Jurnal Elemen, 9(2), 558-577, July 2023
https:/doi.org/10.29408/jel.v9i2.15150

e- ISSN: 2442 - 4226

Research trends on flipped classrooms of mathematics creative thinking, critical thinking, and problem-solving skills

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Abstract

Some studies discussed learning outcomes, challenges, and the effect of media learning on flipped classrooms of mathematics creative thinking (MCeT), critical thinking (MCiT), and problem-solving (MPS) skills. None of the studies reviewed the research information. This study aimed to examine trend research by year and the diversity of research methods, quantitative research designs, research subjects, mathematics topics, research variables, data collection tools, test designs, data analysis methods, and learning media in articles published in Scopus, Education Resources Information Centre (ERIC), and *Garba Rujukan Digital* (Garuda) databases of mathematics educational journals from January 2018 to April 2023. The method of this study was the content analysis method. Twenty-two articles were evaluated in this study. The results showed that the research trend by year was increasing. The most type of research methods, quantitative research design, research subjects, mathematics topic, research variables, data collecting tools, kind of test design, data analysis techniques, and learning media were quasi-experimental design, eighth-grade junior high school students, three-dimensional shape, problem-solving, test sheet, pretest-posttest, t-test, and video, respectively. This study gave insights to other researchers for future decision-making on flipped classrooms of MCeT, MCiT, and MPS skills.

Keywords: content analysis; creative thinking skills; critical thinking skills; flipped classroom; mathematics educational journals; problem-solving skills

How to cite: Fayakuun, M., & Agoestanto, A. (2023). Research trends on flipped classrooms of mathematics creative thinking, critical thinking, and problem-solving skills. *Jurnal Elemen, 9*(2), 558-577. https://doi.org/10.29408/jel.v9i2.15150

Received: 13 May 2023 | Revised: 15 June 2023
Accepted: 28 June 2023 | Published: 31 July 2023

Introduction

Technology has grown rapidly in recent years, especially artificial intelligence (AI) (Duan et al., 2019; Garrido, 2012; Paschen et al., 2019; Prakash et al., 2013; Soc et al., 2020). AI allows computers to learn from experience and perform tasks only humans can do (Riedl, 2019; Zanzotto, 2019). In many industries, AI has brought higher efficiency and productivity and improved customer service quality (Li et al., 2022; Ostrom et al., 2019; Y. Xu et al., 2020). AI can replace humans in some areas, so humans need the ability to survive in the AI era (Ormerod, 2021). Individuals with psychosocial solid competence were more likely to enhance their chances of survival (Bhat & Aminabhavi, 2011; Sukenti et al., 2021). According to the World Health Organization in Joynes et al. (2019), creative thinking, critical thinking, and problem-solving are skills needed for psychosocial competence. Individuals must master mathematics creative thinking (MCeT), mathematics critical thinking (MCiT), and mathematics problem-solving (MPS) skills to compete in the worldwide competition of the twenty-first century (Setiana et al., 2021).

The United Kingdom's teachers and elsewhere were being urged to encourage students' creativity in all course material subjects, including mathematics, because creativity is a personal activity that aims to produce a new thing and is unpredictable; thus, fostering creativity with guidance could help to raise the learner's character growth (Sriwongchai, 2015). The innate ability to think critically was not inherent in students and their previous educational encounters might not have necessitated such thinking, so it meant that educators who aimed to incorporate this skill into their instructional practices must first exemplify the behavior; thus, students had to acquire the ability to think critically before students could effectively employ it in various content scenarios (Ebiendele Ebosele Peter, 2012). Columbia University students might use critical thinking to arrange multi-assignment projects in computer design, business networking, and mathematical function systems (Facione, 2011). Students might use their multidisciplinary problem-solving skills to solve multi-projects (Yanuarto & Hapsari, 2022).

Improving in creative thinking (Alkhatib, 2019; Maharani, 2014; Sari et al., 2018; Yayuk et al., 2020), critical thinking (Aizikovitsh-Udi & Amit, 2011; Alkhatib, 2019; Ebiendele Ebosele Peter, 2012), and problem-solving (Alkhatib, 2019) skills in mathematics is needed effective learning models (Sanders, 2016; Simanjuntak et al., 2021). One effective learning model was flipped classroom because it could improve MCeT, MCiT, and MPS skills (Al-Zoubi & Suleiman, 2021; Atwa et al., 2022; Azizah et al., 2022; Puspitasari et al., 2020; Ramadhani et al., 2020; Wei et al., 2020). The learning sessions are divided into two types under the flipped classroom model: individual learning sessions and face-to-face sessions with the teacher (Bergmann & Sams, 2014). Students have a greater degree of flexibility regarding the rate at which they study and how they use their time when participating in independent learning sessions (Horn & Staker, 2012; Vogelsang et al., 2019).

In international and national research, several studies on flipped classrooms of MCeT, MCiT, and MPS skills were found, notably in the context of mathematical education. Studies that examined the effects of media learning (Ariani et al., 2022; Tabieh & Hamzeh, 2022) and another study discussed learning challenges in flipped classrooms to improve critical thinking

(Yuliana et al., 2022). The correlation between flipped classrooms of MCeT, MCiT, and MPS and other measures of academic success has also been investigated (Chang et al., 2020; Pratama et al., 2019). However, the studies still need to review the research information that has been conducted.

The current study aimed to collect data on several papers that discussed flipped classrooms of MCeT, MCiT, and MPS skills by using content analysis on data from numerous scientific journals in Scopus, The Education Resources Information Centre (ERIC), and *Garba Rujukan Digital* (Garuda) databases that were published from January 2018 to April 2023. The items discussed in this study were trend research by year and diversity of research methods, quantitative research designs, research subjects, mathematics topics, research variables, data collection tools, test designs, data analysis methods, and learning media. The trend year by year was also discussed in this study.

This study differs from previous ones that focused on MCeT, MCiT, and MPS skills due to using the flipped classroom treatment in specific components. The present investigation centered on comprehensive articles published from January 2018 to April 2023, including Scopus, ERIC, and Garuda databases. The present study was dedicated to examining several articles that centered on implementing the flipped classroom approach to develop MCeT, MCiT, and MPS skills. Thirdly, diverse parameters were employed as the basis for conducting content analysis.

Methods

The study utilized content analysis following the guidelines of Fauzi and Pradipta (2018), Susetyarini and Fauzi (2020), and Turmuzi et al. (2023) with a specific focus on analyzing findings from various scientific journals from all researchers in the world that were indexed in Scopus, ERIC, and Garuda. There were three steps. The first step was planning, including finding research questions and making inclusion and exclusion. The second step was the conducting step, which included collecting data. In this study, data collection had data sources, the study selection process, and the research instrument. The third step was reporting step, which includes data synthesis and description of data.

Inclusion and exclusion

All the literature acquired during the identification phase was reviewed and chosen as the primary research using two criteria, namely inclusion and exclusion. The inclusion criteria in this review were: (1) journal or academic proceeding; (2) related to flipped classroom and mathematics critical thinking or creative thinking or problem-solving skills; (3) published from January 2018 to April 2023; (4) mathematics education scope. The exclusion criteria in this review were: (1) not journal and academic proceeding; (2) not related to flipped classroom and mathematics critical thinking or creative thinking or problem-solving skills; (3) not published from January 2018 to April 2023; (5) not mathematics education scope.

Data sources

The data was collected through a content analysis of articles related to mathematics education, utilizing a specific keyword: (1) flipped classroom; and (2) mathematics critical thinking skill or mathematics creative thinking skill or mathematics problem-solving skill in Scopus, ERIC, and Garuda databases which was published from 2018 to 2023. Scopus is one of the most credible databases in the world. ERIC is an internet-based educational research and information repository supported by the Institute of Education Sciences (IES) within the United States Department of Education. Garuda is the database created by the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia.

Study selection process

There were 129 articles from all researchers in the world indexing by Scopus, ERIC, and Garuda. By using the keyword TITLE-ABS-KEY("flipped classroom") AND TITLE-ABS-KEY("mathematics" or "mathematical) AND TITLE-ABS-KEY("critical thinking" or "creative thinking" or "problem-solving") in Scopus, there were 44 papers. Then, by using the keyword "flipped classroom" AND (mathematics OR mathematical) AND ("creative thinking" OR "critical thinking" or "problem-solving") in ERIC, there were 70 papers. Using keywords related to flipped classroom and mathematics critical thinking skill or mathematics creative thinking skill or mathematics problem-solving skill in English terms and Indonesian terms, there were 15 papers in Garuda. After removing duplicate articles, unavailable articles, and papers that did not match the inclusion criteria, twenty-two articles were acquired for literature review.

Research instruments

The research employed a content analysis guide to examine relevant features (Table 1). This study involved assessing up to nine distinct elements to conduct content analysis. The factors above encompassed various aspects such as (1) the annual publication count, (2) research types, (3) quantitative research types, (4) research subjects, (5) mathematical topics chosen for the studies, (6) research variables, (7) data collection instruments; (8) test design types; (9) data analysis methods; and (10) learning media. The categories Table 1 for components (1), (5), and (10) were not selected initially due to the absence of prior studies that could have served as a reference point for determining the constituents of these categories. Additionally, the emergence of extensive categories was possible following the content analysis of specific articles. Furthermore, the establishment of component categories (2), (3), (4), (6), (7), (8), and (9) preceded the process of data collection. Table 1 displays the categories that have been derived from previous studies by Fauzi and Pradipta (2018), Susetyarini and Fauzi (2020), and Turmuzi et al. (2023), with specific alterations.

Data synthesis

Each data from the articles that have been collected will be included in the analysis component. Abstract, methods, and discussion will be the primary considerations in this selection. These sections were the primary criteria for selecting relevant data for further analysis.

Once the relevant data was identified, it would be processed and represented using a bar or pie chart format. To facilitate the analysis and visualization process, the researchers employed Google Spreadsheets and Microsoft Excel as a tool. These apps provided features for data entry, organization, and basic data manipulation, which could be utilized to input, manipulate, and visualize the collected data in a bar chart or pie chart.

Table 1. The Components and categories used for content analysis in the study

Component	Categories	
Type of Research	A1-Quantitative A2-Qualitative A3-Research and Development (R&D)	A4-Class Action Research (CAR) A5-Mixed Method A6-Literature Study
Type of Quantitative Research	B1-Observation studies (OS) B2-Correlational research (CR) B3-Survey research (SR) B4-Pre-experimental designs (PED)	B5-True experimental methods (TED) B6-Quasi-experimental designs (QED) B7-Ex post facto designs (EPFD)
Research Subject	C1-Seventh-grade junior high school (JHS) students (7^{th} grade) C2-Eight-grade JHS students (8^{th} grade) C3-Ninth-grade JHS students (9^{th} grade) C4-Tenth-grade senior high school (SHS) students (10^{th} grade)	C5-Eleventh-grade SHS students (11^{th} grade) C6-Twelfth-grade SHS students (12^{th} grade) C7-Undergraduate/pre-service teacher C8-Others
Research Variable	D1-Creative thinking skill D2-Critical thinking skill	D3-Problem-solving skill
Data Collection Instruments	E1-Questionnaire sheet E2-Observation sheet E3-Test sheet	E4-Interview sheet E5-Unidentified
Type of Test Design	F1-Pretest-posttest F2-Posttest Only	
Data Analysis Techniques	G1-Mean/SD G2-Frequency/Percentage G3-Gain score/N-Gain G4-T-test G6-ANOVA G7-ANCOVA	G8-MANOVA G9-MANCOVA G10-Correlation G11-Regression G12-Factor analysis G13-Non-parametric tests G14-Others

Results

This study analyzed twenty-two articles that were eligible for inclusion and exclusion. The data of trends of publications, research methods, quantitative research designs, research subjects, mathematics topics, research variables, data collection tools, test designs, data analysis methods, and learning media from twenty-two articles were reported in the following section.

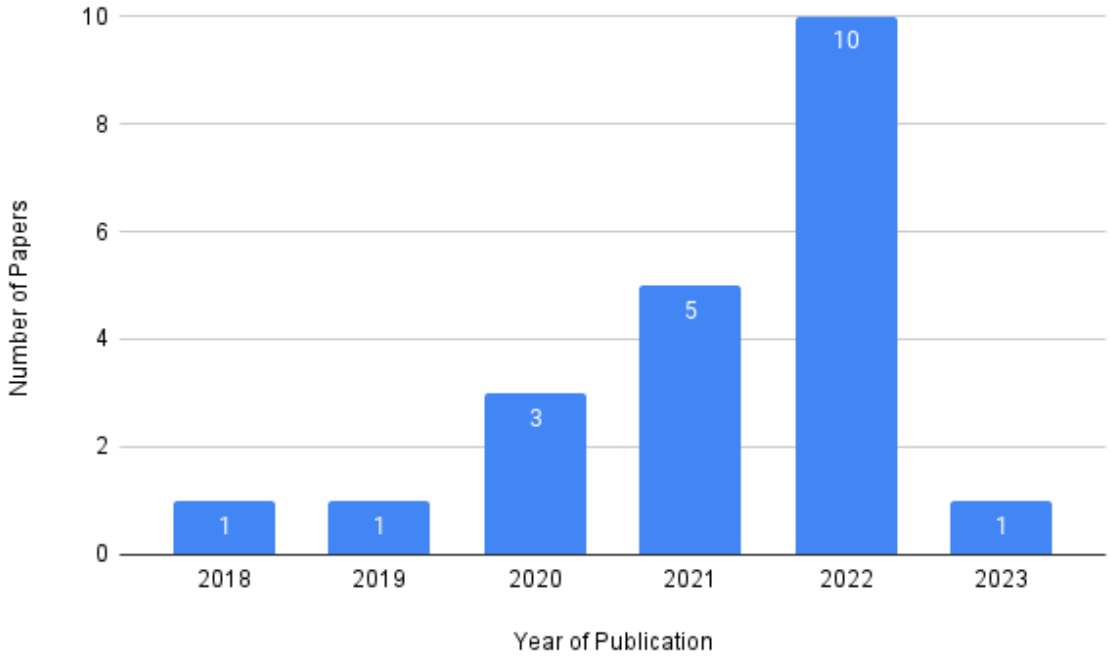

Figure 1. Flipped classroom trend in the quantity of educational studies in MCeT, MCiT, and MPS skills

Trend of publications

Publications regarding flipped classroom teaching methods were gathered from the given period, particularly in MCeT, MCiT, and MPS skills. Figure 1 shows that the research articles have been accessible since 2018 from the three databases (Scopus, ERIC, and Garuda). Overall, the number of publications experienced an increasing trend in the first five years and plunged at the end of the period. The details will be explained in the following paragraph.

To begin with, the chart shows that there were twenty-two papers found. In the first two years, the numbers leveled off at 1. Then, there was a gradual rise from 3 to 5 in the next two years and peaked at 10 in 2022. This observed trend of a rising number of publications on flipped classrooms that incorporate MCeT, MCiT, and MPS skills indicated a notable increase in researchers actively exploring higher-order flipped classroom methods with these skills. However, the research on flipped classrooms with these skills decreased in 2023, which can be inferred that researchers in scientific journals published articles concerning flipped classrooms with these skills in April 2023.

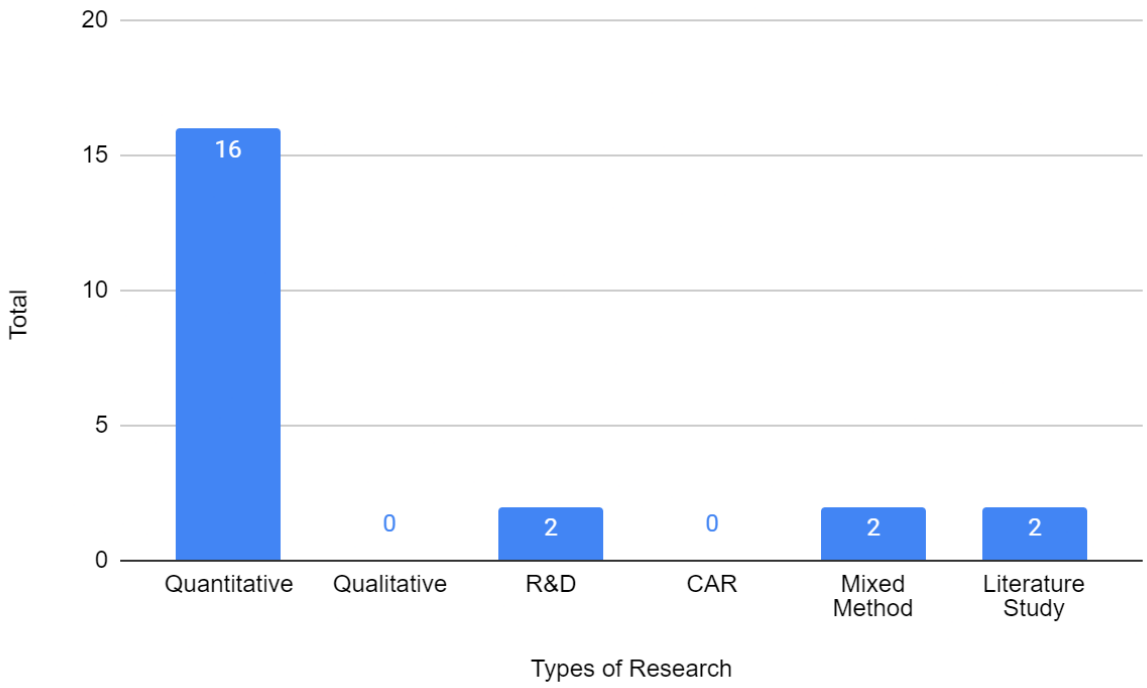

Figure 2. The distribution of research types used on articles of flipped classroom of MCeT, MCiT, and MPS skills

Types of research

The various approaches used in the research are called "types of research.". Based on **Error! Reference source not found.Error! Reference source not found.**, most of the types of research utilized in the articles were quantitative, with 16 articles, followed by research and development (R&D), mixed method, and literature study with two articles. No article used qualitative research and classroom action research (CAR) on this topic. In conclusion, the quantitative method was the most commonly used in this topic. Therefore, it gave advantages to the qualitative approach and CAR to be explored in this topic, which can subsequently define it thoroughly and comprehensively.

Types of quantitative research

Quantitative research involves systematically collecting and analyzing numerical data to test a hypothesis or identify patterns and correlations within the data. Quantitative research was most of the types of research used on this topic. There are seven types of quantitative research. However, only three out of the seven types were found in the publications. According to Figure 3, a quasi-experimental design was the most widely used type of quantitative research, as many as 15 times. Then, it is followed by pre-experimental and true-experimental designs, which were three times and once, respectively. At the same time, the other four types of quantitative research still needed to be created.

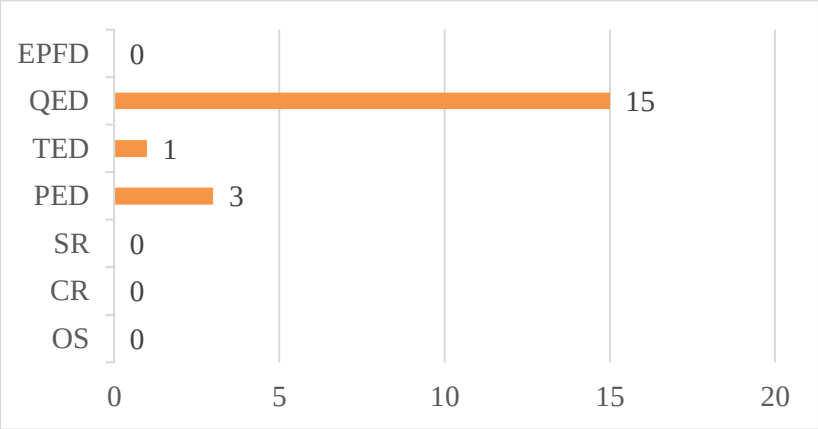

Figure 3. The distribution of quantitative research types used on articles of flipped classroom of MCeT, MCiT, and MPS skills

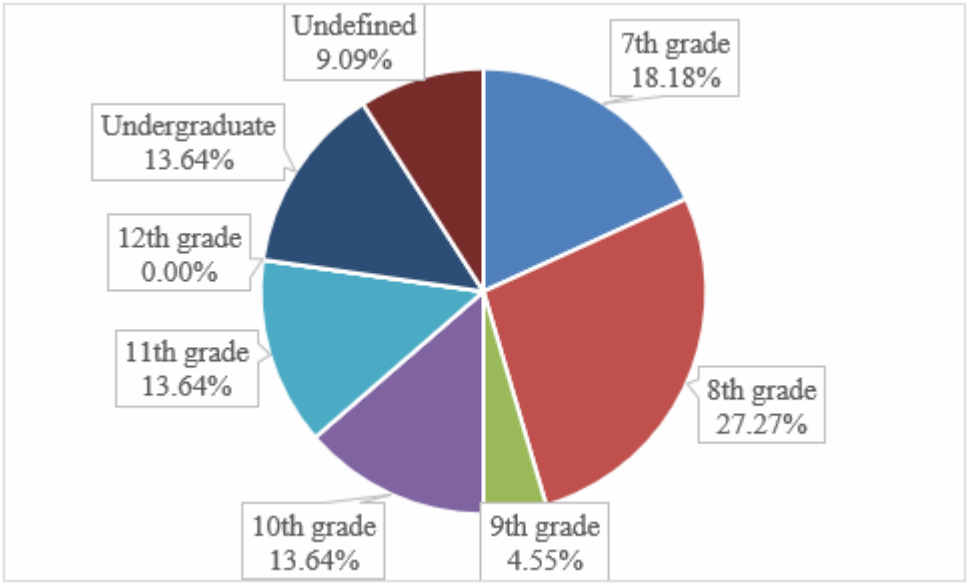

Figure 4. Research subject in select educational studies with a primary focus on flipped classroom of MCeT, MCiT, and MPS skills

Research subjects

Flipped classrooms were applied in MCeT, MCiT, and MPS skills for students to be targeted from junior high school to higher educational levels. Figure 4 depicts the various study subjects in the research articles analyzed for this study. According to the chart in Figure 4, the research's subjects who were the most commonly utilized in the 22 publications evaluated were eighth-grade junior high school students (27.27%). Following this, the second most common study subjects were seventh-grade junior high school students (18.18%). Interestingly, three research subjects were the third most common study subject as they had the same proportion: tenth-grade senior high school students, eleventh-grade senior high school students, and undergraduates (13.64%). These results indicated that some researchers conducted studies with

subjects in ninth (4.55%) and twelfth grades (0%) who were preparing for graduation exams in fewer numbers than other classes. On the other hand, students in grades nine and 12 also need to be explored to discover their skills in MCeT, MCiT, and MPS in flipped classrooms in preparing for graduation exams and preparing them to be better prepared at the next level. Unfortunately, some articles (9.09%) did not give the research's subjects grade information.

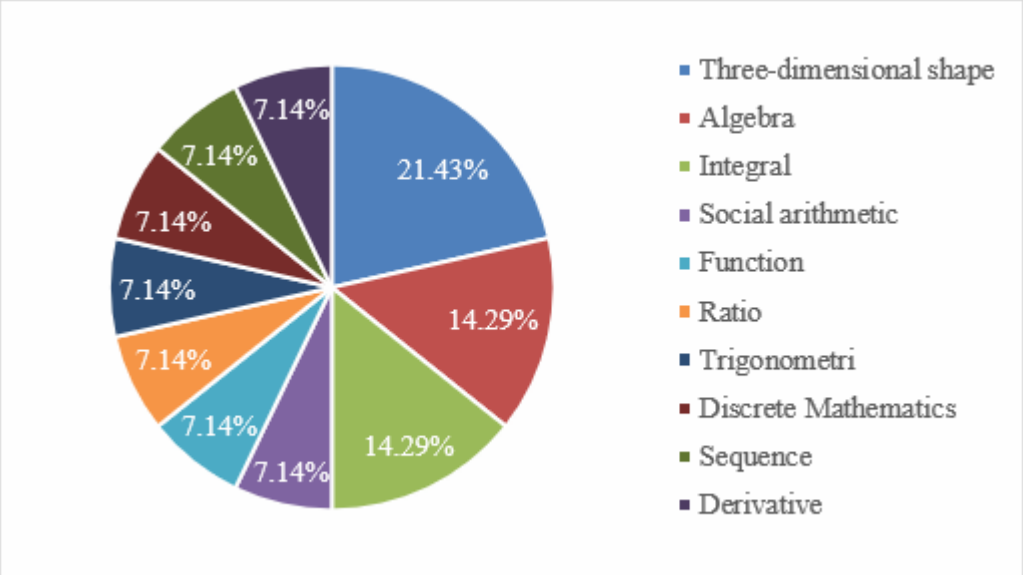

Figure 5. Mathematics topics in educational research in flipped classroom of MCeT, MCiT, and MPS skills

Mathematics topics

Mathematics is one of the scientific disciplines with various subjects. Some topics were deemed simple, while others remained challenging for students. Several publications deviated from the analysis by focusing on a single issue, whereas other sources highlighted multiple issues. Based on **Error! Reference source not found.**, various topics in mathematics were chosen to pilot the researcher in the school. It can be seen that the superior case in mathematics found in the publications was three-dimensional shape (21.43%), which is utilized to know the effectiveness of flipped classroom implementation regarding MCeT, MCiT, and MPS skills in the classroom. Studies piloted in **Error! Reference source not found.** can be used as a reference in a further study concerning flipped classrooms regarding MCeT, MCiT, and MPS skills. The most frequent mathematics topics from the articles were three-dimensional shape (21.43%), algebra (14.29%), and integral (14.29%) to assess students in the flipped classroom of MCeT, MCiT, and MPS skills. At the same time, the rest of the topics were about half of the whole proportion (49.98%).

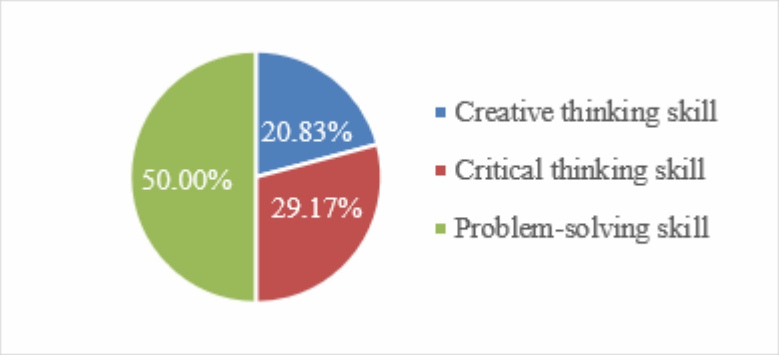

Figure 6. Research variables of flipped classroom as main concern

Research variables

Among the several studies gathered, each used a different set of factors in their investigations. The diversity of the research variables is presented in **Error! Reference source not found.**. According to the trend in **Error! Reference source not found.**, studies that investigated problem-solving skills (50%) in flipped classrooms were the most prevalent. The second and the third skills to be regarded as the research variables were critical thinking skills (29.17%) and creative thinking skills (20.83%), respectively. Thus, these results indicated that problem-solving skill was the most likely effective in conducting research in a flipped classroom.

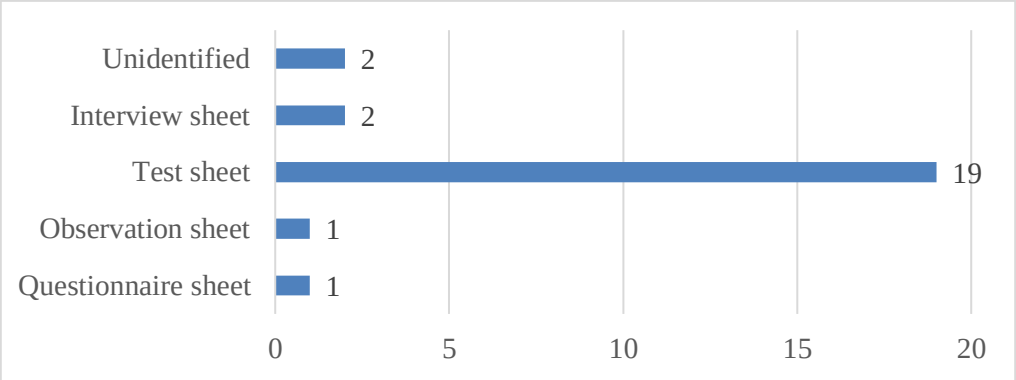

Figure 7. The distribution of data collection instruments that used articles on flipped classroom of MCeT, MCiT, and MPS skills

Data collection instruments

Data collection instruments are tools to gather information on substantially identical items. Based on the data presented in Figure 7, the test sheet was the most chosen tool on this topic as many as 19 times. In contrast, the questionnaire sheet and observation sheet were used once. Meanwhile, the interview sheet was used two times, and the last two articles needed to tell what instrument they used. According to these results, it suggested using test sheets as the most feasible instrument for quantitative research. In addition, the test sheet data collection was considered more objective than others in the flipped classroom MCeT, MCiT, and MPS skills.

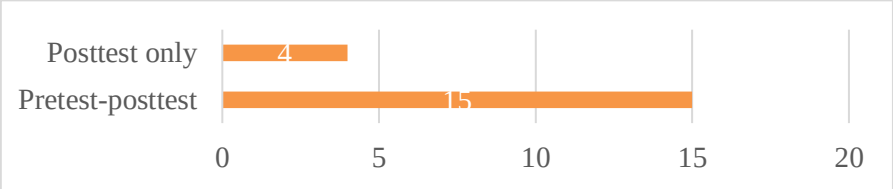

Figure 8. The distribution of test design type used on articles of flipped classroom of MCeT, MCiT, and MPS skills

Type of test design

Based on **Error! Reference source not found.**, only two test designs were used: pretest-posttest (15) and posttest only (4). It indicated that pretest-posttest was commonly used in the flipped classroom research of MCeT, MCiT, and MPS skills. Using a pretest to create a baseline enables educators to monitor better and assess their students' progress in each skill criterion. The pretest identifies what the students require to learn, whereas the posttest demonstrates what they achieved. Using a design that includes both a pre-test and a post-test enabled researchers to determine the quantity of a change or growth that occurred across the pre-test and the post-test. On the other hand, using a pretest-posttest design allows a researcher to analyze data before and after the study.

Data analysis techniques

Data analysis techniques are the process of extracting useful information by analyzing data. Figure 9 shows data analysis techniques used in articles on the flipped classroom of MCeT, MCiT, and MPS skills. The most utilized data analysis techniques were t-test (8), n-gain (4), ANOVA (4), and MANCOVA (4). In addition, ANCOVA and other tests were twice (2) SD, MANCOVA, and non-parametric tests (1). Conversely, percentage, correlation, regression, and factor analysis were not found in any articles.

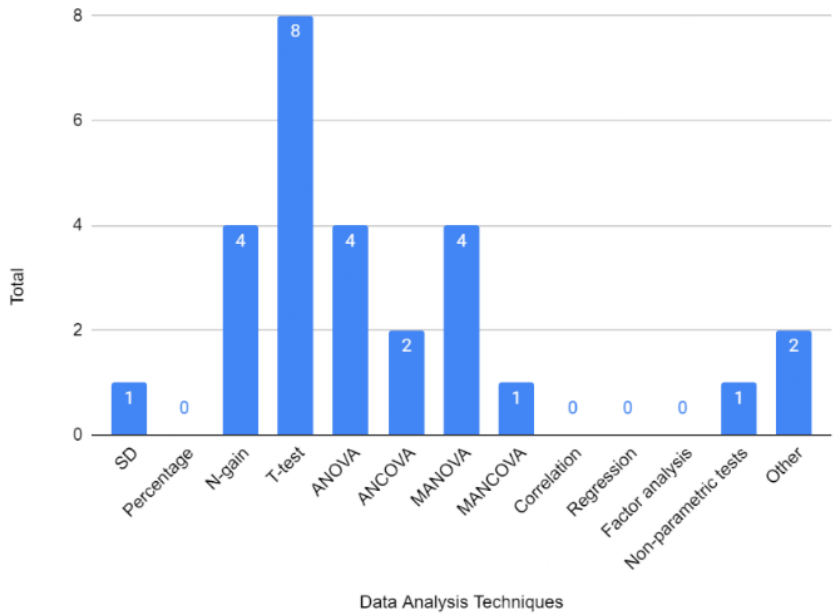

Figure 9. The Distribution of Data Analysis Techniques Used on Articles of Flipped Classroom of MCeT, MCiT, and MPS Skills

Learning media

The learning media used to assess students' MCeT, MCiT, and MPS in the flipped classroom are shown in **Error! Reference source not found.**. Based on **Error! Reference source not found.**, videos were the most frequently used learning media (63.16%). The second most utilized learning media of this focus study were android apps (10.53%), chat apps (10.53%), and learning management systems (10.53%). In addition, augmented reality (5.26%) was the most rarely found in research studies throughout the period in question. Based on these results, the video was the most likely chosen in a flipped classroom to improve students' MCeT, MCiT, and MPS skills. Furthermore, students who demand greater attention for comprehending information in real time can benefit from the individualized learning experience, allowing them to understand complicated topics with relative ease by using videos. Students became enthusiastic when they watched a video during a lesson, which enabled them to understand the lesson clearly. This was because of its engaging visual explanation, in which a brief video might help students quickly grasp any difficult idea.

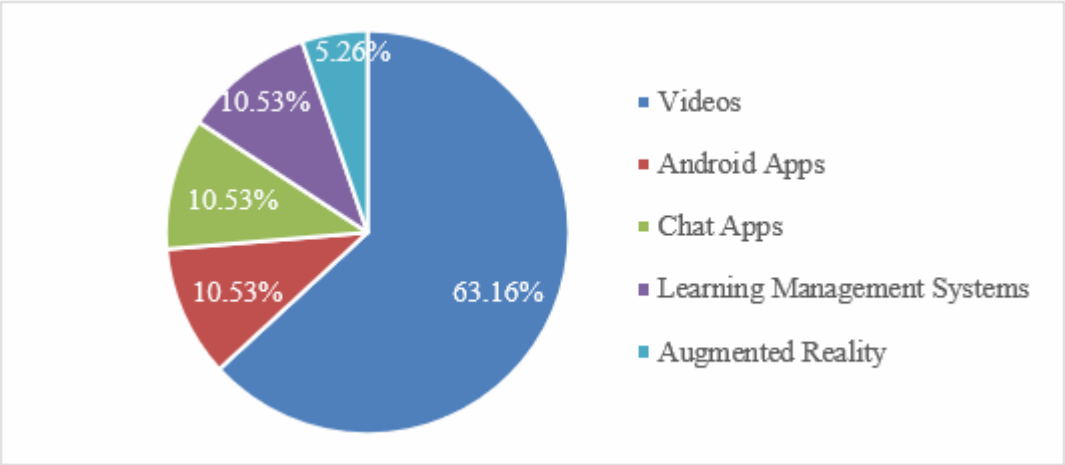

Figure 10. Learning media that used on articles of flipped classroom of MCeT, MCiT, and MPS skills

Discussion

Based on the results, a brief discussion will be presented starting from the trend of the publications, research methods, quantitative research designs, research subjects, mathematics topics, research variables, data collection tools, test designs, data analysis methods, and learning media. Turning into details, the results showed an increasing number of annual publications from 2019 to 2022. The growing number of researchers investigating the effect of flipped classrooms on MCeT (Nida et al., 2020; Rahmadani et al., 2020; Zakiyah et al., in press.), MCiT (Al-Zoubi & Suleiman, 2021; Atwa et al., 2022; Shai, 2022) and MPS (Gao & Hew, 2022) skills suggested that this approach holds promise for advancing educational development. According to Susetyarini and Fauzi (2020), a higher number of research would influence future educational practices. The underlying concept posited that the paramount objective of the study was to enhance educational practices (Coburn & Penuel, 2016).

The dominant research subject found in this study was junior high school. It differed from a study by Lin et al. (2014), which showed that senior high school was the dominant research subject used. However, it had the same result when taking ninth and twelfth grades as research subjects, with a lower number of students appointed as research subjects. This is because the school was strict in giving permission on which classes could be used for research subjects for ninth- and twelfth-graders needed preparation for school exams that determined their graduation. On the other hand, researching the ninth and twelfth grades was also crucial for student success and graduation rates (McCallumore & Sparapani, 2010).

Three-dimensional became the topic that was chosen. Students can be assisted in acquiring geometry mastery by enhancing their cognitive spatial abilities or imparting targeted geometric knowledge and problem-solving skills (Zhang, 2017). It meant that problem-solving skills were critical in acquiring mastery of geometry (tree-dimensional). Since MPS was the

most chosen research variable, it was normal three-dimensional becoming the most chosen topic.

The pedagogical approach of collaborative problem-solving has gained significant traction in the educational sphere to foster students' critical thinking skills (Xu et al., 2023). Critical thinking can be considered a problem-solving skill (Papastephanou & Angeli, 2007). It indicated that problem-solving skill was broader in context than critical thinking. It was the reason MPS was more chosen than MCiT.

The test sheet was the most chosen to measure MCeT, MCiT, and MPS skills. The validity and reliability of the test sheet could be measured statistically (Sürücü & Maslakçi, 2020). It indicated that test sheets are a more objective tool to measure student skills. According to Rintayati et al. (2020), the test sheet allowed for evaluating higher-order thinking skills and provided limited opportunities for students to obtain more in-depth knowledge while modifying students' ability to recognize and solve problems. Furthermore, the test sheet encouraged students to show their mastery of specific skills and abilities by doing or creating something; it provided us with data about the student's daily progress and perspective on the learning process (Abosalem, 2015).

The positive result was shown in the selection of test designs conducted by the researchers because quasi-experiments using the posttest-only method were not recommended. According to Krishnan (2019), quasi-experiments using a posttest-only design have low inference power, quickly threatened internal validity, and uncontrollable external variables. Unfortunately, the selection of data analysis techniques showed negative things. According to Oakes & Feldman (2001), Wu & Lai (2015), and Susetyarini & Fauzi (2020), ANCOVA was more strongly recommended than the t-test for quasi-experiments using the pretest-posttest design. This study showed that the t-test was the one that was more widely used than ANCOVA or MANCOVA. ANCOVA is beneficial in eliminating uncontrolled external variables (Pardo, 2023). ANCOVA could reduce bias in research (H. Lin & Larzelere, 2020). Based on this study, the next researcher recommends using ANCOVA if the researcher uses a quasi-experimental design in a pretest-posttest.

Flipped classrooms of MCeT, MCiT, and MPS needed media, especially video (Beatty et al., 2019; Long et al., 2016) because it was used the most for media learning (see **Error! Reference source not found.**), but it was contrary to type research used rarely (see **Error! Reference source not found.Error! Reference source not found.**) that was research and development (R and D). Making videos to use in flipped classrooms of MCeT, MCiT, and MPS was challenging (Voogt et al., 2013) because of its complexity, content quality, easier-to-understand lessons, etc. Nabayra (2020) developed a video based on the e-module in the Mathematics in Nature class and recorded students' learning experiences with the e-modules in a flipped classroom approach. The video-based e-modules included the following sections: title, learning goals, summary, discussion, references, assessment activity, and answer key. The instructional videos aid students in comprehending the material (Insorio & Macandog, 2022; Wijaya et al., 2021). On the other hand, to make video learning, firstly, researchers must do R and D. According to Fatahillah et al. (2020), R and D are needed in effective and valid learning

media. In this study, the recommendation for the following research uses R and D on the type of research in the flipped classroom of MCeT, MCiT, and MPS skills.

Conclusion

The results of this content analysis study were drawn from the several related articles published in Scopus, ERIC, and Garuda. They showed that the trend of the related publication by year increased. Besides, the most frequently used research method type, quantitative research design, research subject, mathematics topic, research variable, data collecting tool, kind of design, data analysis technique, and learning media were quasi-experimental design, eighth-grade junior high school students, three-dimensional shape, problem-solving, test sheet, pretest-posttest, t-test, and video, respectively.

The limitations of this study were, first, it was only analyzing 22 articles. Next, it analyzed all research from the world in which Scopus, ERIC, and Garuda indexed the articles found. Lastly, three variables (MCeT, MCiT, and MPS skills) focused on flipped classrooms were explored in this study. It is suggested in future research to expand the research sample while narrowing down the analysis focusing on one country only, as well as one variable investigation. The recommendations from this study are using a quasi-experiment pretest-posttest design with ANCOVA data analysis technique and doing research and developments (R&D) method to produce an effective learning media for flipped classrooms of MCeT, MCiT, and MPS skills.

Acknowledgment

The authors wish to express their gratitude to those who contributed to the writing of this article.

Conflicts of Interest

The authors assert that there are no conflicts of interest about the publication of this manuscript. Furthermore, the authors have addressed the ethical concerns about plagiarism, misconduct, data fabrication and falsification, double publication and submission, and redundancies.

Funding Statement

This work received no specific grant from any public, commercial, or not-for-profit funding agency.

Author Contributions

Muhammad Fayakuun: Conceptualization, writing - original draft, investigation, methodology, and visualization; **Arief Agoestanto:** Writing - review & editing, formal analysis, and validation.

References

Abosalem, Y. (2015). Assessment techniques and students' higher-order thinking skills. *ICSIT 2018 - 9th International Conference on Society and Information Technologies, Proceedings*, *4*(1), 61–66. https://doi.org/10.11648/j.ijsedu.20160401.11

Aizikovitsh-Udi, E., & Amit, M. (2011). Developing the skills of critical and creative thinking by probability teaching. *Procedia - Social and Behavioral Sciences*, *15*, 1087–1091. https://doi.org/10.1016/j.sbspro.2011.03.243

Al-Zoubi, A. M., & Suleiman, L. M. (2021). Flipped classroom strategy based on critical thinking skills: Helping fresh female students acquire derivative concept. *International Journal of Instruction*, *14*(2), 791–810. https://doi.org/10.29333/iji.2021.14244a

Alkhatib, O. J. (2019). A framework for implementing higher-order thinking skills (problem-solving, critical thinking, creative thinking, and decision-making) in engineering humanities. *2019 Advances in Science and Engineering Technology International Conferences, ASET 2019*, 1–8. https://doi.org/10.1109/ICASET.2019.8714232

Ariani, D. N., Sumantri, M. S., & Wibowo, F. C. (2022). The impact of android module-based inquiry flipped classroom learning on mathematics problem solving and creative thinking ability. *International Journal of Interactive Mobile Technologies*, *16*(24), 32–46. https://doi.org/10.3991/ijim.v16i24.35749

Atwa, Z., Sulayeh, Y., Abdelhadi, A., Jazar, H. A., & Eriqat, S. (2022). Flipped classroom effects on grade 9 students' critical thinking skills, psychological stress, and academic achievement. *International Journal of Instruction*, *15*(2), 737–750. https://doi.org/10.29333/iji.2022.15240a

Azizah, T., Fauzan, A., & Harisman, Y. (2022). "Flipped classroom type peer instruction-based learning" based on a website to improve student's problem solving. *Infinity Journal*, *11*(2), 325–348. https://doi.org/10.22460/infinity.v11i2.p325-348

Beatty, B. J., Merchant, Z., & Albert, M. (2019). Analysis of student use of video in a flipped classroom. *TechTrends*, *63*(4), 376–385. https://doi.org/10.1007/s11528-017-0169-1

Bergmann, J., & Sams, A. (2014). *Flip your classroom: reach every student in every class every day*. International Society for Technology in Education.

Bhat, A., & Aminabhavi, V. (2011). Home environment and psychosocial competence of adolescents. *Journal of Psychology*, *2*(1), 57–63. https://doi.org/10.1080/09764224.2011.11885464

Chang, C.-Y., Kao, C.-H., & Hwang, G.-J. (2020). Facilitating students' critical thinking and decision making performances. *Educational Technology & Society*, *23*(2), 32–46. https://www.jstor.org/stable/26921132

Coburn, C. E., & Penuel, W. R. (2016). Research–practice partnerships in education: Outcomes, dynamics, and open questions. *Educational Researcher*, *45*(1), 48–54. https://doi.org/10.3102/0013189X16631750

Duan, Y., Edwards, J. S., & Dwivedi, Y. K. (2019). Artificial intelligence for decision making in the era of big data – evolution, challenges and research agenda. *International Journal of Information Management*, *48*(January), 63–71. https://doi.org/10.1016/j.ijinfomgt.2019.01.021

Ebiendele Ebosele Peter. (2012). Critical thinking: Essence for teaching mathematics and mathematics problem solving skills. *African Journal of Mathematics and Computer Science Research*, *5*(3), 39–43. https://doi.org/10.5897/AJMCSR11.161

Facione, P. a. (2011). *Critical thinking: What it is and why it counts* (Issue ISBN 13: 978-1-891557-07-1.). Insight Assessment.

Fatahillah, A., Puspitasari, I. D., & Hussen, S. (2020). The development of schoology web-based learning media with geogebra to improve the ICT literacy on quadratic functions.

JRAMathEdu (Journal of Research and Advances in Mathematics Education), *5*(3), 304–316. https://doi.org/10.23917/jramathedu.v5i3.10692

Fauzi, A., & Pradipta, I. W. (2018). Research methods and data analysis techniques in education articles published by Indonesian biology educational journals. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *4*(2), 123–134. https://doi.org/10.22219/jpbi.v4i2.5889

Gao, X., & Hew, K. F. (2022). Toward a 5E-based flipped classroom model for teaching computational thinking in elementary school: Effects on student computational thinking and problem-solving performance. *Journal of Educational Computing Research*, *60*(2), 512–543. https://doi.org/10.1177/07356331211037757

Garrido, A. (2012). Ai and mathematical education. *Education Sciences*, *2*(1), 22–32. https://doi.org/10.3390/educ2010022

Horn, M. B., & Staker, H. C. (2012). Classifying k–12 blended learning. *INNOSIGHT Institute*, *May*, 1–22. https://www.christenseninstitute.org/wp-content/uploads/2013/04/Classifying-K-12-blended-learning.pdf

Insorio, A. O., & Macandog, D. M. (2022). Youtube video playlist as mathematics supplementary learning material for blended learning. *European Journal of Interactive Multimedia and Education*, *3*(2), e02212. https://doi.org/10.30935/ejimed/12490

Joynes, C., Rossignoli, S., & Amonoo-Kuofi, E. F. (2019). 21st century skills: Evidence of issues in definition, demand and delivery for development contexts. *Brighton, UK: Institute of Development Studies.*, *August*, 1–75. https://opendocs.ids.ac.uk/opendocs/handle/20.500.12413/14674

Krishnan, P. (2019). A review of the non-equivalent control group post-test-only design. *Nurse Researcher*, *26*(2), 37–40. https://doi.org/10.7748/nr.2018.e1582

Li, M., Yin, D., Qiu, H., & Bai, B. (2022). Examining the effects of AI contactless services on customer psychological safety, perceived value, and hospitality service quality during the COVID-19 pandemic. *Journal of Hospitality Marketing and Management*, *31*(1), 24–48. https://doi.org/10.1080/19368623.2021.1934932

Lin, H., & Larzelere, R. E. (2020). Dual-centered ANCOVA: Resolving contradictory results from Lord's paradox with implications for reducing bias in longitudinal analyses. *Journal of Adolescence*, *85*, 135–147. https://doi.org/https://doi.org/10.1016/j.adolescence.2020.11.001

Lin, T.-C., Lin, T.-J., & Tsai, C.-C. (2014). Research trends in science education from 2008 to 2012: A systematic content analysis of publications in selected journals. *International Journal of Science Education*, *36*(8), 1346–1372. https://doi.org/10.1080/09500693.2013.864428

Long, T., Logan, J., & Waugh, M. (2016). Students' perceptions of the value of using videos as a pre-class learning experience in the flipped classroom. *TechTrends*, *60*(3), 245–252. https://doi.org/10.1007/s11528-016-0045-4

Maharani, H. R. (2014). Creative thinking in mathematics: Are we able to solve mathematical problems in a variety of way?. *International Conference on Mathematics, Science, and Education 2014*, 120–125.

McCallumore, K., & Sparapani, E. (2010). The importance of the ninth grade on high school graduation rates and student success. *Education Digest: Essential Readings Condensed for Quick Review*, *130*.

Nabayra, J. N. (2020). Video-based e-module for mathematics in nature and students' learning experiences in a flipped classroom. *Journal of Science and Mathematics Education …*, *43*(December), 1–21. http://myjms.mohe.gov.my/index.php/jsmesea/article/view/8813

Nida, N. K., Usodo, B., & Saputro, D. R. S. (2020). *Effectiveness of the flipped classroom model on the students' mathematical creative thinking skills*. *440*(Icobl 2019), 107–110. https://doi.org/10.2991/assehr.k.200521.022

Oakes, J. M., & Feldman, H. A. (2001). Statistical power for nonequivalent pretest-posttest designs: The impact of change-score versus ANCOVA models. *Evaluation Review*, *25*(1), 3–28. https://doi.org/10.1177/0193841X0102500101

Ormerod, R. (2021). The fitness and survival of the OR profession in the age of artificial intelligence. *Journal of the Operational Research Society*, *72*(1), 4–22. https://doi.org/10.1080/01605682.2019.1650619

Ostrom, A. L., Fotheringham, D., & Bitner, M. J. (2019). Customer acceptance of AI in service encounters: Understanding antecedents and consequences. In P. P. Maglio, C. A. Kieliszewski, J. C. Spohrer, K. Lyons, L. Patrício, & Y. Sawatani (Eds.), *Handbook of Service Science, Volume II* (pp. 77–103). Springer International Publishing. https://doi.org/10.1007/978-3-319-98512-1_5

Papastephanou, M., & Angeli, C. (2007). Critical thinking beyond skill. *Educational Philosophy and Theory*, *39*(6), 604–621. https://doi.org/10.1111/j.1469-5812.2007.00311.x

Pardo, S. A. (2023). Product design: Factorial experiments. In *Statistical Methods and Analyses for Medical Devices* (pp. 57–87). Springer International Publishing. https://doi.org/10.1007/978-3-031-26139-8_6

Paschen, J., Kietzmann, J., & Kietzmann, T. C. (2019). Artificial intelligence (AI) and its implications for market knowledge in B2B marketing. *Journal of Business and Industrial Marketing*, *34*(7), 1410–1419. https://doi.org/10.1108/JBIM-10-2018-0295

Prakash, D., Mageshwari T, U., Prabakaran, K., & Suguna, A. (2013). Detection of heart diseases by mathematical artificial intelligence algorithm using phonocardiogram signals. *International Journal of Innovation and Applied Studies*, *3*(1), 145–150.

Pratama, R. W., Sudiyanto, S., & Riyadi, R. (2019). The development of attention, relevance, confidence, and satisfaction (ARCS) model based on active learning to improve students'learning motivation. *Al-Jabar : Jurnal Pendidikan Matematika*, *10*(1), 59–66. https://doi.org/10.24042/ajpm.v10i1.4044

Puspitasari, R. D., Herlina, K., & Suyatna, A. (2020). A need analysis of STEM-integrated flipped classroom e-module to improve critical thinking skills. *Indonesian Journal of Science and Mathematics Education*, *3*(2), 178–184. https://doi.org/10.24042/ijsme.v3i2.6121

Rahmadani, Herman, T., Dareng, S. Y., & Bakri, Z. (2020). Education for industry revolution 4.0: Using flipped classroom in mathematics learning as alternative. *Journal of Physics: Conference Series*, *1521*(3), 0–8. https://doi.org/10.1088/1742-6596/1521/3/032038

Ramadhani, R., Bina, N. S., Sihotang, S. F., Narpila, S. D., & Mazaly, M. R. (2020). Students' critical mathematical thinking abilities through flip-problem based learning model based on LMS-google classroom. *Journal of Physics: Conference Series*, *1657*(1), 012025. https://doi.org/10.1088/1742-6596/1657/1/012025

Riedl, M. O. (2019). Human-centered artificial intelligence and machine learning. *Human Behavior and Emerging Technologies*, *1*(1), 33–36. https://doi.org/10.1002/hbe2.117

Rintayati, P., Lukitasari, H., & Syawaludin, A. (2020). Development of two-tier multiple choice test to assess Indonesian elementary students' higher-order thinking skills. *International Journal of Instruction*, *14*(1), 555–566. https://doi.org/10.29333/IJI.2021.14133A

Sanders, S. (2016). Critical and creative thinkers in mathematics classrooms. *Journal of Student Engagement: Education Matters*, *6*(1), 19–27.

Sari, D. M., Ikhsan, M., & Abidin, Z. (2018). The development of learning instruments using the creative problem-solving learning model to improve students' creative thinking skills in mathematics. *Journal of Physics: Conference Series*, *1088*(1), 012018. https://doi.org/10.1088/1742-6596/1088/1/012018

Setiana, D. S., Purwoko, R. Y., & Sugiman. (2021). The application of mathematics learning

model to stimulate mathematical critical thinking skills of senior high school students. *European Journal of Educational Research*, *10*(1), 509–523. https://doi.org/10.12973/EU-JER.10.1.509

Shai, S. S. (2022). Practice research on mathematics critical thinking ability cultivation strategy based on flipped classroom. *Journal of Educational Research and Policies*, *4*(8). https://doi.org/10.53469/jerp.2022.04(08).35

Simanjuntak, M. P., Hutahaean, J., Marpaung, N., & Ramadhani, D. (2021). Effectiveness of problem-based learning combined with computer simulation on students' problem-solving and creative thinking skills. *International Journal of Instruction*, *14*(3), 519–534. https://doi.org/10.29333/iji.2021.14330a

Soc, K., Vol, M. E., & Data, B. (2020). *인공지능 (artificial intelligence)과 대학수학교육 [Artificial intelligence and university mathematics education]*. *2017*, 354–359.

Sriwongchai, A. (2015). Developing the mathematics learning management model for improving creative thinking in Thailand. *International Education Studies*, *8*(11), 77–87. https://doi.org/10.5539/ies.v8n11p77

Sukenti, D., Tambak, S., & Siregar, E. (2021). Learning assessment for madrasah teacher: Strengthening Islamic psychosocial and emotional intelligence. *AL-ISHLAH: Jurnal Pendidikan*, *13*(1), 725–740. https://doi.org/10.35445/alishlah.v13i1.552

Sürücü, L., & Maslakçi, A. (2020). Validity and reliability in quantitative research. *Business & Management Studies: An International Journal*, *8*(3 SE-Articles), 2694–2726. https://doi.org/10.15295/bmij.v8i3.1540

Susetyarini, E., & Fauzi, A. (2020). Trend of critical thinking skill researches in biology education journals across Indonesia: From research design to data analysis. *International Journal of Instruction*, *13*(1), 535–550. https://doi.org/10.29333/iji.2020.13135a

Tabieh, A. A. S., & Hamzeh, M. (2022). The impact of blended-flipped learning on mathematical creative thinking skills. *Journal of Educators Online*, *19*(3), 15. https://doi.org/10.9743/JEO.2022.19.3.15

Turmuzi, M., Suharta, I. G. P., & Suparta, I. N. (2023). Ethnomathematical research in mathematics education journals in Indonesia: A case study of data design and analysis. *Eurasia Journal of Mathematics, Science and Technology Education*, *19*(1), em2220. https://doi.org/10.29333/ejmste/12836

Vogelsang, K., Droit, A., & Liere-Netheler, K. (2019). *Designing a flipped classroom course-a process model*. *14*(4), 1–23. https://doi.org/10.18417/emisa.14.4

Voogt, J., Erstad, O., Dede, C., & Mishra, P. (2013). Challenges to learning and schooling in the digital networked world of the 21st century. *Journal of Computer Assisted Learning*, *29*(5), 403–413. https://doi.org/10.1111/jcal.12029

Wei, X., Cheng, I. L., Chen, N. S., Yang, X., Liu, Y., Dong, Y., Zhai, X., & Kinshuk. (2020). Effect of the flipped classroom on the mathematics performance of middle school students. *Educational Technology Research and Development*, *68*(3), 1461–1484. https://doi.org/10.1007/s11423-020-09752-x

Wijaya, T. T., Li, L., Hermita, N., Putra, Z. H., & Alim, J. A. (2021). Helping junior high school student to learn fibonacci sequence with video-based learning. *International Journal of Interactive Mobile Technologies*, *15*(11), 183–191. https://doi.org/10.3991/ijim.v15i11.23097

Wu, X. W., & Lai, D. (2015). Comparison of statistical methods for pretest–posttest designs in terms of type I error probability and statistical power. *Communications in Statistics - Simulation and Computation*, *44*(2), 284–294. https://doi.org/10.1080/03610918.2013.775295

Xu, E., Wang, W., & Wang, Q. (2023). The effectiveness of collaborative problem solving in promoting students' critical thinking: A meta-analysis based on empirical literature.

Humanities and Social Sciences Communications, *10*(1). https://doi.org/10.1057/s41599-023-01508-1

Xu, Y., Shieh, C. H., van Esch, P., & Ling, I. L. (2020). AI customer service: Task complexity, problem-solving ability, and usage intention. *Australasian Marketing Journal*, *28*(4), 189–199. https://doi.org/10.1016/j.ausmj.2020.03.005

Yanuarto, W. N., & Hapsari, I. (2022). The model of creative thinking, critical thinking, and entrepreneurial skills among university students. *JTAM (Jurnal Teori Dan Aplikasi Matematika)*, *6*(2), 411–424. https://doi.org/10.31764/jtam.v6i2.7467

Yayuk, E., Purwanto, As'Ari, A. R., & Subanji. (2020). Primary school students' creative thinking skills in mathematics problem solving. *European Journal of Educational Research*, *9*(3), 1281–1295. https://doi.org/10.12973/eu-jer.9.3.1281

Yuliana, Wijayanti, S., & Yuwono, M. R. (2022). Tantangan pembelajaran matematika mPBL pada flipped classroom untuk membangun kemampuan berpikir kritis siswa [The challenge of learning mathematics of mPBL in a flipped classroom to build students' critical thinking skills]. *AKSIOMA: Jurnal Matematika Dan Pendidikan Matematika*, *13*(1), 101–118.

Zakiyah, Z., Karlimah, K., & Hidayat, S. (in press). Fostering creative mathematical thinking with a flipped classroom approach. *IndoMath: Indonesia Mathematics Education*.

Zanzotto, F. M. (2019). Viewpoint: Human-in-the-loop artificial intelligence. *Journal of Artificial Intelligence Research*, *64*, 243–252. https://doi.org/https://doi.org/10.1613/jair.1.11345

Zhang, D. (2017). Effects of visual working memory training and direct instruction on geometry problem solving in students with geometry difficulties. *Learning Disabilities: A Contemporary Journal*, *15*(1), 117–138. https://eric.ed.gov/?id=EJ1141989