Uniciencia Vol. 37(1), pp. 1-13, January-December, 2023
www.revistas.una.ac.cr/uniciencia
revistauniciencia@una.cr

DOI: http://dx.doi.org/10.15359/ru.37-1.6
E-ISSN: 2215-3470

Learning To Promote Students' Mathematical Curiosity And Creativity

Aprendiendo a promover la curiosidad matemática y la creatividad estudiantiles

Aprendendo a promover a curiosidade matemática e a criatividade dos alunos

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Received: Jun/1/2022 • Accepted: Aug/25/2022 • Published: Jun/1/2023

Abstract

[**Background**] Discovery learning is a model that guides students to actively learn in finding concepts or knowledge through an inquiry process based on the data or information obtained from experiments or observations. [**Objective**] The present study examined the implementation of a modification of discovery learning using mind mapping in promoting students' mathematical curiosity and creativity. [**Method**] A Classroom Action Research (CAR) design was employed in this study. The participants were 250 students in Middle Indonesian who registered in the academic year of 2020/2021. [**Results**] The descriptive analysis showed that the students achieved an average score of 44.04 with a standard deviation of 18.716 in pre-CAR, 52.48 with a standard deviation of 22.978 after cycle I, and 76.72 with a standard deviation of 17.097 after cycle II. Based on the students' mathematical creative thinking scores, 2 (8%) students could perform creative thinking in pre-CAR, 6 (24%) students after cycle I, and 22 (88%) students after cycle II. These figures indicated that the students classically achieved the ability to think creatively in mathematics after cycle II. [**Conclusion**] It was concluded that the implementation of modified discovery learning and mind mapping could promote students' mathematical creative thinking ability. The interview results also suggest that the learning model could increase mathematical curiosity of both the low and high achievers.

Keywords: creative thinking ability, discovery learning, mind mapping

Resumen

[**Antecedentes**] El razonamiento ha sido ampliamente estudiado por muchas personas expertas. Sin embargo, la investigación sobre el razonamiento de estudiantes en la resolución de problemas trigonométricos, en particular los relacionados con las habilidades de pensamiento lógico, sigue siendo muy necesaria. [**Objetivo**] Esta investigación es un estudio cualitativo que tuvo como objetivo explorar el razonamiento de estudiantes en la resolución de problemas trigonométricos en términos de su habilidad lógica. [**Método**] Los sujetos participantes del estudio fueron tres estudiantes con diferentes habilidades

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DOI: http://dx.doi.org/10.15359/ru.37-1.6
E-ISSN: 2215-3470

de pensamiento lógico (baja, alta y media). El instrumento en este estudio fue el propio investigador como instrumento principal apoyado en tareas de resolución de problemas matemáticos y pautas de entrevista válidas y confiables. La recolección de datos se llevó a cabo mediante entrevistas basadas en tareas y pensamiento en voz alta. [**Resultado**s] En cuanto a los resultados obtenidos: (1) Lo que tienen en común participantes con habilidad de pensamiento lógico alta (ST) y media (SS) en cuanto a su razonamiento es que solían comenzar con el razonamiento inductivo y luego razonaban deductivamente, y (2) la diferencia en su razonamiento es que el estudiante con baja habilidad de pensamiento lógico (SR) no mostró ningún proceso de razonamiento en absoluto. [**Conclusión**] Para resumir, el razonamiento de estudiantes podría usarse como referencia en el desarrollo de modelos de aprendizaje matemático para mejorar sus habilidades de razonamiento.

Palabras clave: Razonamiento matemático; razonamiento inductivo; razonamiento deductivo; trigonometría.

Resumo

[**Contexto**] O raciocínio tem sido extensivamente estudado por muitos especialistas. No entanto, a pesquisa sobre o raciocínio do aluno na resolução de problemas trigonométricos, particularmente aqueles relacionados às habilidades de pensamento lógico, ainda é muito necessária. [**Objetivo**] Esta pesquisa é um estudo qualitativo que teve como objetivo explorar o raciocínio de alunos na resolução de problemas trigonométricos em termos de sua habilidade lógica. [**Método**] Os participantes do estudo foram três alunos com diferentes habilidades de raciocínio lógico (baixa, alta e média). O instrumento neste estudo foi o próprio pesquisador como o principal instrumento apoiado por tarefas de resolução de problemas matemáticos e modelos de entrevista válidos e confiáveis. A coleta de dados foi realizada por meio de entrevistas baseadas em tarefas e reflexões em voz alta. [**Resultados**] Em relação aos resultados obtidos: (1) O que os participantes com capacidade de raciocínio lógico alta (ST) e média (SS) têm em comum em termos de raciocínio é que costumavam começar com raciocínio indutivo e depois raciocinar dedutivamente, e (2) a diferença em seu raciocínio é que o aluno com baixa habilidade de raciocínio lógico (RL) não apresentou nenhum processo de raciocínio. [**Conclusão**] Resumindo, o raciocínio dos alunos pode ser usado como referência no desenvolvimento de modelos de aprendizagem matemática para melhorar as habilidades de raciocínio dos alunos.

Palavras-chave: raciocínio matemático; raciocínio indutivo; raciocínio dedutivo; trigonometria.

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Introduction

Previous investigations have proven a good deal of the relationship between learning attitudes, curiosity, anxiety, and learning outcomes (Huang *et al*., 2020). Harackiewicz *et al*. (2008) found that students' learning attitudes were positively related to interest in learning. Curiosity is a significant predictor of student achievement in mathematics (Harackiewicz *et al*., 2008). Krapp (1999) also emphasizes that a lack of curiosity leads to underperformance. In fact, connections in the four constructs are quite strong.

Zaremba and Smoleński (2000) examined the history of research on student curiosity and found that interest in learning influenced student achievement. Moreover,

DOI: http://dx.doi.org/10.15359/ru.37-1.6
E-ISSN: 2215-3470
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Harackiewicz and Hulleman (2010) state that one's interest in a topic will lead to better results. The findings of the 2015 Trends in International Mathematics and Science Study (TIMSS) survey show that achievement in mathematics is positively related to students' interest in learning (Mullis *et al*., 2012). Jensen *et al*. (2002) also highlighted that students with an interest in learning showed high achievement in mathematics.

These findings suggest that there is a positive correlation between learning attitudes and interests in learning as well as a correlation between learning interests and learning outcomes. In Addition, Wu *et al*. (2012) found that math anxiety decreases students' achievement in mathematics. Also, students' low interest in learning and negative attitudes toward learning may result in continual anxiety and low performance (Aksu & Bikos, 2002).

However, Yu and Singh (2018) argue that there is an insignificant relationship between curiosity and performance in mathematics. Wong and Wong (2019) can explain the inconsistent related findings. They found that interest in learning was not significantly associated with math performance for high-performing students, but that curiosity had a significant positive relationship with math performance for low-ability students. High-achieving students may still study vigorously even when their curiosity is low. The TIMSS results also indicate that students with low achievement normally have negative attitudes and low interest in studying mathematics. Therefore, it is interesting to examine how to increase student achievement, attitudes, and interest in learning mathematics by reducing the anxiety of the students, especially those with low academic ability.

The learning approach applied in the classroom has an impact on students' interests and attitudes toward learning (Savelsbergh *et al*., 2016). However, in a conventional mathematics learning setting, teachers usually adopt a teacher-directed approach. For example, Menegale (2008) found that teachers dominated class discussions and all students received the same information from the teacher. When this happens, the result in the aforementioned psychological constructs (i.e., learning attitudes, curiosity, anxiety, and learning outcomes) is poor ratings. Battista (1999) observed that school mathematics involves memorizing and forgetting facts and procedures from the student's perspective. In turn, learning became meaningless. Students only memorize and use several techniques taught by the teacher in answering questions (Menegale, 2008). Lerkkanen *et al*. (2012) also emphasize that teacher-directed learning activities are inflexible; the students are merely engaged in memorizing activities and are provided with few opportunities to develop interpersonal skills. It could thus be stated that when learning episodes have little to no focus on student input, learning outcomes are compromised.

Mathematics is formed from human empirical experience, then processed through a rational thinking process and analyzed by reasoning through cognitive structures (Hafiz *et al*., 2017). These processes generate understandable mathematical concepts that can be manipulated appropriately, so a universally acceptable mathematical notation is obtained (Rahmah, 2018). Some experts say that creativity in mathematics is a combination of divergent thinking and logical thinking based on intuition but within a consciousness that pays attention to flexibility, fluency, and novelty (Muzaini et al., 2023, 2000; Molad *et al*., 2020; Rahayuningsih *et*

DOI: http://dx.doi.org/10.15359/ru.37-1.6
E-ISSN: 2215-3470

al., 2020). Thinking skills that can assemble concepts and manipulate them can be categorized as creativity. In other words, thinking skills in which concepts can be investigated through manipulating mathematical information may precipitate mathematical creativity. In other words, students' creative abilities may be developed through appropriate mathematics learning sessions. In fact, according to Fardah (2012), many primary and secondary education teachers pay less attention to their students' creativity. Besides, according to Abdurrozak and Jayadinata (2016), Indonesian students tend to have poor creativity.

When discussing creativity in education, researchers usually focus on creativity on a small scale, namely the creative and meaningful insights that students experience when learning new concepts (Kaufman & Beghetto, 2009). Even though students may not find methods to solve new problems in the larger area of mathematics, they are still creating new solutions and ideas in their learning trajectories (Gajda, 2016). One way to bring out mathematical creativity in the classroom is to involve students in open-ended mathematical problems (Haylock, 1997; Kwon *et al*., 2006; Silver, 1997). Open-ended problems do not have one definite solution but various solutions (Silver, 1997). Specifically, there may be more than one final correct answer, but, more importantly, there are several possible solutions to an open-ended problem. Open-ended problems are also considered capable of producing different solutions that lead to fluency, flexibility, originality, and elaboration (Haylock, 1997, and Kattou *et al*., 2013).

Following the results of Pre-CAR observations in class, mathematics learning has been conducted as teacher-centered learning; hence teachers seem less interested in participating in the learning process, and the students are more likely to remain passive. Learning is mostly focused on the presentation of the material and, therefore, ignores the implication of the material being taught. As a result, students lose opportunities to manipulate and discover new concepts. They also experience a decrease in creativity and learning outcomes. Overcoming these problems needs to develop a learning model to help teachers encourage students to think creatively. A variety of learning models, such as discovery learning and mind mapping, need to be applied in the classroom to promote students' innovative skills.

According to Purwaningrum (2016), that Mathematical creative ability needs to be nurtured and developed to enable children to realize their optimal potential. Some of the ways that teachers can do to develop this ability include providing opportunities for children to express their thoughts and feelings (discovery). According to Thao *et al*. (2020), discovery learning is an inquiry process. It is also a learning method that requires teachers to be creative in generating situations that allow students to learn actively and discover knowledge. Furthermore, Neber (2012) explains that discovery is a learning process that focuses on the mental intellectual of students in solving various problems, so they can find a concept or generalization that can be applied in the field".

It can be concluded that discovery learning is an approach that guides students to actively learn in making sense of concepts or knowledge through an inquiry process based on the data or information obtained from experiments or observations. The application of discovery learning goes through several stages. According to Suyitno and Artikel (2015), the stages and

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DOI: http://dx.doi.org/10.15359/ru.37-1.6
E-ISSN: 2215-3470
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procedures for implementing discovery learning in mathematics are stimulation, problem statement, data collection, data processing, verification, and generalization. These stages can be modified by incorporating mind-mapping steps into the syntax.

Mind mapping is a learning model that helps students understand a concept using a mind map and optimize the two parts of the brain (Jin & Wong, 2015). Meanwhile, Norton and Deater-Deckard (2014) explain that mind mapping is a summarizing technique that allows students to project the problem being studied into a mind map or a graphic. Furthermore, according to Uysal and Sidekli (2020), mind mapping is the easiest way to encode information into the brain and access information from outside the brain. Mind mapping is a creative and effective way of taking notes that assist students in mapping their thoughts. Yanti *et al*. (2019) found that mind mapping had a significant effect on students' mathematical creativity.

According to Hafiz *et al*. (2017) and Arriah, (2019), mathematics learning using the mind-mapping method may consist of the following stages: (1) the teacher shows students how to make a concept map at the beginning of the lesson. (2) The teacher presents the material. (3) The students are assigned into groups of 4-5 that have mixed abilities. (4) One of the pairs in each group is asked to explain the material being studied, while the other is asked to listen while making small notes in the form of a concept map, then they change roles. The other groups are also asked to do the same. (5) All students take turns or randomly deliver the results of the interview with their partner in front of the classroom until some or all students have the opportunity to make a presentation. (6) The teacher repeats or re-explains the material. (7) The teacher concludes the lesson.

According to Thao *et al*. (2020) and Norton and Deater-Deckard (2014), discovery learning can be modified by integrating mind-mapping steps into it. Modifying this model intends to improve students' creativity. Therefore, with this study, it is hoped that (1) students' mathematical creativity and curiosity can be developed by implementing discovery learning and mind mapping, and that (2) teachers can be inspired to use this learning model to promote students' mathematical creativity and curiosity.

Methodology

This study employed a reflective, participatory and collaborative classroom action research (CAR) design that aimed to improve a learning system, procedure, process, content, and situation, and increase student competence. In this study, discovery learning was modified by incorporating the mind-mapping steps into the syntax. The CAR was implemented in two interrelated cycles, where the cycle II was the follow-through of the cycle I. Each cycle contained the following activities: (1) planning, where learning tools and research instruments were developed; (2) implementing, where learning was conducted according to the modified discovery learning and mind-mapping model (the syntax is clearly stated in the lesson plans); (3) observing, that included observing student activity and the model implementation as well as conducting an evaluation on the students' mathematical creativity; (4) reflecting, that refers to evaluating the learning process and result to decide on whether to stop at the cycle or continue to another cycle (Cintia *et al*., 2018).

The participants were 250 students from Makassar, Middle Indonesian. This study was performed in the 2020-2021

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DOI: http://dx.doi.org/10.15359/ru.37-1.6
E-ISSN: 2215-3470

academic year. The research instruments consisted of (1) a creative thinking test administered at the end of each cycle and (2) a student questionnaire used to gain the participants' perspective on the implementation of the learning model (i.e., the combination of discovery learning and mind mapping). The creative thinking test was developed based on the mathematical creative thinking ability indicators, as presented in Table 1.

Data analysis was performed qualitatively and quantitatively. The quantitative data were gathered using a creative thinking test administered at the end of each cycle. These data were analyzed using descriptive statistics. Meanwhile, the participants' responses elicited through a questionnaire survey were analyzed qualitatively. In accordance with the research objective, the criterion of success of the treatment was that 85% of the students could achieve a score of ≥75 (the passing grade or KKM) in mathematical creative thinking ability.

Findings and Discussion

Student Mathematical Creative Thinking Ability

The data obtained after implementating the learning model (i.e., the combination of discovery learning and mind mapping) were analyzed using descriptive statistics. The results of the statistical analysis performed on the cycle I and cycle II end tests are recorded in Table 2.

Table 1. *Indicators of Mathematical Creative Thinking Ability*

No.	Indicator	Operational Definition
1	Originality	a. Find an unorthodox strategy to solve a problem b. Develop a different way of thinking
2	Fluency	c. Plan and use various strategies to solve a difficult problem and a challenging situation d. Replace the solution when it fails to solve the problem
3	Flexibility	e. Think of many different ways to solve a problem f. Offer various solutions to SPLDV problems
4	Elaboration	g. Execute detailed steps to find a deeper meaning of a problem

Source: Rahayuningsih *et al*. (2020) and Singer *et al*. (2013).

Table 2. *Descriptive Analysis of Cycle I and Cycle II End Tests*

Statistics	Pre-CAR	Cycle I	Cycle II
Number of participants	250	250	250
Total score	1101	1272	1965
Mean score	44.04	52.48	76.72
Standard deviation	18.716	22.978	17.097
Highest score	78	89	95
Lowest score	14	18	29
Percentage of students with mathematical creative thinking ability	8%	24%	88%
Percentage of students without mathematical creative thinking ability	92%	76%	12%

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DOI: http://dx.doi.org/10.15359/ru.37-1.6
E-ISSN: 2215-3470

Table 2 shows that in the pre-CAR test before the learning model was applied, the participants obtained a mean score of 44.04 on the linear program creativity test. This indicates that the students' mathematical creativity level was centered at 44.04 with a standard deviation of 18.716, where only 8% of these students demonstrated mathematical creativity. Meanwhile, after cycle I, the participants were able to achieve a mean score of 52.48, indicating that the level of the students' mathematical creativity was centered at 52.48 with a standard deviation of 22.978, where 24% of these students performed mathematical creative thinking ability. Furthermore, the results of the end test of cycle II showed that the students achieved a mean score of 76.72 with a standard deviation of 17.097, where 88% of these students were able to think creatively in solving math problems.

Students' Responses at the End of Cycle I

The participants' provided various responses regarding the teacher's method of delivering the material. Some students said that they could understand the lessons if they considered them useful. They admitted that a better understanding of the topic could be obtained through peer explanations because group activities were fun and enjoyable. A group of students said that the teacher was not assertive in rectifying the problem, and others sitting in the back did not hear the teacher's voice clearly because other students were making noise.

According to the participants, the applied learning model, which is a combination of discovery learning and mind mapping, can help them find mathematical concepts through concept maps. Therefore, the participants showed high enthusiasm for applying this learning model. They also felt that this model was very suitable for supporting group learning. Learning in groups accommodates the exchange of ideas between fellow students, so mathematics lessons look easier when discussed with friends.

When faced with the implementation of the learning model, the students assumed that the teacher had to be more assertive in carrying out the learning activities. Besides that, the students highly favored the teacher's loud voice. The students enjoyed learning with discovery learning and mind mapping. The students' responses helped the teacher plan cycle II and see the shortcomings of cycle I.

Students' Responses at the End of Cycle II

The teacher provided an opportunity for the students to write responses or express their opinions about the implementation of the research. Overall, the students thought that the learning process carried out in cycle II was better than that in cycle I. This may have been confirmed by the students' end-test scores in cycle II, which were higher than those obtained in cycle I.

The selection of discovery learning and mind mapping is based on findings from past studies. Previous studies have focused on improving students' creative thinking ability through discovery learning, mind mapping, or a combination of discovery learning and other learning models, as well as a combination of mind mapping with other learning models, approaches, or methods. Some of these studies are described below.

Regarding the implementation of discovery learning, Muslim (2016) found that the model had a positive effect on students' mathematical creative thinking ability. Likewise, Cintia *et al*. (2018) argue that discovery

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DOI: http://dx.doi.org/10.15359/ru.37-1.6
E-ISSN: 2215-3470

learning can improve students' mathematical creativity. Moreover, students who are taught using discovery learning perform better in trigonometry creativity than those who are engaged in the conventional learning process (Chrysmawati *et al*., 2017).

Darusman (2014) found that the increase of mathematical creativity of students whose learning was facilitated with the mind-mapping method was more significant than that of the students who were taught using conventional methods. Furthermore, Syahidah (2015) explains that the use of the mind-mapping method can combine the abilities of the two brain spheres to develop student creativity. Besides, Fitriyah *et al*. (2015) argue that the creative problem-solving and mind-mapping model positively affect students' creative thinking abilities. Meanwhile, Rahayu *et al*. (2018) have proven that mind mapping and the thinking aloud pair problem-solving (TAPPS) learning model were more effective than conventional learning in improving students' mathematical creative thinking. Savitri and Saadi (2019) also found that the CORE learning model assisted by mind mapping had a significant effect on students' mathematical creativity. In line with the results of the previous research, Safii (2019) adds that students who are taught using the mind mapping and active knowledge-sharing strategy can perform better in mathematical creativity than those taught using conventional learning methods.

Research shows that combining discovery learning with other instructional models or methods can improve students' mathematical creative thinking ability. Likewise, mind mapping combined with certain learning models can also have a positive impact on students' creative thinking ability. Therefore, in this study, discovery learning was combined with the mind-mapping method in an attempt to improve students' mathematical creativity. The difference between this study and previous research lies in the combination of the implemented learning model or method.

The learning activities performed in this study consisted of six steps, with the first being (1) stimulation. At this stage, the learning objective and learning material were delivered by the teacher, and the students were asked to sit in pairs, and each pair was given a problem to solve. The learning process continued without generalization, so the students were encouraged to investigate the problem by themselves; (2) problem statement. Each group was allowed to identify the problem and formulate a hypothesis; (3) data collection. The students collected information (doing experiments, observations, interviews, reading some literature, and performing other investigation activities) to justify the hypothesis; (4) data processing. The students interpreted and processed the information; (5) verification. The students did a careful examination of the hypothesis and investigation results. At this stage, one of the pairs was given a chance to present the group's investigation results to other students; his or her partner should write down a note on the presentation. Then, the pairs took a turn giving a presentation. (6) generalization. The students had to draw a general conclusion that can apply to a similar problem in the future (generalization). These steps were implemented through Classroom Action Research that was conducted within two cycles.

In the pre-CAR, the students achieved a mean score of 44.04 on the creativity test, with a standard deviation of 18.716, where only 8% of the students could perform creative thinking ability in the test. This finding

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E-ISSN: 2215-3470
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suggests that before the implementation of the discovery and mind-mapping model, the students had poor performance in mathematical creativity.

However, the students showed an improvement at the end of cycle II, where they obtained a mean score of 52.48 and a standard deviation of 22.978. In the cycle II end-test, 24% of the students started to demonstrate creativity in mathematics. The cycle II test result showed that the learning model's implementation affected the students' mathematical creative thinking ability.

Finally, at the end of cycle II, the students reported a better achievement in mathematical creative thinking ability. It was indicated by a mean score of 76.72 and a standard deviation of 17.097. More than half (88%) of the students were already able to think creatively in solving the given mathematical problem. This finding suggests that implementing discovery learning and mind mapping in cycle II improved the students' mathematical creative thinking ability by 64%. It is partially confirmed by the results of the previous studies that also show that discovery learning was effective in improving students' mathematical creativity (Leksani *et al*., 2018). In addition, Wulandari *et al*. (2019) observed an increase in students' mathematical creativity after they were taught using mind mapping. Therefore, it can be said that the students' performance at the end of cycle II (with a mean score of 76.72) fulfilled the predetermined criteria of success in this study. Also, 85% of the students could achieve 88% requirements of mathematical creative thinking ability. These satisfactory results were obtained likely due to the implementation of discovery learning and mind-mapping methods in students Makassar.

The interview results also revealed that the combination of discovery learning and mind mapping could promote the students' interest and attitude toward mathematics learning. It was also found that the model implementation could reduce students' anxiety during the learning process. The students showed great enthusiasm in the learning activities, and it positively impacted their learning outcomes. According to Harackiewicz and Hulleman (2010), interest in learning contributes greatly to students' learning process and achievement. When students are curious about a topic, they generally feel motivated to perform and achieve better in the classroom (Hidi, 1990) than they might otherwise. Moreover, Harackiewicz and Hulleman (2010) explain that curiosity plays a crucial role in fostering performance and achievement; thus, it can be viewed as important in terms of adjustment and happiness in life. On the other hand, a lack of curiosity will result in low performance (Krapp, 1999).

The participants' responses and feedback to the implementation of the learning model in cycles I and II were apt to be positive, and the students' anxiety levels toward the learning activities performed in the study were relatively low. In addition, the results of the questionnaire analysis showed slight differences in attitudes between high and low-achieving students. These data should be interpreted in a rather parsimonious manner, as non-parametric statistical procedures were not employed for analysis. These findings may suggest that the learning activities conducted in discovery learning and mind mapping can increase the mathematical curiosity of high and low-achieving students. All students showed high satisfaction and high appreciation of the learning process. The right topics and assignments

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E-ISSN: 2215-3470

can provide opportunities for students to develop their creativity and reflection because they are provided with problems that require multiple procedural solutions (Szabo *et al*., 2020) and conceptual knowledge that can be interpreted, demonstrated, and represented in different ways (Greene, 2014).

Conclusions

The results of the research analysis and discussion suggest that the combination of discovery learning and mind mapping can improve the mathematical curiosity and creative thinking ability of students. The findings from this study show that (1) the students obtained a mean score of 44.04 with a standard deviation of 18.716 in the pre-CAR, 52.48 with a standard deviation of 22.978 at the end of cycle I, and 76.72 with a standard deviation of 17.079 at the end of cycle II; (2) 2 (8%) students could perform creative thinking in the pre-CAR, 6 (24%) students were able to think creatively in cycle II and 22 (88%) students could successfully pass 85% of the success criteria at the end of cycle II. However, 3 (12%) students failed in achieving the criteria of success at the end of the cycles.

It is highly recommended for the education practitioners and teachers, especially those in mathematics, to be more creative and innovative in formulating instructional models, approaches, strategies, and methods that are effective and relevant to the material to be taught. One alternative is to apply a combination or a modification of discovery learning and mind mapping.

Conflict of Interest

- The authors declared no potential conflicts of interest with respect to the research, authorship, and / or publication of this article.

Author contribution statement

S.R. conceived the idea of the research presented. S.R. collected the data. The three authors (S.R.., M.I., and N.I.) actively participated in the development of the theory, methodology, data organisation and analysis, discussion of results and approval of the final version of the work.

All the authors declare that the final version of this paper was read and approved.

The total contribution percentage for the conceptualization, preparation, and correction of this paper was as follows: S.R. 40 %., M.I. 30 % and N.I. 30 %.

Data availability statement

The data supporting the results of this study will be made available by the corresponding author, **[S.R]**, upon reasonable request.

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DOI: http://dx.doi.org/10.15359/ru.37-1.6
E-ISSN: 2215-3470
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