Systematic Literature Review: Analysis of The Influence of ICT Integration in Mathematics Learning on Students' Mathematical Creative Thinking Ability

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Abstract

Mathematical creative thinking ability is a very important competency in the process of learning and mastering mathematics, because with the mathematical creative thinking ability, students can easily understand mathematical objects and associate facts, concepts, and mathematical principles. This article was written to determine the effect of ICT (Information and Communication Technology) integration in learning mathematics on students' mathematical creative thinking abilities. The method used is SLR (Systematic Literature Review), namely by collecting, analyzing, and concluding articles related to ICT and students mathematical creative thinking abilities from national and international journals on the *Google Schoolar* database. The articles reviewed were articles published in 2019-2023 that were searched for with the keywords (1) mathematical creative thinking ability, (2) ICT based mathematics learning, and (3) ICT to improve mathematical creative thinking ability. The analysis of the 25 articles that have been collected show that the integration of ICT in learning mathematics has an impact on student's mathematical creative thinking abilities.

Keywords:

. Mathematical Creative Thinking Ability, ICT

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1. Introduction

Mathematics is one of the compulsory subjects at the elementary and middle school levels (UU No. 20 Tahun 2003 tentang Sistem Pendidikan Nasional, 2003). This cannot be separated from the role of mathematics which is so important in everyday life. (Susanto, 2016) said that mathematics learning is a teaching and learning process designed by teachers to foster creative thinking and improve the ability to construct knowledge as an effort to master mathematics. To learn and master mathematics, students are required to have high order thinking skills (Mardhiyana & Sejati, 2016). Creative thinking ability is one of the inherent competencies for solving mathematical problems (Hadar & Tirosh, 2019).

Students mathematical creative thinking abilities are usually associated with a fundamental process or embodied product (Suherman & Vidákovich, 2022). According to Programme for International Student Assessment (PISA), mathematical creative thinking ability is a competency to engage productively in learning, evaluating, and improving ideas that can generate original and practical solutions (OECD, 2019). Mathematical creative thinking ability is a cognitive ability to solve problems in a divergent manner which is measured based on aspects of fluency, refers to the many responses received; flexibility, refers to many different response types; originality,

refers to how often the response is generated; and elaboration, refers to solving problems with detailed steps and creating work plans (Mardhiyana & Sejati, 2016). Creative thinking allows students to generate new ideas, find the connection between one thing and another, build imagination, and see a problem from many perspectives (Mardhiyana & Sejati, 2016).

As stated by (Murdiani, 2018), mathematics is an abstract science. This is because the basic objects of mathematics are not real and are only limited to imagination or wishful thinking in the head. In addition, there are many facts, concepts, and principles in mathematics that are related to one another. Without mathematical creative thinking ability, students will find it difficult to understand mathematical objects and relate facts, concepts, and mathematical principles so that it is not uncommon for learning mathematics to be limited to memorizing formulas without understanding them as a whole. Therefore, mathematical creative thinking ability is very essential in the process of learning and mastering mathematics.

Along with the changing times, the rapid development of ICT has brought many changes in the world of education (Hernandez, 2017). The changes that occur have a major influence on what is learned, how to learn it, when and where the learning process takes place, and who learns and who teaches (Henderson, 2020). It is undeniable, that the development of ICT provides many conveniences in the learning process (Wirawan & Supriyanto, 2020).

ICT offers new ways to achieve educational/learning objectives more effectively and efficiently (Supianti, 2018). There are many learning innovations such as teaching aids, modules, and ICT-based learning media that are developed massively so that teachers have many choices in designing the learning needed so that learning objectives can be achieved. In addition, ICT also provides new learning experiences for students, so that it is expected to stimulate students to learn and develop high-order thinking skills, such as mathematical creative thinking abilities.

(Park & Seung, 2008) in (Mardhiyana & Sejati, 2016) a suggested that creativity can be an innate characteristic, but it can also be improved through various means in the classroom. Based on these arguments, student's mathematical creative thinking ability can be improved by implementing various innovations and integration of ICT in learning mathematics. This article was written to determine the effect of ICT integration in mathematics learning on student's mathematical creative thinking abilities.

2. Method

This study uses the SLR (Systematic Literature Review) method. SLR is carried out by identifying, reviewing, evaluating, and interpreting the research results (Putra & Afrilia, 2020). With this, the researcher conducts a structured review of articles in national and international journals in accordance with the steps of the SLR research by (Triandini, Jayanatha, Indrawan, Putra, & Iswara, 2019). The researched articles were sourced from the *Google Scholar* database with the following keywords:

- Mathematical creative thinking ability
- ICT based mathematics learning

- ICT to improve mathematical creative thinking ability

To fulfill factual and relevant principles, the resercher have developed a literature selection strategy as shown below.

Tabel 2. 1 Inclusion-Exclusion

Inclusion	Exclusion
Articles that match the topic of discussion	Article off the topic of discussion
Articles that are relevant to the topic of discussion	Articles that are irrelevant to the topic of discussion
Articles in English and Indonesian	Articles in languages other than English and Indonesian
Artikel published between 2019-2023	Articles published under 2019

Next, the researcher records these articles in a tabulation table which includes the researcher and the year, journal, and conclusions of the research results. After that, the researcher conducted an in-depth analysis and review of the article, especially on the discussion and conclusion sections. In the end, the researcher compares the findings of the articles and gives conclusions (Sartika & Octafiani, 2019).

3. Result and Discussion

According to (Drijvers, Boon, & Van Reeuwijk, 2010), there are three roles and functions of technology in mathematics education, namely (1) as a tool for calculating mathematics, (2) as a learning place to train mastery and mathematical skills, and (3) as a tool to build sense of mathematical concepts. In the first function, the use of technology is only limited to shortening the time to solve mathematical problems without the need to show the process to the user. An example is the use of *Microsoft Excel* to solve statistical problems. In the second function, the use of technology is intended to hone students' mathematical skills by carrying out a number of problem solving procedures, such as in *Scratch* and *GeoGebra*. As for the third function, technology is used as a tool in the process of guided investigation or can also be used as a mathematical teaching tool, for example, *GeoGebra 3D*.

In an effort to improve student's mathematical creative thinking abilities, the use of ICT in learning mathematics mostly uses software that involves students directly in a mathematical activity. Popular platforms such as *GeoGebra*, *Kvisoft Flipbook*, and *Scratch* are widely used by teachers to train mathematical skills or build students' concepts and understanding. The research data on the influence of ICT on improving student's mathematical creative thinking abilities are available in **Table 3. 1**.

Table 3. 1 Data on the influence of ICT integration in mathematics learning on student's mathematical creative thinking ability

Researcher and Year	Journal	Conclusion of Research Results
(Cibro, Siregar, & Rambe, 2021)	Journal of Mathematics Technology and Education	This study useses the R&D (Research and Development) method in GeoGebra assisted learning with the PBL learning model on geometry transformation material for Vocational High Schools with the result of increasing students' creative thinking abilities by 25.7%.
(Yuliastuti, Sukajaya, & Mertasari, 2019)	Jurnal Pendidikan dan Pembelajaran Matematika Indonesia	This study uses a quantitative method with cluster random sampling with the conclusion that junior high school students who are taught by creative problem solving learning model supported by ICT-based media have better creative thinking abilities in mathematical problem solving.
(Muktiari & Dewi, 2021)	PRISMA, Prosiding Seminar Nasional Matematika	This study used the SLR method with conclusion that the development of textbooks oriented to the ICT-assisted Preprospec learning model can improve mathematical creative thinking ability.
(Yaniawati, Kariadinata, Sari, Pramiarsih, & Mariani, 2020)	International Journal of Emerging Technology in Learning	This study uses a mixed-method method in learning that integrates e-learning with the RBL (Resource-Based Learning) model with scientific approach to junior high school quadrilateral material with conclusion that there is a significant increase in student’s creative thinking skills and self-confidence.
(Amalia, Zaiyar, Fadilah, & Santoso, 2021)	Journal of Physics: Conference Series	This study uses a mixed-method method with conclusion that Android-Based Learning Environment in COVID-19 online learning has a positive impact on junior high school student's MCT abilities and self-efficacy.
(Wannapiroon & Pimdee, 2022)	Education and Information Technologies	This study uses a mixed-method method in conceptual model learning using digital virtual classroom learning environment with university students as research subjects and produces a conclusion stating that these students achieve higher amounts of creativity and innovation.
(Wijaya, Zhou, Ware, & Hermita, 2021)	International Journal of Emerging Technologies in	This study uses a quantitative method with learning-based college students using the Hawgent dynamic mathematics software package with the conclusion that

	Learning (iJET)	the students improved their problem-solving and communication skills, creative thinking abilities, and self-confidence.
(Octaviani, Dwijanto, & Ahmadi, 2019)	Journal of Research and Educational Research Evaluation	This study used a mixed-method method in learning with the ICT-based SAVI model seen from student's life skills with the research subjects of elementary school students and resulted in the conclusion that there was an increase in student's MCT skills in the experimental group.
(Arifuddin, Wahyudin, Prabawanto, Yasin, & Elizanti, 2022)	Al Ibtida: Jurnal Pendidikan Guru MI	This research uses quasi-experimental method with a pretest-posttest control group design in learning with a scientific approach assisted by Augmented Reality which conclude that scientific approach assisted by augmented reality is effective in increasing elementary school student's mathematical creative thinking abilities.
(Kartika, Wahyuni, Sinaga, & Rajagukguk, 2020)	International Journal for Educational and Vocational Studies	This study uses the R&D (Research and Development) method using Analysis, Design, Development, Implementation, and Evaluation (ADDIE) with the conclusion that the development of Android-based educational games can improve high school student's creative thinking skills in geometry material by providing problems in mathematics in the the form of animation and interesting games in accordance with math problems in everyday life.
(Samura, Juandi, Said, & Malaka, 2021)	International Journal of Interactive Mobile Technologies	This study uses a quantitative method with conclusion that the GeoGebra-assisted learning community can improve junior high school (JHS) student's creative thinking skills.
(Sartono, Sukowati, & Soleha, 2021)	Al Ibtida: Jurnal Pendidikan Guru MI	This research uses quasi-experimental method with the conclusion that the game *Kahoot!* based on local wisdom has a substantial impact on increasing the ability to think creatively and the national spirit of students in madrasah ibtidaiyah/elementary schools.
(Rudyanto, Ghufron, & Hartono, 2019)	International Association of Online Engineering	This study uses the R&D (Research and Development) method using Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model

		development procedure with the conclusion that the developed of mobile application integrated with realistic mathematics is effective in improving student's creative thinking ability of elementary school students.
(Setiyani, Waluya, Sukestiyarno, & Cahyono, 2022)	International Journal of Interactive Mobile Technologies	This study uses the R&D (Research and Development) method using Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model with the conclusion that the design of e-module using Kvisoft Flipbook maker application based on MCT skills is suitable for use in the learning process for class 8 number pattern material.
(Andriani, Dewi, & Sagala, 2019)	Journal of Physics: Conference Series	This study uses the R&D (Research and Development) method referring to the Thiagarajan theory with the conclusion that blended learning media using Mentimeter application was valid according to six experts, practical, and getting a positive response from university students, but can't improve student MCT skills on mathematics department.
(Septian, Sugiarni, & Monariska, 2020)	Al-Jabar: Jurnal Pendidikan Matematika	This research is a quasi-experimental study using a nonequivalent group pretest-posttest design with the conclusion that the MCT abilities of junior high school students in learning quadratic equation material using Android-based GeoGebra are better and getting a positive response from students.
(Komarudin, 2022)	Cartesian: Jurnal Pendidikan Matematika	This study used the quantitative descriptive method through survey techniques with respondents of mathematics teachers and students from various school levels which resulted that there is a need to develop STEM integrated e-modules in improving student's MCT abilities.
(Rodi'ah & Hasanah, 2021)	Ideas: Jurnal Pendidikan, Sosial, Dan Budaya	This study used the qualitative methods with the conclusion that project-based mathematics learning assisted by e-modules in fourth grade elementary school students can be applied online to explore their creative thinking abilities..

(Dewi, Rochmad, & Dwijanto, 2022)	Unnes Journal of Mathematics Education Research	This study used the mixed method with a sequential explanatory model with the conclusion that e-learning assisted problem based learning method is promotive to the development of junior high school student's MCT skills.
(Siregar, Solfitri, & Siregar, 2022)	Proceedings of the UR International Conference on Educational Sciences	This study used the R&D (Research and Development) method using Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model with the conclusion that the e-worksheet can be developed to improve the ability of mathematical creative thinking of students on the subject of integral calculus.
(Simanjuntak & Hutabarat, 2022)	Budapest International Research and Critics in Linguistics and Education (BirLE) Journal	This research is a quasi-experimental with one-group pretest-posttest design which concluded that the *Kvisoft Flipbook* Maker-based math practicum e-book is effective in the learning process.
(Solfitri, Siregar, Syofni, Anggraini, & Apristi, 2023)	Journal of Educational Research and Evaluation	This study used the R&D (Research and Development) method using Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model with the conclusion that the Rational Function Integral E-Worksheet with Linear Factor Denominators developed is feasible to use and can improve student's MCT abilities.
(Setiawan, Fitriani, & Sabandar, 2022)	MaPan: Jurnal Matematika dan Pembelajaran	This study used the R&D (Research and Development) method using Analysis, Design, Development, Implementation, and Evaluation (ADDIE) model with the conclusion that the teaching materials for grade VII junior high school students that have been developed using the help of GeoGebra is valid and practical for the learning process.
(Kusuma, Zaenuri, & Wardono, 2021)	Journal of Physics: Conference Series	This study used the mix method with a sequential explanatory design with the conclusion that the Blended Learning Model using E-Module was effective for increasing high school student's ability to think creatively, but student's creative thinking abilities also depend on metacognition.

(Selvy, Ikhsan, Johar, & Saminan, 2020)	Journal of Physics: Conference Series	This study used the experimental method with the randomized pre-test post-test control group design with the conclusion that there was an increase of senior high school student's MCT abilities and motivation who are taught using PBL model with GeoGebra and highly recommended as a tool for constructing mathematics concepts.

Researchers have collected 25 articles related to keywords as contained in **Table 3. 1** These articles can be grouped based on the methodology used, the research subject, and the conclusions on the integration of increasing student's mathematical creative thinking skills as presented in the following diagram.

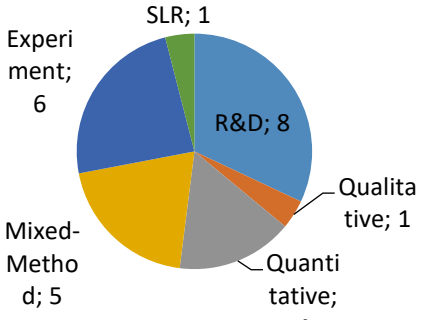

Figure 3. 1 Articles based on research methods

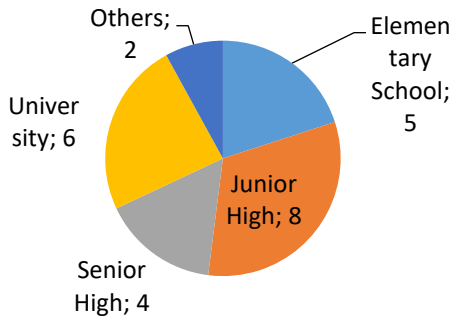

Figure 3. 2 Articles based on research subjects

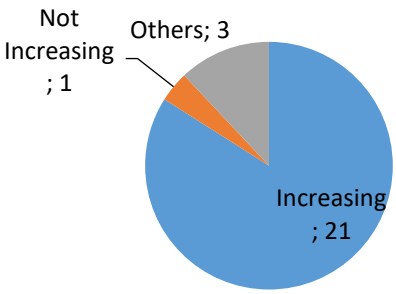

Figure 3. 3 Article based on the conclusion of the influence of ICT integration on mathematical creative thinking ability

3.1. *Integration of ICT in Mathematics Learning*

The integration of ICT in mathematics learning is flexible (Hallal, Hellmann, Sandmann, Carvalho, Reinaldo, & Hotz, 2016) and easy to use (Saputra & Fahrizal, 2019), so that it can improve student's mathematical creative thinking ability (Septian, Sugiarni, & Monariska, 2020), communication and problem-solving skills, self-

confidence (Wijaya, Zhou, Ware, & Hermita, 2021), and student innovation level (Wannapiroon & Pimdee, 2022). In addition, ICT-integrated mathematics learning has also proven effective in the learning process (Simanjuntak & Hutabarat, 2022). It got a positive response from students (Septian, Sugiarni, & Monariska, 2020), as well as bring a positive influence on student self-efficacy (Amalia, Zaiyar, Fadilah, & Santoso, 2021).

3.2. *Integration of ICT with Specific Learning models and Approaches in Mathematics Learning*

The combination of ICT with various learning models such as the Problem Based Learning (Cibro, Siregar, & Rambe, 2021), creative problem soving learning (Yuliastuti, Sukajaya, & Mertasari, 2019), Blended Learning (Kusuma, Zaenuri, & Wardono, 2021), PjBL (Rodi'ah & Hasanah, 2021), and SAVI (Octaviani, Dwijanto, & Ahmadi, 2019), is proven to be able to improve student's mathematical thinking ability. Likewise with the combination of ICT with learning approaches and methodes such as scientific learning approach (Arifuddin, Wahyudin, Prabawanto, Yasin, & Elizanti, 2022) and STEM integration (Komarudin, 2022), which can also improve students' mathematical thinking ability, including the mathematical creative thinking ability.

The use of ICT also has a positive effect on student's affective such as motivation (Selvy, Ikhsan, Johar, & Saminan, 2020), spirit of nationality (Sartono, Sukowati, & Soleha, 2021), and student self-confidence (Yaniawati, Kariadinata, Sari, Pramiarsih, & Mariani, 2020). The use of ICT, especially *GeoGebra* using the Problem Based Learning model is highly recommended as a tool to construct mathematical concepts such as geometry (Selvy, Ikhsan, Johar, & Saminan, 2020).

3.3. *Development of ICT Integration in Mathematics Learning*

The use of ICT in learning mathematics is also constantly being developed with various studies conducted. Research by (Setiawan, Fitriani, & Sabandar, 2022) concluded that the development of teaching materials using *GeoGebra* is valid and practical for use in learning. (Solfitri, Siregar, Syofni, Anggraini, & Apristi, 2023) through their research also concluded that the Rational Function Integral E-Worksheet with Linear Factor Denominators developed is feasible to use and can improve student's MCT abilities. As well as with the research conducted by (Setiyani, Waluya, Sukestiyarno, & Cahyono, 2022) which concluded that e-module using Kvisoft Flipbook maker application based on MCT skills is suitable for use in the learning process of class 8 number pattern material. In addition, SLR research by (Muktiari & Dewi, 2021) conclude that the development of textbooks oriented towards the ICT-assisted Preprospec learning model can improve MCT ability.

3.4. *Lack and Error*

The integration ICT in learning mathematics to improve student's mathematical creative thinking ability is not always smooth and produces good results. Research by (Andriani, Dewi, & Sagala, 2019) on the topic of blended learning media by using the Mentimeter application is valid, practical, and getting a positive response from university students, but can't improve student's mathematics creative thinking skills. Besides, (Kusuma,

Zaenuri, & Wardono, 2021) stated that student's creative thinking abilities also depend on metacognition. Therefore, the integration of ICT into learning mathematics is not always able to improve student's mathematical creative thinking abilities. In order to get maximum results, the integration of ICT in mathematics learning must be carefully prepared and the ICT tools used are appropriate to the teaching materials.

4. Conclusions and Recomendations

Most of the articles analyzed concluded that there was an increase in student's mathematical creative thinking abilities in mathematics learning that was integrated with ICT. Thus, it can be concluded that ICT integration in mathematics learning has a positive impact on increasing student's mathematical creative thinking ability. This is because the integration of ICT in learning mathematics can increase motivation (Selvy, Ikhsan, Johar, & Saminan, 2020), self-confident (Yaniawati, Kariadinata, Sari, Pramiarsih, & Mariani, 2020), and self-efficacy (Amalia, Zaiyar, Fadilah, & Santoso, 2021) which is directly proportional to the increase in student's mathematical creative thinking abilities.

It is clear that the integration of ICT in learning mathematics has a positive impact on improving student's mathematical creative thinking abilities, but it does not always improve student's mathematical creative thinking abilities. This can be influenced by student's metacognitive conditions (Kusuma, Zaenuri, & Wardono, 2021) or other things related. Therefore, further research is needed regarding the causes of the failure of ICT integration in mathematics learning to improve student's mathematical creative thinking skills, as well as its concrete solutions.

Researcher also highly recommend the integration and use of ICT in learning mathematics. This cannot be separated from the positive impact of ICT on learning such as being able to improve student's creative thinking skills, communication, problem solving, motivation, and self-efficacy. ICT is available with various types and uses, making it easier for teachers to use it according to the needs and conditions of the field. In addition, there is a lot of research and development related to ICT in learning that is carried out massively and continuously, thus enabling the use of ICT in learning mathematics in a more optimal and sustainable manner.

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