Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Effectiveness of Inquiry Learning Strategy on Students' Critical Thinking Skills in Mathematics

Firdausi

firdausi@uinjkt.ac.id

UIN Syarif Hidayatullah Jakarta: Universitas Islam Negeri Syarif Hidayatullah Jakarta
https://orcid.org/0000-0002-6145-313X

Wardani Rahayu

Universitas Negeri Jakarta https://orcid.org/0000-0002-9806-4744

Pinta Deniyanti

Universitas Negeri Jakarta

Research Article

Keywords: Strategy, Ability, Inquiry Learning, Students' Critical Thinking

Posted Date: May 28th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-9774772/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: The authors declare no competing interests.

Abstract

This study aimed to determine how inquiry learning strategies affect students' critical thinking skills in mathematics. In this study, the Mann–Whitney test was performed using a quasi-experimental method. The sampling technique used random cluster sampling to select two sample classes. The results of the study concluded that the inquiry learning strategy proved to be effective; therefore, we affirm that it should be emphasized in schools because it can positively affect students' critical thinking skills in mathematics. Some factors of the effective use of inquiry learning strategies on students' critical thinking skills in mathematics are: 1) the learning carried out has been oriented towards the development of students' intellectuality, 2) the teacher has carried out learning activities with the principle of interaction between students and teachers, students with other students, as well as between students and learning resources, 3) learning with the principle of questioning, and 4) learning with the principle of openness by conducting reflection activities on the material that has been discussed with students.

Introduction

In certain cases, information must be selected before it is used to make an important decision, so critical thinking skills are needed to address and overcome these conditions. Critical thinking is recognized in a person when they are evaluating an argument to be sure its claim is true and, further, evaluating how far an argument is true and then formulating it. It is important to develop critical thinking early on through learning in schools, including mathematics learning, to encourage students to develop critical thinking skills in mathematics. According to Makina (2010), students' critical thinking skills play an important role as an evaluation tool for new ideas that are relevant and useful for the task at hand. Tasks oriented towards complex simulation inquiry skills can help students understand a problem (Teig, Scherer et al. 2020).

Students' critical thinking skills in mathematics have not been optimally developed in schools in Indonesia, and students still have difficulty solving problem-solving tasks. We draw this connection from a previous study by Almulla (2023), which found that critical thinking has a direct positive impact on problem-solving ability. This study is based on the results of previous research that revealed that students' critical thinking skills in mathematics are still 50% below the required level. This assertion of being “50% below the required level” is made because the indicator shows that students are not accustomed to working on mathematical problems that require them to be able to analyze and evaluate (Sari 2020). Teachers need to encourage critical thinking in mathematics so that students can easily understand the various mathematical problems faced. Previous research by Olteanu, C. and L. Olteanu (2010) that by developing an understanding of the critical aspects of students will be able to be a productive basis for helping teachers make fundamental changes in their instruction and to improve mathematics communication in the classroom. However, teachers need a model that can help them diagnose students' difficulties and provide feedback to support mathematical problem solving by those

students (Sidenvall, Granberg et al. 2022), and a learning model that can predict deep learning strategies in a positive way (Feyzioğlu 2019).

The scientific development of teaching materials that guide students in developing their thinking skills can be achieved through an inquiry-based learning model. Therefore, this model needs to be encouraged to improve students' critical mathematical thinking skills. Based on previous research by Sutiani (2021), inquiry-based learning strategies with science literacy have proven to be effective in developing students' critical thinking skills. Inquiry-based learning is effective in improving these skills in mathematics, including the skills of interpretation, analysis, inference, evaluation, explanation, and self-regulation (Wale & Bishaw, 2020). The inquiry learning model can be used to improve such skills by paying attention to the active role of teachers, the quality and design of teaching materials, the learning environment, and the active participation of students (Saputro, A. D., Rohaeti, E., & Prodjosantoso, A. K., 2018). With inquiry-based learning strategies, teachers can create more active learning activities and train students' critical thinking skills in mathematics (Rahmi, Y. L., Alberida, H., & Astuti, M. Y., 2019).

Students' Critical Thinking Ability in Math

Students' critical thinking skills in this subject are theoretically based on the notion of critical thinking in general, and then approached through learning activities for mathematics in schools based on the opinions of experts in the field of education and teaching. According to Ennis (1998), critical thinking is a way of thinking that is reasonable and reflective and focuses on activities to decide what to believe and what to do, that is, what actions to take. At the same time, according to Cottrell (2011), critical thinking is a tool for using skepticism and doubt constructively so that a person can analyze what is in front of him or her.

Solving problems based on persuasive, logical, and rational argumentation involves verification, evaluation, and selection of the correct answer for a given task. Therefore, providing a reason for rejection and creating another alternative solution is a way of thinking and working that needs to be built into students during their learning at school (Florea & Hurjui, 2015). The ability to engage in prior knowledge, use mathematical reasoning, perform cognitive strategies to make inferences, and provide proof activities for new and unfamiliar mathematical situations in a reflective manner can be achieved through appropriate learning strategies (Glazer, 2001; Tee, Leong et al. 2018).

In learning activities, students should be directed to think critically by emphasizing complex intellectual activities, which include formulating and reformulating problems, evaluating problems, and showing sensitivity to a problem (Maričić & Špijunović, 2015). Convincing students to correctly interpret what is said and what is written by providing correct arguments is something that needs to be developed as a habit of critical and rational thinking (Bowell & Kemp, 2005). This kind of thinking activity calls for an attitude of deep thinking related to mathematical problems by involving students' previous mathematical experience, their mathematical reasoning, and cognitive strategies in drawing conclusions, proving, or evaluating mathematical problems that are less known as reflective (Abdullah, 2016).

The Relationship between Inquiry Learning Strategies and Students' Critical Thinking

Critical thinking needs to be fostered and formalized in school learning activities. To achieve this, appropriate learning strategies need to be created and selected to optimize students' critical thinking skills in mathematics so that they are accustomed to thinking logically, with the result that the degree of student reasoning will be of a higher quality. In this regard, as we argue, an inquiry learning approach can be proposed to effectively enhance the learning effects of students in terms of learning achievement, motivation, and level of satisfaction (Hwang, Chiu et al., 2015). According to Steele et al. (2016), an inquiry learning strategy must consider a teacher’s work through the lens of student autonomy or self-determination. This demands a pedagogical position that enables the pursuit of inquiry in directions that interest and engage the students. If the process ignores active learning, it will cause negative changes in students because they are not epistemologically involved in the learning process, particularly in the stages of observing, measuring, and calculating. (Laliyo, Sumintono et al. 2022).

An inquiry learning strategy can improve the quality of student participation in the classroom (Kersting, Karlsen et al., 2020) and is considered appropriate for improving the learning outcomes of students in their mathematics studies (Siregar & Sirega, 2019). Therefore, efforts to improve students' critical thinking skills in mathematics as part of their learning outcomes can be made through inquiry learning strategies (Falahudin et al., 2016). Such strategies have been proven to be effective and should be emphasized in schools, as they include problem solving, reasoning, and proof to improve students' critical thinking skills in mathematics (Kitot et al., 2010). Using the inquiry model, students experience real and active learning experiences. In addition, inquiry-based learning that students often experience has the potential to foster a positive disposition towards mathematics – something that we have identified as necessary in the previous paragraph – and to perceive it as a creative and interesting subject that will be useful to them in the future (Pedersen and Haavold 2023). The steps of the inquiry learning strategy include: 1) orientation by conditioning students, 2) bringing students to a question whose answers exist and can be found by students, 3) estimating “temporary” answers, 4) collecting data, and 5) determining answers based on the data obtained.

Research Questions and Hypotheses

Based on the background we have explained above, we formulated research questions that will guide a more focused explanation that can prove our research hypothesis. The research questions were as follows: 1) Can the inquiry learning strategy be proven effective in influencing students' critical thinking skills in mathematics? 2) Is the inquiry learning strategy oriented towards the intellectual development of students and other factors so that it can effectively improve students' critical thinking skills in mathematics?

Methods

Research Design

In the research conducted, we provide treatment and see the changes from the given treatment. Our treatment tested the causal consequences of long-term care outside the laboratory, so the research design was a quasi-experimental method (Cook 2015). This quasi-experimental method was chosen because it does not have strict restrictions on randomization and at the same time can simultaneously control for threats (Abraham and Supriyati 2022). The quasi-experimental method is also used to examine the relationship between variables and clarify the cause of the relationship; therefore, we have to provide treatment and examine changes from the treatment that has been given. Another reason for choosing the quasi-experimental method in this study is that it can be implemented in the field in natural settings outside the laboratory, such as classrooms, schools, organizations, and communities (Hastjarjo, 2019).

Sampling Techniques

The sampling technique used in this study was cluster random sampling because the population investigated was very large and difficult to reach individually; therefore, the researchers took samples from several clusters that represented the population as a whole. The cluster random sampling technique was performed by randomizing the existing classes; then, two groups of class samples were selected for use in the study. Each class was taught using different learning strategies: one class was taught using an inquiry learning strategy as the experimental class and the other class as the control class using an expository learning strategy. The teacher delivered the same materials to the experimental and control classes and acted as a facilitator.

Data Analysis Technique

Data analysis was performed using inferential statistics using the Mann–Whitney test. This test was used because the assumptions of parametric statistics were not met and the data collected were not normally distributed (Pérez et al., 2015; Cucala, 2016). Before being analyzed using inferential statistics, the data were first described using descriptive statistics to see how students' critical thinking skills in mathematics were measured from various dimensions.

Research Instruments

These critical thinking skills are measured by a test instrument developed through a rigorous development process that can be used to collect data and conduct an analysis. The test instrument for students' critical thinking skills in mathematics refers to a combination of problem solving, reasoning, and mathematical proof so that it can perform in the following dimensions: 1) knowing what action to take and need a lot of information in solving mathematical problems; 2) knowing between facts and opinions, between questions in mathematics that are important and those that are not; 3) having new

ideas in solving mathematical problems; and 4) knowing the difference between correct and incorrect conclusions (Midgett & Eddins, 2001).

Research Process

The first stage of the process was to design the necessary instruments that included the following activities and considerations: 1) analyzing the need for the influence of the use of inquiry learning strategies used by teachers of students' critical thinking skills in mathematics; 2) conducting theoretical studies and looking at other research related to inquiry learning strategies and students' critical thinking skills in mathematics to further construct the relationship between inquiry learning strategies logically and students' critical thinking skills in mathematics or the research framework, to be continued by compiling the submission of research hypotheses; 3) developing instruments in the form of teaching program plans as teacher instructions in using inquiry learning strategies, and student worksheets that will be used by students during the learning activity process; and 4) conducting a trial process of the instruments in order to ensure their validity and reliability in the measurement of students' critical thinking skills in mathematics.

The second stage was carried out by implementing learning activities in two classes that were selected using random cluster sampling techniques. As outlined in Section 3.2, one class was taught using inquiry learning strategy, and the other was taught using expository learning strategy, which is commonly used by teachers in the classes we studied. In each case, the teachers were highly professional and confident that the inquiry learning strategy could improve the students' critical thinking skills in mathematics. The number of learning activities conducted by the teacher for the experimental and control classes was the same (i.e., eight sessions), and the material delivered by the teacher to the two classes was also the same.

The third stage is to test the analysis requirements as an assumption of parametric statistics to determine whether the data comes from a normally distributed population, and whether the data has come from two groups that have homogeneous variance. Based on the results of the parametric statistical analysis requirements test, it is known that the data obtained are not from a normally distributed population; therefore, the inferential statistics used are the Mann-Whitney test, which is used to answer the research question that the inquiry learning strategy is effective on students' critical thinking skills in mathematics.

Results

From the data collected, the critical thinking skills of students in mathematics taught using inquiry learning strategies and the value of critical thinking skills of students in mathematics taught using conventional learning strategies, based on the dimensions of students' mathematical critical thinking skills, are known and described in the following table:

Table 1
Development of IMWA membership between January 2010 and December 2014

D i m e n s i	**Inquiry Strategy**			**Expository Strategy**			$\Delta\%X_i$
	$X_i maks$	X_i	$\%X_i$	$X_i maks$	X_i	$\%X_i$	
Knowing what action to take and needing a lot of information in solving math problems	135	91.8	68	130	60.5	46.54	21.46
Knowing which are facts and which are opinions between important or not questions in maths	108	80.8	74.82	104	52.2	50.19	24.63
Having new ideas in solving math problems	81	54.2	66.91	78	51.6	66.15	0,76
Know the difference between correct and incorrect conclusions	54	40.5	75	52	37.4	71.92	30.8

From the table above, it is known that the score of the dimension of knowing the difference between correct and incorrect conclusions is characterized by the indicator of providing logical reasons for a conclusion based on the previous premise with an average score of 30.8. Meanwhile, the dimension of knowing which facts and which opinions between questions are important in mathematics is characterized by the following indicators: 1) determining evidence for the truth of a mathematical statement and 2) determining evidence of the error of a mathematical statement with a score of 24.63. The other two dimensions, namely, 1) knowing which facts and opinions between questions are important or not in mathematics, and 2) having new ideas in solving mathematical problems obtained an average score that was below the average on the two dimensions mentioned earlier.

Table 2
Rank Mann-Whitney Test

	Forms of Learning Strategies	N	Mean Rank	Sum of Ranks
Students' Critical Thinking Skills in Mathematics	Inquiry learning strategies	54	66.08	3568.50
	Expository Learning Strategies	51	39.15	1996.50
	Total	105		

Table 3
Test Statistics

Mann-Whitney U	**Students' Critical Thinking Skills in Mathematics**
	670.500
Wilcoxon W	1996.500
Z	-4.538
Asymp. Sig. (2-tailed)	.000
a. Grouping Variable: Forms of Learning Strategies	

From the results of the SPSS programme calculations in Table 3 above, we see that the significance value is 0.000 < 0.05. This means that there are differences in students' critical thinking skills in mathematics according to the form of the learning strategies. Of the two learning strategies used by teachers, inquiry learning strategy has been proven to affect students' critical thinking skills (Seranica, Purwoko et al. 2018) and positively affects students' critical thinking skills in mathematics compared to using conventional learning strategies. This is in line with previous research showing the positive effect of the inquiry learning model on students' critical thinking skills (Maryam et al., 2020; Hidayat & Aripin, 2019).

Discussion

Based on the calculated average scores obtained by the two class groups, we showed that the critical thinking skills in mathematics of the class group taught using the inquiry learning strategy were positively affected (Soltis, Verlinden et al. 2015; Goodchild, Apkarian et al. 2021). The contributing factors identified in this study were: 1) learning that is oriented towards students' intellectual development is done well, 2) paying attention to the principle of interaction, 3) paying attention to the principle of questioning, and 4) the principle of openness is carried out during the process of learning activities. This reinforces the research conducted by (Gómez-Chacón, Bacelo et al. 2023; Steinberg, Empson et al. 2004) that inquiry learning based on greater immersion in the nature and culture of mathematics can help students improve their critical thinking attitude towards mathematics in the form of reflective knowledge in relation to mathematics learning (Barwell 2013; Chronaki and Yolcu 2021).

Inquiry learning aims to not only master the subject matter, but also provide meaningful and contextual learning that empowers students' intellectual abilities (Laurens, Batlolona et al. 2017), which will make students more creative (Ndiung, Dantes et al. 2019). The inquiry learning strategy must be oriented towards the analytical thinking process to find answers to a questionable problem, because the important principle of inquiry learning is constructivism, in which students themselves construct their knowledge (Kurniati et al., 2015; Forster, 1999). Learning that is oriented towards finding concepts that are correctly accepted by students can improve student performance in the classroom (Wilson et al. 2019). The process of analytical thinking needs to be carried out through discussion because students

can make connections between claims and evidence to improve their critical mathematical thinking skills (Al Mamun et al., 2022). In learning activities, mathematics teachers have carried out the stages of inquiry learning, starting from formulating questions, making hypotheses, and conducting experiments through student worksheets that have been provided for reflection activities (Herranen and Aksela 2019), to encourage students' critical thinking skills in this subject. This is supported by previous research showing that critical thinking skills in mathematics learning need to be supported by the use of learning models, strategies, or approaches (Duran & Dökme, 2016). This activity has successfully fostered students' thinking processes reflectively, logically, and systematically so that it affects their critical thinking skills in mathematics.

During learning activities using inquiry learning strategies, the interaction process takes place between teachers and students, students with students, and students with other learning environments by first inviting students to a learning consensus on the strategies that will be used to make it easier for students to understand the problem (Inoue 2011). Teachers will have provided guidance during learning activities using inquiry learning strategies and directed students to complete worksheets, multiple-choice objective tests, and descriptive tests as part of tasks designed to support deeper engagement in students' reasoning about mathematics (Andrews-Larson, Johnson et al. 2021). The interaction process has also occurred between students and students, students, and other learning resources that do not occur in activities using conventional learning strategies with textbooks and student worksheets (Ridwan et al., 2022). Based on observations after learning activities over three meetings, we found that students can convey ideas during the discussion process and can provide the necessary reasons when rejecting other ideas that are less appropriate. The emergence of this ability in students is because teachers can provide meaningful learning authority for students and avoid classroom activities that tend to be individual (Arnesen and Rø 2022; Murphy, Abu-Tineh et al. 2021).

As an integral part of learning activities using inquiry learning strategies, we also provide questions that ask for higher-order thinking skills (Delcourt and McKinnon 2011). According to van Schijndel et al. (2018), children with high levels of curiosity gain more knowledge than do children with low curiosity. However, the questions in learning must be guided and arranged in such a way as to trigger students' mathematical and logical abilities. This is in line with previous research showing that logical thinking can improve because the questions made have been arranged in such a way that students come to the correct conclusion (Andriani et al., 2019). Questioning activities are carried out with the aim of motivating and provoking students' enthusiasm for seeing unfinished mathematical problems or rules and must be known to solve them, so inquiry learning is also seen as a strategy used to question, seek knowledge, or study a phenomenon with strict validation (Windschitl et al., 2008).

According to Hughes and Marhatta (2023) the use of inquiry learning needs to be supported as students successfully develop questions related to the discipline The form of questions and problem formulations made by the teacher aims to get students involved in the process of searching and finding answers to the questions asked, for example: 1) what is the form of the problem from the subject matter taught? 2) What is the strategy for solving each form of problem from the material taught? This is based on

observations that students are good at finding the concepts of the material taught in the source book. The process of searching for and finding answers, especially the second problem formulation, affects students' critical thinking skills in mathematics (Kaczkó and Ostendorf 2023).

Learning has also been conducted with the principle of openness through the skills of teachers who strictly implement the rules of inquiry to facilitate learning (Makar and Fielding-Wells 2018; Leikin and Rota 2006; Joubert and Sutherland 2010) so that students have space to engage in problem solving and reasoning together (Kriewaldt, Robertson et al. 2021). Students are given the freedom to give their opinions regarding the results of their answers to the mathematical problems given through student worksheets that they complete, which are then discussed with the teacher to obtain the correct answer to the question asked. These efforts strengthen the findings of previous research that the development of guided inquiry-based student worksheets can improve students' critical mathematical thinking power (Yasin et al., 2019). The inquiry learning strategy provides freedom when students present the results of their discussions, such as increasing self-confidence, developing logical thinking, and always being objective about the problem, which is the answer to the mathematical problems asked, especially those related to the mathematics materials being taught. This also means that students who believe in their own abilities when presenting tend to use cognitive abilities as an important aspect of inquiry learning so that the level of their mathematical critical thinking skills is raised (Manalo et al., 2013).

Conclusions

The results of our study concluded that the inquiry learning strategy proved effective in influencing students' critical thinking skills in mathematics, a conclusion that affirmed and strengthened the results of previous research (Pahrudin et al., 2021). Our quantitative data showed that there were significant differences in the scores on the dimensions of students' critical thinking skills in mathematics between the experimental and control classes. After learning by using inquiry learning strategies, students understood the difference between correct and incorrect conclusions; they knew which facts and opinions were important and which were not in questions in mathematics. They knew what actions to take and how much information was needed to solve the mathematical problems.

Students' critical thinking skills in mathematics are important in terms of knowing the difference between correct and incorrect conclusions and when students can have the ability to provide logical reasons for a conclusion based on a previous premise. The ability to differentiate between facts and opinions that are important and those that are unimportant is seen when students can determine evidence for the truth of a mathematical statement and when they can determine evidence of the error of a mathematical statement. Students' ability to know what actions to take and need a lot of information in solving mathematical problems, students can already solve mathematical problems in many ways, and students can also solve mathematical problems that involve mathematical connection skills.

The significance of our results is not restricted to mathematics alone. These results also reinforce previous findings that inquiry learning strategies can effectively improve students' critical thinking skills (Kitot, Ahmad et al. 2010; Qing, Jing et al. 2010). Some of the factors that lead to the effectiveness of the use of inquiry learning strategies for students' critical thinking skills in mathematics are that the learning carried out has been oriented towards the intellectual development of students; that learning activities have been delivered using the principle of interaction between students and teachers, students, and other students, as well as between students and other learning resources. These learning activities have used the principle of questioning and openness, with reflection activities on the material that has been discussed with students.

All of these activities are not solely aimed at mastering the material but are also oriented towards the intellectual development of students through the process of learning and thinking critically and analytically to seek and find their own answers to a questionable problem. The stages of inquiry learning were led by formulating questions, making hypotheses, conducting experiments through student worksheets, and providing activities for reflection. The use of this strategy with this principle has succeeded in fostering students' thinking processes critically, logically, and systematically, to positively affect their critical thinking skills in mathematics.

During learning activities using inquiry strategies, the activity of asking questions is an integral part of learning. These questions aim to motivate and provoke students' enthusiasm in seeing unfinished mathematical problems or rules that must be known to arrive at solutions. Specifically, the formulation of problems in learning activities refers to the formulation of problems created in the learning program plan as part of the learning steps using the inquiry learning strategy.

Learning activities have also been conducted based on the principles and spirit of openness. By this, we mean that students can be given the freedom to give their opinions related to mathematical problems in the question sheet and discussed together with the teacher to obtain the correct answers. By extending the notion of openness in learning activities using inquiry learning strategies, students can also be given the same freedom when presenting the results of their discussions to foster self-confidence. In this way, they can develop logical thinking and always be objective in their answers to the mathematical problems asked.

Recommendations

From our qualitative and quantitative data, we show that learning by using inquiry learning strategies leads to improvements in students' critical thinking skills in mathematics. It is expected that related parties such as local governments and school principals will encourage teachers to use inquiry learning strategies as support for teaching and learning process activities to facilitate their duties in achieving mathematics learning objectives, to help students have critical thinking skills, and to prepare students to live responsibly in society. Local governments also need to encourage and prepare teachers through training to be skilled in using inquiry learning strategies to improve students' critical thinking skills in

mathematics, as an integral part of mathematics learning objectives. In implementing inquiry learning strategies to improve critical thinking skills in mathematics, teachers are expected to pay attention to and use important principles in inquiry learning strategies.

Declarations

This study protocol was reviewed and approved by Institute for Research and Community Service, UIN Syarif Hidayatullah Jakarta, approval number Un. 01/KPA/370/2016

Competing interests

The authors have no competing interests to declare that are relevant to the content of this article

Ethics approval

Respondent data was obtained with consent, and respondents involved in the study understood that their participation was voluntary.

Author contributions

All authors have approved the content of this article, and they have contributed to this research activity according to their respective roles.

Data availability

The findings of this study are supported by data that is publicly available and accessible. However, the data may be provided by the author upon reasonable request.

References

1. Abraham I, Supriyati Y (2022) Desain kuasi eksperimen dalam pendidikan: Literatur review. Jurnal Ilmiah Mandala Educ 8(3). http://dx.doi.org/10.58258/jime.v8i3.3800
2. Al Mamun MA et al (2022) Exploration of learner-content interactions and learning approaches: The role of guided inquiry in the self-directed online environments. Comput Educ 178:104398. https://doi.org/10.1016/j.compedu.2021.104398
3. Almulla MA (2023) Constructivism learning theory: A paradigm for students' critical thinking, creativity, and problem solving to affect academic performance in higher education. Cogent Educ 10(1):2172929. https://doi.org/10.1080/2331186X.2023.217292
4. Andrews-Larson C et al (2021) Doing math with mathematicians to support pedagogical reasoning about inquiry-oriented instruction. J Math Teacher Educ 24:127–154. https://doi.org/10.1007/s10857-019-09450-3

5. Andriani S et al (2019) The effect of process oriented guided inquiry learning (PGIL) model toward students' logical thinking ability in mathematics. Journal of Physics: Conference Series, IOP Publishing. https://iopscience.iop.org/article/10.1088/1742-6596/1157/4/042108/meta
6. Arnesen KK, Rø K (2022) The complexity of supporting reasoning in a mathematics classroom of shared authority. Math Think Learn 1–26. https://doi.org/10.1080/10986065.2022.2059628
7. Barwell R (2013) The mathematical formatting of climate change: Critical mathematics education and post-normal science. Res Math Educ 15(1):1–16. https://doi.org/10.1080/14794802.2012.756633
8. Chronaki A, Yolcu A (2021) Mathematics for citizenship and its other in a global world: Critical issues on mathematics education, globalisation and local communities. Res Math Educ 23(3):241–247. https://doi.org/10.1080/14794802.2021.1995780
9. Cook TD (2015) Quasi-experimental design. Wiley encyclopedia of management: 1–2. https://doi.org/10.1002/9781118785317.weom110227
10. Cottrell S (2011) Critical thinking skills: Developing effective analysis and argument, palgrave macmillan Basingstoke. https://www.proquest.com/openview/4c45c7c9bd287dd85cf4fa4c23e7bf73/1?pq-origsite=gscholar&cbl=32203
11. Cucala L (2016) A Mann–Whitney scan statistic for continuous data. Commun Statistics-Theory Methods 45(2):321–329. https://doi.org/10.1080/03610926.2013.806667
12. Delcourt MA, McKinnon J (2011) Tools for inquiry: Improving questioning in the classroom. Learn Landscapes 4(2):145–159. https://doi.org/10.36510/learnland.v4i2.392
13. Duran M, Dökme I (2016) The effect of the inquiry-based learning approach on student's critical-thinking skills. Eurasia J Math Sci Technol Educ 12(12). http://doi.org/10.12973/eurasia.2016.02311a
14. Ennis RH (1998) Is critical thinking culturally biased? Teaching Philosophy, 21 (1), p.16 33. https://doi.org/10.5840/teachphil19982113
15. Epstein R, Kernberger (2005) Carolyn. Critical Thinking. Thomson Wadsworth, (USA
16. Falahudin I et al (2016) Pengaruh model pembelajaran inkuiri terbimbing terhadap kemampuan berpikir kritis siswa pada pembelajaran materi pengelolaan lingkungan di SMP Negeri 2 Tanjung Lago. Kabupaten Banyuasin Bioilmi: Jurnal Pendidikan 2(2). https://doi.org/10.19109/bioilmi.v2i2.1133
17. Feyzioğlu B (2019) The role of inquiry-based self-efficacy, achievement goal orientation, and learning strategies on secondary-school students' inquiry skills. Res Sci Technological Educ 37(3):366–392. https://doi.org/10.1080/02635143.2019.1579187
18. Forster P (1999) Applying constructivist theory to practice in a technology-based learning environment. Math Educ Res J 11(2):81–93. https://link.springer.com/article/ 10.1007/BF03217062
19. Glazer E (2001) Using internet primary sources to teach critical thinking skills in mathematics. Greenwood Publishing Group. https://books.google.co.id/books?hl=id&lr=&id=K7bOEAAAQBAJ&o

20. Goodchild S et al (2021) Critical stance within a community of inquiry in an advanced mathematics course for pre-service teachers. J Math Teacher Educ 24:231–252. https://doi.org/10.1007/s10857-020-09456-2
21. Gómez-Chacón IM et al (2023) Inquiry-based mathematics education and attitudes towards mathematics: tracking profiles for teaching. Math Educ Res J 1–29. https://link.springer.com/article/ 10.1007/s13394-023-00468-8
22. Herranen J, Aksela M (2019) Student-question-based inquiry in science education. Stud Sci Educ 55(1):1–36. https://doi.org/10.1080/03057267.2019.1658059
23. Hidayat W, Aripin U (2019) The improvement of students' mathematical understanding ability influenced from argument-driven inquiry learning. Journal of Physics: Conference Series, IOP Publishing. https://iopscience.iop.org/article/10.1088/1742-6596/1157/3/032085/meta
24. Hughes RE, Marhatta P (2023) Learning to ask their own questions: How elementary students develop social studies inquiry questions. Teach Teacher Educ 127:104094. https://doi.org/10.1016/j.tate.2023.104094
25. Hwang G-J et al (2015) A contextual game-based learning approach to improving students' inquiry-based learning performance in social studies courses. Comput Educ 81:13–25. https://doi.org/10.1016/j.compedu.2014.09.006
26. Abdullah H (ed) Berpikir kritis matematika, Delta-Pi, Journal matematika dan pendikan matematika https://doi.org/10.33387/dpi.v2i1.100
27. Inoue N (2011) Zen and the art of neriage: Facilitating consensus building in mathematics inquiry lessons through lesson study. J Math Teacher Educ 14:5–23. https://link.springer.com/article/ 10.1007/s10857-010-9150-z
28. Joubert M, Sutherland R (2010) Understanding teacher enquiry. British Society for Research into Learning Mathematics, University of Nottingham. https://doi.org/10.1080/14794802.2011.550741
29. Kaczkó É, Ostendorf A (2023) Critical thinking in the community of inquiry framework: An analysis of the theoretical model and cognitive presence coding schemes. Comput Educ 193:104662. https://doi.org/10.1016/j.compedu.2022.104662
30. Kersting M et al (2023) Studying the quality of inquiry-based teaching in science classrooms. A systematic video study of inquiry-based science teaching in primary and lower-secondary schools. Int J Sci Educ 1–22. https://doi.org/10.1080/09500693.2023.2213386
31. Kitot AKA et al (2010) The effectiveness of inquiry teaching in enhancing students' critical thinking. Procedia-Social Behav Sci 7:264–273. https://doi.org/10.1016/j.sbspro.2010.10.037
32. Kurniati K et al (2015) Mathematical critical thinking ability through contextual teaching and learning approach. J Math Educ 6(1):53–62. https://ejournal.unsri.ac.id/index.php/jme/article/view/1901
33. Kriewaldt J et al (2021) Examining the nature of teacher interactions in a collaborative inquiry-based classroom setting using a Kikan-Shido lens. Int J Educational Res 108:101776. https://doi.org/10.1016/j.ijer.2021.101776

34. Laliyo LAR et al (2022) Measuring changes in hydrolysis concept of students taught by inquiry model: stacking and racking analysis techniques. Rasch model Heliyon 8(3). https://doi.org/10.1016/j.heliyon.2022.e09126
35. Laurens T et al (2017) How does realistic mathematics education (RME) improve students' mathematics cognitive achievement? EURASIA J Math Sci Technol Educ 14(2):569–578. https://doi.org/10.12973/ejmste/76959
36. Leikin R, Rota S (2006) Learning through teaching: A case study on the development of a mathematics teacher's proficiency in managing an inquiry-based classroom. Math Educ Res J 18(3):44–68. http://dx.doi.org/10.1007/BF03217442
37. Makar K, Fielding-Wells J (2018) Shifting more than the goal posts: Developing classroom norms of inquiry-based learning in mathematics. Math Educ Res J 30:53–63. https://link.springer.com/article/ 10.1007/s13394-017-0215-5
38. Makina A (2010) The role of visualisation in developing critical thinking in mathematics. Perspect Educ 28(1):24–33. https://www.ajol.info/index.php/pie/article/view/76898
39. Manalo E et al (2013) To what extent do culture-related factors influence university students' critical thinking use? Think Skills Creativity 10:121–132. https://doi.org/10.1016/j.tsc.2013.08.003
40. Maryam M et al (2020) Jurnal Pijar Mipa 15(3):206–213. https://doi.org/10.29303/jpm.v15i3.1355. Pengaruh Model Pembelajaran Inkuiri Terhadap Keterampilan Berpikir Kritis Siswa.
41. Midgett CW, Eddins SK (2001) NCTM's principles and standards for school mathematics: Implications for administrators. Nassp Bull 85(623):35–42. https://doi.org/10.1177/019263650108562305
42. Murphy C et al (2021) Teachers and students' views prior to introducing inquiry-based learning in Qatari science and mathematics classrooms. Teach Teacher Educ 104:103367. https://doi.org/10.1016/j.tate.2021.103367
43. Nadia, Florea. Mirela., Hurjui E (2015) Critical Thinking in Elementary School Children, Procedia - Social and Behavioral Sciences. 180, 565–572. https://doi.org/10.1016/j.sbspro.2015.02.161
44. Ndiung S et al (2019) Treffinger Creative Learning Model with RME Principles on Creative Thinking Skill by Considering Numerical Ability. Int J Instruction 12(3):731–744. https://doi.org/10.29333/iji.2019.12344a
45. Olteanu C, Olteanu L (2010) To change teaching practice and students' learning of mathematics. Educ Inq 1(4):381–397. https://doi.org/10.3402/edui.v1i4.21952
46. Pahrudin A et al (2021) The Effectiveness of Science, Technology, Engineering, and Mathematics Inquiry Learning for 15–16 Years Old Students Based on K-13 Indonesian Curriculum: The Impact on the Critical Thinking Skills. Eur J Educational Res 10(2):681–692. https://doi.org/10.12973/eu-jer.10.2.681
47. Pedersen IF, Haavold PØ (2023) Students' mathematical beliefs and motivation in the context of inquiry-based mathematics teaching. Int J Math Educ Sci Technol 1–15. https://doi.org/10.1080/0020739X.2023.2189171

48. Pérez NP et al (2015) Improving the Mann–Whitney statistical test for feature selection: An approach in breast cancer diagnosis on mammography. Artif Intell Med 63(1):19–31. https://doi.org/10.1016/j.artmed.2014.12.004
49. Qing Z et al (2010) Promoting preservice teachers' critical thinking skills by inquiry-based chemical experiment. Procedia-Social Behav Sci 2(2):4597–4603. https://doi.org/10.1016/j.sbspro.2010.03.737
50. Ridwan MR et al (2022) Teachers' Perceptions in Applying Mathematics Critical Thinking Skills for Middle School Students: A Case of Phenomenology. Anatol J Educ 7(1):1–16. https://doi.org/10.29333/aje.2022.711a
51. Sanja M, Špijunović K (2015) Developing Critical Thinking in Elementary Mathematics Education through a Suitable Selection of Content and Overall Student Performance. Procedia - Social Behav Sci 180:653–659. https://doi.org/10.1016/j.sbspro.2015.02.174
52. Sari DR (2020) The analysis of mathematical critical thinking skills of students in junior high school. International Conference on Progressive Education (ICOPE 2019), Atlantis Press. https://doi.org/10.2991/assehr.k.200323.103
53. Seranica C et al (2018) Influence of guided inquiry learning model to critical thinking skills. IOSR J Res Method Educ 8(1):28–31. https://www.iosrjournals.org/iosr-jrme/papers/Vol-8%20Issue-1/Version-2/E0801022831.pdf
54. Sidenvall et al (2022) Supporting teachers in supporting students' mathematical problem solving. Int J Math Educ Sci Technol 1–21. https://doi.org/10.1080/0020739X.2022.2151067
55. Siregar E, Sirega S (2019) Inquiry learning strategy to improve mathematics achievement of junior high school. Journal of Physics: Conference Series, IOP Publishing. https://iopscience.iop.org/article/10.1088/1742-6596/1188/1/012047/meta
56. Soltis R et al (2015) Process-oriented guided inquiry learning strategy enhances students' higher level thinking skills in a pharmaceutical sciences course. Am J Pharm Educ 79(1). https://doi.org/10.5688/ajpe79111
57. Steele A et al (2016) Stories of learning: Inquiry-based pathways of discovery through environmental education. Cogent Educ 3(1):1202546. https://doi.org/10.1080/2331186X.2016.1202546
58. Steinberg RM et al (2004) Inquiry into children's mathematical thinking as a means to teacher change. Journal of Mathematics Teacher Education 7: 237–267. https://link.springer.com/article/10.1023/B:JMTE.0000033083.04005.d3
59. Tee KN et al (2018) The mediating effects of critical thinking skills on motivation factors for mathematical reasoning ability. Asia-Pacific Educ Researcher 27:373–382. https://link.springer.com/article/ 10.1007/s40299-018-0396-z
60. Teig N et al (2020) Identifying patterns of students' performance on simulated inquiry tasks using PISA 2015 log-file data. J Res Sci Teach 57(9):1400–1429. https://doi.org/10.1002/tea.21657
61. Bowel T, Kemp G (2005) Critical Thinking, A concise Guide. Routledge, (USA

62. van Schijndel TJ et al (2018) Do individual differences in children's curiosity relate to their inquiry-based learning? Int J Sci Educ 40(9):996–1015. https://doi.org/10.1080/09500693.2018.1460772
63. Wilson J et al (2019) Investigating teaching in conceptually oriented mathematics classrooms characterized by African American student success. J Res Math Educ 50(4):362–400. https://doi.org/10.5951/jresematheduc.50.4.0362
64. Windschitl M et al (2008) Beyond the scientific method: Model-based inquiry as a new paradigm of preference for school science investigations. Sci Educ 92(5):941–967. https://doi.org/10.1002/sce.20259
65. Yasin M et al (2019) The guided inquiry to improve students mathematical critical thinking skills using student's worksheet. J Educ Gifted Young Scientists 7(4):1345–1360. https://doi.org/10.17478/jegys.598422