies for lifelong learning (Sujana, 2019). Therefore, students need these two competencies in the digital era to complete their assignments. Students not only read books, photocopies, and lecture notes to complete their tasks, but they also read the information online. They search for and read the information on blogs and websites. Likewise, students write by hand and use laptops and smartphones. Students explore, collect, select, and process information differently when using a computer, smartphone, or printed text, as Chaudron (2015) points out. Based on the structural model, information literacy influences students' critical thinking skills (H4 hypothesis test results). Wertz's research (2013) shows a strong relationship between information literacy, writing, and critical thinking. Information literacy is closely related to critical thinking skills (Supriyanti, 2020). Activities to explore and evaluate information to form opinions based on relevant information require critical thinking skills (Crist, Duncan, & Bianchi, 2017). Critical thinking is needed to distinguish relevant and irrelevant information (Dimmitt, 2017).

Based on the description above, this study proves that in a lesson (in this case, conservation and environmental knowledge learning), more than one 21st-century skill can be developed. Developed 21st-century skills include digital literacy, information literacy, and critical thinking (Shao & Purpur, 2016; Voogt et al., 2013). These three skills are developed through writing scientific articles by optimizing digital and information literacy use by applying the group investigation learning model. Therefore the novelty of this study is that the task of students writing scientific articles through optimizing the use of digital literacy and information literacy is a method for developing critical thinking.

4. CONCLUSION

In conclusion, this study shows that writing scientific articles by optimizing digital and information literacy use affects students' critical thinking skills. Digital and information literacy affect acquiring information students need to write scientific articles. The findings of this study are that digital literacy affects information literacy and scientific article writing. Information literacy influences scientific article writing and students' critical thinking skills. Writing scientific articles influences students' critical thinking. The contribution of research to education is that writing scientific articles is a medium for developing digital literacy, information literacy, and critical thinking as 21st-century skills that students need to master. The implication in education is that writing scientific articles by optimizing the use of digital literacy and information literacy can be used as an alternative task for students to improve critical thinking skills.

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