PRISMA 7 (2024): 427-436
PRISMA, Prosiding Seminar Nasional Matematika
https://proceeding.unnes.ac.id/prisma
ISSN 2613-9189

Study Literature Review: The Influence of STEM-nuanced Mathematics Learning with the Project Based Learning Group Investigation Method on Students' Critical Thinking Abilities

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Abstract

This study is a literature review to investigate the influence of learning with STEM nuances (Science, Technology, Engineering and Mathematics) using the project based learning method with a group investigation model on students' critical thinking abilities. This project based learning method with a group investigation model is an alternative mathematics learning style that teachers can apply to improve student's critical thinking skills. In this study, the author used a literature review method with a qualitative approach from various articles, journals and books that were relevant to the author's research. The results of the literature review show that STEM-based mathematics learning using the Project Based Learning Group Investigation method can have a positive effect on improving student's critical thinking skills. Students who are involved in learning become able to relate mathematical concepts to real life, find alternative solutions, and make decisions based on evidence in a problem. In conclusion, this article can be an appropriate basis for educators to develop STEM nuanced mathematics learning using the Project Based Learning method with a Group Investigation model in improving student's critical thinking abilities.

Kata kunci:

Project based learning, Group Investigation, STEM, Critical Thinking

1. Introduction

1.1. Background

Education is an important aspect in advancing the intelligence of the nation's successors, especially in learning mathematics which is considered difficult. Mathematics can be related to everyday life in this modern era with various aspects of life that are increasingly advanced. One approach to learning is by adding STEM nuances to math learning. This is in line with research conducted by Ibnah & Rosidin (2018), namely through the STEM approach, students are exposed to situations that make them think more creatively, think critically, and systematically by solving a task or problem, so this has an impact on achieving good learning outcomes (Ibnah & Rosidin, 2018). So with the STEM approach, it is hoped that students can face the development of the world of education.

In recent years, STEM (Science, Technology, Engineering, and Mathematics) nuanced learning has become a major focus in mathematics education reform. According to Sanders (2009), integrative STEM education is a learning approach between two or more STEM components, or between one STEM component and other disciplines. One of the learning methods often used in the STEM context is Project Based Learning (PjBL) with a Group Investigation approach. The Group Investigation (GI) learning

To cite this article:
Ramadhan, F, S, N., Arifadewi, A, A P., Kribiyantoro, A, O & Susilo, B, E. (2024). Study Literature Review: The Influence of STEM-nuanced Mathematics Learning with the Project Based Learning Group Investigation Method on Students' Critical Thinking Abilities. *PRISMA, Prosiding Seminar Nasional Matematika 7*, 427-436.

model is a learning approach where students are required to be active in solving problems given by educators by forming groups and discussing together. (Diani, 2019)

Project Based Learning is a learning model that encourages students to be more active, independent, and creative in solving a problem (Safitri et al., 2018). Kristiyanto (2020) also mentioned that the application of the Project Based Learning (PJBL) learning model not only improves learning outcomes but also improves students' critical thinking skills in mathematics subjects. It can be concluded that learning mathematics using the Project Based Learning method with STEM nuances can improve students' critical thinking skills based on the results of research conducted by Priatna & Lorenzia (2018).

As a contribution to educational research and development, this literature review study is expected to provide guidance and a foundation for educators, researchers, and policy makers in developing mathematics learning strategies with STEM nuances that are more effective in promoting students' critical thinking skills.

1.2. Problem Statement

The research questions have been formulated as follows:

- How does learning mathematics with STEM nuances using the PjBL Group Investigation method affect the development of students' critical thinking skills?
- What empirical evidence from related literature studies shows the positive and negative effects of using the PjBL Group Investigation method in mathematics learning on critical thinking skills?
- What are the factors that can affect the PjBL Group Investigation method in learning mathematics on students' critical thinking skills?

1.3. Purpose of Study

The purpose of this study:

- Investigating how STEM nuanced mathematics learning with the PjBL Group Investigation method affects the development of students' critical thinking skills.
- Analyze and compile empirical evidence from related literature studies that reveal the effect of the PjBL Group Investigation method with STEM-nuances in mathematics learning on students' critical thinking skills.
- Identify the factors that affect the PjBL Group Investigation method with STEM-nuances in learning mathematics on students' critical thinking skills.

2. Discussion

The results of this research were obtained from the analysis of 12 articles and studies containing the influence of the implementation of project based learning, group investigation, and STEM on students' critical thinking abilities in learning mathematics.

2. 1. Analysis of Previous Research Data

2. 1. 1. The Influence of Project Based Learning in Mathematics Learning on Students' Critical Thinking Ability

There are various definitions of project based learning, according to Murniati (2016) Project Based Learning is a learning method that focuses on direct practical activities through the provision of a learning project by the teacher where this problem can be related to the direct implementation of learning material carried out by the students themselves. Continuing, according to Murniati (2016) stated that "This method

can be carried out in several ways such as: group work, individual investigation, achieving a high level of understanding, and developing individual and social skills". Apart from that, according to the Ministry of Education and Culture (2013) on the BPMP Aceh page, in project based learning, students carry out exploration, assessment, interpretation, synthesis and information in their efforts to find solutions or produce new products that do not have to be physical as a result of learning.

Meanwhile, critical thinking can be interpreted as the ability to think rationally and structured with the aim of understanding the relationships between various information obtained. In other words, critical thinking is an ability that can help students decide what they will do in making a decision. There are various meanings of critical thinking, according to Robert Ennis, quoted from the Gramedia page (2022), stating that critical thinking is a reasoning process regarding testing beliefs and actions that will be carried out by someone which must be reasonable. Meanwhile, according to Michael Scriven, quoted from the Gramedia page (2022), "Critical thinking is an intellectual discipline process for actively and skillfully creating concepts, applying, analyzing, synthesizing, and/or evaluating information."

In improving critical thinking skills, project based learning is one of the efforts that can be implemented by teachers in the learning process according to the results of research by the AutoDesk Foundation published in Global School Net (2000). Project based learning has several characteristics, namely: students make conceptualized decision solutions. There are contextual problems whose solutions students must think about, students process themselves to find solutions, students are given the freedom to access various information with responsibility, evaluation occurs regularly, students must really think carefully about the actions they take, project results will be evaluated , and open class with all kinds of errors. So, project based learning can be said to be a project-based learning model where students are given contextual problems and are often carried out in groups where students will hone their ability to solve any problems they have never encountered, so that their critical thinking skills will definitely improve. self-honed in solving various problems.

In mathematics learning, from the results of the analysis of various articles and journals, various data was found which shows that learning by implementing the project based learning model can indeed improve students' critical mathematical thinking skills. Examples of samples from the results of analysis of literature studies examining influence are as follows:

Table 1. Example of article analysis results on the influence of PjBL on critical thinking skills in elementary school mathematics learning

Authors	(Fitriyani, Houtman, Suroyo, & Saabighoot, 2023)
Title	*Pengaruh Model Project Based Learning Terhadap Hasil Belajar Matematika Ditinjau Dari Kemampuan Berpikir Kritis Siswa Sekolah Dasar*
Journal's Name	*Jurnal Nuansa Akademik*
Method	Quasi Experiment
Result	From the results of data analysis and hypothesis testing in the form of an ANOVA test, there is a difference in the average increase in students' critical thinking abilities at elementary school level from the PjBL learning model. Where, for students who were experimented with the PjBL learning method, the students' abilities on average increased and were higher compared to conventional learning, namely for students who were only experimented with conventional learning methods, on average their critical thinking abilities were lower.

Table 2. Example of article analysis results on the influence of PjBL on critical thinking skills in middle school mathematics learning

Authors	(Rifqi Hidayat, Saerah, 2016)

Title	*Kontribusi Model Pembelajaran Project Based Learning Terhadap Kemampuan Berpikir Kritis Matematis Siswa Madrasah Tsanawiyah*
Journal's Name	*Jurnal EduMa*
Method	Quasi Experiment
Result	From the results of data analysis, it was concluded that students who received the project based learning learning model found that their mathematical thinking ability had increased when compared to conventional learning methods.

Table 3. Example of article analysis results on the influence of PjBL on critical thinking skills in high school mathematics learning

Authors	(Ratna Yulis Tyaningsih, Nurita Primasatya, 2016)
Title	*Mengembangkan Disposisi Berpikir Kritis Siswa Pada Materi Menggambar Grafik Fungsi Trigonometri Melalui Model Pembelajaran Berbasis Proyek*
Journal's Name	*Jurnal DIKMA (Pendidikan Matematika)*
Method	Qualitative descriptive
Result	From the results of data analysis, students' critical thinking skills in drawing trigonometric function graphs after implementing the PjBL learning model were classified as good with the average data being 86.09, much higher than before PjBL was applied to students, namely 70.75. So, it can be said that the students' responses were positive and they were able to accept the PjBL learning model well.

Based on the results of the analysis of the three sample articles which discuss the influence of the project based learning model on critical thinking skills, the three concluded that the PjBL learning model has a positive impact on students' critical thinking skills. Where, all three researches at the elementary, middle and high school levels revealed that students' levels of critical thinking had increased.

2. 1. 2. The Influence of PjBL Group Investigation in Mathematics Learning on Students' Critical Thinking Ability

As is known, project based learning is a project-based learning model which can be done in groups. Apart from that, based on the results of the analysis by taking three sample articles that discuss the influence of project based learning on students' critical thinking abilities, it can be concluded that this PjBL learning model has a positive impact in improving students' critical thinking abilities.

In implementing project based learning, this learning model can be collaborated with the group investigation method. In short, group investigation is a method that involves students starting from the planning stage, both in the process of dividing problem topics to how they will investigate any information found by each group of students who have been divided. In mathematics learning, this collaboration from PjBL and Group Investigation can certainly be used to improve students' critical thinking skills based on the results of analysis from several articles. Examples of samples from the results of this analysis are as follows:

Table 4. Example of Analysis Results of the Influence PjBL Collaboration Articles with Group Investigation of Critical Thinking Abilities in Mathematics Learning.

Authors	(Esti Rahayu, H. Hartono, 2016)
Title	*Keefektifan Model PBL dan PjBL Ditinjau dari Prestasi, Kemampuan Berpikir Kritis, dan Motivasi Belajar Matematika Siswa SMP*
Journal's Name	*PYTHAGORAS: Jurnal Pendidikan Matematika*
Method	Quasi experiment
Result	From the results of research analysis. It was found that the PjBL collaboration with Group Investigation in mathematics learning had a positive or effective impact on students' mathematical critical thinking abilities. Although the difference in effectiveness between PjBL collaboration with group investigation and PBL with group investigation is not much different and both can be said to be effective for implementation in the learning process

Table 5. Example of Article Analysis Results of the Influence of Group Investigation on Critical Thinking Ability in Mathematics Learning.

Authors	(Haridi, 2018)
Title	*Penerapan Pembelajaran Group Investigation Untuk Meningkatkan Hasil Belajar Matematika Siswa Kelas X IPA 1 MAN 2 Banyuwangi*
Journal's Name	*AXIOM: Jurnal Pendidikan dan Matematika*
Method	Penelitian Tindakan Kelas (PTK)
Result	Dari hasil analisis data penelitian tindakan kelas, didapatkan fakta bahwa metode pembelajaran *Group investigation* efektif dalam peningkatan kemampuan berpikir kritis siswa di kelas X IPA 1 MAN 2 Banyuwangi pada pembelajaran matematika materi trigonometri. Dan disarankan agar metode ini dapat diimplementasikan terhadap materi-materi matematika lainnya.

Table 6. Example of Article Analysis Results on the Effect of PjBL Collaboration and Group Investigation on Critical Thinking Abilities in Mathematics Learning.

Authors	(Erna Lestari, Hendarto Cahyono, Awaluddin, 2019)
Title	*Penerapan Model Pembelajaran Group Investigation Pada Materi Lingkaran Untuk Meningkatkan Kemampuan Berpikir Kritis*
Journal's Name	*Jurnal Math Educator Nusantara*
Method	Qualitative Research, *Penelitian Tindakan Kelas (PTK)*
Result	From the results of data analysis, it was found that the application of the Group Investigation method was proven to be able to improve students' critical thinking skills in mathematics learning, especially in circle material in class 11 high school students where the average critical thinking ability of students increased to 74.34% from the initial percentage. 48.09% with a total increase of 25.44%.

Based on the results of the analysis of the three sample articles which discuss the influence of the project based learning model using the group investigation method on critical thinking abilities, the three concluded that the PjBL learning model has a positive impact on students' critical thinking abilities. Where, all three of them both revealed that the level of students' critical thinking increased.

2. 1. 3. The Influence of STEM-based Mathematics Learning based on Project Based Learning on Students' Critical Thinking Ability

As previously known, STEM is an abbreviation for Science, Technology, Engineering, and Mathematics. This learning with STEM nuances, as reported on the Ministry of Education and Culture's page (2021), BPMP Aceh, is a learning atmosphere that trains students' knowledge and skills simultaneously to solve contextual problems related to STEM. At this time, the STEM nuanced learning approach is still being developed because with this STEM nuance learning can be expected to produce students who excel both effectively, psychomotorically and cognitively.

This STEM nuanced learning can of course be collaborated with a project based learning model to improve students' critical thinking skills. This PjBL model has previously been proven to be able to increase students' critical thinking skills, so that based on the results of the analysis of articles discussing the influence of implementing STEM nuanced learning with PjBL the results are effective in increasing students' critical thinking skills. Examples of sample articles are as follows:

Table 7. Example of Article Analysis Results of the Effect of PjBL Learning with a STEM Nuance on Critical Thinking Abilities in Mathematics Learning.

Authors	(Laili Rahmawati, Dadang Juandi, Elah Nurlaelah, 2022)
Title	*Implementasi STEM dalam Meningkatkan Kemampuan Berpikir Kritis dan Kreatif Matematis*
Journal's Name	*AKSIOMA: Jurnal Program Studi Pendidikan Matematika*
Method	Systematic Literature Review (SLR)
Result	From the results of data analysis of various articles that have been reviewed, information was obtained that learning with a STEM approach or nuance has a positive effect on the level of students' critical thinking abilities. Apart from that, collaborative learning with STEM nuances with the PjBL learning model is still very relevant because both can be used to hone students' critical thinking skills in solving contextual problems.

Table 8. Example of Article Analysis Results of the Effect of PjBL Learning with a STEM Nuance on Critical Thinking Abilities in Mathematics Learning.

Authors	(Nanang Priatna, Silviana Ayu Lorenzia, 2018)
Title	*Project Based Learning Terintegrasi STEM untuk Meningkatkan Kemampuan Berpikir Kritis Matematis*
Journal's Name	*Prosiding SNIPS*
Method	Theoretical Review
Result	From the existing theoretical results, information was obtained that learning

	with the PjBL-STEM model can improve students' mathematical critical thinking skills. Where, in this learning model students are trained to think more logically, so that students can make the right decisions.

Table 9. Example of Article Analysis Results of the Effect of PjBL Learning with a STEM Nuance on Critical Thinking Abilities in Mathematics Learning.

Authors	(Suyanto, 2023)
Title	*Peningkatan Ketrampilan Berpikir Kritis, Berkomunikasi, Berkolaborasi, dan Kreativitas pada Matriks melalui Kriptografi Menggunakan PjBL-STEM*
Journal's Name	*Ideguru: Jurnal Karya Ilmiah Guru*
Method	Qualitative research, *Penelitian Tindakan Kelas (PTK)*
Result	From the results of data analysis, information was obtained that group discussions in the learning process using the PjBL-STEM model had a positive impact on students. Where, students can be more enthusiastic in learning and also the average achievement of daily tests has reached the target. Apart from that, students can more easily do their assignments well.

Based on the results of the analysis of three sample articles which discuss the influence of the STEM nuanced project based learning model on critical thinking skills, the three concluded that the PjBL-STEM learning model has a positive impact on students' critical thinking abilities. Where, all three of them both revealed that students' levels of critical thinking increased and students became more enthusiastic in learning activities because they learned mathematics through the things around them.

2. 2. Analysis of Factors That Influence the Improvement of PjBL-GI Modeled STEM Learning Models on Critical Thinking Abilities

Previously, it was known that the PjBL-GI STEM Nuanced Learning Model could improve students' critical thinking abilities. And below is a description of the factors that can cause this to happen. Based on several articles, these factors are as follows:

Table 10. Factors that Influence Increasing Critical Thinking Abilities through the PjBL Learning Model.

Authors	(Sularmi , Dwiyono Hari Utomo , I Nyoman Ruja, 2018)
Title	*Pengaruh Project-Based Learning terhadap Kemampuan Berpikir Kritis*
Journal's Name	*Jurnal Pendidikan: Teori. Penelitian. dan Pengembangan*
Method	Quasi Experiment
Result	From the results of the research analysis, the factors causing the increase in students' critical thinking abilities are First, project based learning has a significant effect in improving students' critical thinking abilities. This happens because students experience an increased (active) role in the learning process, and their motivation also increases. Second, project based learning that is carried out properly can create a good learning environment. A good learning environment is learning that fosters interaction between students, so that they work together to find ways to solve problems. Third, project based learning can be used to achieve the desired learning goals. Learning in contextual project

	based learning will be better able to achieve learning goals

Table 11. Factors that Influence Increasing Critical Thinking Abilities through the PjBL-GI Learning Model.

Authors	(Esti Rahayu, H. Hartono, 2016)
Title	*Keefektifan Model PBL dan PjBL Ditinjau dari Prestasi, Kemampuan Berpikir Kritis, dan Motivasi Belajar Matematika Siswa SMP*
Journal's Name	*PYTHAGORAS: Jurnal Pendidikan Matematika*
Method	Quasi experiment
Result	From the results of the research analysis, the factor causing the increase in students' critical thinking skills is that students in this learning model are required to be able to plan, complete and produce a final product in the form of a solution to the problems discussed in each study group. So, in this activity, students can be directly involved in knowing, remembering, and applying mathematical concepts, especially in this research material about geometry.

Tabel 12. Factors that Influence Increasing Critical Thinking Abilities through the PjBL-STEM Learning Model.

Authors	(Suyanto, 2023)
Title	*Peningkatan Ketrampilan Berpikir Kritis, Berkomunikasi, Berkolaborasi, dan Kreativitas pada Matriks melalui Kriptografi Menggunakan PjBL-STEM*
Journal's Name	*Ideguru: Jurnal Karya Ilmiah Guru*
Method	Qualitative research, *Penelitian Tindakan Kelas (PTK)*
Result	From the results of data analysis, it was found that group discussions in the learning process using the PjBL-STEM model had a positive impact on students. Where, the influencing factors can be seen from the assessment of each aspect observed, namely in learning students are required to be able to make logical mathematical statements, then be able to analyze information to be used later in solving problems, apart from that from the factors of each individual learner inspired to improve inductive and deductive reasoning. So, in other words, the ability to reason and think more logically is an important factor in improving critical thinking skills.

From these three articles, it can be concluded that the factors that do influence the improvement of students' critical thinking skills in STEM nuanced learning models modeled on PjBL-GI are external and internal factors, where external factors include students' direct involvement in learning activities and also internal factors, namely students' interest in learning that can increase which is triggered by external factors.

3. Conclusion

From the results of the literature study on the effect of STEM nuanced learning modeled by project-based learning group investigation, it is concluded that learning with this system can improve students' critical thinking. This is based on 12 articles or studies that discuss the effect of PjBL, PjBL Group investigation, and PjBL-STEM on students' critical thinking skills in mathematics learning. In addition, from some of

the articles and studies that have been analyzed, on average, the application of this learning model is applied to geometry and trigonometry learning where there is a lot of material that requires students to be able to model a problem carefully and be rational. However, this learning model is also expected to be integrated and further innovated in other mathematics materials.

In the application of STEM nuanced learning modeled by Project-Based Learning Group Investigation (PjBL-GI), it is seen that this method is effective in improving the quality of mathematics learning. Students showed a higher level of enthusiasm in learning, and the daily test results reached the desired target. Students' ability to complete tasks also improved significantly. This shows that PjBL, both with the STEM approach and with Group Investigation, helps students understand math materials better and train their critical thinking skills effectively.

In addition, the conclusions from this literature review indicate that the STEM-infused PjBL-GI learning model can be successfully applied to a variety of other mathematics materials. The flexibility of this approach allows its use in a variety of mathematics learning contexts. In the context of factors influencing the improvement of students' critical thinking skills, external factors such as students' active participation in learning activities are key. This also impacts on internal factors, where students' learning motivation increases in response to these external factors.

Overall, this article provides strong support for the use of PjBL with STEM and Group Investigation approaches as effective learning strategies in improving students' critical thinking skills in the context of mathematics learning. The article provides a comprehensive view of the positive impact of this learning method on mathematics learning.

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