Enhancing students' creativity in problem-solving through online reading-concept mapping-group investigation

Nur Lina Safitri, Siti Zubaidah, Fatchur Rohman, Sulisetijono

Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Malang, Indonesia

Article Info	ABSTRACT
	Enhancement of students' creativity and problem-solving is essential to science education. The learning accentuating students' interaction to generate creative ideas becomes the ideal forum for developing those two skills. This study aims to amplify the current understanding of the effects of reading-concept mapping (Remap)–cooperative learning on college students' creative and problem-solving skills. For cooperative learning, we used group investigation (GI). This study involved 60 college students from three Biology Education classes. Further, each class consists of 20 students with Remap-GI, GI, and conventional learning. The analysis results suggested that the creativity and problem-solving skills of students from all classes increased, with the most significant increase observed in students attending Remap-GI class which also presented substantial differences from the other two classes. In conclusion, GI presents positive effects in enhancing prospective teachers' skills. However, an additional structured program (Remap) is still required to improve the future teachers' contribution to their group.
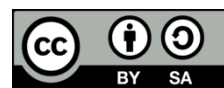
Corresponding Author:

Siti Zubaidah
Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang
Jalan Semarang No 5, Malang, East Java, Indonesia
Email: siti.zubaidah.fmipa@um.ac.id

1. INTRODUCTION

Creativity and problem-solving skills must be incorporated into science learning [1]. As these two skills can stimulate someone's career path, they attain greater concern in science education [2]. Creativity represents flexibility and fixation during problem-solving [3]. Through high creativity, students can employ a more broad perspective in examining an issue, developing ideas, and resolving undefined problems [4]. Creativity and problem-solving are intercorrelated and interdependent. Their interdependency places these two skills as crucial in 21st-century curriculum development [2].

A number of studies suggested that creativity and problem-solving skills are stimulated by several contextual factors [5], [6], such as the teacher's characteristics [7]. An educator plays essential roles in developing students' creativity and problem-solving skills [4]. Accordingly, teachers have to transform their teaching practice following students' needs [8]. Besides, teachers must have the capacity to provide supportive and encouraging facilities to improve students' creativity skills for the problem-solving process [9].

In addition, developing students' creativity also requires a social setting that enables students to conduct self-exploration to generate innovative ideas [10]. Further, that environment helps students exchange ideas and information, which later aids them in enhancing their learning efficiency using creative means [9]. Therefore, teachers are expected to provide training on cooperative work for students [11]. Accordingly, to influence students' learning outcomes, cooperative learning should be implemented in the learning

process [12]. Cooperative learning has been acknowledged as a pedagogical means that positively affects students' creative [13] and problem-solving skills [14].

However, cooperative learning cannot be carried out simply by asking students to work in groups [15]. Collaborative learning requires a structured work allocation and individual accountability [16]. Further, a previous study suggested that cooperative learning did not improve personal accountability [17]. To date, only a minimum number of teachers can formulate innovative means for the cooperative learning process by constructing a data collection system [14]. Accordingly, we need a specific effort to help students complete their work so they do not incriminate another group member [18].

A previous study reported that students' problem-solving skills could be accelerated if the students have sufficient comprehension of the problem while understanding the procedure and pattern [3]. Another research described that direct reading airs students construct creative problem-solving [2]. Besides, teachers must emphasize students' conceptual understanding during cooperative learning [19]. Thus, students must build their initial knowledge, such as through reading and creating map concepts activities, before the cooperative learning process.

This study explores the differences between students who attended learning using reading-concept mapping (Remap)-cooperative learning (with problem-solving and creativity enhancement) and those with conventional learning. In this study, Remap was positioned as the primary element of structured cooperative learning. Besides, group investigation (GI) was selected as the cooperative learning implemented in this study for several reasons. First, this model encourages students to resolve a problem based on various perspectives or ideas [20]. Second, it improves the learning level, further enhancing individual accountability (participation, interaction, and investigation) [21]. Therefore, GI is a robust and effective type of cooperative learning to increase problem-solving [22] and creative thinking skills [23]. Another research also reported that Remap-GI improved students' thinking and skills [24].

This study was conducted to identify the student's creativity and problem-solving skills after they attended learning using Remap-GI. Further. We used quasi-experiment to compare the creative and problem-solving skills of a group of students who attended learning using Remap-GI and those attending learning with GI and conventional methods. Further, we also analyzed the capacity of Remap to improve students' role in the cooperative learning process conducted online. Thus, this study also promotes online learning.

Generally, many students do not favor online learning as they feel isolated and perceive online learning as accentuating high independence [25], [26]. This shortcoming obstructs students' further participation and high-order thinking skills [27]. Also, we aimed to report the means to overcome these hindrances and promote the students' creativity and problem-solving skills in online learning. Thus, this study filled the gap by identifying the positive effects of Remap-GI on students' skills during online learning, as a previous study has confirmed the positive impact of cooperative learning during online learning [28].

2. RESEARCH METHOD

2.1. Participant and design

This study used a quasi-experimental approach with a pretest-posttest nonequivalent control group design [29] in evaluating the differences between GI-Remap class (class A), GI-only class (class B as a positive control group) and conventional class with discussion-presentation (class C as a negative control group). The learning efficiency of these three classes was evaluated. The learning was carried out online using an e-learning platform provided by the university for asynchronous and synchronous models (video conference and google meeting).

In this study, 60 students from the Biology Education Department of one of the private institutions in East Java, Indonesia, participated. They were divided into three classes. At the beginning of the semester, all students in classes A and B used GI for two sessions (one session per week and 100 minutes per session). Meanwhile, class C used conventional learning. In the first two meetings, students were given explanations related to the details of the learning process. During this adaptation, the student's initial skills were also measured. Class A was given additional reading and concept (Remap) learning model, while classes B and C were given the same model. Further, the same learning model was applied until the fifteenth meeting. In the last session, we measured students' skills to identify the effects of each learning model.

2.2. Procedure

This study was completed through some stages. We sent a permission letter to the target university in the initial step. After we obtained the permission, we attained informed consent from the candidate of participants. During this stage, we explained our research procedure and told the candidate they have the right to walk out of the research at any time. They also said that the variables measured throughout the research would not affect their scores.

In the end, 60 students agreed to participate in this study voluntarily. They were not obligated to attend every session, but they must be present in 14 out of 16 meetings and attend the pretest and posttest in the first and last meetings. All of the 60 students have agreed and fulfilled this minimum requirement. Therefore, we obtained complete data and proceeded with the data analysis process. The same lecturer taught all the classes with five years of experience in cell courses. All the class were given the same learning topics, namely cell course development in Biology, the concept of the cell, the position of the cell in an organism, structure, and function of the plasma membrane, cell communication and death, structure and function of energy-producing organelles, structure and function of the nucleus as the center of information, as well as organelles that regulate life at the cellular level.

2.3. Intervention

The interventions provided in classes A, B, and C were Remap-GI, GI, and discussion-presentation learning methods. The learning process of these three classes was carried out online, synchronously, and asynchronously. The example of learning activities for cell development in Biology material is summarized in Table 1 [24], [30].

Two non-participant observers supervised the learning and ensured that all learning models were carried out properly by filling out the observation sheet. At the end of the period, the observers calculate their scores to achieve agreement. The average calculation showed a higher kappa index than 80%.

Table 1. Intervention in three classes

	Class B	Class C	Syntax (mode)	Activity
✓	-	-	Reading (asynchronous)	Students were asked to read the materials related to cell biology and general analysis technique for cell biology (SEM, PCR, Microsatellites, and so forth) to build their initial knowledge
✓	-	-	Creating a map concept (asynchronous)	Students were assigned to make a map concept based on their reading results as a summary of information they had collected.
✓	✓	✓	Identifying topics and forming groups (synchronous)	Students were provided four topics of plasmolysis, SEM, the difference between animal and plant cells, and PCR. Ther, they were asked to form a group of four to five people.
✓	✓	-	Designing investigation (synchronous)	Students were asked to determine the topic for their investigation and formulate their design of the investigation. For instance, if the students selected a topic of differences between animal and plant cells, then their design of investigation is practice or experiment.
✓	✓	-	Investigating (synchronous)	Students gather data and information from different sources, such as through an experiment on the cell of *Lumbricina sp* (worm) and *Allium cepa* (shallot).
✓	✓	✓	Writing a final report (synchronous)	Students construct a final report using the results of their GI in the form of a map concept.
✓	✓	✓	Presenting investigation results (synchronous)	In groups, the students orally presented their work and held a question-and-answer session. Then, they also stated the evaluation related to their learning process.

2.4. Instrument

We used two instruments in this study, namely the test of creativity and problem-solving skills, in the form of an open-ended question. We developed these two instruments. Then, these instruments were validated by three experts in Biology from Indonesia concerning their content and face validity. The results of empirical try-out involving students from Biology education showed that both instruments were valid and reliable as the p-value from coefficient correlation was 0.05 and more than 0.70 Cronbach alpha.

2.4.1. Test of creativity

Students' creativity was evaluated using an essay test adapted from Greenstein [31]. The creativity test included many creativity indicators, such as curiosity, fluency, originality, elaboration, imagination, and flexibility. The example of the creativity question and the assessment rubric is presented in Table 2.

2.4.2. Test of problem-solving

Students' problem-solving skills were measured using an essay test adapted from Polya [32]. The problem-solving essay test consisted of some indicators such as problem identification, problem-solving plan development, information gathering, and analysis, as well as interpreting the findings and problem-solving. The example of the problem-solving skills question item and its assessment rubric adapted from the Association of American Colleges and University [33] is presented in Table 3.

Table 2. Example of question in creativity test and its assessment rubric

Material	Indicator and item	Rubric
Development of knowledge in cells in the biology field	A human is an organism that consists of groups of cells. Each part of the human body contains many cells. These groups of cells originate from stem cell division. Therefore, a cell is regarded as the fundamental of a living creature. One of the cell knowledge development in Biology is stem cell therapy. This therapy is believed to be capable of c healing the damaged cells caused by chronic diseases. 1. Based on the description, what question emerged in your mind? (indicator: curiosity) 2. Can you mention some reasons for cell damage? (indicator: fluency) 3. Please write down some solutions to cure the damaged cells. (indicator: originality) 4. If you need treatment for healing the damaged cells, what do you have in mind related to the cell condition in your body? Mention some. (indicator: imagination) 5. Please provide some alternatives for people with cell damage symptoms aside from cell therapy. (indicator: flexibility) 6. Please mention some other options for stem cell therapy and elaborate on your alternative, from the simplest to the most complex options. (indicator: elaboration)	Each question item was given 1-4 sores. For instance, for the fluency indicator (creating several ideas), students will get a score of 4 if they write down four alternatives relevant to the question. They were given a score of 3 for writing down three appropriate alternatives, a score of 2 for two relevant alternatives, and a score of 1 for writing down only one or no alternative.

Table 3. Example of problem-solving item and its assessment rubric

Material	Indicator and item	Rubric
Understanding the cell division and cancer cells	Cancer is the third leading cause of highest mortality in Indonesia, after heart disease and stroke. The Director of Prevention and Control of Non-Communicable Diseases, Directorate of Disease Prevention and Control, dr. Cut Putri Arianie, M.H. Kes mentioned several risk factors for cancer: age, gender or hereditary factor, race, and ethnicity. The director also added that the yearly mortality number of cancer reached 9.6 million by 2018. Meanwhile, in the same year, the annual mortality in Indonesia was 207.210. a. Based on the description, what are the factors of cancer? (indicator: problem identification) b. Please mention and describe four alternatives for preventing the risks of cancer. (indicator: developing problem-solving plan) c. If we observe the cancer problem in Indonesia, one of its risk factors is age. Please analyze that statement. (indicator: information collection and analysis) d. The head of your village conducts a community service collecting data on youth with leukemia in the past year. How will you participate in reducing the number of people with leukemia? (Category: interpreting findings and problem-solving).	Every questionnaire item is given a 1-4 score. For instance, in the indicator of problem identification, students get four scores if they can explain the problem clearly and identify the fundamental issues. They get a score of 3 if they can describe the situation without correlating the problem to its real issues. They attain a score of 2 if they can explain the issue and a score of one if they cannot describe the problem.

2.5. Data analysis

The obtained data were analyzed using descriptive and inferential statistics. The researchers analyzed the mean (M) and standard deviation (SD) for the descriptive statistic. Meanwhile, for the inferential statistic, we carried out an analysis of covariance (ANCOVA) test to identify the learning efficiency in the experiment class and compare it with the other two control classes. If the ANCOVA test generated significant results, we analyzed the data using least-significant-difference (LSD) to find the class with the highest scores and potential and the significant difference from other classes. Before this analysis, the normality and homogeneity of data had been tested using one-sample Kolmogorov-Smirnov and Levene's equality of error variances. The results of these two tests showed that all of our data were homogeneous and normally distributed.

3. RESULTS AND DISCUSSION
3.1. Results
3.1.1. Creativity

All of the students in the three classes had similar initial creativity skills of 46.33 (SD=2.25), 46.71 (SD=2.01), and 45.06 (SD=1.95) for classes A, B, and C, respectively. In contrast, they presented relatively different creative skills at the end of the research. Class A and B had comparable average creativity scores of 94.96 (SD=2.08) and 91.06 (SD=2.60), respectively. Meanwhile, the average creativity for class C was 69.96 (SD=2.11), lower than for classes A and B. The initial and final creativity scores from the three classes are summarized in Table 4.

Table 4. Descriptive statistical calculation results in creativity variable

Class	Test	M	SD
Experiment class (A)	Pretest	46.33	2.25
	Posttest	94.96	2.08
Positive control class (B)	Pretest	45.71	2.01
	Posttest	91.06	2.60
Negative control class (C)	Pretest	45.06	1.95
	Posttest	69.96	2.11

Further, we conducted an ANCOVA test to confirm the significant difference between the three groups. The analysis results presented in Table 5 show significantly different creativity between students who attended Remap-GI class and the ones attending learning using GI and conventional methods (F=1691.955; p=0.000). To find the most effective learning method for enhancing students' creativity, we carried out an LSD test. As presented in Table 6, the LSD results show that students' creativity skills in class A increased by 104.99%. Meanwhile, the students in classes B and C experienced a 99.20 and 55.26% increase in creative skills. From the gap between the average pretest and posttest, we concluded that students in class A (EM score=94.40) presented greater creativity than classes B (EM score=91.05) and C (EM score=70.53). Thus, the Remap-GI learning model has the potential to improve students' creativity.

Table 5. Results of ANCOVA test on creativity variable

Source	Type III sum of squares	df	Mean square	F	Sig.
Corrected model	7441.494a	3	2480.498	1323.197	.000
Intercept	245.420	1	245.420	130.917	.000
Pretest	206.507	1	206.507	110.159	.000
Class	6343.562	2	3171.781	1691.955	.000
Error	104.979	56	1.875		
Total	444367.810	60			
Corrected total	7546.472	59			

Table 6. Results of LSD test on creativity variable

Class	Pretest	Posttest	Difference	EM score	Notation*	Increase (%)
Conventional	45.1	69.96	24.90	70.53	a	55.26
GI	45.7	91.06	45.35	91.05	b	99.20
Remap-GI	46.3	94.96	48.64	94.40	c	104.99

Note: * Different notation represents significant differences with other classes.

3.1.2. Problem-solving

Different from creative skills, students' initial problem-solving skills were slightly different. Class A had an initial problem-solving score of 53.15 (SD=2.08), followed by classes B and C, with scores of 49.72 (SD=6.08) and 46.59 (SD=6.98), respectively. Similarly, students' posttest scores also showed that class A had the highest problem-solving score (M=93.77; SD=4.84), followed by classes B (M=82.84; SD=7.63) and C (M=65.65; SD=6.39). The results of students' problem-solving skills evaluation are presented in Table 7.

Table 7. Descriptive statistic results on problem-solving variable

Class	Test	Average	Std. Deviation
Experiment class (A)	Pretest	53.15	2.08
	Posttest	93.77	4.84
Positive control class (B)	Pretest	49.72	6.08
	Posttest	82.84	7.63
Negative control class ©	Pretest	46.59	6.98
	Posttest	65.65	6.39

In addition, the results of the ANCOVA test presented in Table 8 showed significantly different problem-solving skills of students after the learning process. The results suggested a significant difference in problem-solving skills between the students who attended learning using Remap-GI and those who used GI and conventional learning methods (F=89.056; p=0.000). We carried out the LSD test as a further test to identify the class with the most substantial potential. As shown in Table 9, the LSD results suggested that class A presented the highest problem-solving skills increase of 76.43%, compared to classes B and C, which had 66.62 and 40.91% increases. Additionally, from the difference between the average pretest and posttest scores,

we concluded that class A (EM score=94.36) had better results than classes B (EM score=82.82) and C (EM score=65.08). Consequently, the Remap-GI learning method has more extensive potential to enhance students' problem-solving skills.

Table 8. Results of ANCOVA test on problem-solving skills

Source	Type III sum of squares	df	Mean Square	F	Sig.
Corrected model	8122.038[a]	3	2707.346	64.047	.000
Intercept	8553.665	1	8553.665	202.352	.000
Pretest	84.485	1	84.485	1.999	.163
Class	7529.029	2	3764.515	89.056	.000
Error	2367.192	56	42.271		
Total	401739.130	60			
Corrected total	10489.230	59			

Table 9. Results of LSD test on problem solving variable

Class	Pretest	Posttest	Difference	EM score	Notation*	Increase (%)
Conventional	46.6	65.65	19.06	65.08	a	40.91
GI	49.7	82.84	33.12	82.82	b	66.62
Remap-GI	53.2	93.77	40.62	94.36	c	76.43

Note: * Different notation represents significant differences with other classes

3.2. Discussion

The primary purpose of this study was to compare the effects of three different learning models, consisting of two cooperative GI learning models (with and without Remap) and one conventional learning (discussion and presentation method). Our data analysis results suggested that students attending the GI learning method presented significantly different learning results compared to the other control method (GI and conventional learning), with two main variables of creativity and problem-solving. This study aimed to report the level of Remap-GI efficiency in online learning.

Our finding is linear with the result of a previous study reporting the use of the same learning model increases students' high-order thinking skills in face-to-face learning [24]. Meanwhile, our results confirm the capacity of the Remap-GI learning model to promote student creativity and problem-solving skills in online learning. A combination of Remap and GI learning model reinforce their ability to improve students' cooperative learning features, especially their accountability [16] and cooperation with their colleagues [2], leading to higher creativity and problem-solving skills.

Our analysis results on the first data set suggested that the students attending the experiment class (using the Remap-GI learning model) experienced increasing creativity skills, which were significantly different from the control groups. This finding reinforces the theory describing that creativity can be improved by associating the initial knowledge (through Remap) with the strategy for cultivating cognitive skills (GI) [34]. Studies investigating GI learning models have been massively carried out [20], [23], but this study offered a different context as it used online learning.

The explanation provided during the learning using Remap-GI can trigger students' creativity development critical space for digital resource awareness, which further help students find new digital learning resources [35]. Besides, reading construction also presents a close correlation with creativity skills [36]–[38]. According to previous studies, reading activities have received significant consideration as they may help students enhance their creativity [39], [40].

In addition, the results of our study also confirmed that the Remap-GI learning model should be designed and implemented synchronously at first, followed by asynchronous learning. In this study, the reading and concept mapping (Remap) was carried out asynchronously using e-learning and guidelines in the form of students' worksheets. Meanwhile, creative learning was carried out synchronously using video conference instruments. This stage is analogous to the results of the previous study in engaging students in cooperative online learning settings [41]–[43]. The precise use of technology in the learning process facilitates students to develop their ideas using their initial knowledge [44]. Synchronous cooperative learning facilitates students' discussion and enables the realization of creative and effective learning [45].

The analysis results on the second data set indicated that the problem-solving skills of students who attended learning using the GI learning method also increased significantly. This finding is consistent with the results reported by previous studies that GI enhances students' problem-solving skills [20], [22]. Combining problem-solving and cooperative learning strategies promotes students' high-order thinking skills through collaborative interaction [46]. Further analysis suggested that students attending the Remap-GI learning model

have higher problem-solving skills than students who were provided with only group interaction and conventional learning. Cooperative learning in this study was initiated by reading and creating a map concept (Remap) activity, followed by group discussion (Remap-GI) improves the results.

Remap plays a substantial role in shaping students' knowledge before participating in cooperative learning. In daily life, problem-solving skills frequently cover the collection and interpretation of information [47]. Therefore, reading activity is essential for problem and situation comprehension. Additionally, in relation to concept mapping, map concept connects conceptual and practical knowledge (from reading) with students' collaboration (cooperative learning process) [48]. Previous studies have highlighted that the map concept has the potential to promote problem-solving skills [49] as it lowers word retention and improves knowledge transfer [50]. Therefore, institutions interested in applying cooperative learning should be aware that GI cannot be carried out by merely forming groups. Therefore, the formative activities should be prepared carefully to ensure that students can be held accountable for their actions and give maximum group participation. In other words, cooperative learning should be started by synchronous meetings (such as through an online e-learning platform) to ensure that they have sufficient understanding. Then, students should also be encouraged to allow and listen to other people's opinions to generate creative ideas.

This study also has some limitations. First, this study was carried out using the existing group. Second, this study involved a relatively small group, with only 20 students per group. Third, we completed this study in only 13 meetings, with two initial and one last session not included in the data collection process as those meetings were used for the pretest and posttest. Therefore, the future experiment study has to pay attention to the distribution of participants, with a greater sample size and a more extended intervention period. Besides, this study used a methodological approach of the Remap-GI learning method in the online learning context, so further research in the same context is still required to gain more extensive findings.

4. CONCLUSION

In conclusion, GI is one of the cooperative learning strategies with positive effects on students' creativity and problem-solving skills enhancement. However, this learning model should be carried out in a structured manner (involving Remap) to attain a maximum result. The analysis results generally confirmed that an effective cooperative learning process requires a structured learning framework, such as by associating Remap and cooperative learning model. Besides, this study also corroborates that creative learning presents equal positive results for online learning. Thus, it can be used to decrease students' dependence and face-to-face interaction.

REFERENCES

[1] M. S. Fredagsvik, "The challenge of supporting creativity in problem-solving projects in science: a study of teachers' conversational practices with students," *Research in Science & Technological Education*, vol. 41, no. 1, pp. 289–305, Jan. 2023, doi: 10.1080/02635143.2021.1898359.

[2] B. Martz, J. Hughes, and F. Braun, "Creativity and problem-solving: Closing the skills gap," *Journal of Computer Information Systems*, vol. 57, no. 1, pp. 39–48, Jan. 2017, doi: 10.1080/08874417.2016.1181492.

[3] P. Ø. Haavold and B. Sriraman, "Creativity in problem solving: integrating two different views of insight," *ZDM – Mathematics Education*, vol. 54, no. 1, pp. 83–96, Apr. 2022, doi: 10.1007/s11858-021-01304-8.

[4] B. Barbot, M. Besançon, and T. Lubart, "Creative potential in educational settings: its nature, measure, and nurture," *Education 3-13*, vol. 43, no. 4, pp. 371–381, Jul. 2015, doi: 10.1080/03004279.2015.1020643.

[5] A. Kozbelt, R. A. Beghetto, and M. A. Runco, "Theories of creativity," in *The Cambridge Handbook of Creativity*, Cambridge University Press, 2010, pp. 20–47, doi: 10.1017/CBO9780511763205.004.

[6] D. Quin, "Longitudinal and contextual associations between teacher–student relationships and student engagement," *Review of Educational Research*, vol. 87, no. 2, pp. 345–387, Apr. 2017, doi: 10.3102/0034654316669434.

[7] R. A. Beghetto and J. C. Kaufman, "Classroom contexts for creativity," *High Ability Studies*, vol. 25, no. 1, pp. 53–69, Jan. 2014, doi: 10.1080/13598139.2014.905247.

[8] X. Yue, "Exploring effective methods of teacher professional development in University for 21st century education," *International Journal for Innovation Education and Research*, vol. 7, no. 5, pp. 248–257, May 2019, doi: 10.31686/ijier.vol7.iss5.1506.

[9] M. Fan and W. Cai, "How does a creative learning environment foster student creativity? An examination on multiple explanatory mechanisms," *Current Psychology*, vol. 41, no. 7, pp. 4667–4676, Jul. 2022, doi: 10.1007/s12144-020-00974-z.

[10] M. Csikszentmihalyi, *Creativity: Flow and the psychology of discovery and invention*. Harper Perennial; Reprint edition, 2013.

[11] C. Conradty and F. X. Bogner, "STEAM teaching professional development works: effects on students' creativity and motivation," *Smart Learning Environments*, vol. 7, no. 1, Dec. 2020, doi: 10.1186/s40561-020-00132-9.

[12] N. Kimmelmann and J. Lang, "Linkage within teacher education: cooperative learning of teachers and student teachers," *European Journal of Teacher Education*, vol. 42, no. 1, pp. 52–64, Jan. 2019, doi: 10.1080/02619768.2018.1547376.

[13] M. Ekoningtyas, "Effect of learning think-pair-share think through the combined pattern empowerment question on metacognitive skills, creative thinking, understanding concepts IPA and retention as well as social attitudes students," *Jurnal Pendidikan Sains*, vol. 1, no. 4, pp. 332–342, 2013.

[14] L. Baloche and C. M. Brody, "Cooperative learning: Exploring challenges, crafting innovations," *Journal of Education for Teaching*, vol. 43, no. 3, pp. 274–283, May 2017, doi: 10.1080/02607476.2017.1319513.

[15] D. Kuhn, "Thinking together and alone," *Educational Researcher*, vol. 44, no. 1, pp. 46–53, Jan. 2015, doi: 10.3102/0013189X15569530.

[16] A. Gillespie and B. Richardson, "Exchanging social positions: Enhancing perspective taking within a cooperative problem solving task," *European Journal of Social Psychology*, vol. 41, no. 5, pp. 608–616, Aug. 2011, doi: 10.1002/ejsp.788.

[17] S. Veenman, N. van Benthum, D. Bootsma, J. van Dieren, and N. van der Kemp, "Cooperative learning and teacher education," *Teaching and Teacher Education*, vol. 18, no. 1, pp. 87–103, Jan. 2002, doi: 10.1016/S0742-051X(01)00052-X.

[18] D. W. Johnson and R. T. Johnson, "New developments in social interdependence theory," *Genetic, Social, and General Psychology Monographs*, vol. 131, no. 4, pp. 285–358, Nov. 2005, doi: 10.3200/MONO.131.4.285-358.

[19] M. S. Lerang, S. K. Ertesvåg, and T. Havik, "Perceived classroom interaction, goal orientation and their association with social and academic learning outcomes," *Scandinavian Journal of Educational Research*, vol. 63, no. 6, pp. 913–934, Sep. 2019, doi: 10.1080/00313831.2018.1466358.

[20] N. Ainiyah *et al.*, "Group investigation model to improve interpersonal skills," *International Journal of Evaluation and Research in Education (IJERE)*, vol. 11, no. 1, Mar. 2022, doi: 10.11591/ijere.v11i1.21914.

[21] M. H. Siddiqui, "Group investigation model of teaching: Enhancing learning level," *Indian Journal of Research*, vol. 3, no. 4, pp. 78–80, 2013.

[22] M. F. Tsoi, N. K. Goh, and L. S. Chia, "Using group investigation for chemistry in teacher education," *Asia-Pacific Forum on Science Learning and Teaching*, vol. 5, no. 1, 2004.

[23] E. Irawati and C. Ismaniati, "GI Assisted go: An innovative learning model to improve students creative thinking ability," *KnE Social Sciences*, vol. 3, no. 10, p. 113, Mar. 2019, doi: 10.18502/kss.v3i10.3893.

[24] S. Zubaidah, A. D. Corebima, S. Mahanal, and M. Mistianah, "Revealing the relationship between reading interest and critical thinking skills through remap GI and remap jigsaw," *International Journal of Instruction*, vol. 11, no. 2, pp. 41–56, Apr. 2018, doi: 10.12973/iji.2018.1124a.

[25] W. C. Adi, M. Saefi, M. E. Setiawan, and N. Sholehah, "The impact of COVID-19 to biology teacher education: Emergency distance learning at Islamic Universities in Indonesia," *Journal of Turkish Science Education*, vol. 18, pp. 60–75, 2021.

[26] B. A. Barr and S. F. Miller, "Higher education: The online teaching and learning experience," *Online Submission*, 2013.

[27] C. P. Dwyer and A. Walsh, "An exploratory quantitative case study of critical thinking development through adult distance learning," *Educational Technology Research and Development*, vol. 68, no. 1, pp. 17–35, Feb. 2020, doi: 10.1007/s11423-019-09659-2.

[28] J. A. Cecchini, A. Carriedo, A. Méndez-Giménez, and J. Fernández-Río, "Highly-structured cooperative learning versus individual learning in times of COVID-19 distance learning," *European Journal of Teacher Education*, pp. 1–16, Oct. 2021, doi: 10.1080/02619768.2021.1991305.

[29] J. W. Creswell, *Educational research: Planning, conducting, and evaluating quantitative and qualitative research*. 4th ed. Boston: Pearson, 2012.

[30] S. Sharan, "Cooperative learning in small groups: Recent methods and effects on achievement, attitudes, and ethnic relations," *Review of Educational Research*, vol. 50, no. 2, pp. 241–271, Jun. 1980, doi: 10.3102/00346543050002241.

[31] L. Greenstein, *Assessing 21st century skills: A guide to evaluating mastery and authentic learning*. Corwin, 2012.

[32] G. Polya, *How to solve it: A new aspect of mathematical method*. Princeton University Press, 1945, doi: 10.1515/9781400828678.

[33] Association of American Colleges and University, "Problem Solving Value Rubric." 2009. [Online]. Available: https://www.aacu.org/value/rubrics/problem-solving.

[34] A. Ayob, A. Hussain, and R. A. Majid, "A review of research on creative teachers in higher education," *International Education Studies*, vol. 6, no. 6, May 2013, doi: 10.5539/ies.v6n6p8.

[35] C. Richardson, P. Mishra, and D. Henriksen, "Creativity in online learning and teacher education: An interview with Leanna Archambault," *TechTrends*, vol. 65, no. 6, pp. 914–918, Nov. 2021, doi: 10.1007/s11528-021-00669-7.

[36] W. M. Bart, I. Can, and B. Hokanson, "Exploring the relation between high creativity and high achievement among 8th and 11th grader," *International Online Journal of Education and Teaching (IOJET)*, vol. 7, no. 3, pp. 712–720, 2020.

[37] A. Gajda, M. Karwowski, and R. A. Beghetto, "Creativity and academic achievement: A meta-analysis.," *Journal of Educational Psychology*, vol. 109, no. 2, pp. 269–299, Feb. 2017, doi: 10.1037/edu0000133.

[38] C. Leopold, R. E. Mayer, and S. Dutke, "The power of imagination and perspective in learning from science text," *Journal of Educational Psychology*, vol. 111, no. 5, pp. 793–808, Jul. 2019, doi: 10.1037/edu0000310.

[39] S. Ketabi, R. Zabihi, and M. Ghadiri, "Bridging theory and practice: How creative ideas flourish through personal and academic literacy practices," *International Journal of Research Studies in Psychology*, vol. 2, no. 2, pp. 61–70, Aug. 2012, doi: 10.5861/ijrsp.2012.182.

[40] A. Y. Wang, "Exploring the relationship of creative thinking to reading and writing," *Thinking Skills and Creativity*, vol. 7, no. 1, pp. 38–47, Apr. 2012, doi: 10.1016/j.tsc.2011.09.001.

[41] M. Nussbaum *et al.*, "Taking critical thinking, creativity and grit online," *Educational Technology Research and Development*, vol. 69, no. 1, pp. 201–206, Feb. 2021, doi: 10.1007/s11423-020-09867-1.

[42] S. Mentari, E. S. Andayani, S. Sulikah, and P. M. Nagari, "Online-based simple cooperative learning design (SCL-D) for accounting," *Dinamika Pendidikan*, vol. 16, no. 1, pp. 12–23, Jun. 2021, doi: 10.15294/dp.v16i1.27450.

[43] F. M. Ivone, G. M. Jacobs, and W. A. Renandya, "Far apart, yet close together: Cooperative learning in online education," *Studies in English Language and Education*, vol. 7, no. 2, pp. 271–289, Sep. 2020, doi: 10.24815/siele.v7i2.17285.

[44] X. Yang, L. Lin, P.-Y. Cheng, X. Yang, Y. Ren, and Y.-M. Huang, "Examining creativity through a virtual reality support system," *Educational Technology Research and Development*, vol. 66, no. 5, pp. 1231–1254, Oct. 2018, doi: 10.1007/s11423-018-9604-z.

[45] L. A. Giacumo and W. Savenye, "Asynchronous discussion forum design to support cognition: effects of rubrics and instructor prompts on learner's critical thinking, achievement, and satisfaction," *Educational Technology Research and Development*, vol. 68, no. 1, pp. 37–66, Feb. 2020, doi: 10.1007/s11423-019-09664-5.

[46] P. Balch, "A more powerful marriage: Cooperative learning and problem solving inquiry," *Kappa Delta Pi Record*, vol. 27, no. 2, pp. 37–39, Jan. 1991, doi: 10.1080/00228958.1991.10531833.

[47] J. Krawitz, Y.-P. Chang, K.-L. Yang, and S. Schukajlow, "The role of reading comprehension in mathematical modelling: improving the construction of a real-world model and interest in Germany and Taiwan," *Educational Studies in Mathematics*, vol. 109, no. 2, pp. 337–359, Feb. 2022, doi: 10.1007/s10649-021-10058-9.

[48] C. T. Machado and A. A. Carvalho, "Concept mapping: Benefits and challenges in higher education," *The Journal of Continuing Higher Education*, vol. 68, no. 1, pp. 38–53, Jan. 2020, doi: 10.1080/07377363.2020.1712579.

[49] P. A. Okebukola, "Can good concept mappers be good problem solvers in science?" *Educational Psychology*, vol. 12, no. 2, pp. 113–129, Jan. 1992, doi: 10.1080/0144341920120203.

[50] A. J. Pintoi and H. J. Zeitz, "Concept mapping: A strategy for promoting meaningful learning in medical education," *Medical Teacher*, vol. 19, no. 2, pp. 114–121, Jan. 1997, doi: 10.3109/01421599709019363.

BIOGRAPHIES OF AUTHORS

Nur Lina Safitri ⓘ 🄶 sc ↻ is a student at Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Indonesia. She also a lecturer at Institute of Technology and Science Nahdlatul Ulama Pasuruan. She can be contacted at email: Safitrilina1992@gmail.com or nurlinasafitri@itsnupasuruan.ac.id.

Siti Zubaidah ⓘ 🄶 sc ↻ is a professor at Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Indonesia. Her research areas: biology education, critical and creative thinking skills, metacognitive skills, 21st century learning. She can be contacted at email: siti.zubaidah.fmipa@um.ac.id.

Fatchur Rohman ⓘ 🄶 sc ↻ is Professor of Ecology at the Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Indonesia. His research focuses on ecology, agriculture, and the development of learning biology. He can be contacted at email: fatchur.rohman.fmipa@um.ac.id.

Sulisetijono ⓘ 🄶 sc ↻ is a lecturer at the Department of Biology, Universitas Negeri Malang, Indonesia. He completed undergraduate program from IKIP Malang, in biology education program, master degree at the Bandung Institute of Technology (ITB), and doctoral education at Brawijaya University. His research interest and expertise are plant development and biostatistics. He can be contacted at email: sulistijono.fmipa@um.ac.id.