
The Contribution of Communication and Digital Literacy Skills to Critical Thinking

Astuti Muh. Amin*¹, Romi Adiansyah², Noor Hujjatusnaini³

¹Department of Tadris Biology, FTIK, IAIN Ternate, Jl. Lumba-Lumba, Dufa-Dufa, Ternate City, North Maluku, Indonesia.

²Department of Tadris Biology, FTIK, IAIN Palangkaraya, Central Kalimantan, Indonesia.

³Department of Biology Education, FKIP, Universitas Muhammadiyah Bone, South Sulawesi, Indonesia.

*Email: astutimuhamin@iain-ternate.ac.id

Article History:

Received date: February 14, 2023

Received in revised from: June 27, 2023

Accepted date: July 23, 2023

Available online: July 30, 2023

Citation:

Amin, A.M., Adiansyah, R., & Hujjatusnaini, N. 2023. The contribution of communication and digital literacy skills to critical thinking. *Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education)*, 11(3):697-712.

Abstract. The contribution of communication and digital literacy skills to critical thinking in biology are rarely explored. The present study employed a correlational research design to determine how communication and digital literacy skills contributed to students' critical thinking. In this study, communication and digital literacy skills served as the predictor variables, whereas critical thinking served as the criterion variable. Fourth semester students from Tadris Biology department at IAIN Ternate in North Maluku made up the research sample. Essay questions, questionnaires, and observation sheets were used to collect data. Research results show that communication skills and digital literacy simultaneously and significantly affect critical thinking skills. The study's findings proved that communication skills and digital literacy contribute to critical thinking skills as much as 34.93% and 29.67%, respectively. These findings indicate that educators need to incorporate components of communication skills and digital literacy into their instruction in order to enhance students' critical thinking skills.

Keywords: correlation, communication skills, digital literacy, critical thinking skills.

Introduction

Digital literacy is associated with information processing, cognitive, and socio-emotional skills, all of which are critical in assisting pupils in properly carrying out tasks in a digital context (Kaeophanuek et al., 2019). Digital literacy has an essential role in the process of learning, education and society (Saputra & Al Siddiq, 2020). Digital literacy refers to the capacity to explore, retrieve, organize, merge, assess, scrutinize, and amalgamate digital materials, acquire novel insights, generate multimedia representations, and interact with peers within real-life scenarios (Cohen et al., 2020; Fallon, 2020; Marini et al., 2020; McKinstry et al., 2020). Digital literacy can positively affect students' social skills (Mewangi et al., 2020).

Cognitive, technical, and sociological interactions are all linked to digital literacy (Abdelraheem & Ahmad, 2018). The utilization of digital literacy can facilitate learning endeavors in digital communication through the provision of recommendations, contributions, and accounts pertaining to specific educational topics (Lukitasari et al., 2022). Academic achievement and student learning achievement are both influenced by

digital literacy (Pagani et al., 2016). The incorporation of digital media in educational settings has the potential to promote enhanced self-efficacy experiences for students, thereby influencing their cognitive processes and self-confidence (Marci-Boehncke & Vogel, 2018). The acquisition of digital literacy skills can facilitate the development of critical thinking abilities among students, thereby enabling them to attain a higher level of maturity and awareness in information creation, communication, and consumption (Yasdin et al., 2021).

Critical thinking begins with asking important questions, clearly formulating information, acquiring relevant information, exploring novel ideas, thinking honestly, and effectively communicating with others (Adeoti & Adeoye, 2012). The ability to identify inferential relationships between various forms of representation, such as statements, concepts, data descriptions, beliefs, judgments, experiences, reasons, information, or opinions, is indicative of the presence of critical thinking. Critical thinking is essential for college students, as it enables them to become discerning consumers of scientific information and make informed decisions in response to various scientific advancements (Pradana et al., 2017).

Critical thinking and communication skills in the classroom can be effectively fostered if students are encouraged to participate in learning and practice problem solving in class (Goel & Chauhan, 2019). Critical thinking plays a significant part in developing human quality. Individuals who possess critical thinking abilities can formulate appropriate inquiries, integrating relevant data, demonstrating productivity and efficacy, exhibiting ingenuity, constructing sound reasoning, and attaining coherent and persuasive outcomes (Carter et al., 2006). Critical thinking factors develop when students use their critical thinking skills to gather, process, analyze, and respond to information (Fok et al., 2021; Wale & Bishaw, 2020). In information technology, digital literacy may be regarded as a contributing factor that has the potential to impact the critical writing abilities of students, while simultaneously facilitating their productivity and efficacy (Lustyantie et al., 2022). The significance of critical thinking in enhancing student learning outcomes is widely acknowledged. Critical thinking facilitates the assimilation of knowledge through both oral and written communication, while also enhancing the coherence and rationality of language produced (Anjaniputra, 2020).

The utilization of proficient communication abilities can aid in averting instances of misapprehension and miscommunication (Putri et al., 2021). Scientific communication indicators include the ability to obtain information, read scientifically, listen, observe, write scientifically, and present information (Spektor-Levy, 2008). The hallmark of effective communication is the ability to convey information clearly and express thoughts and ideas proficiently through verbal, written, and nonverbal modes. Effective communication also includes the ability to listen meaningfully, interpret to achieve goals, use various media and technology, and convey messages in various situations (Khoerunisa & Habibah, 2020).

The addressee of a message should possess the ability to comprehend the sender's purpose, analyze the contextual background of the message, rectify any misinterpretations, precisely decipher the information conveyed, and determine the appropriate course of action. These abilities are imperative for acquiring knowledge, fostering positive interpersonal connections, creating a sense of belongingness, and attaining career advancement (Velentzas & Borni, 2014). Communication in class must be dynamic and participatory so that students may readily reply, conclude, assess, and contribute comments and suggestions as feedback (Uyen et al., 2021). It is imperative for learners to possess the ability to assimilate recently acquired information and

integrate it within a social framework, while also utilizing communication principles to formulate cogent discourse (Mwakapina, 2020).

Past studies rarely explored how communication and digital literacy skills contributed to critical thinking skills, especially in biology learning design courses. This study is essential since it provides an overview of the elements that influence university students' critical thinking skills. The findings of this study can also help instructors reflect on the learning process that has been implemented to increase students' competence in the twenty-first century. Educators can create their own learning designs while empowering students to communicate, think critically, and perform well in digital literacy. The goal of this study was to determine the contribution of communication skills and digital literacy to university students' critical thinking skills.

Methods

The present study employed a correlational research design. Communication skills and digital literacy served as the predictor variables, whereas critical thinking served as the criterion variable. The research population comprised all students from Tadris Biology department, FTIK, IAIN Ternate, North Maluku, Indonesia. The research sample was twenty fourth-semester students from Tadris Biology department, FTIK, IAIN Ternate, North Maluku. This study was conducted in the biology instructional design course during the even semester of the 2021/2022 academic year. A quasi experiment was done before conducting the correlational analysis. This quasi-experimental study used a pretest posttest control group design in which one experimental research class implemented the two stay two stay learning model. The research sample was determined using the purposive sampling technique conducted based on a previous needs analysis.

The research data were gathered using a test administered to the participants from the two stay two stay (experimental) group. The test was conducted before the implementation of the two stay two stay learning model. The test consisted of essay questions to measure students' critical thinking skills. In addition, questionnaires were distributed to assess students' digital literacy and communication skills. Participants' digital literacy and communication skills were also observed during the implementation of the two stay two stay learning model by the lecturer. The observations were done using an observation sheet. Participants were given a test of their critical thinking skills at the conclusion of fourteen face-to-face class meetings. After implementing the two stay, two stay learning model, questionnaires on digital literacy and communication skills were distributed. ANOVA was utilized to conduct descriptive and inferential data analysis techniques. The multiple linear regression analysis was also done using ANOVA.

Research instruments included instruments used to collect data on communication skills, digital literacy, and critical thinking skills. The instruments used to measure participants' digital literacy consisted of observation sheets and a questionnaire. These instruments were developed based on aspects of 1) internet searching, 2) hypertextual navigation, 3) content evaluation, and 4) knowledge assembly. The instruments used to evaluate participants' communication skills were a questionnaire and an observation sheet. These instruments contained indicators of speaking, listening, writing, and nonverbal communication. Essay questions were used to assess participants' critical thinking skills. Before use, the instruments were subjected to expert and empirical validation. The research data were gathered by distributing the questionnaires and essay

questions, as well as conducting class observations. Multiple linear regression analysis with SPSS was employed in data analysis.

Results and Discussion

A multiple linear regression analysis was used to investigate the contribution of independent variables, X1 and X2, to the dependent variable Y. Table 1 summarizes the results of a multiple linear regression analysis using ANOVA.

Table 1. ANOVA on the contribution of communication skills (x1) and digital literacy (x2) to critical thinking skills (y)

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	929.800	2	464.900	16.435	.000 ^b
	Residual	509.182	18	28.288		
	Total	1438.982	20			

a. dependent variable: critical thinking skills (y)

b. predictors: (constant), digital literacy (x2), communication skills (x1)

Table 2 shows an F-calculated of 16.435 and a significance level of 0.000. A significance level smaller than 0.05 indicates that variables X1 and X2 had a simultaneous contribution to Y. Therefore, it can be concluded that communication skills and digital literacy simultaneously and significantly affect critical thinking skills. The acquisition of communication skills and digital literacy skills is known to exert a favorable impact on the enhancement of critical thinking skills among students. According to Han et al. (2019), there exists a positive correlation between communication skills, critical thinking skills, self-confidence, curiosity, and problem-solving abilities. The cultivation of higher order thinking skills (HOTS) can be facilitated through the provision of instruction that prompts students to engage in critical and creative thinking, as well as problem solving (Panggabean et al., 2021). The capacity to engage in critical thinking when comprehending concepts is positively correlated with the capacity to establish connections among interrelated concepts. Critical thinking is also demonstrated by the ability to access information. According to Supriyanti et al. (2020), the availability of information has the potential to enhance knowledge, diminish uncertainty, and enhance reasoning abilities. Sasson (2018) has identified that a limitation to the improvement of literacy rates is the employment of singular information sources in learning processes. The acquisition of critical thinking can be influenced by one's possession of information and digital literacy. According to Leaning (2019), students' abilities to critically evaluate information and discern credible sources enable them to exercise greater selectivity and employ their analytical faculties in acquiring information. Literacy is also perceived as a tool that can be utilized to obtain and disseminate information (Rahman et al., 2019).

Table 2. The regression coefficient of communication skills and digital literacy on critical thinking skills

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
	B	Std. Error	Beta			Zero-order	Partial	Part
1 (Constant)	11.169	10.769		1.037	.313			
Communication Skills (X1)	.128	.042	.494	3.070	.007	.707	.586	.430
Digital Literacy (X2)	.238	.087	.437	2.722	.014	.679	.540	.382

a. dependent variable: critical thinking skills (y)

Table 2 reveals the regression equation for communication skills (X1), digital literacy (X2), and critical thinking skills (Y): $Y = 11.169 + 0.128 X_1 + 0.238 X_2$.

Based on the regression equation, it is known that:

- a. if X1 and X2 equal 0 (zero), then Y is 11.169.
- b. X1 has a positive (unidirectional) effect on Y, where one unit increase in X1 results in 0.128 increase in Y, and vice versa.
- c. X2 has a positive (unidirectional) effect on Y, where one unit increase in X2 results in 0.238 increase in Y and vice versa.

The findings suggest a positive correlation between students' critical thinking skills and their communication and digital literacy skills, with respective coefficients of 0.128 and 0.238. Digital media significantly facilitates the enhancement of students' communication skills. Digital media can serve as a valuable resource for students in various educational contexts, such as presentations, studies, discussions, and problem solving activities (Rahman et al., 2019). Communication skills encompass the capacity to effectively convey ideas through both verbal and written means, as well as the ability to articulate viewpoints, provide coherent directives, and inspire others through speech (Mishra & Mehta, 2017). Possessing effective communication skills can aid in the prevention of misunderstandings and miscommunication (Mahajan, 2015). Effective communication skills play a crucial role across various domains (Putri et al., 2021). The evaluation of digital literacy is contingent upon the extent to which students can utilize cognitive frameworks in both academic and non-academic contexts. The concept of digital literacy encompasses the ever-changing technological landscape and necessitates responsible access to information contributions (Meyers et al., 2013).

In the age of globalization, students must cultivate digital literacy. This competency can increase students' digital knowledge and motivation to pursue information from different reference sources (Amin et al., 2023). Students with high levels of digital literacy can acquire the information or knowledge they require because they can use digital media more selectively. Digital literacy contributes to an increase in students' ability to argue in each and every response or statement (Darmaji et al., 2023). The submission of evidence, such as examples or data, can support an argument. Using

their digital literacy skills, students can utilize their learning experiences to comprehend a piece of information (Hilala et al., 2023). The use of technology in education has a positive effect on learning, including making learning more effective and evaluation and assessment more adaptable because they can be conducted from anywhere (Putri & Asrizal, 2023).

Students need to develop their critical thinking skills in order to meet the challenges of the twenty-first century (Marlina et al., 2022). By paying attention to the characteristics and potential of the students' learning environment, critical thinking skills can be enhanced (Hanum et al., 2023). Teachers need to promote learning activities that can stimulate students' critical thinking and communication skills and train students' ability to solve problems, become independent, and be more disciplined (Bahtiar et al., 2023). Critical thinking not only aids in the acquisition of knowledge, but also in the application of knowledge when searching for a solution to a problem (Istiqomah et al., 2022). Learners from a variety of social, cognitive, and personality backgrounds should be able to cultivate active learning environments in which they can communicate expansively in order to comprehend topics (Amin et al., 2022a).

Teachers must pose questions that activate students' prior knowledge and help them focus their learning efforts and assess their knowledge (Amin et al., 2022b). Students require higher-level reasoning skills not only during examinations, but also throughout the learning process (Fitri et al., 2021). Critical thinking is also associated with cognitive skills because it entails problem-solving activities (Musliman & Damayanti, 2023). Critical thinking is beneficial for comprehending the interaction of factors that influence results and calculating various possibilities and scenarios in order to make the best decision. Students must possess 21st century skills such as critical thinking skills in order to face global challenges (Wati & Syafriani, 2023).

The results of the multiple regression analysis on communication skills, digital literacy, and critical thinking skills presents a determination coefficient (R-squared) of 0.646, suggesting that 64.6% of Y are influenced by X1 and X2, while the remaining 35.4% are influenced by other factors. In other words, the simultaneous contribution of communication skills (X1) and digital literacy (X2) on critical thinking skills (Y) is 64.6%. Individuals with critical thinking skills are capable of drawing inferences from a wide range of information, adeptly utilizing said information to address a given problem, and effectively identifying pertinent sources to facilitate problem-solving (Haryanto et al., 2020). The term "critical thinking" encompasses the ability of students to utilize acquired information to make informed decisions and effectively communicate their thoughts through reflection and logical reasoning. Critical thinking is a skill that involves reflective evaluation, analysis, and utilization of pertinent information within a specific context through effective communication (Gut, 2011). Individuals who possess competencies in communication, collaboration, critical thinking, problem solving, creativity, and innovation within their field of expertise are likely to achieve greater success in higher education, professional settings, and within the broader community (Wrahatnolo & Munoto, 2018). Based on the figures presented in Table 3, the effective contribution (EC) was calculated using the formula: $EC = \text{Beta} \times \text{Zero Order}$.

Table 3. The contribution of communication skills and digital literacy on critical thinking skills

Variable	RC (%)	EC (%)
Communication Skills (X1)	54.07	34.93
Digital Literacy (X2)	45.93	29.67
Total	100	64.60

Communication skills (X1) and digital literacy (X2) make up 34.93% and 29.67% of the effective contribution to critical thinking skills (Y), respectively. Critical thinking skills are inextricably connected to information literacy. Critical thinking skills are necessary for investigating and assessing information in order to generate opinions based on relevant and reliable data (Crist et al, 2017). The capacity to obtain information also demonstrates critical thinking. Information broadens knowledge, eliminates uncertainty, and improves thinking abilities. Students with strong information literacy will be able to use a variety of sources of information, as well as analyze and evaluate material more comprehensively (Subekti, et al, 2018). Reading habits have a favorable impact on critical thinking abilities (Taglieber, 2000).

Answering questions demonstrates pupils' ability to think critically (Trisdiono et al., 2019). Learning environment and enthusiasm in learning enhance critical thinking skills (Erwiza, 2019). Digital information and media are available everywhere, allowing students to readily, rapidly, and in enormous quantities access to content. As a result, educators must continue to seek to develop learning methodologies that can help students absorb information critically (Dimmit, 2017). Critical thinking also includes the ability to synthesize and filter numerous arguments and information so that it may be accepted correctly (Syafaren, 2019).

Multidisciplinary instruction has the potential to facilitate the integration and amalgamation of knowledge from a variety of perspectives, thereby augmenting students' capacity for analytical reasoning. Students may investigate and analyze various forms of material by developing critical thinking skills (Supriyanti et al., 2020). Literacy is extremely beneficial to students in terms of developing communication skills, the capacity to work in a variety of teams, cooperate, and form interpersonal relationships. Students with these skills can always position themselves in harmonious interactions (Setiyadi et al., 2022). Students with sufficient digital literacy can detect the risks and negative impacts of using the internet or online resources (Helsper & Smahel, 2020; Ruenphongphun, 2021).

Good reasoning assists in the comprehension of information, the transmission of information, and the exchange of information from information sources. In other words, there is a relationship between reasoning skill and communication ability (Makur, 2019). Communication skills have an essential place in teamwork to create a collaborative environment that requires team spirit (Kereluik et al., 2013). Communication is required to promote science process skills, which include how students explain an item, event, action, and discussion findings using words, symbols, drawings, and figures or tables (Omeodu et al., 2021). Students must use verbal communication to communicate their findings and views orally through oral presentations, discussions, and debates. Students' verbal communication skills might also predict their writing test scores (Haworth & Garrill, 2003).

Digital literacy in educational settings encompasses more than mere technical proficiency with digital tools. It entails the capacity to effectively navigate and evaluate information, engage in critical thinking, and exhibit appropriate conduct in online environments (Tang & Chaw, 2016). Digital literacy contains several elements such as critical thinking skills, creativity, the ability to build and evaluate information, the ability to use digital media effectively, and the ability to develop digital writing results (Al-Qallaf & Al-Mutairi, 2016). The dynamism and entertainment value of classroom learning can be enhanced through the acquisition of digital literacy by students. In summary, the acquisition of digital literacy is crucial for students' academic progress, as it enables them to engage in critical discourse on significant issues pertaining to technology utilization (Khan et al., 2022). Furthermore, according to Hague (2010), digital literacy encompasses the capacity to proficiently generate, collaborate, and communicate, while also comprehending the optimal utilization of digital technology to facilitate these activities. Individuals possessing this aptitude are commonly receptive and flexible in response to alterations.

Research has found a relationship between digital literacy and high to moderate creative self-concept (Alsoud et al., 2021; Alt & Raichel, 2020). Digital literacy contributes to meeting students' learning demands and their future professional needs (Tham et al., 2021). A person is said to be able to think critically if s/he can put experience to the test, appraise information and ideas, and evaluate prior arguments (Mezirow, 1998). Individuals who are digitally literate have the technical knowledge and abilities required to use, access, and analyze technological information to create digital information, as well as to use online networks for communication, socialization, and learning (Ustundag et al., 2017). Therefore, digital literacy should not be seen as only "using technology". Social and cognitive abilities are also required for digital literacy (van Laar et al., 2017).

Students must gain digital literacy to obtain 21st century abilities (Yasa & Arnelia, 2023). The five components of digital literacy are 1) identifying, finding, retrieving, storing, organizing, and analyzing digital information, 2) communicating in a digital environment and being able to interact in communities and networks, 3) creating and editing new content, integrating and redefining prior knowledge, and generating creative expression from media output, 4) identifying digital needs and resources, and 5) effectively and creatively using technology to solve conceptual problems through digital means (Phuapan et al, 2016). Digital learning is more effective than traditional learning in enhancing student motivation and achievement (Lin et al., 2017). The integration of digital literacy into learning resources can enhance the overall quality of students' education (Scanlon, 2000). Digital media is important in education because it can present culturally, visually, and audibly engaging and participatory learning content (Rusydiyah, 2020). Students' creativity will suffer if they do not understand the fundamental concepts of the technology they own (Gomez-Trigueros et al., 2019).

Conclusion

The results of the data analysis and the research discussion reveal the contribution of communication skills and digital literacy to critical thinking skills. Communication skills and digital literacy make up 34.93 and 29.67% of the effective contribution to critical thinking skills, respectively. According to the findings of this study, communication skills and digital literacy are factors that affect critical thinking skills. As a result, educators must design learning to enhance students' critical thinking skills. It is recommended that

future researchers conduct a more in-depth study on the importance of communication skills and digital literacy to critical thinking skills, with a larger number of research samples and a longer research duration.

References

- Abdelraheem, A.Y. & Ahmed, A.M. 2018. The impact of using mobile social network applications on students' social-life. *International Journal of Instruction*, 11(2):1-14. <https://doi.org/10.12973/iji.2018.1121a>.
- Adeoti, Y.F. & Adeoye, E.A. 2012. Developing critical thinking and communication skills in students: implications for practice in education. *African Research Review*, 6(1):311-324. <http://dx.doi.org/10.4314/afrrrev.v6i1.26>.
- Al-Qallaf, C.L. & Al-Mutairi, A.S.R. 2016. Digital literacy and digital content support learning. *The Electronic Library*. <https://doi.org/10.1108/el-052015-0076>.
- Alsoud, A.R., Al-Debei, M.M., Johar, M., Ab Yajid, M.S., Alshareef, H.N., & Ariffin, I. 2021. Digitalization in educational technologies for edtech solutions: a comparative study of Jordanian and Malaysian universities. *Educational Sciences: Theory & Practice*, 21(4):83-99. <https://jestp.com/index.php/estp/article/view/1502/816>.
- Alt, D. & Raichel, N. 2020. Enhancing perceived digital literacy skills and creative self-concept through gamified learning environments: insights from a longitudinal study. *International Journal of Educational Research*, 101(101561). <https://doi.org/10.1016/j.ijer.2020.101561>.
- Amin, A.M., Karmila, F., Laode, Z.A., Ermin, E., Akbar, A.Y., & Ahmed, M.A. 2023. The WE-ARE model's potential to enhance digital literacy of preservice biology teachers. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, 9(1):36-45. <https://doi.org/10.22219/jpbi.v9i1.23061>.
- Amin, A.M., Karmila, F., Pantiwati, Y., Adiansyah, R., & Yani, A. 2022a. The communication skills profile of pre-service biology teachers. *Jurnal Penelitian Pendidikan IPA*, 8(4):2109-2115. <https://doi.org/10.29303/jppipa.v8i4.1825>.
- Amin, A.M., Ahmad, S.H., Zulkarnaim., & Adiansyah, R. 2022. RQANI: A learning model that integrates science concepts and Islamic values in biology learning, 15(3):695-718. <https://doi.org/10.29333/iji.2022.15338a>.
- Anjaniputra, A.G. 2020. Prevalence of tertiary level students' critical thinking skills in speaking. *International Journal of Education*, 13(1):18-25. doi: 10.17509/ije.v13i1.18196.
- Bahtiar, Maimun, & Ibrahim. 2023. Analysis of collaboration, communication, critical thinking, and creative thinking ability of students in solving science problems in terms of gender. *Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education)*, 11(2):379-400. doi.org/10.24815/jpsi.v10i4.29065.

- Carter, L., Rukholm, E., Mossey, S., Dresler, G.V., Baker, D., & Sheehan, C. 2006. Critical thinking in the online nursing education setting: raising the bar. *Canadian Journal of University Continuing Education*, 32(1):27-46. <https://doi.org/10.21225/D5BS38>.
- Crist, C.A., Duncan, S.E., & Bianchi, L.M. 2017. Incorporation of cross-disciplinary teaching and a wiki research project to engage undergraduate students to develop information literacy, critical thinking, and communication skills. *Journal of Food Science Education*, 16(3):81-91. <https://doi.org/10.1111/1541-4329.12111>.
- Cohen, R., Parmentier, A., Melo, G., Sahu, G., Annamalai, A., Chi, S., & Sakhuja, S. 2020. Digital literacy for secondary school students: using computer technology to educate about credibility of content online. *Creative Education*, 11(05):674-692. <https://doi.org/10.4236/ce.2020.115050>.
- Darmaji, Astalini, Kurniawan, D.A., & Prameswari, N. 2023. Analysis science process skills, arguing ability and digital literacy of MAN 5 Batanghari students based on gender differences. *Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education)*, 11(2):221-235. <https://doi.org/10.24815/jpsi.v11i2.27678>.
- Dimmitt, N. 2017. The power of project-based learning: experiential education to develop critical thinking skills for university students. In *CBU International Conference Proceedings*, 5:575-579. <https://doi.org/10.12955/cbup.v5.988>.
- Erwiza, E., Kartiko, S., & Gimin, G. 2019. Factors affecting the concentration of learning and critical thinking on student learning achievement in economic subject. *Journal of Educational Sciences*, 3(2):205-215. <http://dx.doi.org/10.31258/jes.3.2.p.205-215>.
- Falloon, G. 2020. From digital literacy to digital competence: the teacher digital competency (TDC) framework. *Educational Technology Research and Development*, 68(5):1-24. <https://doi.org/10.1007/s11423-02009767-4>.
- Fithri, S., Pada, A.U.T., Artika, W., Nurmaliah, C., & Hasanuddin. 2021. Implementasi LKPD berbasis STEM untuk meningkatkan keterampilan berpikir kritis peserta didik. *Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education)*, 9(4):555-564. <https://doi.org/10.24815/jpsi.v9i4.20816>.
- Fok, L.Y., Morgan, Y.C., & Zee, S.M. 2021. A multi-industry study of sustainability, total quality management, organizational culture, and performance. *International Journal of Operations and Quantitative Management*, 27(1):45-60. <https://doi.org/10.46970/2021.27.1.3>.
- Goel, N. & Chauhan, S. 2019. Rolling a role: enhancing critical thinking and communication skills. *Literacy Information and Computer Education Journal*, 10(1):3114-3118. Doi: [10.20533/licej.2040.2589.2019.0408](https://doi.org/10.20533/licej.2040.2589.2019.0408).
- Gómez-Trigueros, I.M., Ruiz-Bañuls, M., & Ortega-Sanchez, D. 2019. Digital literacy of teachers in training: moving from ICTS (information and communication

- technologies) to LKTS (learning and knowledge technologies). *Education Sciences*, 9(274):1-10. doi:10.3390/educsci9040274.
- Gut, D.M. 2011. Integrating 21st century skills into the curriculum. In G. Wan & D.M. Gut (Eds.), *Bringing schools into the 21st century* (pp.137-157). Dordrecht, the Netherlands: Springer.
- Hague, C. & Payton, S. 2011. Digital literacy across the curriculum. *Curriculum Leadership*, 9(10) <https://www.semanticscholar.org/paper/Digital-literacy-across-the-curriculum-HaguePayton/35c81071e79dad22cea0460481869bb4536536de>.
- Han, J., Ahn, E., & Hwang, J. 2019. Effects of critical thinking and communication skills on the problem-solving ability of dental hygiene students. *Journal of Dental Hygiene Science*, 19(1):31-38. <https://doi.org/10.17135/jdhs.2019.19.1.31>.
- Hanum, L., Hasan, M., Pada, A.U.T., Rahmatan, H., Rahmayani, R.F.I., Elisa, & Yusrizal. 2023. Development of learning devices based on ethnoscience-project based learning to improve students' critical thinking skills. *Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education)*, 11(2):288-305. <https://doi.org/10.24815/jpsi.v11i2.28294>.
- Haryanto, H., Ghufro, A., & Suyantiningsih, S., & Kumala, F.N. 2020. The correlation between digital literacy and parents' roles towards elementary school students' critical thinking. *Cypriot Journal of Educational Science*, 17(3):828-839. <https://doi.org/10.18844/cjes.v17i3.6890>.
- Haworth, I.S. & Garrill, A. 2003. Assessment of verbal communication in science education a comparison of small and large classes. *The International Union of Biochemistry and Molecular Biology*, 31(1):24-27. Doi: [10.1002/bmb.2003.494031010164](https://doi.org/10.1002/bmb.2003.494031010164).
- Helsper, E.J. & Smahel, D. 2020. Excessive internet use by young europeans: psychological vulnerability and digital literacy? *Information, Communication & Society*, 23(9):1255-1273. <https://doi.org/10.1080/1369118x.2018.1563203>.
- Hilala, R., Laliyo, L.A.R., Kilo, J.L., Tangio, J., Mohammad, E., & Sihaloho, M. 2023. Scientific argumentation skills in explaining phenomena related to acid-base concepts. *Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education)*, 11(2):360-378. DOI: doi.org/10.24815/jpsi.v10i4.27822.
- Istiqomah, N., Hujjatusnaini, N., Septiana, N., & Amin, A.M. 2022. Implementasi model pembelajaran project based learning terintegrasi praktikum studi antagonisme *Escherichia coli* dan *Candida albicans* terhadap keterampilan berpikir kritis mahasiswa. *Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education)*, 10(4):892-904. DOI: doi.org/10.24815/jpsi.v10i4.26281.
- Kaeophanuek, S., Na-Songkhla, J., & Nilsook, P. 2019. A Learning process model to enhance digital literacy using critical inquiry through digital storytelling (CIDST).

International Journal of Emerging Technologies in Learning, 14(3):22-37. <https://doi.org/10.3991/ijet.v14i03.8326>.

Kereluik, K., Mishra, P., Fahnoe, C., & Terry, L. 2013. What knowledge is of most worth: teacher knowledge for 21 st century learning. *Journal of Digital Learning in Teacher Education*, 29(4):127-140. <https://doi.org/10.1080/21532974.2013.10784716>.

Khan, N., Sarwar, A., Chen, T.B., Khan, S. 2022. Connecting digital literacy in higher education to the 21st century workforce. *Knowledge Management & E-Learning*, 14(1):45-61. <https://doi.org/10.34105/j.kmel.2022.14.004>.

Khoerunisa, E., & Habibah, E. 2020. Profil keterampilan abad 21 (21st century soft skills) pada mahasiswa. *Iktisyaf: Jurnal Ilmu Dakwah Dan Tasawuf*, 2(2):55-68. DOI: [10.53401/iktsf.v2i2.20](https://doi.org/10.53401/iktsf.v2i2.20).

Leaning, M. 2019. An approach to digital literacy through the integration of media and information literacy. *Media and Communication*, 7(2):4-13. <https://doi.org/10.17645/mac.v7i2.1931>.

Lin, M.H., Chen, H.C., & Liu, K.S. 2017. A study of the effects of digital learning on learning motivation and learning outcome. *Eurasia Journal of Mathematics, Science and Technology Education*, 13(7):3553-3564. doi:10.12973/eurasia.2017.00744a.

Lukitasari, M., Murtafiah, W., Ramdiah, S., Hasan, R., & Sukri, A. 2022. Constructing digital literacy instrument and its effect on college students' learning outcomes. *International Journal of Instruction*, 15(2):171-188. <https://doi.org/10.29333/iji.2022.15210a>.

Lustyantie, N., Suriyati, Y., Isnani, F., Ramli, N., Yudha, R.P. 2022. The Effect of cognitive style, critical thinking, and digital literature on argumentative writing skills. *Educational Sciences: Theory and Practice*, 22(1):27-35. <http://dx.doi.org/10.12738/jestp.2022.1.0003>.

Mahajan, R. 2015. The key role of communication skills in the life of professionals. *IOSR Journal of Research & Method in Education (IOSRJRME)*, 20(12):36-39. <https://doi.org/10.9790/0837-201223639>.

Makur, A.P. 2019. The influence of PQ4R strategy and mathematical reasoning ability towards mathematical communication skills. *SJME (Supremum Journal of Mathematics Education)*, 3(1):18-31. <https://doi.org/10.35706/sjme.v3i1.1467>

Marci-Boehncke, G. & Vogel, T. 2018. Digital literacy and inclusion: The impact of theory and practice in teachers' education. *INTED2018 Proceedings. Valencia: IATED Academy*, p.6872-6879. DOI: [10.21125/inted.2018.1618](https://doi.org/10.21125/inted.2018.1618)

Marlina, L., Paramitha, G.P., & Sriyanti, I. 2022. Development of electronic modules based on critical thinking skills on vibration, waves, and sound materials for junior high school students. *Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education)*, 10(2):324-354. <https://doi.org/10.24815/jpsi.v10i2.23844>.

- Marini, S., Hanum, F., & Sulistiyo, A. 2020. Digital literacy: empowering Indonesian women in overcoming digital divide. In 2nd International Conference on Social Science and Character Educations (ICoSSCE 2019), p.137-141. Atlantis Press. <https://doi.org/10.2991/assehr.k.200130.029>.
- McKinstry, C., Iacono, T., Kenny, A., Hannon, J., & Knight, K. 2020. Applying a digital literacy framework and mapping tool to an occupational therapy curriculum. *Australian Occupational Therapy Journal*, 67(3):210-217. <https://doi.org/10.1111/1440-1630.12644>.
- Mewangi, A.B., Purnomo, A., & Ginanjar, A. 2020. Pengaruh literasi digital terhadap keterampilan sosial dalam pembelajaran IPS pada peserta didik kelas IX SMP Islam Al azhar 29 Semarang. *Harmony*, 5(1):40-46. <http://journal.unnes.ac.id/sju/index.php/harmony>.
- Meyers, E.M., Erickson, I., & Small, R.V. 2013. Digital literacy and informal learning environments. *An Introduction, Learning, Media and Technology*, 38(4):355-367. DOI: 10.1080/17439884.2013.783597.
- Mezirow, J. 1998. On critical reflection. *Adult Education Quarterly*, 48(3):185-198. <https://doi.org/10.1177/074171369804800305>.
- Mishra, P. & Mehta, R. 2017. What we educators get wrong about 21 century learning: results of a survey. *Journal of Digital Learning in Teacher Education*, 33(1):6-19. DOI: [10.1080/21532974.2016.1242392](https://doi.org/10.1080/21532974.2016.1242392).
- Musliman, A. & Damayanti, F. 2023. Use of science process skills indicators in "avicom" science creativity competition to improve student critical thinking. *Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education)*, 11(2):236-250. DOI: doi.org/10.24815/jpsi.v10i4.27696.
- Mwakapina, J.W. 2020. Communication skills course in bridging the gap of weak students' communicative competence and accentuating performance: a case of sokoine university of agriculture. *International Journal of Language and Linguistics*, 8(1):1-10. doi: 10.11648/j.ijll.20200801.11.
- Omeodu, M.D., Oduh., & Nathaniel, V.A. 2021. Significance of field trip on biology students acquisition of science process skills in abua odual local government area. *International Journal of Innovative Social & Science Education Research*, 9(1):37-45. <https://seahipaj.org/journals-ci/mar-2021/IJISSER/full/IJISSER-M-4-2021.pdf>.
- Pagani, L., Argentin, G., Gui, M., & Stanca, L. 2016. The impact of digital skills on educational outcomes: evidence from performance tests. *Educational Studies*, 42(2):137-162. <https://doi.org/10.1080/03055698.2016.1148588>.
- Panggabean, F.T.M., Pardede, P.O., Sitorus, R.M.D., Situmorang, Y.K., Naibaho, E.S., & Simanjuntak, J.S. 2021. Application of 21st century learning skills oriented digital-age literacy to improve student literacy HOTS in science learning in class IX

SMP. *Jurnal Mantik*, 5(3):1992-1930. <https://iocscience.org/ejournal/index.php/mantik/article/view/1796/1384>.

Phuapan, P., Viriyavejakul, C., & Pimdee, P. 2016. An analysis of digital literacy skills among thai university seniors. *International Journal of Emerging Technologies in Learning (IJET)*, 11(3):24-31. <https://doi.org/10.3991/ijet.v11i03.5301>.

Putri, R.K., Bukit, N., & Simanjuntak, M.P. 2021. The effect of project based learning model's on critical thinking skills, creative thinking skills, collaboration skills, & communication skills (4C) physics in senior high school. *Advances in Social Science, Education and Humanities Research*, 591, p.323-330. Doi: [10.2991/assehr.k.211110.103](https://doi.org/10.2991/assehr.k.211110.103).

Putri, R.M. & Asrizal. 2023. Need analysis of developing digital teaching materials to improve 21st century skills. *JUPI (Jurnal IPA dan Pembelajaran IPA)*, 7(2):108-117. DOI: [dx.doi.org/10.24815/jupi.v7i2.29797](https://doi.org/10.24815/jupi.v7i2.29797).

Rahman, Sopandi, W., Widya, R.N., & Yugafiat, R. 2019. Literacy in the context of communication skills for 21st century teacher education in primary school students. *International Journal of Science and Applied Science: Conference Series*, 3(1):101-108. <https://doi.org/10.20961/ijsascs.v3i1.32462>.

Ruenphongphun, P., Sukkamart, A., & Pimdee, P. 2021. Thai undergraduate digital citizenship education skills: A second-order confirmatory factor analysis (CFA). *World Journal on Educational Technology: Current Issues*, 13(3):370-385 <https://doi.org/10.18844/wjet.v13i3.5937>.

Rusydiah, E.F., Purwati, E., & Prabowo, A. 2020. How to use digital literacy as a learning resource for teacher candidates in Indonesia. *Cakrawala Pendidikan*, 39(2):305-318. doi:10.21831/cp.v39i2.30551.

Saputra, M., & Al Siddiq, I.H. 2020. Social media and digital citizenship: the urgency of digital literacy in the middle of a disrupted society era. *International Journal of Emerging Technologies in Learning*, 15(7):156-161. <https://doi.org/10.3991/IJET.V15I07.13239>.

Scanlon, E., Jones, A., Barnard, J., Thompson, J., & Calder, J. 2000. Evaluating information and communication technologies for learning. *Educational Technology and Society*, 3(4):101-107. doi:10.1016/j.sbspro.2009.01.375.

Setiyadi, D., Fortuna, D., & Ramadhan, A. 2022. Pemanfaatan video kreatif dan media sosial youtube sebagai media pembelajaran matematika kelas tinggi. *Dawuh Guru: Jurnal Pendidikan MI/SD*, 2(1):31-42. <https://doi.org/10.35878/guru.v2i1.344>.

Spektor-levy, O., Eylon, B., & Scherz, Z. 2008. Teaching communication skills in science : tracing teacher change. *Teaching and Teacher Education*, 24:462-477. <https://doi.org/10.1016/j.tate.2006.10.009>.

- Subekti, H., Taufiq, M., Susilo, H., Ibrohim, & Suwono, H. 2018. Mengembangkan literasi informasi melalui belajar berbasis kehidupan terintegrasi stem untuk menyiapkan calon guru sains dalam menghadapi era revolusi industri 4.0: review literatur. *Education and Human Development Journal*, 3(1):81-90. <https://doi.org/10.33086/ehdj.v3i1.90>.
- Supriyanti, S., Permanasari, A., & Khoerunnisa, F. 2020. Correlation between information literacy and critical thinking enhancement through PjBL-information literacy learning model. *Journal of Educational Science*, 4(4):774-784. <https://doi.org/10.31258/jes.4.4.p.774-784>.
- Syafaren, A., Yustina, Y., Mahadi, I., & Vebrianto, R. 2019. Increasing critical thinking skills through natural science learning based on the integration of guided inquiry with numbered heads together. *Journal of Educational Sciences*, 3(3):433-444. DOI: <http://dx.doi.org/10.31258/jes.3.3.p.433-444>.
- Taglieber, L.K. 2000. Critical reading and critical thinking the state of the art. *Ilha do Desterro A Journal of English Language, Literatures in English and Cultural Studies*, (38):015-037. <https://periodicos.ufsc.br/index.php/desterro/article/view/8263>.
- Tang, C.M., & Chaw, L.Y. 2016. Digital literacy: a prerequisite for effective learning in a blended learning environment? *Electronic Journal of ELearning*, 14(1):54-65. <https://files.eric.ed.gov/fulltext/EJ1099109.pdf>.
- Tham, J.C.K., Burnham, K.D., Hocutt, D.L., Ranade, N., Misak, J., Duin, A.H., Campbell, J.L. 2021. Metaphors, mental models, and multiplicity: understanding student perception of digital literacy. *Computers and Composition*, 59:102628. <https://doi.org/10.1016/j.compcom.2021.102628>.
- Trisdiono, H., Siswandari, S., Suryani, N., & Joyoatmojo, S. 2019. Development of multidisiplin integrated project-based learning model to improve critical thinking and cooperation skills. *JPI (Jurnal Pendidikan Indonesia)*, 8(1):9-20. <https://doi.org/10.23887/jpi-undiksha.v8i1.17401>.
- Ustundag, M.T., Gunes, E., & Bahcivan, E. 2017. Turkish adaptation of digital literacy scale and investigating pre-service science teachers' digital literacy. *Journal of Education and Future*, (12):19-29. <https://dergipark.org.tr/tr/download/article-file/332115>.
- Uyen, B.P., Tong, D.H., & Tram, N.T.B. 2021. Developing mathematical communication skills for students in grade 8 in teaching congruent triangle topics. *European Journal of Educational Research*, 10(3):1287-1302. <https://doi.org/10.12973/eujer.10.3.1287>.
- Van Laar, E., van Deursen, A.J.A.M., van Dijk, J.A.G.M., & de Haan, J. 2017. The relation between 21st century skills and digital skills: a systematic literature review. *Computers in Human Behavior*, 72:577-588. <https://doi.org/10.1016/j.chb.2017.03.010>.

- Velentzas, J.O.H.N., & Broni, G. 2014. Communication cycle: definition, process, models and examples. Recent advances in financial planning and product Development. *Proceedings of the 5th International Conference on Finance, Accounting and Law (ICFA '14)*, Istanbul, Turkey, 15-17 December 2014, p.117-131.
- Wale, B.D., & Bishaw, K.S. 2020. Effects of using inquiry-based learning on EFL students' critical thinking skills. *Asian-Pacific Journal of Second and Foreign Language Education*, 5(1):1-14. <https://doi.org/10.1186/s40862-020-00090-2>.
- Wati, W.W. & Syafriani. 2023. Validity of physics e-modules based on an inquiry model integrated with the science, environment, technology, and society approach to 21st century skills. *JUPI (Jurnal IPA dan Pembelajaran IPA)*, 7(2):133-144. DOI: [dx.doi.org/10.24815/jupi.v7i2.30002](https://doi.org/10.24815/jupi.v7i2.30002).
- Wrahatnolo, T., & Munoto. 2018. 21st centuries skill implication on educational system. *IOP Conf. Series: Materials Science and Engineering*, 296(012036). doi:10.1088/1757-899X/296/1/012036.
- Yasa, A.D., & Rahayu, S. 2023. A Survey of elementary school students digital literacy skills in science learning. *AIP Conference Proceeding*, 2569, 060015. <https://doi.org/10.1063/5.0113483>.
- Yasdin, Y., Yahya, M., Yusuf, A.Z., Musa, M.I., Sakaria, S. & Yusri, Y. 2021. The role of new literacy and critical thinking in students' vocational development. *Cypriot Journal of Educational Science*, 16(4):1395-1406. <https://doi.org/10.18844/cjes.v16i4.5991>.