

# Students' Critical Thinking Skills during the Pandemic through Online GI-DMM

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## ABSTRACT

The COVID-19 pandemic has transformed the higher education system in Indonesia, where faculty members and students must learn online to prevent and minimize virus transmission. The purpose of this study was to determine the impact of online GI-DMM (Group Investigation-Digital Mind Map) on the critical thinking skills of college students. This study is quasi-experimental and used a pretest-posttest non-equivalent control group design. Fifty-four students from STKIP PGRI West Sumatra, Indonesia participated in this study. Data were collected using twelve essay questions and a scoring rubric used to measure six indicators of critical thinking ability, namely Focus, Reason, Conclusion, Situation, Clarity, and Overview (FRISCO). Data analysis was performed using ANCOVA followed by tests for normality and homogeneity of variance. The results showed a statistically significant difference in critical thinking between the online GI-DMM group and the online conventional DMM group. The critical thinking score of the students enrolled in the GI-DMM online course was higher (80.07) than that of the students engaged in traditional learning (71.06). Consequently, GI-DMM can be used in online learning to improve the critical thinking skills of students in higher education during the COVID-19 pandemic and the new post-pandemic era.

**Key words:** critical thinking skills, college students, online GI-DMM, online conventional-DMM

## INTRODUCTION

Educational institutions in Indonesia must be prepared for the advancement of science and technology in the 21st century. They need to ensure their graduates are globally competitive and equipped with 21st century skills such as critical thinking (Kharbach, 2012). Critical thinking is a reflective thinking skill used to make decisions on what should be believed or done (Ennis, 2013). Critical thinking is important for examining and evaluating assumptions as well as verifying conclusions (Myers, 2023). Critical thinking skills are higher order thinking skills that aid in problem solving and decision making (Facione, 2011). Anyone can benefit from critical thinking, especially in education. Therefore, critical thinking skills are essential for achieving educational goals (Moon, 2008).

According to research conducted in Indonesia, students' critical thinking skills are still lacking (Valentoya & Brecka, 2020; Dholo et al, 2018; Rusmansyah et al, 2019). In line with this, a preliminary study conducted at STKIP PGRI in West Sumatra revealed that the university students possessed inadequate critical thinking skills, where 82.4% of the students struggled to connect one concept to another (Rahmatika, Lestari & Sari, 2020). Another study revealed that students enrolled in one Taxonomy of Higher Plants course exhibited poor critical thinking skills. The study showed that these students had difficulty comprehending the material concerning gymnosperms and angiosperms,

because the topics were presented in the form of rote theories. The complexity of scientific name system in Latin or the classification of living things failed to capture students' attention. In addition to that, the instructor did not utilize appropriate instructional strategies to teach the material.

Inadequately developed learning processes, in which instruction is primarily theoretical and repetitive, may contribute to a lack of critical thinking skills among students. Critical thinking skills, which include the processes of analyzing, synthesizing, and evaluating, are inadequately taught in the classroom (Rosba, Zubaidah, Mahanal & Sulisetijono, 2021). Additionally, the appropriate pedagogical

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strategy to develop students' critical thinking skills in higher education has yet to be discovered. However, it is crucial to enhance the learning process in the classroom, particularly to adapt to learning conditions during the COVID-19 pandemic.

The COVID-19 pandemic (corona virus disease 2019) has been spreading very quickly and almost to all countries, so the World Health Organization (WHO) declared this outbreak a global pandemic in March 2020 (Chukusol & PiriyaSurawong, 2022). This pandemic has affected all aspects of life in Indonesia, including education, economy, culture, and society (Lai, 2011). Particularly in the field of education, the learning process at different educational levels, from elementary school to college, has shifted from face-to-face to online mode. Online learning is the remote acquisition of knowledge through the internet and other aiding technologies, such as smartphones, computer devices, and laptops (BBC, 2020). Due to the simultaneous nature of learning (Dolighan & Owen, 2021), the use of smartphones in the classroom may make learning more engaging and encouraging for students (Latifah et al, 2020).

Because of these changes, educators need to enhance their skills to facilitate distance learning (Papadakis, Kalogiannakis, Sifaki & Vidakis, 2018). In the pandemic era, educators must innovate the learning process by implementing strategies or learning models that meet the needs of online learning. Besides, the use of media and tools is crucial to support the process of teaching and learning. Learning innovation is essential for molding students' cognitive abilities during online learning during the pandemic. To accommodate all the objectives, Group Investigation (GI) can be applied.

Group Investigation (GI) is one of the innovative learning models that can be used to improve students' critical thinking in higher education. Group Investigation can motivate students to actively complete assignments, analyze, and assess their knowledge (Laili & Natsir, 2021). The GI instructional model aims to improve all abilities and experiences of students relevant to learning in cognitive and social domains (Friedman & Friedman, 2020). However, stages in GI are extremely complex, especially when implemented in an online classroom. The GI learning process incorporates teaching-learning dimensions and student collaboration in skill formation (Ahiri, Yuniarsih & Rasto, 2018). Therefore, it is crucial to present a tool, such as the Digital Mind Map (DMM), to facilitate the implementation of GI in the learning process.

College students can use Digital Mind Map (DMM) to conceptualize knowledge, exchange ideas, and organize concepts. DMM also aids students in acquiring knowledge and carefully resolving problems (Mite & Corebima, 2017). DMM is advantageous to students because it assists them

in shaping, organizing, and visualizing cognitive processes during learning. In addition, DMM stimulates students' critical thinking, creativity, and collaboration skills and boosts their confidence in contributing to classroom discussions (Waluyo, 2018). Consequently, the combination of Digital Mind Map and Group Investigation can facilitate learning throughout the pandemic.

Online Group Investigation and Digital Mind Map (GI-DMM) creates a collaborative learning environment in which students conduct DMM-assisted investigations individually and in groups (Umami, 2016). Through social media platforms such as WhatsApp and Zoom, GI-DMM can be implemented online. Social media contribute to online learning by enabling users to communicate, collaborate, and share via available platforms (Miler, 2019). Moreover, online GI-DMM makes students accountable for their own education (Rosba, Zubaidah, Mahanal & Sulisetijono, 2021). The GI-DMM learning model is based on constructivist theory, which directs students to self-regulate and play an active role in learning by setting goals and evaluating their progress (Selwyn, 2011). Because of this, online GI-DMM can improve students' thinking skills. Through available media platforms, the online GI-DMM also helps students develop their own knowledge and hone their critical thinking skills.

The preceding description explains the online learning problems that have been happening in the field and the desired outcomes for online learning during the pandemic. Considering the benefits of GI and DMM, it is necessary to conduct a study to determine the impact of GI-DMM integration in higher education online courses on students' critical thinking skills. This study was conducted to determine the impact of online GI-DMM on students' critical thinking skills.

## METHOD

### Research Design

The current study was a quasi experimental in nature, employing the pretest posttest nonequivalent control group design. The pretest and the posttest were conducted to two treatment groups, namely experimental and control. The experimental group received treatment in the form of online GI-DMM learning, while the control group was involved in an online conventional-DMM classroom. The design of the study is presented in Table 1.

**Table 1: Research Design**

<i>Treatment Group</i>	<i>Pre-test</i>	<i>Treat-ment</i>	<i>Post-test</i>
Online GI-DMM (experimental)	O <sub>1</sub>	X <sub>1</sub>	O <sub>2</sub>
Online conventional-DMM (control)	O <sub>3</sub>	X <sub>2</sub>	O <sub>4</sub>

## Participants

The research population contained all four-semester students from the 2018-batch group who were actively enrolled in the target university courses during the academic year of 2019/2020. The research sample consisted of fifty-four students from two different classes who were taking the Taxonomy of Higher Plants course at STKIP PGRI Sumatera Barat, Indonesia. An equivalence test, i.e., t-test was performed using the students' grade point average as the data. The test was done to examine the equivalence of the participants' academic ability. The test results showed that the average GPA of both classes did not differ significantly (class A = 3.28, class B = 3.34). These results indicated that both classes were equivalent in terms of academic ability. Therefore, the selection of the experimental and control groups was done randomly. The experimental (online GI-DMM) group consisted of 28 students, while the control (online conventional-DMM) group consisted of 26 students.

## Research Procedures

The initial phase of this study was to conduct a pretest via Zoom. The pretest was distributed to participants from the experimental and control classes. The pretest was carried out in the form of a written test consisting of 12 essay questions on gymnosperms and angiosperms. After completing the pretest, both classes conducted the learning process with different learning models for eight sessions. The experimental class learned using the online GI-DMM model, while the control class was facilitated with the online conventional-DMM model. The learning steps in the two treatment classes are shown in Table 2. The conclusion of the study was the post-test, which was assigned to the experimental and control

classes via zoom. Generally, the learning process was done through Zoom breakout rooms, WhatsApp voice note, and WhatsApp video calls.

## Research Instruments

A written test was used as the instrument to collect data on participants' critical thinking skills. The test contained 12 essay questions, such as "Student A and Student B discussed the most advanced open seed plants among the gymnosperm plant groups. Student A said *Gnetum gnemon* was the most advanced plant while B chose *Cycas rumphii*. What do you think is the correct answer? provide arguments!"

Students' responses to the test were assessed using a critical thinking rubric developed by Zubaidah et al. and Finken & Ennis (2001). The rubric measures six indicators of critical thinking, namely Focus, Reason, Conclusion, Situation, Clarity and Overview (FRISCO). The test questions were subjected to a validity test. Each item scored between 0.334 and 0.735 (valid). The test was also declared reliable after passing the Cronbach alpha test (0.657).

## Data Analysis

Data analysis was performed in *three* stages as follows.

1. Participants' critical thinking score was analyzed using the following formula:  $X \times 100$
2. Participants' pretest and posttest results were analyzed using tests for normality (Kolmogorov-Sminov) and homogeneity of variance (Levenes test). The results showed a value of 0.745 for the normality of the pretest score and a value of 0.290 for the normality of the posttest score. These numbers suggest that the research data

**Table 2. The Learning Phases and Learning Activities conducted in the Online GI-DMM and Online Conventional-DMM Classrooms**

Organizing students into groups	Students are assigned into heterogeneous groups based on their academic ability levels (upper, middle, lower) sedang, bawah). Each group consists of 4-5 students. The assignment of the group assignment is delivered via zoom.	Motivating students	Motivating students to learn the material that is going to be discussed via zoom
Selecting the discussion topic and planning tasks	Group representatives select a topic shared via WhatsApp group. The group leader divides the task to his/her members. Each of the group members is responsible for their own task. This activity should be announced via WhatsApp group.	Delivering the learning material	The lecturer delivers the material via zoom.

<i>Online GI-DMM</i>		<i>Online Conventional-DMM</i>	
<i>Learning Phases</i>	<i>Learning Activities</i>	<i>Learning Phases</i>	<i>Learning Activities</i>
Conducting an investigation	Every group member conducts an individual investigation by observing parts of a plant. They send photos or videos containing the investigation results to the zoom breakout room, WA Voice Note and WA Video Call.	Answering questions	The lecturer asks the students to answer questions on the topic via Zoom Breakout Room, WA Voice Note or WA Video Call.
Preparing an investigation report	The results of the individual investigation are analyzed and discussed in groups. The discussion results are written in a report. The report will be presented via zoom breakout room, WhatsApp video call.	Delivering the answers to the questions	The lecturer asks students to deliver their answers via Zoom Breakout Room, WA Voice Note or WA Video Call.
Presenting the report	Each group sends their representative to present the results of the group investigations via zoom.	Providing reinforcement	The lecturer provides reinforcement.
Conducting an evaluation	Each group member evaluates or summarizes the lesson in the form of a digital mind map, saves it in pdf format and emails it to the lecturer.	Conducting an evaluation	The lecturer asks students to conclude the lesson and write the summary in the form of a digital mind map, save it in pdf format and email it to the lecturer.

was normally distributed. Meanwhile, the homogeneity test showed  $p > 0.05$ , with the pre-test data receiving the p-value of 0.548 and the post-test data receiving the p-value of 0.705. This result showed that the homogeneity of the research variance was satisfied.

- After ensuring the normality and homogeneity of the data, ANCOVA was performed to examine the impact of the learning model on students' critical thinking skills.

## FINDINGS

The results of ANCOVA showed that online GI-DMM had an impact on college students' critical thinking skills (Table 3).

**Table 3. The ANCOVA Results**

<i>Source</i>	<i>Type III Sum of Squares</i>	<i>df</i>	<i>Mean Square</i>	<i>F</i>	<i>Sig.</i>
Corrected Model	1590.609a	2	795.305	20.235	.000
Intercept	9021.821	1	9021.821	229.545	.000
pretest	425.994	1	425.994	10.839	.002
Model	1090.998	1	1090.998	27.759	0.000
Error	2004.459	51	39.303		
Total	313306.535	54			
Corrected Total	3595.068	53			

Table 3 showed an F-calculated value of 27.759 with a significance value of 0.000, which is less than alpha 0.05. This result indicated that online GI-DMM had an impact on participants' critical thinking skills. The ANCOVA results served as the basis for the mean score analysis. Table 4 shows the results of the mean analysis obtained by the treatment groups.

Table 4 shows the difference between the two treatment groups in terms of critical thinking scores, where the online GI-DMM group obtained a higher mean score (80.07) than the online conventional-DMM (71.06). Thus, it can be concluded that the experimental (online GI-DMM) group

**Table 4. Analysis of the Participants' Mean Scores on Critical Thinking**

No	Model	Pre test	Post test	Difference	Mean Score
1.	Online GI-DMM	47.24	80.20	32.96	80.07
2.	Online Conventional-DMM	46.23	70.91	24.68	71.06

achieved better than the control (online conventional-DMM) in critical thinking skills.

This study proved that online GI-DMM differed significantly from conventional online DMM in improving critical thinking skills in college students. This result is consistent with those of Thashwinny and Prabha (2020) who found that mind mapping helps students express ideas openly, think in directions, and better express their feelings (Chrayah, El Kadiri, Sbihi & Akin, 2012). In addition, mind mapping offers opportunities for students to develop critical thinking (Hall & Zarro, 2012).

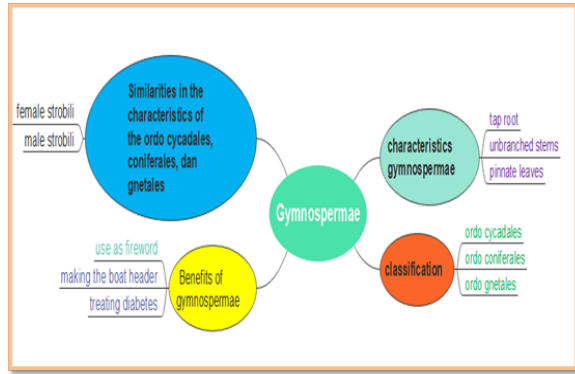
The online GI-DMM learning model can greatly improve students' critical thinking skills because the phases in the online GI-DMM, specifically conducting investigations, preparing reports, presenting reports, and conducting assessments, are designed to support the development of critical thinking. For example, in the investigating phase, students worked together to collect information from different sources on the topic under investigation. In the investigating phase, students analyzed and clarified the information, then discussed it with other students via Zoom breakout rooms, WA voice notes, and WA video calls. Through the investigation process, the students exchanged information and practiced independent thinking (Pahmi & Niah, 2021). They became more understanding of what was being examined because they must find answers to the questions themselves, which were later checked together in the group for their truthfulness (Thaswinny & Prabha, 2020). Collaboration empowers students to build their knowledge and develop critical thinking (Paloya & Vejacka, 2022). In this study, students actively solved existing learning problems using worksheets provided online (Zoom Breakout Room). These students seemed confident in voicing their ideas to other students who were also in the breakout room.

In the next phase of the online GI-DMM, each group wrote an investigation report. The students seemed to try to write down the correct concepts based on the results of the investigation, supported by relevant online learning resources, and to combine each group member's thoughts. Writing research reports helps college students build their knowledge (Mohaidat, 2018). Therefore, it can be said that in this phase the process of knowledge formation took place for the second time; the first happened during the investigating phase.

Even though the report writing activity was conducted online, it could indirectly encourage critical thinking in students.

The fourth phase of the online GI-DMM is the online presentation of investigation reports. At this stage, all groups were required to make interesting presentations on various topics explored during the inquiry process, allowing all students to gain a broad perspective on the topic and develop critical thinking skills. Interestingly, at this stage, it was seen that the students were actively involved in asking questions. With online learning, students cannot meet in person, but they can ask questions and present their arguments in discussion forums because they do not have to be afraid or ashamed of making mistakes. Supiandi & Ege (2017) said that presentations can shape students' critical thinking skills because students can transform their knowledge by asking or answering questions as well as expressing opinions (Zingaro, 2008). In addition, a confident presentation testifies to a livelier understanding, in which the student can find in-depth answers to problems in the investigation process (Asyari, Al Muhdar, Susilo & Ibrohim, 2017). This stage helps students reflect on the knowledge they gained during the investigating process. In addition, online presentations also led to social interaction between the students, which enables the students to develop their character (Adnan & Zamari, 2012).

The fifth or final phase of the online GI-DMM is conducting an evaluation. In this phase, the students reflected on their learning process by rewriting their learning experiences and knowledge in a digital mind map. The mind maps were collected and emailed to the instructor. This stage affected students' memory and indirectly affected their critical thinking skills. Knowledge built up by students stays in their memory for a long time (Zingaro, 2008). In addition, the GI-DMM learning model can improve student learning outcomes more accurately, effectively, and efficiently (Fuad, Zubaidah, Mahanal & Suarsini, 2017; Mittal, Kaur & Jain, 2022; Ismail & Balariksman, 2016). The online learning process during the pandemic has not hampered the formation of critical thinking processes in students. The existence of online learning applications can make a real contribution to the online learning process. Figure 1 shows a digital mind map created by one of the research participants before learning online with the GI-DMM model, while Figure 2 shows a digital mind map



**Fig. 1: An Example of a Digital Mind Map Created by Participants during the Pretest**

created by the participant after going through the online GI-DMM learning process .

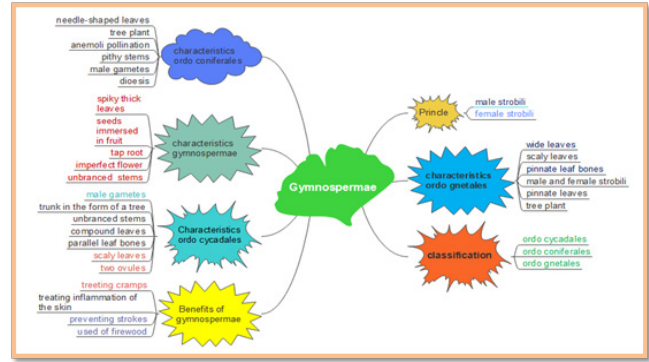
The digital mind map in Figure 1 has only four main branches that contain less related concepts. The number of branches formed by this student is small, as it is assumed that the student had little knowledge of the material to be taught in class. Students can think critically when they have prior knowledge of the material being taught in the classroom. Students' thinking abilities can be seen from the branch structure of a mind map (Fuad, Zubaidah, Mahanal & Suarsini, 2017).

Figure 2 shows a digital mind map created by a student in the experimental class. The mind map contains six main branches of related concepts in gymnosperms. The mind map shows a clear direction of thought as the concepts covered are interrelated. In addition, the language used in the mind map is also easy for the reader to understand. The student was also able to answer the questions correctly using the mind map (Jamaluddin, Zubaidah, Mahanal & Gofur, 2022). These answers are straightforward. Thus, it can be concluded that the student has mastered critical thinking, particularly in relation to the indicators Focus, Reason, Conclusion, Situation, Clarity, and Overview (FRISCO).

In general, the results of this study suggest that online GI-DMM is effective in improving college students' critical thinking skills. The online GI-DMM allows students to conduct independent research, create and present reports, and evaluate the learning process via social media platforms such as WhatsApp and Zoom. Through the online GI-DMM, college students can develop and apply existing knowledge, add new knowledge, and develop critical thinking skills.

## CONCLUSION

The current study proved that the online GI-DMM model was more effective in increasing college students' critical thinking than the online conventional-DMM learning model.



**Figure 2. An Example of a Digital Mind Map Created by Participants during the Post-test**

Learning stages in the online GI-DMM learning model are ideal stages that can empower students to think critically. The results of this study can be used as a consideration for using GI-DMM online learning as an alternative learning model to improve critical thinking skills of college students in the New Normal era. However, this study suffers from limitations due to the research subjects, as the study was only conducted on biology department students during the COVID-19 pandemic. Therefore, future research is recommended to examine the effectiveness of online GI-DMM at different educational levels and for different student groups.

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## REFERENCES

- Adnan, A. H. M. & Zamari, Z. M. (2012). "I am a Techno-Rebel!" Malaysian academics & their personal experiences of progressing into e-Learning. *Procedia - Social and Behavioral Sciences*, 67, 61-72
- Ahiri, Y., Yuniarsih, T & Rasto. (2018) The Effect of Reciprocal Teaching and Group Investigation Toward Students' Critical Thinking. *International Journal of Education, Learning and Development*. Vol.6, No.3, 37-46
- Asyari, M., Al Muhdar, M.H.I, Susilo, H & Ibrohim. (2017). Improving Critical Thinking Skills Through the Integration of Problem Based Learning and Group Investigation. *International Journal for Lesson and Learning Studies*, 5(1), 36-44
- BBC. (2020). Coronavirus: Windows of Opportunity to Act, World Health Organization Says. Retrieved December, 2021, from <https://www.bbc.com/news/world-asiachina-51368873>

- Chukusol, C & Piriyasurawong, P. (2022). Development of Flipped Classroom using Cloud-Based Learning and Board Games Model to Enhance Critical Thinking Skills, *TEM J.* vol. 11, no. 1, pp. 94-103. Doi: 10.18421/TEM111-11.
- Chrayah, M., El Kadiri, K. E., Sbihi, B., & Aknin, N. (2012). Brainstorming 2.0: Toward collaborative tool based on social networks. *International Journal of Advanced Computer Science and Applications*, 3(8), 115e120.
- Dolighan T, Owen M. (2021) Teacher efficacy for online teaching during the COVID-19 pandemic. *Brock Educ J.* ;30(1):95.
- Dholo, T.F., Firman, H., Kaniawati, I & Rusdiana, D. (2018). Profile of critical thinking skills of pre-service physics teachers: a preliminary study. *International Conference on Mathematics and Science Education (ICMScE 2018)*. IOP Conf. Series: Journal of Physics: Conf. Series 1157(2019) 032059 doi:10.1088/1742-6596/1157/3/032059
- Ennis, R.H. 2013. *The Nature of Critical Thinking: Outlines of General Critical Thinking Dispositions and Abilities*. (Online), (<http://www.criticalthinking.net/longdefinition.html>)
- Facione, P.A. 2011. *Think Critically*. Englewood Cliffs, NJ. Pearson Education.
- Fuad, N.M., Zubaidah, S., Mahanal, S., & Suarsini, E. (2017). Improving junior high schools critical thinking skills based on test three different models of learning. *International Journal of Instruction*, 10(1), 101-116.
- Friedman, L. W., Friedman, H. H. (2020). Using social media technologies to enhance online learning. *Journal of Educators Online*, 10(1), 1-22.
- Hall, C., & Zarro, M. (2012). Social curation on the website. *Proceedings of the American Society for Information Science and Technology*, 49(1), 1e9. <https://doi.org/10.1002/meet.14504901189>. Pinterest.com
- Ismail Md. Zain & M. Balakrishnan. (2016). *ASIE Instructional Design Model for the 21st Century Learning: An Integrated Approach In Instructional Designing for Teachers*. Saarbrucken, Deutschland. Germany: School's Press. Pub.novak
- Jamaluddin, A.B., Zubaidah, S., Mahanal. S & Gofur, A. (2022). Exploration of the Indonesian Makassar-Buginese Siri' educational values: The foundation of character education. *International Journal of Evaluation and Research in Education (IJERE)*. 11(1). 10.11591/ijere.v11i1.21670
- Kharbach, M. 2012. *The 21st Century skills Teachers and Student Need to Have*. Halifax: Creative Commons Attribution Mount Saint Vincent University
- Lai, R.E. (2011). *Critical Thinking: a literature review*, The United Kingdom: Pearson
- Laili, R.N & Natsir, M. (2021). Higher Education Students' Perception on Online Learning during Covid-19 Pandemic. *Edukatif*. Vol. 3 No. 3.
- Latifah, S., Koderi, Firdaos, R., Khoeriyah, E.T., Hidayah, N & Ahmad, M.N.F. (2020). The Influence of Mobile Instant Messaging with Scientific Approach on Srtudents' Critical-Thingking Skills in Physics Learning During Covid-19 Pandemic. *Young Scholar Symposium on Science Education and Environment (YSSSEE)*. *Journal of Physics: Conference Series* 1796, 012057 IOP Publishing doi: 10.1088/1742-6596/1796/1/012057
- M. Mohaidat (2018). The Impact of Electronic Mind Maps on Students' Reading Comprehension. *English Language Teaching*; 11(4).
- Mite, Y & Corebima, A. D. (2017). The Correlation Between Critical Thinking And The Learning Results Of The Senior High School Students In Biology Learning Implementing Group Investigation (GI) Learning In Malang, Indonesia. *Journal of Applied and Advanced Research*, 2(2): 56–62. doi.: 10.21839/jaar.2017.v2i2.57.
- Miller, F. (2019). The 25 Best Mind Mapping Software. <https://productivityland.com/best-mind-mapping-software/>
- Mittal, P.,Kaur, A & Jain, R. (2022). Online Learning for Enhancing Employability Skills in Higher Education Students: The Mediating Role of Learning Analytics. *TEM J.* vol.11, no.4, pp. 1469-1476. Doi: 10.18421/TEM114-06
- Myers, D.G. 2003. *Exploring Psychology*. New York: Worth.
- Moon, J. 2008. *Critical Thinking: An Exploration of Theory and Practice*. New York: Taylor and Francis Group.
- Papadakis, S., Kalogiannakis, M., Sifaki, E & Vidakis, N. (2018). Evaluating Moodle use via Smart Mobile Phones. A case study in a Greek University. *EAI Endorsed Transactions on Creative Technologies* 04 2018 - 07 2018 | Volume 5 | Issue 16 | e1.
- Pahmi & Niah, S. (2021). Students' Voices Towards Online Debate Through WhatsApp as Alternative Media to Enhance Critical Thinking Skills During Covid-19 Pandemic. *ijIM-Vol. 15, No, 05*.
- Palova, D & Vejacka, M. (2022). Project-based Learning in the University Course and its Effectiveness. *TEM J.* vol. 11, no. 4, pp. 477-1484. Doi: 10.18421/TEM11407
- Rusmansyah, Yuanita, L., Ibrahim, M., Isnawati & Prahani, B.K. (2019). Innovative Chemistry Learning Model: Improving the Critical Thinking Skill And Self-Efficacy of Pre-Service Chemistry Teachers. *Journal of Technology and Science Education JO-TSE*, 9(1): 59-76 – Online ISSN: 2013-6374 – Print ISSN: 2014-5349 <https://doi.org/10.3926/jotse.555>
- Rahmatika, H., Lestari, S.R & Sari, M.S. (2020). Preliminary Study of PBL-Based E-Module Development Based on Research Results to Improve Students' Critical Thinking Skills and Cognitive Learning Outcomes. *The 4th International Conference on Mathematics and Science Education (ICoMSE)*. AIP Conf. Proc. 2330, 0300467-1-030046-7; <https://doi.org/10.1063/5.0043319>
- Rosba, E., Zubaidah, S., Mahanal, S & Sulisetijono. (2021). College students' critical thinking skills and creativity. *AIP Conference Proceedings* 2330, 070016; <https://doi.org/10.1063/5.0043294>
- Rosba, E. Zubaidah, S. Mahanal, S & Sulisetijono. 2021. Digital Mind Map Assisted Group Investigation Learning for College Students' Creativity. *International Journal Interactive Mobile Technologies*. Vol.15 No. 5
- Supiandi, M.I & Ege, B. (2017). The Effect Of Group Investigation (GI) Learning Model on the Student Problem Solving Ability and Students Academic Achievement on the Digestive System Material for Biology Students. *Anatolian Journal of Education*.

- Selwyn, N. (2011). Social media in higher education. In Gladman, A., (Ed.), *The Europa world of learning* (pp. 1-9). London, UK: Routledge.
- Thashwinny & Prabha (2020). Effectiveness of Using Poly Category Mind Map for Vocabulary Development. *Arab World English Journal (AWEJ)* 11(2).
- Umami, R. (2016). The Effectiveness of using Digital Mind Mapping Toward The Students' Achievement in Writing Descriptive Text to the First Grader at MAN 2 Tulungagung in Academic Year 2015/2016. Thesis. English Education Department Faculty of Tarbiyah and Teacher Training. IAIN Tulungagung.
- Waluyo, E. (2018). The implementation of group investigation, problem based learning and critical thinking in geometry learning. *Int. J. Adv. Res.* 6(12), 1282-1288.
- Zingaro, D. (2008). *Group Investigation: Theory and Practice*. Ontario Institute for Studies in Education, Toronto, Ontario.