Improving Students' Critical Thinking Skills: Is Interactive Video and Interactive Web Module Beneficial?

https://doi.org/10.3991/ijim.v17i03.34699

Asyti Febliza[1], Zul Afdal[2](✉), Jimmi Copriady[3]
[1] Universitas Islam Riau, Riau, Indonesia
[2] Universitas Negeri Padang, Padang, Indonesia
[3] Universitas Riau, Riau, Indonesia
zulafdal@fe.unp.ac.id

Abstract—This study compares students' critical thinking skills through interactive media based on learning phenomena. The phenomenon of learning-based interactive media used are interactive web modules and interactive videos on the topic of the colloid system. Comparative research with a quantitative approach is the method used. In this study's sample, all chemistry education students at the University of Riau and the State Islamic University of Sultan Syarif Kasim Riau in the academic year 2020–2021. Saturated sampling is the method that is used. There were a total of 68 students used as samples. Each group had 34 students. The control group used interactive video-based learning phenomena, and the experimental group used interactive web modules based on phenomena learning. The essay test instrument is used to measure students' critical thinking skills. We used paired t-tests and N-gain to analyze the data. The results showed that interactive web modules were better than interactive videos at helping students improve their critical thinking skills. So, teachers can think of appropriate instructional media used in distance learning as a way to help students improve their critical thinking.

Keywords—phenomenon-based learning, interactive video, interactive web module, critical thinking skills

1 Introduction

Since learning has become a goal of education in the 21st century, students need to be able to think critically [1]. Education is a means of preparing students to join the workforce who can think analytically, solve problems and critically so that they can become a productive workforce and generate knowledge; be able to exchange information and encourage progress that helps the development of community welfare [2][3][4]. The peak of critical thinking is the ability to make a decision where it works in the brain; that is, the ability to think convergent because students have to establish what is best [5][6]. Critical thinking has become one of the tools used in everyday life to solve a problem because it involves the ability to reason, interpret, and the ability to

evaluate information to allow making a valid and trusted decision [7][8][9]. Critical thinking processes can also train students to draw conclusions and synthesize information [10][11][12].

The current issue is that Indonesian students still need to be rated as having low critical thinking skills. The science scores of Indonesian students are ranked 45th out of 50 countries in the Trends in International Mathematics and Science Study (2018) [13]. This shows that there is room for growth in Indonesian students' capacity to answer questions requiring critical thinking [14]. Students are still expected to memorize formulas and answer questions correctly in chemistry class without being encouraged to think critically and creatively [15]. Learning media is less effective, and understanding leads to memorization [11]. Students are less motivated to develop their thinking skills using conventional media [10]. Students are more innovative in terms of theory rather than in practical fields [16][9]. Learning is only directed at memorizing and hoarding information, so students' critical thinking skills are difficult to develop [17][18]. The number of students who are weak in critical thinking is a challenge for teachers in teaching students to have necessary thinking skills [19][20].

Referring to the findings above, implementing chemistry learning should direct students to help the critical thinking process. Research results [21][22] indicate that the student's critical thinking will automatically develop after mastering all the learning materials. It is necessary to emphasize critical thinking skills to obtain fun and more meaningful learning experiences for students [23][24]. If educators routinely model critical thinking at each stage of the teaching and learning process, students are more likely to acquire these abilities and put them to use in their own lives [25]. [26][27][6] says that activities that train students' critical thinking skills should be used in the learning process to give students a chance to improve their critical thinking skills. Students can improve in school if they learn to think critically [28][29]. Learning media can make it easier for teachers to explain lessons, and appealing media designs can get students to think more critically [30][31][10]. In addition, the learning approach is also the most important component of learning and must be included in learning [32][33][34][35].

Using PhenoBL (Phenomenon-Based Learning) media is another way to help students improve their critical thinking skills. PhenoBL media is a learning media that uses phenomena as a learning resource [36][37][38]. Through PhenoBL media, students can develop the ability to explain causes and connect components of phenomena to the natural environment [39][40]. Students can also learn 21st-century skills through phenomenon-based learning, such as critical thinking, creativity, communication, and working together [41]. PhenoBL media as a digital module can be used as an alternative to strengthening students' necessary thinking skills [42]. Interactive modules can improve students' essential thinking skills [43][87]. Critical thinking and student participation in interactive video classes are much higher than in typical lecture groups [44]. Based on the results of previous studies, it is essential to compare two PhenoBL media—interactive web modules and interactive videos—in terms of how well they help students improve their critical thinking skills in distance learning. Based on the results of previous studies, it is essential to compare two PhenoBL media—interactive web modules and

interactive videos—in terms of how well they help students improve their critical thinking skills in distance learning. The novelty of this study is to compare the effectiveness of the two PhenoBL media presented as interactive web modules and interactive videos in improving students' critical thinking skills. Researchers and teachers can use the results of this study as a guide to choose the right and most effective learning media to help students improve their critical thinking skills using the PhenoBL method.

This study aimed to improve student's critical thinking skills using PhenoBL media. The main problem in the study is "*Is there a significant improvement in students' critical thinking skills through interactive videos compared to interactive web modules*?".

2 Literature review

2.1 The importance of critical thinking skills for students

Critical thinking is one of the higher-level skills that students need to learn [45]. Critical thinking skills are fundamental in learning in the disruption era [25][46]. Critical thinking skills include accessing, analyzing, and synthesizing information that can be taught and mastered [47][48]. In order to understand the learning process, students must develop deep and high-level thinking skills. In order to understand the learning process, students must develop deep and high-level thinking skills [49]. Critical thinking skills become essential for students to have because they can help students make decisions [50][1][51].

Training students to acquire critical thinking skills can be done on campus through the learning process because critical thinking can be trained by choosing the right learning strategies [52]. Without practice and habituation, critical thinking skills can only be acquired slowly [27]. Student-centered and problem-solving-oriented learning processes can help improve critical thinking skills in students [53]. According to [54][29], several steps need to be taken in developing critical thinking skills, including (a) recognizing the problem; (b) finding ways you can deal with your problem; (c) collecting and compiling the necessary information for problem-solving; (d) identify assumptions and values that are not stated; (e) Talk about an issue or something it accepts in a way that is clear and easy to understand; (f) evaluate the facts and statements and the data; (g) figuring out how the problems and answers fit together logically; (h) draw conclusions or form opinions about the topic or topics being talked about.

Thus, critical thinking skills can be learned and developed according to the indicators of critical thinking skills [55][56][57]. Include: a) provide a simple explanation (elementary clarification) which includes activities to focus questions, analyze arguments, ask and answer questions and classify challenging questions; b) building essential support includes considering whether sources are reliable or not, observing and considering observation results; c) making inferences related to the activities of deducting and considering deductions and reviewing the values of the results of consideration; d) making further explanations (advanced clarification) refers to the activities of defining terms and considering definitions, identifying assumptions; e) strategies and tactics include activities to decide on an action and the ability to interact with others.

2.2 Interactive media based on phenomenon learning

Phenomenon-based interactive media is a media designed based on learning built on observing phenomena that we often encounter in everyday life [58]—phenomenon-based learning media (PhenoBL) in the form of interactive videos and digital modules. The use of this interactive medium aims to overcome the limitations of traditional learning by exploring natural phenomena from different points of view as a complex process [59][60][61]. There are five parts to a phenomenon-based education: the whole, the real, the context, problem-based inquiry learning, and the learning process [62][63]. Holistic education is based on real-world phenomena and looks at them from many angles [38][64]. Authenticity means using the methods, tools, and materials needed in real life to solve problems related to student life and the learning community [65][66]. The conceptuality dimension refers to phenomenon-based learning as a systematic unit in which meaningful learning in a natural context [42][59].

The phenomenon cannot be determined simply as something vague and ambiguous that the student must have in observing the broader context [67]. Problem-based inquiry learning is a way for students to learn by asking questions and building knowledge together. This is a planned way for students to develop hypotheses and theories of work [68]. Learning tasks help students learn and make them more aware of what they are learning (knowledge) [69][70]. At the next stage, the student plans the learning process by creating his tasks and learning tools [71][72]. The learning process framework is essential for students to acquire knowledge beyond what they currently know and know what they need to know [73][74].

3 Methods

3.1 Type of study

This is a comparison study that uses quantitative methods [75]. This study will compare how two different phenomenon-based learning media help students improve their critical thinking skills. The first is an interactive web module based on a phenomenon, and the second is an interactive video based on a phenomenon. Critical thinking is the dependent variable, and the two media are independent variables. The research design is presented in Table 1.

Table 1. Research design

Pretest	Learning Process	Posttest
O1	Phenomenon Based learning with interactive video	O2
O3	Phenomenon-Based learning with the interactive web module	O4

3.2 Participants

All chemistry education students at the University of Riau and the State Islamic University of Sultan Syarif Kasim Riau during the 2020–2021 school year were included in this study. Saturated sampling is used, where the number of samples equals the number of people in the population [76][77]. Sixty-eight students were used as samples. There were four boys and 64 girls. The sample was split into two groups of 34 students each. The control group used interactive videos to learn about phenomena, while the experimental group used interactive web modules to learn about phenomena. All respondents had enrolled in introductory chemistry courses and were taught by female lecturers with more than 14 years of teaching experience in chemistry education.

3.3 Data collection instrument

The instrument used in this study was an essay test to measure critical thinking skills consisting of 10 items with assessment indicators, namely a) inducing and considering the results of induction, b) identifying assumptions, c) concluding and evaluating deduction results, d) interacting with other people, e) observing and considering observation reports, f) analyzing arguments [10]. Critical thinking skills assessment instruments are presented in Table 2.

Table 2. Indicators of critical thinking skills

Learning Indicators	Critical Thinking Indicator	Items
Distinguishing colloidal systems	Inducing and considering the results of induction	1
Explain the characteristics of colloids	Identify assumptions	2
Identify the colloidal phase	Deduce and evaluate the results of the deduction	3
Analyzing colloidal properties	Interacting with other people	4
Explain the benefits of colloid systems in everyday life	Identify assumptions	5
Applying colloidal principles in daily life	Observing and considering observation reports	6
Analyzing colloid creation	Analyzing argument	7
Analyze colloid properties	Identify assumptions	8
Making colloid system products with several types of colloids	Identify assumptions	9
Apply the application of colloids in everyday life	Identify assumptions	10

With the help of SPSS 26, this study verifies the tools used to test students' critical thinking skills. As shown in Table 3, the validation test results show that the ten items are the valid criteria.

Table 3. The instrument validity from critical thinking skills

Item-Total Statistics					
Items	**Scale Mean if Item Deleted**	**Scale Variance if Item Deleted**	**Corrected Item-Total Correlation**	**Squared Multiple Correlation**	**Cronbach's Alpha if Item Deleted**
Item_1	22.94	29.809	.686	.707	.844
Item _2	23.00	29.375	.697	.783	.843
Item _3	22.82	32.278	.473	.589	.862
Item _4	22.67	33.042	.569	.568	.856
Item _5	22.70	32.155	.624	.592	.851
Item _6	23.06	31.559	.439	.354	.867
Item _7	23.30	31.093	.541	.496	.857
Item _8	23.00	31.625	.639	.603	.850
Item _9	23.24	30.689	.597	.531	.852
Item _10	23.45	30.256	.614	.552	.851

Cronbach's alpha reliability coefficient was found to be 0.866, which is very high. This is shown in Table 4.

Table 4. The instrument reliability from critical thinking skills

Reliability Statistics		
Cronbach's Alpha	**Cronbach's Alpha Based on Standardized Items**	**N of Items**
.866	.871	10

3.4 Procedure

The treatment was carried out for six meetings (6 x 50 minutes = 400 minutes), including two sessions for the pretest and posttest and four meetings to study the material on the colloid system. The media used in this research is a phenomenon-based learning media presented in two types: interactive videos and web modules. The description of the media used in the study is shown in Table 5.

Table 5. Phenomenon-based learning media description

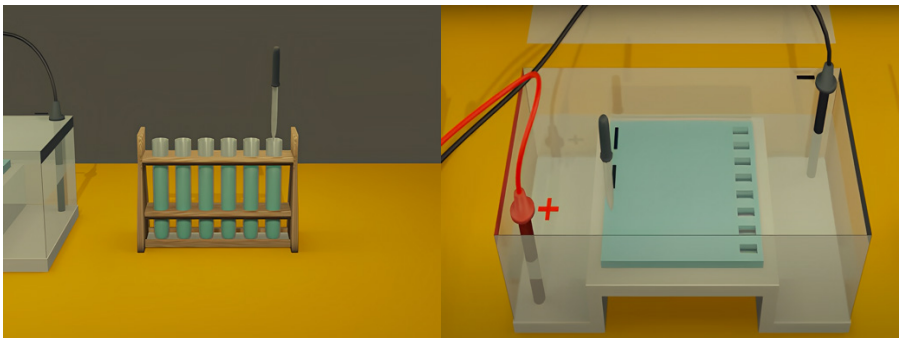
PhenoBL Media	Description
Interactive Video	Content: Environmental and industry phenomena relating colloid with 3D videos, namely; the red sky phenomenon during a forest fire, the process of pearl formation, the process of cloud formation, the movement of milk solution particles visible under a microscope, and the appearance of dust particles when exposed to sunlight ht, the process of paint formation, manufacture whipped cream, making brass sculptures, making latex mattresses, the phenomenon of sky colour differences, the process of absorption of body lotion on the skin, formation of deltas, filtering systems on masks, DNA identification, blood filtering processes and how soap works in killing the covid-19 virus. Practical simulation video about the concept of colloid material.

PhenoBL Media	Description
	Interactivity: A quiz with direct feedback during the video (screencast), questions that help students find personal meaning, and quiz grading sent to the lecturer via email. Presentation: Published in Camtasia screencast.
Interactive Web Module	Content: Environmental and daily life phenomena relating to colloids, such as the phenomenon of differences in the properties of the types of solutions, projectors in cinemas, the phenomenon of disagreements in sky colour, the manufacture of jelly, the movement of particles of milk solution visible under a microscope, the process of separating metals, adsorption processes, how detergents and water cleaning process—practical simulation video about the concept of colloid material with user control. Interactivity: simulation with user control, questions that help students to find personal meaning, and quizzes with direct feedback (Moodle quiz). Presentation: Learning source of Moodle.

The appearance of the two media is presented in Figures 1(a,b) and 2 (a,b).

a b

Fig. 1. (a,b). Interactive video-based learning phenomena



a b

Fig. 2. (a,b). Interactive web module-based learning phenomena

3.5 Data analysis

The normality test was used to see if the distribution of the data to be analyzed was expected, and the homogeneity test was used to see how similar normally distributed population variants were. A significant value (p=0.08) > 0.05 from the Kolmogorov-Smirnov test means that the data is normally distributed. On the other hand, the homogeneity test uses the Levene test, and a significant value (p =0.336) > 0.05 means that the data is homogeneous. The average score on the pretest differs from the average score on the posttest. The N-gain test measures how much the students' critical thinking skills scores improve before and after the intervention. The results of the calculations are then broken down into three groups, which are:

Table 6. Gain value classification[76]

Average Gain	Criteria
$0.00 < g \leq 0.30$	Low
$0.30 < g \leq 0.70$	Medium
$0.70 < g \leq 1.00$	High

4 Results and discussions

In this meeting, the results of the t-test analysis were shown. There is no statistically significant difference in post-test scores between the control and experimental groups (t=-5.659; p= 0.191). The results can be seen in Table 7.

Table 7. T-test result

Independent Samples Test										
		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	*Upper*
Critical Thinking Skills	Equal variances assumed	1.744	.191	-5.659	66	.000	-12.559	2.219	-16.989	-8.128
	Equal variances not assumed			-5.659	62.702	.000	-12.559	2.219	-16.994	-8.124

According to Table 7, there is no statistically significant difference between the experimental and control classes regarding students' ability to think critically. This is because phenomenon-based learning media, like web modules and interactive videos, positively impact the development of students' capacity for critical thinking. This is

reinforced by [39][40][62] that through PhenoBL media, students can develop the ability to explain causes and connect components of phenomena to the natural environment. Students' critical thinking, imagination, communication, and teamwork abilities can all benefit from being exposed to real-world phenomena in the classroom [41]. A digital module like PhenoBL media can replace traditional methods of teaching critical thinking to students [42][78]. Interactive modules can significantly enhance students' ability to think critically [43]. Compared to traditional lecture classes, those taught using interactive video encourage significantly more critical thinking and active student participation [44].

Improving students' critical thinking skills through interactive video and interactive web modules Students' critical thinking skills were measured with the N-gain test after being exposed to learning phenomena-based interactive video and web modules. Specifically, Tables 8-9 display the results of the analysis.

Table 8. Student critical thinking skills through using interactive video

Indicators	Pretest	Posttest	Gains Score
Identify assumptions	5.3972	7.6618	0.4920
Inducing and considering the results of induction	4.8529	8.1618	0.6429
Deduce and evaluate the results of the deduction	6.9118	8.6765	0.5714
Interacting with other people	7.0588	8.75	0.5750
Observing and considering observation reports	3.3824	7.2794	0.5889
Analyzing argument	3.4559	7.5375	0.6237
All indicators			0.5823

Table 9. Student critical thinking skill through using interactive web module

Indicators	Pretest	Posttest	Gains Score
Identify assumptions	5.8676	8.75	0.6975
Inducing and considering the results of induction	5.2941	8.6029	0.7031
Deduce and evaluate the results of the deduction	5.7353	8.0882	0.5517
Interacting with other people	6.8382	8.75	0.6047
Observing and considering observation reports	4.6324	8.3088	0.6849
Analyzing argument	4.4853	7.7206	0.5867
All indicators			0.6381

Table 8-9 shows that the average N-gain score in the interactive web module group is higher than in the interactive video group. These results indicate that interactive web modules improve students' critical thinking skills more than interactive videos. This is because interactive web modules are equipped with video content, simulations with user control, and questions with live feedback. Based on the findings of previous research, it was revealed that the use of interactive web modules could increase students' self-confidence in completing case studies and improve students' critical thinking skills *and* increase competence [79][80][39]. According to the cone theory of role-playing experience, conducting simulations and doing real things can absorb learning up to 90% of what has been learned [81]. Other research reveals that using interactive modules

can facilitate students in improving critical thinking skills [82]. Additional effects of the web module videos' interactivity on critical thinking development [83]. This is even more important now that search engines are the only ones who use content knowledge [84].

Several studies have revealed that through PhenoBL, students can develop the ability to explain causes and relate them to non-phenomenon components. Zhukov says phenomenon-based learning can help students develop 21st-century skills like critical thinking, creativity, communication, and working with others [38]. Also, Habash shows that putting fun activities into phenomena and project-based learning can significantly improve students' analytical thinking, knowledge creation, reflective judgment, self-efficacy, and, most importantly, their ability to do graduate work [85]. Also, the research shows that using phenomenon-based learning in science classes with the help of videos has positive effects on students, such as helping them improve their critical thinking, conceptual understanding, and scientific argumentation skills and letting them ask questions about what they saw on film or video [86][58]. Also, Slemmons backed up the research findings that using video content will affect the development of critical thinking skills [79]. In the digital age, thinking skills become more critical when information can be found with a search engine [81].

The results of this study can be used as a guide for teachers who want to use instructional media to help their students improve their critical thinking skills. Phenomenon-based learning media in interactive web modules with content, user-controlled simulations, and interactive quizzes are better at helping students improve their critical thinking skills than interactive videos with content, pre-screen simulations, and interactive quizzes. In the future, this media can be used to enhance students' creative thinking skills. Furthermore, this research has limitations in the form of a slow internet network, so access to videos and modules is slow.

5 Conclusion

The study shows that interactive web modules are better than interactive videos at helping students improve their critical thinking skills. The impact of this research is that it can provide a reference in choosing an appropriate and effective PhenoBL-based interactive media for teaching students critical thinking skills. Future researchers should prepare excellent and smooth internet access to avoid obstacles in accessing the media used during the learning process.

6 Acknowledgement

Thanks to Indonesia's Ministry of Education and Culture for funding this study.

7 References

[1] U. C. Okolie, P. A. Igwe, I. K. Mong, H. E. Nwosu, C. Kanu, and C. C. Ojemuyide, "Enhancing students' critical thinking skills through engagement with innovative pedagogical practices in Global South," *Higher Education Research & Development*, vol. 41, no. 4, pp. 1184–1198, 2022. https://doi.org/10.1080/07294360.2021.1896482

[2] W. Li, "Studying creativity and critical thinking skills at university and students future income," *Thinking Skills and Creativity*, vol. 43, p. 100980, 2022. https://doi.org/10.1016/j.tsc.2021.100980

[3] R. RISTANTO, A. SABRİNA, and R. Komala, "Critical Thinking Skills of Environmental Changes: A Biological Instruction Using Guided Discovery Learning-Argument Mapping (GDL-AM)," *Participatory Educational Research*, vol. 9, no. 1, pp. 173–191, 2022. https://doi.org/10.17275/per.22.10.9.1

[4] S. A. Samaras, C. L. Adkins, and C. D. White, "Developing critical thinking skills: Simulations vs cases," *Journal of Education for Business*, vol. 97, no. 4, pp. 270–276, 2022. https://doi.org/10.1080/08832323.2021.1932703

[5] M. Giacomazzi, M. Fontana, and C. C. Trujillo, "Contextualization of critical thinking in sub-Saharan Africa: A systematic integrative review," *Thinking Skills and Creativity*, vol. 43, p. 100978, 2022. https://doi.org/10.1016/j.tsc.2021.100978

[6] P. Brečka, M. Valentová, and D. Lančarič, "The implementation of critical thinking development strategies into technology education: The evidence from Slovakia," *Teaching and Teacher Education*, vol. 109, p. 103555, 2022. https://doi.org/10.1016/j.tate.2021.103555

[7] K. Kleemola, H. Hyytinen, and A. Toom, "Exploring internal structure of a performance-based critical thinking assessment for new students in higher education," *Assessment & Evaluation in Higher Education*, vol. 47, no. 4, pp. 556–569, 2022. https://doi.org/10.1080/02602938.2021.1946482

[8] S. IŞIKLAR and Y. A. ÖZTÜRK, "The effect of philosophy for children (P4C) curriculum on critical thinking through philosophical inquiry and problem solving skills," *International Journal of Contemporary Educational Research*, vol. 9, no. 1, pp. 130–142, 2022. https://doi.org/10.33200/ijcer.942575

[9] L. Heliawati, L. Lidiawati, and I. D. Pursitasari, "Articulate Storyline 3 multimedia based on gamification to improve critical thinking skills and self-regulated learning," *Int J Eval & Res Educ*, vol. 11, no. 3, pp. 1435–1444, 2022. https://doi.org/10.11591/ijere.v11i3.22168

[10] M. Erna, C. A. Dewi, and Elfizar, "The Development of E-Worksheet Using Kvisoft Flipbook Maker Software Based on Lesson Study to Improve Teacher ' s Critical Thinking Ability," *International Journal of Interactive Mobile Technologies (iJIM)*, vol. 15, no. 01, pp. 39–55, 2021. https://doi.org/10.3991/ijim.v15i01.15679

[11] C. A. Dewi, M. Muhali, Y. Kurniasih, D. Lukitasari, and A. Sakban, "The impact of Google Classroom to increase students' information literacy," *Int J Eval & Res Educ*, vol. 11, no. 2, pp. 1005–1014, 2022. https://doi.org/10.11591/ijere.v11i2.22237

[12] C. A. Dewi, Pahriah, and A. Purmadi, "The Urgency of Digital Literacy for Generation Z Students in Chemistry Learning," *International Journal of Emerging Technologies in Learning*, vol. 16, no. 11, pp. 88–103, 2021. https://doi.org/10.3991/ijet.v16i11.19871

[13] A. P. Utomo, K. Yuana, E. Narulita, K. Fikri, and B. Wahono, "Studentsâ€™ Errors in Solving Science Reasoning-Domain of Trends in International Mathematics and Science Study (TIMSS)," *Jurnal Pendidikan IPA Indonesia*, vol. 7, no. 1, pp. 48–53, 2018. https://doi.org/10.15294/jpii.v7i1.11352

[14] S. Suteja and D. Setiawan, "Students' Critical Thinking and Writing Skills in Project-Based Learning," *International Journal of Educational Qualitative Quantitative Research*, vol. 1, no. 1, pp. 16–22, 2022. https://doi.org/10.58418/ijeqqr.v1i1.5
[15] R. Perdana and Y. Wahyudin, "Inquiry Social Complexity-Based Chemistry Module to Empower Critical and Creative Thinking Skills," *Jurnal Pendidikan Progresif*, vol. 12, no. 2, pp. 777–784, 2022. https://doi.org/10.23960/jpp.v12.i2.202229
[16] F. M. Ippoliti, J. V Chari, and N. K. Garg, "Advancing global chemical education through interactive teaching tools," *Chemical Science*, 2022. https://doi.org/10.1039/D2SC01881K
[17] K. Osman and A. N. Lay, "MyKimDG module: An interactive platform towards development of twenty-first century skills and improvement of students' knowledge in chemistry," *Interactive Learning Environments*, vol. 30, no. 8, pp. 1461–1474, 2022. https://doi.org/10.1080/10494820.2020.1729208
[18] R. S. Bowen, A. A. Flaherty, and M. M. Cooper, "Investigating student perceptions of transformational intent and classroom culture in organic chemistry courses," *Chemistry Education Research and Practice*, 2022. https://doi.org/10.1039/D2RP00010E
[19] M. A. L. Blackie, "Knowledge building in chemistry education," *Foundations of Chemistry*, vol. 24, no. 1, pp. 97–111, 2022. https://doi.org/10.1007/s10698-022-09419-w
[20] Ş. Tuzlukaya, N. G. G. Şahin, and C. Cigdemoglu, "Extending peer-led team learning to management education: The effects on achievement, critical thinking, and interest," *The International Journal of Management Education*, vol. 20, no. 2, p. 100616, 2022. https://doi.org/10.1016/j.ijme.2022.100616
[21] F.-H. Hsu, I.-H. Lin, H.-C. Yeh, and N.-S. Chen, "Effect of Socratic Reflection Prompts via video-based learning system on elementary school students' critical thinking skills," *Computers & Education*, vol. 183, p. 104497, 2022. https://doi.org/10.1016/j.compedu.2022.104497
[22] K. J. Plummer, M. Kebritchi, H. M. Leary, and D. M. Halverson, "Enhancing Critical Thinking Skills through Decision-Based Learning," *Innovative Higher Education*, pp. 1–24, 2022. https://doi.org/10.1007/s10755-022-09595-9
[23] M. Noris and S. Saputro, "The Virtual Laboratory Based on Problem Based Learning to Improve Students' Critical Thinking Skills," *The Virtual Laboratory Based on Problem Based Learning to Improve Students' Critical Thinking Skills*, vol. 3, no. 1, pp. 35–47, 2022. https://doi.org/10.12973/ejmse.3.1.35
[24] N. Nurhayati, R. Agustini, and E. Sudibyo, "Analysis of Critical Thinking Skills of Middle School Students on Environmental Pollution Materials," *IJORER: International Journal of Recent Educational Research*, vol. 3, no. 1, pp. 100–109, 2022. https://doi.org/10.46245/ijorer.v3i1.186
[25] M. M. Chusni, S. Saputro, and S. B. Rahardjo, "Enhancing Critical Thinking Skills of Junior High School Students through Discovery-Based Multiple Representations Learning Model.," *International Journal of Instruction*, vol. 15, no. 1, pp. 927–945, 2022. https://doi.org/10.29333/iji.2022.15153a
[26] Y. Liu and A. Pásztor, "Effects of problem-based learning instructional intervention on critical thinking in higher education: A meta-analysis," *Thinking Skills and Creativity*, vol. 45, p. 101069, 2022. https://doi.org/10.1016/j.tsc.2022.101069
[27] N. H. Rofiah *et al.*, "Critical Thinking Ability among Gifted and Slow Learner Students in Higher Education. What is the Recommended Learning Model?," *Turkish Journal of Computer and Mathematics Education (TURCOMAT)*, vol. 13, no. 2, pp. 26–30, 2022.
[28] N. Xhomara, "Critical thinking: student-centred teaching approach and personalized learning, as well as previous education achievements, contribute to critical thinking skills of

students," *International Journal of Learning and Change*, vol. 14, no. 1, pp. 101–120, 2022. https://doi.org/10.1504/IJLC.2022.119513

[29] V. H. Paulsen and S. D. Kolstø, "Students' reasoning when faced with test items of challenging aspects of critical thinking," *Thinking Skills and Creativity*, vol. 43, p. 100969, 2022. https://doi.org/10.1016/j.tsc.2021.100969

[30] A. Kanmaz, "Middle School Teachers' Critical Thinking Skills and Awareness towards Teaching Critical Thinking Skills.," *International Online Journal of Education and Teaching*, vol. 9, no. 4, pp. 1648–1671, 2022.

[31] I. Listiqowati, "Budijanto., Sumarmi., & Ruja, IN (2022). The impact of project-based flipped classroom (PjBFC) on critical thinking skills," *International Journal of Instruction*, vol. 15, no. 3, pp. 853–868. https://doi.org/10.29333/iji.2022.15346a

[32] M. Alberto de la Puente Pacheco, C. M. de Oro Aguado, E. Lugo Arias, H. Rico, D. Cifuentes, and M. Tafur, "Effectiveness of model ASEAN meeting in enhancing critical thinking: a Colombia case study," *Interactive Learning Environments*, pp. 1–23, 2022. https://doi.org/10.1080/10494820.2022.2046109

[33] C.-Y. Chang, P. Panjaburee, H.-C. Lin, C.-L. Lai, and G.-H. Hwang, "Effects of online strategies on students' learning performance, self-efficacy, self-regulation and critical thinking in university online courses," *Educational technology research and development*, vol. 70, no. 1, pp. 185–204, 2022. https://doi.org/10.1007/s11423-021-10071-y

[34] L. N. Duffy, G. A. Stone, J. Townsend, and J. Cathey, "Rethinking curriculum internationalization: Virtual exchange as a means to attaining global competencies, developing critical thinking, and experiencing transformative learning," *SCHOLE: A Journal of Leisure Studies and Recreation Education*, vol. 37, no. 1–2, pp. 11–25, 2022. https://doi.org/10.1080/1937156X.2020.1760749

[35] K. Lavidas, Z. Apostolou, and S. Papadakis, "Challenges and opportunities of mathematics in digital times: Preschool teachers' views," *Education Sciences*, vol. 12, no. 7, p. 459, 2022. https://doi.org/10.3390/educsci12070459

[36] K. WAKIL, R. RAHMAN, D. HASAN, P. MAHMOOD, and T. JALAL, "Phenomenon-based learning for teaching ict subject through other subjects in primary schools," *Journal of Computer and Education Research*, vol. 7, no. 13, pp. 205–212, 2019. https://doi.org/10.18009/jcer.553507

[37] N. Manowaluilou, O. Butkatunyoo, and P. Mahavijit, "Phenomenon-based teaching competency development for teacher educators in higher education in Thailand," *Kasetsart Journal of Social Sciences*, vol. 43, no. 3, pp. 727–734, 2022. https://doi.org/10.34044/j.kjss.2022.43.3.26

[38] E. A. Valanne, R. M. Al Dhaheri, R. Kylmalahti, and H. Sandholm-Rangell, "Phenomenon Based Learning Implemented in Abu Dhabi School Model," *International Journal of Humanities and Social Sciences*, vol. 9, no. 3, pp. 1–17, 2017.

[39] R. Habash, "Phenomenon-based Learning for Age 5.0 Mindsets: Industry, society, and Education," in *2022 IEEE Global Engineering Education Conference (EDUCON)*, 2022, pp. 1910–1915. https://doi.org/10.1109/EDUCON52537.2022.9766521

[40] E. V Permites and L. S. Lomibao, "Phenomenon-based Conversational Microlesson Packets on Students' Mathematics Achievement and Appreciation," *American Journal of Educational Research*, vol. 10, no. 5, pp. 349–354, 2022.

[41] D. R. Towns-Belton, "Teachers' Reported Use of Phenomenon-Based Learning in Secondary STEM Classrooms." Tennessee State University, 2022.

[42] B. Pratiwi, J. Copriady, and L. Anwar, "Implementation of phenomenon-based learning e-module to improve critical thinking skills in thermochemistry material," *Jurnal Pendidikan Sains Indonesia*, vol. 9, no. 4, pp. 575–585, 2021. https://doi.org/10.24815/jpsi.v9i4.21114

[43] G. Gunawan, A. Harjono, L. Herayanti, and S. Husein, "Problem-based learning approach with supported interactive multimedia in physics course: Its effects on critical thinking disposition," *Journal for the Education of Gifted Young Scientists*, vol. 7, no. 4, pp. 1075–1089, 2019. https://doi.org/10.17478/jegys.627162

[44] S. Dehghanzadeh and F. Jafaraghaee, "Comparing the effects of traditional lecture and flipped classroom on nursing students' critical thinking disposition: A quasi-experimental study," *Nurse education today*, vol. 71, pp. 151–156, 2018. https://doi.org/10.1016/j.nedt.2018.09.027

[45] C. Martinez, "Developing 21st century teaching skills: A case study of teaching and learning through project-based curriculum," *Cogent Education*, vol. 9, no. 1, p. 2024936, 2022. https://doi.org/10.1080/2331186X.2021.2024936

[46] I. F. Eze, C. G. Iwu, and J. Dubihlela, "Students' views regarding the barriers to learning critical thinking," *International Journal of Research in Business and Social Science (2147-4478)*, vol. 11, no. 4, pp. 355–364, 2022. https://doi.org/10.20525/ijrbs.v11i4.1797

[47] M. Arifuddin, S. B. Thalib, and M. S. Ali, "The Development of Modeling Physics Learning to Improve Critical Thinking Ability of Student," *Asian Journal of Applied Sciences*, vol. 10, no. 1, 2022. https://doi.org/10.24203/ajas.v10i1.6842

[48] Ö. Ceylan, "The effect of the waste management themed summer program on gifted students' environmental attitude, creative thinking skills and critical thinking dispositions," *Journal of Adventure Education and Outdoor Learning*, vol. 22, no. 1, pp. 53–65, 2022. https://doi.org/10.1080/14729679.2020.1859393

[49] E. Pollarolo, I. Størksen, T. H. Skarstein, and N. Kucirkova, "Children's critical thinking skills: perceptions of Norwegian early childhood educators," *European Early Childhood Education Research Journal*, pp. 1–13, 2022. https://doi.org/10.1080/1350293X.2022.2081349

[50] A. Kosasih, T. Supriyadi, M. I. Firmansyah, and N. Rahminawati, "Higher-Order Thinking Skills in Primary School: Teachers' Perceptions of Islamic Education," *Journal of Ethnic and Cultural Studies*, vol. 9, no. 1, pp. 56–76, 2022. https://doi.org/10.29333/ejecs/994

[51] S. Toker and M. H. Baturay, "Developing disposition to critical thinking and problem-solving perception in instructional design projects for producing digital materials," *International Journal of Technology and Design Education*, vol. 32, no. 2, pp. 1267–1292, 2022. https://doi.org/10.1007/s10798-020-09646-2

[52] H. Moeiniasl, L. Taylor, M. deBraga, T. Manchanda, W. Huggon, and J. Graham, "Assessing the critical thinking skills of English language learners in a first year psychology course," *Thinking Skills and Creativity*, vol. 43, p. 101004, 2022. https://doi.org/10.1016/j.tsc.2022.101004

[53] L. Colucci-Gray and D. Gray, "Critical thinking in the flesh: Movement and metaphors in a world in flux," in *Critical Thinking in Biology and Environmental Education*, Springer, 2022, pp. 21–39. https://doi.org/10.1007/978-3-030-92006-7_2

[54] J. Potter, "Critical analysis of critical thinking," *Journal of Media Literacy Education*, vol. 14, no. 1, pp. 108–123, 2022. https://doi.org/10.23860/JMLE-2022-14-1-8

[55] K. Iordanou, "Supporting critical thinking through engagement in dialogic argumentation: taking multiple considerations into account when reasoning about genetically modified food," in *Critical Thinking in Biology and Environmental Education*, Springer, 2022, pp. 93–111. https://doi.org/10.1007/978-3-030-92006-7_6

[56] M. R. Ridwan, H. Retnawati, and S. Hadi, "Teachers' Perceptions in Applying Mathematics Critical Thinking Skills for Middle School Students: A Case of Phenomenology.," *Anatolian Journal of Education*, vol. 7, no. 1, pp. 1–16, 2022. https://doi.org/10.29333/aje.2022.711a

[57] I. M. Zannrni, "Measuring Students' Critical Thinking," *Cihan University-Erbil Journal of Humanities and Social Sciences*, vol. 6, no. 1, pp. 54–58, 2022. https://doi.org/10.24086/cuejhss.v6n1y2022.pp54-58

[58] M. Pareken, A. J. Patandean, and P. Palloan, "Penerapan Model Pembelajaran Berbasis Fenomena terhadap Keterampilan Berpikir Kritis dan Hasil Belajar Fisika Peserta Didik Kelas X SMA Negeri 2 Rantepao Kabupaten Toraja Utara," *Jurnal Sains dan Pendidikan Fisika (JSPF)*, vol. 11, no. 3, pp. 214–221, 2015.

[59] K. Islakhiyah, S. Sutopo, and L. Yulianti, "Scientific explanation of light through phenomenon-based learning on junior high school student," in *1st Annual International Conference on Mathematics, Science, and Education (ICoMSE, 2017)*, 2017, pp. 141–153. https://doi.org/10.2991/icomse-17.2018.31

[60] K. Islakhiyah, S. Sutopo, and L. Yulianti, "Scientific Explanation of Light through Phenomenon-based Learning on Junior High School Student," vol. 218, no. ICoMSE 2017, pp. 173–185, 2018. https://doi.org/10.2991/icomse-17.2018.31

[61] M. Kalogiannakis and S. Papadakis, "The use of developmentally mobile applications for preparing pre-service teachers to promote STEM activities in preschool classrooms," in *Mobile Learning Applications in Early Childhood Education*, IGI Global, 2020, pp. 82–100. https://doi.org/10.4018/978-1-7998-1486-3.ch005

[62] J. F. Symeonidis, V., & Schwarz, "Phenomenon-based teaching and learning through the pedagogical lenses of phenomenology: The recent curriculum reform in Finland," *Forum Oświatowe*, vol. 28, no. 2, pp. 31–47, 2016.

[63] S. Papadakis, J. Vaiopoulou, E. Sifaki, D. Stamovlasis, M. Kalogiannakis, and K. Vassilakis, "Factors That Hinder in-Service Teachers from Incorporating Educational Robotics into Their Daily or Future Teaching Practice.," in *CSEDU (2)*, 2021, pp. 55–63. https://doi.org/10.5220/0010413900550063

[64] S. Papadakis and M. Kalogiannakis, "Exploring preservice teachers' attitudes about the usage of educational robotics in preschool education," in *Research Anthology on Computational Thinking, Programming, and Robotics in the Classroom*, IGI Global, 2022, pp. 807–823. https://doi.org/10.4018/978-1-6684-2411-7.ch035

[65] A. Swandi, S. Rahmadhanningsih, I. Yusuf, and S. W. Widyaningsih, "Exploring the Compton Scattering Phenomenon with Virtual Learning Under Project Based Learning Model (PjBL)," *Kasuari: Physics Education Journal (KPEJ)*, vol. 4, no. 1, pp. 1–12, 2021. https://doi.org/10.37891/kpej.v4i1.159

[66] S. Papadakis, J. Vaiopoulou, E. Sifaki, D. Stamovlasis, and M. Kalogiannakis, "Attitudes towards the use of educational robotics: Exploring pre-service and in-service early childhood teacher profiles," *Education Sciences*, vol. 11, no. 5, p. 204, 2021. https://doi.org/10.3390/educsci11050204

[67] S. Hadiryanto and D. Thaib, "Inquiry Based Learning Model Natural Phenomena to Improve The Curiousity and Mastery of Teh Concept of Junior High School Student," *EduHumaniora| Jurnal Pendidikan Dasar Kampus Cibiru*, vol. 7, no. 1, 2015. https://doi.org/10.17509/eh.v7i1.2782

[68] P. W. Santhalia and L. Yuliati, "An Exploration of Scientific Literacy on Physics Subjects within Phenomenon-based Experiential Learning," *Jurnal Penelitian Fisika dan Aplikasinya (JPFA)*, vol. 11, no. 1, 2021. https://doi.org/10.26740/jpfa.v11n1.p72-82

[69] S. Schmidt-Lauff and R. Bergamini, "The modern phenomenon of adult learning and professional time-sensitivity–a temporal, comparative approach contrasting Italy and Germany," *Adult learning and education in international contexts: Future challenges for its professionalization*, p. 147, 2022.

[70] L. M. Cahyani, K. Kristiani, and M. Sabandi, "The phenomenon of academic procrastination during the Covid-19 pandemic influenced by academic resilience and social support," *Pegem Journal of Education and Instruction*, vol. 13, no. 1, pp. 41–49, 2023. https://doi.org/10.47750/pegegog.13.01.05

[71] S. Amponsah, M. M. van Wyk, and M. K. Kolugu, "Academic experiences of 'Zoom-Fatigue' as a virtual streaming phenomenon during the COVID-19 pandemic," *International Journal of Web-Based Learning and Teaching Technologies (IJWLTT)*, vol. 17, no. 6, pp. 1–16, 2022. https://doi.org/10.4018/IJWLTT.287555

[72] M. Armario, J. M. Oliva, and N. Jiménez-Tenorio, "Spanish preservice primary school teachers' understanding of the tides phenomenon," *International Journal of Science and Mathematics Education*, vol. 20, no. 7, pp. 1361–1386, 2022. https://doi.org/10.1007/s10763-021-10209-7

[73] G. Bini, O. Robutti, and A. Bikner-Ahsbahs, "Maths in the time of social media: conceptualizing the Internet phenomenon of mathematical memes," *International Journal of Mathematical Education in Science and Technology*, vol. 53, no. 6, pp. 1257–1296, 2022. https://doi.org/10.1080/0020739X.2020.1807069

[74] M. C. Munkejord and L. Tingvold, "Challenging Behaviors as a Relational Phenomenon: Findings From a Qualitative Study in a Nursing Home in Norway," *Global Qualitative Nursing Research*, vol. 9, p. 23333936221123331, 2022. https://doi.org/10.1177/23333936–221123331

[75] S. Sugiyono, "Metode penelitian pendidikan:(pendekatan kuantitatif, kualitatif dan R & D). Bandung: Alfabeta." CV, 2015.

[76] C. A. Dewi, "Improving creativity of prospective chemistry teacher through chemo entrepreneurship oriented inquiry module on colloid topics," in *Journal of Physics: Conference Series*, 2019, vol. 1156, no. 1, p. 12017. https://doi.org/10.1088/1742-6596/1156/1/012017

[77] C. C. A. Dewi, M. Erna, I. Haris, and I. N. Kundera, "The effect of contextual collaborative learning based ethnoscience to increase student's scientific literacy ability," *Journal of Turkish Science Education*, vol. 18, no. 3, pp. 525–541, 2021. https://doi.org/10.36681/tused.2021.88

[78] S. ŽivkoviĿ, "A model of critical thinking as an important attribute for success in the 21st century," *Procedia-social and behavioral sciences*, vol. 232, pp. 102–108, 2016. https://doi.org/10.1016/j.sbspro.2016.10.034

[79] K. Slemmons *et al.*, "The Impact of Video Length on Learning in a Middle-Level Flipped Science Setting: Implications for Diversity Inclusion," *Journal of Science Education and Technology*, vol. 27, no. 5, pp. 469–479, 2018. https://doi.org/10.1007/s10956-018-9736-2

[80] B. C. E. Oguguo, F. A. Nannim, J. J. Agah, C. S. Ugwuanyi, C. U. Ene, and A. C. Nzeadibe, "Effect of learning management system on Student's performance in educational measurement and evaluation," *Education and Information Technologies*, vol. 26, no. 2, pp. 1471–1483, 2021. https://doi.org/10.1007/s10639-020-10318-w

[81] N. J. Vickers, "Animal communication: when i'm calling you, will you answer too?," *Current Biology*, vol. 27, no. 14, pp. R713–R715, 2017. https://doi.org/10.1016/j.cub.2017.05.064

[82] B. Sanjaya, D. Djamas, Festyed, and Ratnawulan, "Initial studies for development of interactive multimedia modules assisted games to increase the critical thinking skill of Senior High School students," *Journal of Physics: Conference Series*, vol. 1185, no. 1, 2019. https://doi.org/10.1088/1742-6596/1185/1/012139

[83] A. Syawaludin and P. Rintayati, "Development of Augmented Reality-Based Interactive Multimedia to Improve Critical Thinking Skills in Science Learning.," *International Journal of Instruction*, vol. 12, no. 4, pp. 331–344, 2019. https://doi.org/10.29333/iji.2019.12421a

[84] L. A. Andrew and P. M. Baxter, "Incorporating innovative simulation activities into campus lab to enhance skill competence and critical thinking of second-semester associate degree nursing students," *Nursing Education Perspectives*, vol. 40, no. 1, pp. 58–59, 2019. https://doi.org/10.1097/01.NEP.0000000000000321

[85] M. J. Chae and S. H. Choi, "Effectiveness of student learning with a simulation program focusing on cardiac arrest in knowledge, self-confidence, critical thinking, and clinical performance ability," *Korean Journal of Adult Nursing*, vol. 28, no. 4, pp. 447–458, 2016. https://doi.org/10.7475/kjan.2016.28.4.447

[86] X. D. Tang, Y. Yin, Q. Lin, R. Hadad, and X. Zhai, "M.(2020). Assessing computational thinking: A systematic review of empirical studies," *Computers & Education*, vol. 148, p. 103798. https://doi.org/10.1016/j.compedu.2019.103798

[87] Dewi, C. A., Awaliyah, N., Fitriana, N. ., Darmayani, S. ., Nasrullah, Setiawan, J. ., & Irwanto, I. "Using Android-Based E-Module to Improve Students' Digital Literacy on Chemical Bonding", *International Journal of Interactive Mobile Technologies (iJIM)*, *16*(22), pp. 191–208, 2022. https://doi.org/10.3991/ijim.v16i22.34151

8 Authors

Asyti Febliza is a Lecturer in the Chemistry education program at Universitas Islam Riau, Kaharuddin Nasution 113, Riau-Indonesia. She also works as a teacher training instructor for teachers in the school in Riau (Email: asytifebliza@edu.uir.ac.id).

Zul Afdal is an Assistant Professor in the Economic education program at Universitas Negeri Padang, Prof. Dr Hamka Street, Air Tawar Barat, Padang-Sumatera Barat Indonesia, 25135. He is a scientific researcher in education and economics (Email: zulafdal@fe.unp.ac.id).

Jimmi Copriady is a Professor in the Chemistry education program at Universitas Riau, Bina Widya KM 12.5 Riau-Indonesia. He is a Deputy Academic Dean at Universitas Riau. He is a scientific researcher in education and chemistry (Email: jimmy.c@lecturer.unri.ac.id).

Article submitted 2022-08-14. Resubmitted 2022-12-12. Final acceptance 2022-12-12. Final version published as submitted by the authors.