Students' Scientific Literacy and Critical Thinking Skills: A Pre-Post Study on the Implementation of GI-MM

Indah Panca Pujiastuti[1✉], **Muhammad Mifta Fausan**[2]
(1,2) Biology Education Study Program, Universitas Sulawesi Barat, Indonesia

✉ Corresponding author
[indah_panca@unsulbar.ac.id]

Abstrak

Pembelajaran di tingkat universitas saat ini ditujukan untuk mendorong mahasiswa menguasai keterampilan tingkat tinggi, seperti keterampilan literasi sains dan berpikir kritis. Penelitian ini bertujuan untuk mengetahui perbedaan literasi sains dan berpikir kritis pada mahasiswa sebelum dan setelah dibelajarkan dengan model Group Investigation-Mind Mapping (GI-MM). Penelitian ini merupakan penelitian kuasi eksperimen dengan menggunakan rancangan One-group pretest-posttest design. Populasi dalam penelitian ini adalah seluruh mahasiswa sedang memprogram mata kuliah biokimia yang berjumlah total 55 mahasiswa. Selanjutnya dengan menggunakan teknik cluster random sampling, dipilih satu kelas (jumlah mahasiswa= 19 orang) yang berperan sebagai sampel penelitian. Instrumen yang digunakan dalam penelitian ini yaitu soal tes tertulis berbentuk pilihan ganda untuk mengukur literasi sains mahasiswa, dan soal tes tertulis berbentuk uraian untuk mengukur berpikir kritis mahasiswa. Analisis data yang digunakan adalah analisis deskriptif dan inferensial (uji t-berpasangan). Hasil penelitian menunjukkan bahwa semua indikator literasi sains mahasiswa menunjukkan peningkatan setelah dilakukan penerapan model GI-MM (rerata peningkatan 40,04%). Selain itu, rerata skor pretest dan posttest untuk lima indikator berpikir kritis mahasiswa juga terlihat adanya peningkatan yang signifikan setelah dilakukan penerapan model pembelajaran GI-MM (rerata peningkatan 61,43%). Hasil uji t-berpasangan memperkuat bahwa terdapat perbedaan signifikan keterampilan literasi sains dan berpikir kritis pada mahasiswa sebelum dan setelah dibelajarkan dengan model pembelajaran GI-MM.

Kata Kunci: *group investigation-mind mapping, literasi sains, berpikir kritis.*

Abstract

University-level learning is currently aimed at encouraging students to master high-level skills such as scientific literacy and critical thinking skills. This study aimed to determine the differences in scientific literacy and critical thinking among students before and after being taught using the Group Investigation-Mind Mapping (GI-MM) model. This quasi-experimental study used a one-group pretest-posttest design. The study population comprised of 55 students enrolled in a biochemistry course. Using the cluster random sampling technique, one class (19 students) was selected as the research sample. The instruments used in this study were multiple-choice written test questions to measure students' scientific literacy, and essay-type written test questions to measure students' critical thinking. Descriptive and inferential analyses were used for data analysis (paired t-test). The results showed that all indicators of students' scientific literacy improved after implementation of the GI-MM model, with an average increase of 40.04%. In addition, the mean pretest and posttest scores for the five indicators of students' critical thinking showed significant improvement after implementation of the GI-MM learning model, with an average increase of 61.43%. The paired t-test results reinforced the finding that there were significant differences in the students' scientific literacy and critical thinking skills before and after being taught using the GI-MM learning model.

Keyword: *group investigation-mind mapping, scientific literacy, critical thinking.*

INTRODUCTION

University-level learning is currently aimed at encouraging students to master high-level skills such as scientific literacy. Scientific literacy is the understanding of scientific concepts used as the main capital in problem solving (Fausan et al., 2022), as well as describing problems based on real evidence (Fives et al., 2014). Through scientific literacy, students can face the development of science and technology (Widayoko et al., 2019); and link science to society (Archer-Bradshaw, 2017). Scientific literacy has become the basis of studying many other disciplines (Blyznyuk, 2019). Relevant research has revealed that scientific literacy skills can improve students' thinking skills, formulate questions, and find answers (Jufrida, 2019). Scientific literacy has become a fundamental goal of university-level education, preparing students not only for academic success but also for meaningful engagement with the scientific and technological aspects of our increasingly complex world. As scientific advancements continue to shape society, the importance of scientific literacy in higher education is likely to grow even further, cementing its place as a critical skill for 21st century learners.

Another important skill that students are expected to master in the 21st century is critical thinking. Critical thinking skills are skills in processing intellectual activities through analysis, discovery, and evaluation as a means of solving problems (Arsih, et al., 2019); creating new ideas/concepts and key skills (Saleh, 2019). Critical thinking skills can help students convey material correctly and accurately, in accordance with scientific development (Ristanto et al., 2020). Empowering critical thinking skills is necessary. This is supported by relevant research results, which have revealed that critical thinking skills can improve students' academic achievement in biology and as a manifestation of logical thinking (Fitriani et al., 2020). Furthermore, the development of critical thinking skills aligns with the goals of inquiry-based learning and scientific methods. By cultivating these skills, educators aim to prepare students not only for academic success but also for the challenges they face in their future careers and personal lives.

Students' scientific literacy and critical thinking skills have not been optimally developed (Sutiani, 2021), resulting in a low level of understanding of biological learning (Setiawati & Corebima, 2017). This condition is in line with the results of a preliminary study conducted from July to August 2023 in the Biology Education Program, Universitas Sulawesi Barat. Empirical facts about scientific literacy skills have found that the biology learning process still emphasizes expository learning and lacks investigative activities; therefore, students play less active roles in constructing their concepts. The results of the written test in the preliminary study also showed that the average score of students' critical thinking skills was 2.7 and was in the underdeveloped category.

These problems require solutions in the form of implementing learning models based on a constructivist approach, one of which is the Group Investigation (GI) model (Arsy et al., 2020). GI is a cooperative learning model that encourages students to conduct group investigations in an effort to solve problems (Asyari et al., 2017). GI learning has been proven to improve scientific literacy skills (Nenti et al., 2022), stimulate critical thinking (Purbiyati, 2021; Rosiani et al., 2020), and increase activities (Fauzi et al., 2021). GI learning also has shortcomings, including: (a) students are less courageous in expressing opinions during discussions because their understanding of the material is still low (Achmad et al., 2018); and (b) students with low cognitive levels find it difficult to follow learning activities (Disurya & Hamzah, 2022).

The shortcomings of GI learning can be strengthened by integrating the Mind Mapping (MM) method into learning. MM is the process of mapping thoughts to connect concepts (Shi et al., 2022). The in-depth thinking done by students during the preparation of MM will indirectly make them master the material being studied, so that applied GI learning can take place well and minimize the shortcomings of GI learning. The advantages of MM include improving students' scientific literacy skills (Hariyadi et al., 2023) and critical thinking (Wu & Wu, 2020). Furthermore, the collaborative nature of MM can foster group discussions and peer learning, addressing the social aspects that may be lacking in traditional GI learning models. Consequently, the GI-MM is a learning model that integrates group investigation activities with mind mapping techniques, wherein students collaboratively investigate a topic, collect information, and visualize their understanding through the creation of mind maps. Students not only work together to solve problems, but also utilize mind mapping to deepen their comprehension of the material and enhance their critical thinking and scientific literacy skills.

The problem statements proposed in this study are as follows: 1). Is there a difference in scientific literacy among students before and after being taught using the group investigation-mind mapping model?, 2). Is there a difference in critical thinking among students before and after being taught using the group investigation-mind mapping model?

METHOD

This quasi-experimental study used a one-group pretest-posttest design. This means that, in this study, tests were conducted at the beginning of learning (pre-test) and at the end of learning (post-test) in the experimental class. The population in this study consisted of all students enrolled in the biochemistry course, totaling 55 students from the three classes. Using the cluster random sampling technique, one class (19 students) was selected as the research sample.

The instrument used to measure scientific literacy was a multiple-choice written test, with item development referring to aspects of scientific literacy according to Gormally et al. (2012), including valid scientific arguments, validity of sources, use and misuse of scientific information, elements of experimental design and their influence on scientific findings or conclusions, graphical representation of data, quantitative skills, basic statistical skills, conclusions, predictions, and conclusions based on quantitative data. An essay test was used to measure critical thinking. Five aspects of critical thinking were assessed as adapted from Finken & Ennis (1993): focus, supporting reasons, organization, grammar rules, and integration. Table 1 lists the instruments used in this study.

Table 1. Research Instruments

No	Variable	Instrument	Number of Questions
1	Scientific Literacy	Multiple-choice written test questions	21 questions
2	Critical Thinking	Essay-type written test questions	5 questions

The data analysis was descriptive and inferential. Descriptive analyses included mean, median, standard deviation, minimum, and maximum values. In the inferential statistical analysis, a prerequisite test was first performed, namely, the normality test using the Shapiro-Wilk test. If data were normal, a paired t-test was performed. All analyses were performed using the SPSS software.

RESULTS AND DISCUSSION

Students' Scientific Literacy

Scientific literacy consisted of eight indicators adapted from Gormally et al. (2012): valid scientific arguments, source validity, the use and misuse of scientific information, elements of experimental design and their influence on scientific findings or conclusions, graphical representation of data, quantitative skills, basic statistical skills, conclusions, predictions, and conclusions based on quantitative data. The mean pre- and post-test scores for students' scientific literacy are shown in Table 2. To make it easier to understand, the scientific literacy data are also visualized in Figure 2. Descriptive statistics of the scientific literacy data are presented in Table 3. The normality test of the scientific literacy data is presented in Table 4. Table 5 presents the results of the paired t-tests.

Table 2. Pretest and Posttest Scores of Scientific Literacy

No	Scientific Literacy Indicators	Mean	
		Pretest	Posttest
1	Valid scientific arguments	57.89	87.72
2	Source validity	71.05	78.95
3	Use and misuse of scientific information	65.79	81.58
4	Elements of experimental design and their influence on scientific findings	44.74	78.95
5	Graphical representation of data	50.00	76.32
6	Quantitative skills	59.65	70.18
7	Basic statistical skills	31.58	65.79
8	Conclusions, predictions, and conclusions based on quantitative data	59.65	77.19

As shown in Table 2, all indicators improved after the implementation of the GI-MM learning model. The most significant improvements were observed in the indicators "Valid scientific arguments" (from 57.89 to 87.72) and "Elements of experimental design and their influence on scientific findings or conclusions" (from 44.74 to 78.95). Although it experienced significant improvement, the "Basic Statistical Skills indicator had the lowest score in the posttest (from 31.58 to 65.79).

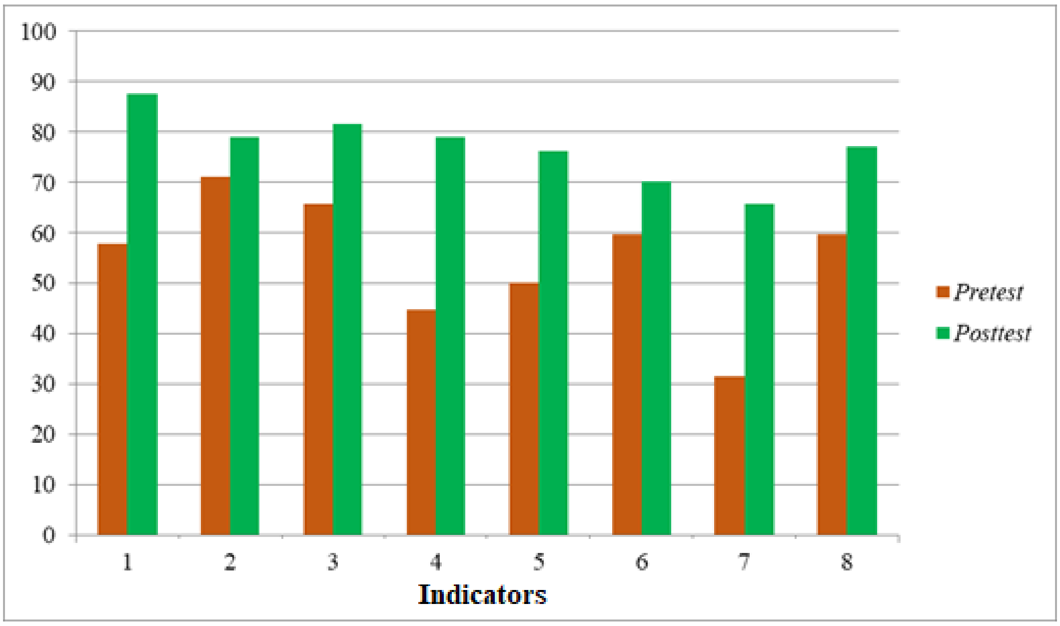

Figure 1. Pretest and Posttest Scores for Each Student's Scientific Literacy Indicator

Figure 1 shows the improvements across all indicators after implementation of the GI-MM learning model. The most significant improvements were observed in the indicators "Valid scientific arguments" (from 57.89 to 87.72) and "Elements of experimental design and their influence on scientific findings or conclusions" (from 44.74 to 78.95). "Basic statistical skills" showed substantial improvement from 31.58 to 65.79, although it remained the indicator with the lowest score, indicating an area that might require further attention. The "Source validity" indicator experienced the smallest improvement (from 71.05 to 78.95), possibly because students already had a fairly good initial understanding.

Table 3. Descriptive Statistics of Students' Scientific Literacy

	Mean	Median	Std. Deviation	Minimum	Maximum
Pretest Scientific Literacy	55.13	57.14	10.91	38.10	80.95
Posttest Scientific Literacy	77.19	76.19	9.98	57.14	90.48

Table 3 presents the descriptive statistics for the overall student scientific literacy data. The mean pre-test score was 55.13 with a standard deviation of 10.91, whereas the mean post-test score increased to 77.19 with a standard deviation of 9.98. This increase in mean indicates a substantial improvement in students' scientific literacy after implementation of the GI-MM learning model. The minimum and maximum values also increased, with the minimum score rising from 38.10 to 57.14 and the maximum score rising from 80.95 to 90.48, showing that improvement occurred across all student abilities.

Table 4. Normality Test of Students' Scientific Literacy

	Shapiro-Wilk		
	Statistic	df	Sig.
Difference between Pretest and Posttest Scientific Literacy	.914	19	.087

Lilliefors Significance Correction

Table 4 displays the results of the Shapiro-Wilk normality test for the difference between the pre-test and post-test scientific literacy scores. With a statistical value of 0.914 and significance value of 0.087 (greater than the threshold of 0.05), it can be concluded that the difference score data were normally distributed. This met the normality assumption required for further analysis using the paired t-test.

Table 5. Paired T-Test Results of Students' Scientific Literacy

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference: Lower	Upper			
Pair 1	Pretest Scientific Literacy – Posttest Scientific Literacy	-22.05526	10.78939	2.47526	-27.25558	-16.85494	-8.910	18	.000

Table 5 presents the results of the paired t-test for the students' scientific literacy data. The mean difference between the pre- and post-test scores was -22.05526, indicating a significant improvement. The calculated t-value of -8.910 with 18 degrees of freedom (df) and a significance value (p-value) of 0.000 (far below the threshold of 0.05) indicated that this difference was statistically significant. The 95% confidence interval for the mean difference ranged from -27.25558 to -16.85494, further strengthening the conclusion that there was a significant and consistent improvement in students' scientific literacy after the implementation of the GI-MM learning model. Thus, it can be concluded that there was a significant difference in the students' scientific literacy before and after being taught using the GI-MM learning model ($p = 0.000 < 0.05$).

The significant difference in students' scientific literacy was also supported by the Group Investigation-Mind Mapping (GI-MM) learning steps, which included identifying topics, planning investigations, conducting investigations, preparing presentations, presenting investigation results, composing mind maps, and conducting evaluations. GI is a cooperative learning model that encourages students to conduct investigations in groups to find, analyze, and solve problems (Asyari et al., 2017), while Mind Mapping helps them visualize and organize complex information into simpler and easier to understand forms. Therefore, the implementation of the GI-MM had a positive impact on students' scientific literacy due to several factors. First, the students worked in groups that allowed them to share different knowledge and perspectives, enriching their understanding of scientific topics. Second, the investigation, which was conducted in groups, encouraged students to think analytically and critically, which are important components of scientific literacy. Third, the use of Mind Mapping helped students organize information and visualize the relationships between concepts, making it easier for them to remember and apply the knowledge they acquired.

The rational reason why scientific literacy is important for empowering learning because it is one of the main keys to facing challenges in the 21st century (United Nations Environment Programme, 2012), provides a broad understanding of science and rapid scientific developments to an individual (DeBoer, 2000), and is used to achieve science learning objectives (Fakhriyah et al., 2017). Another rational reason why scientific literacy needs to be empowered is because it is needed by students to be able to think and act on social and scientific issues, which can affect their quality of life (Solomon, 2021). A scientifically literate person can be competent in science, as they can place science as a basis for identifying relevance, namely, learning to see the significance of science to necessary things (Feinstein, 2010). Students with good scientific literacy showed a high level of sensitivity and concern for environmental problems. In addition, they also have the ability to make appropriate decisions using scientific knowledge that is appropriate to their level of education (Wulandari & Sholihin, 2016).

The findings of this study are in line with the results of Patta et al. (2023), who reported that the Group Investigation learning model had an effect on scientific literacy skills. This could be seen from the scientific literacy abilities of students after using the group investigation learning model, which showed an increase, as evidenced by the higher average post-test score than the average pretest score. The integration of Group Investigation and Mind Map was also previously reported by other researchers; for example, Ciptasari & Iswari (2023), who reported that the application of the Group Investigation (GI) learning model with Mind Mapping was effective in increasing student learning motivation, and Afifah et al. (2023), who reported that the application of the Group Investigation learning model assisted by Digital Mind Map (GI-DMM) had an effect on student learning outcomes in the cognitive domain.

The implementation of the group-investigation learning model had a positive effect on improving students' scientific literacy skills and cognitive learning outcomes. These results are consistent with previous studies which also found that the integration of group investigation with mind mapping or digital mind mapping was effective in increasing students' motivation and learning achievement. Therefore, by combining GI with MM, this study made a novel contribution by showing that this blend of methods was particularly effective in overcoming specific challenges in scientific literacy, such as the ability to analyze and synthesize complex scientific information and scientific arguments.

Students' Critical Thinking

Critical thinking indicators have five components, adapted from Finken & Ennis (1993): focus, supporting reasons, organization, grammar rules, and integration. The mean pre- and post-test scores for students' critical thinking are presented in Table 6. For easier understanding, the critical thinking data are also visualized in Figure 3. The descriptive statistics of the critical thinking data are presented in Table 7. The normality test for critical thinking data is presented in Table 8. Table 9 presents the paired t-test results.

Table 6. Pretest and Posttest Scores of Students' Critical Thinking

No	Critical Thinking Indicators	Mean	
		Pretest	Posttest
1	Focus	52.9	77.6
2	Supporting reasons	35.3	67.9
3	Organization	47.6	74.2
4	Grammar rules	48.9	74.5
5	Integration	43.2	73.7

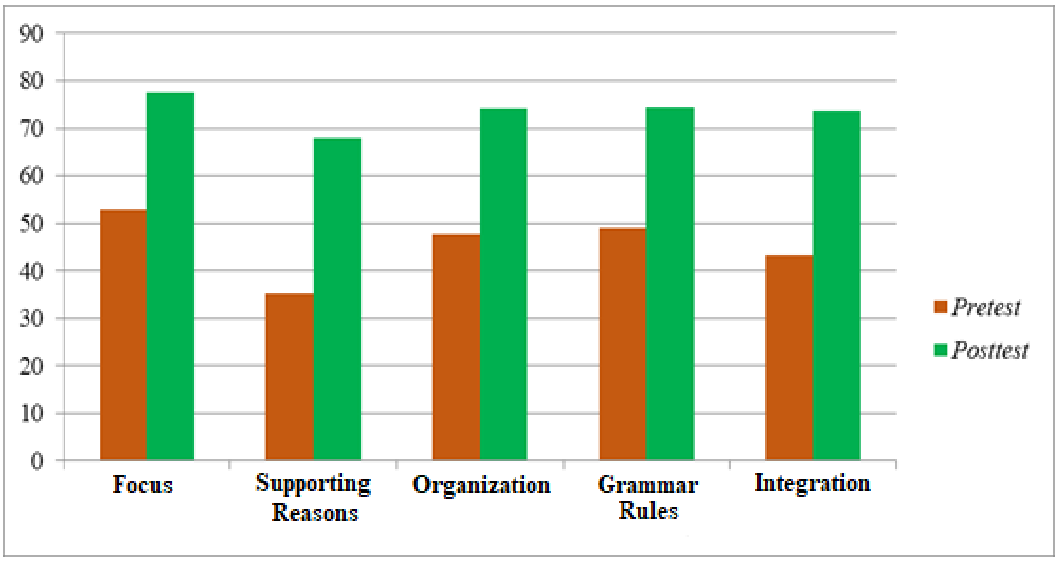

Figure 2. Pretest and Posttest Scores for Each Critical Thinking Indicator

Table 6 shows the mean pre- and post-test scores for the five indicators of the students' critical thinking. There was a significant improvement in all indicators after implementation of the GI-MM learning model. The "Focus" indicator had the highest mean in both pretest (52.9) and posttest (77.6), while "Supporting reasons" showed the largest increase from 35.3 to 67.9. Overall, the data in Table 6 indicate a substantial improvement in students' critical thinking skills across all the measured aspects.

Figure 2 shows a comparison between the pre-test and post-test scores for each critical thinking indicator. The blue bars represent the pre-test scores, whereas the orange bars indicate the post-test scores. This visualization emphasizes the improvement that occurred across all indicators. Thus, the significant height difference between the pre-test and post-test bars for each indicator provided a clear visualization of the effectiveness of the GI-MM learning model implementation in improving various aspects of students' critical thinking.

Table 7. Descriptive Statistics of Students' Critical Thinking

	Mean	Median	Std. Deviation	Minimum	Maximum
Critical Thinking Pretest	45.57	45.00	9.38	30.00	66.00
Critical Thinking Posttest	73.57	76.00	7.60	56.00	85.00

Table 7 presents descriptive statistics of the students' critical thinking data. In the pre-test, the mean score was 45.57 with a standard deviation of 9.38, whereas in the post-test, the mean score increased to 73.57 with a standard deviation of 7.60. The increase in the minimum score from 30.00

to 56.00 and the maximum score from 66.00 to 85.00 also showed consistent improvement across all student groups.

Table 8. Normality Test of Students' Critical Thinking

	Shapiro-Wilk		
	Statistic	df	Sig.
Pretest-Posttest Difference in Critical Thinking	.820	19	.114

a. Lilliefors Significance Correction

Table 8 displays the Shapiro-Wilk normality test results for the difference between pre-test and post-test critical thinking scores. With a statistical value of 0.820 and a significance of 0.114 (greater than 0.05), it was concluded that the pretest-posttest difference data were normally distributed. This met the normality assumption required for further analysis using the paired t-test.

Table 9. Paired T-Test Results of Students' Critical Thinking

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference: Lower	Upper			
Pair 1	Critical Thinking Pretest–Posttest	-28.0000	8.5114	1.9527	-32.1024	-23.8976	-14.339	18	.000

Table 9 shows the paired t-test results for the students' critical thinking data. The mean difference between the pre-test and post-test was -28.0000, with a standard deviation of 8.5114. A t-value of -14.339 with 18 degrees of freedom (df) and a significance value (p-value) of 0.000 (less than 0.05) indicated that there was a statistically significant difference between the pre-test and post-test scores. Thus, it was concluded that there was a significant difference in critical thinking among students before and after being taught using the GI-MM ($p = 0.000 < 0.05$).

Several steps in the GI-MM learning model supported the development of students' critical thinking skills. The first stage was topic identification. In identifying the investigation topics, students were in situations that required them to focus on thinking about important and relevant topics. The focus was on one of the components assessed in critical thinking (Ennis, 2011); therefore, in these situations, students had to think critically to determine the best investigation topic. Second stage: Planning the investigation. At this stage, each group was required to develop an investigative plan. Planning and critical thinking activities were reported to be compatible because planning requires a comprehensive internal debate about achieving goals optimistically and appropriate methods to achieve them. Third Stage: Conducted the Investigation. When the students conducted the investigations, they analyzed the data, discussed them, and analyzed their findings. Specifically, each group found information from various sources, compared and evaluated source relevance, explained and expanded the knowledge and information, and formulated answers to the initial questions. These activities empowered critical thinking skills in terms of the organization. However, it has also been reported that mind mapping as a learning method is a solution for improving students' critical thinking abilities (Sari & Murdiono, 2021).

The results of this study align with the findings of Santyasa et al. (2018) that the GI learning model is superior to direct learning models in terms of achieving critical thinking in science learning. The empowerment of critical thinking in science classes must be implemented so that students can provide logical reasons, solve given problems, make decisions carefully by considering various perspectives, and maintain a good focus (Marin & Halpern, 2011; Saputri et al., 2018; Sasson et al., 2018).

CONCLUSION

Based on the results and discussion, this study concluded that there were significant differences in scientific literacy and critical thinking among students before and after being taught using the Group Investigation-Mind Mapping (GI-MM) learning model ($p = 0.000 < 0.05$). The implementation of the GI-MM learning model had a positive impact on students' scientific literacy and critical thinking because the students worked in groups that allowed them to share different knowledge and perspectives, enriching their understanding of the studied topics. The investigation, conducted in groups, encouraged students to think analytically and critically, which are important components of scientific literacy. The use of Mind Mapping helped students organize information and visualize the relationships between concepts, making it easier for them to remember and apply the knowledge they had acquired.

Lecturers can maximize the GI-MM model by carefully designing group compositions to ensure diverse levels of knowledge and backgrounds, and gradually introducing mind mapping complexity. As for recommendations for future research, it would be advisable to investigate the long-term effects of GI-MM on students' scientific literacy and critical thinking to assess how these skills develop and persist over time.

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