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Article

## Exploring the Transformative Effect of Problem-Based Learning Models in Science, Technology, Engineering, and Mathematics on Students' Rational Thinking Ability across Gender

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### ABSTRACT

The rational thinking abilities of students require development through effective learning strategies. This study investigates the effectiveness of a STEM-based Problem-Based Learning (PBL) model in enhancing students' rational thinking abilities, with consideration for gender differences. This research uses a quantitative approach and a quasi-experimental design. Data analysis involved the application of Two-Way ANOVA and Scheffe tests utilizing SPSS software. Participants consisted of Class VII students from MTs Ma'arif Balong Ponorogo. The findings indicate the following: (1) the initial rational thinking abilities of the experimental and control groups were comparable; (2) the STEM-based PBL model demonstrated superior effectiveness in improving students' rational thinking skills when compared to conventional learning methods; (3) no significant disparity in rational thinking abilities were observed between male and female students; (4) an interaction effect between the learning model and gender was detected, influencing students' rational thinking abilities. Specifically, female students displayed superior rational thinking abilities when exposed to the STEM-based PBL model. Conversely, no gender-based discrepancy in rational thinking abilities was observed among students utilizing the conventional model. These findings underscore the potential of the STEM-based PBL model as an alternative approach to foster students' rational thinking abilities.

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### INTRODUCTION

Education in the era of Society 5.0 should be oriented towards equipping students with various skills needed in this era of disruption. One important skill a student should possess is rational thinking (Putri & Fadly, 2022; Rashidov, 2022). Rational thinking is a type of thinking

that refers to logical and analytical thinking styles (Yang & Mattila, 2020). This indicates that people with high rational thinking skills tend to have stronger logical and analytical thinking, which makes them more likely to understand the reasons and explanations underlying their decisions (Rahman, 2019). Students' rational thinking style is differentiated by gender in their ability to solve problems or issues; males are more inclined toward a mathematical thinking, while females are more inclined towards an abstract thinking style (Tzu-Ling, 2019). Female students prefer abstract materials more than males (Alam, 2022).

Rational thinking ability can also be interpreted as a theoretical quality of the mind. The rational thinking ability of students includes four things: the ability to gather information, the ability to process information, the ability to solve problems, and the ability to draw conclusions (Nuayi et al., 2018). World cognitive scientists also argue that increasing understanding of rational thinking is important in achieving educational goals (Zulva, 2016). The more a person is responsive in thinking, the more he/she can maximize their abilities to seek existing opportunities (Matsunaga et al., 2021). Steps that can be taken in developing students' rational thinking abilities, especially in the world of education, are by finding a suitable learning model to be applied so that students are more enthusiastic and motivated to learn (Rusmansyah et al., 2019; Wahono et al., 2020).

The development of education, knowledge, and technology underlies the emergence of various models and strategies in learning (Crompton et al., 2020). The learning model considered suitable for improving students' rational thinking abilities is the Problem-Based Learning (PBL) model based on STEM. Problem-based or PBL learning is a learning model in which students learn to solve problems that they receive. In PBL, student learning focuses on complex problems, and there are no right or wrong answers, only what solutions to take (Nair et al., 2020). The same goes for STEM-based learning, where the role of students in the implementation of STEM-based learning is also guided to solve more complex problems and requires high skills in solving a problem (Nasir et al., 2022). This allows students to be more active in exchanging ideas, working in groups, and interacting with each other, either with peers or teachers, because in this learning, the teacher is no longer the leading center of learning (Nida'ul Khairiyah, 2019; Roshayanti et al., 2022). However, the role of the teacher here is only as a facilitator and trainer for students.

The Problem-Based Learning (PBL) model of learning is the most innovative learning model that can be applied in education (Smith et al., 2022). This learning model is adequate for solving students' problems, and its application is in daily life. The PBL learning model is also a learning model that combines everyday life problems with knowledge about concepts and materials taught as the essential context for students to learn to support students' creative thinking and problem-solving skills (Al-Qora'n et al., 2023). Other research also reveals that PBL is more effective than conventional learning models (Jabarullah & Iqbal Hussain, 2019). The PBL learning model can improve students' mathematical problem solving ability and metacognition ability (Siagan et al., 2019), PBL model is also effective for the process of acquiring students' knowledge (Ibrahim et al., 2018), and even the PBL model can improve students' critical thinking skills (Dakabesi & Luoise, 2019; Kong et al., 2014).

Various studies on STEM have shown various benefits obtained through STEM-based learning. STEM-based learning models have been more effective than conventional learning (Sagala et al., 2019). STEM has also been shown to improve science process skills (Awalin & Ismono, 2021), reduce students' cognitive load (Sundari et al., 2021), increase students' scientific attitudes (Thahir et al., 2020), as well as students' rational thinking ability (Putri & Fadly, 2022). Combining of PBL and STEM learning models can improve students' metacognitive thinking abilities (Mulyani & Arif, 2021). Meanwhile, this study seeks to see the effectiveness of the STEM-based PBL model in improving students' rational thinking skills at the junior high school level.

PBL is a learning approach that emphasizes real-world problem-solving through critical thinking, collaboration, and the application of knowledge in relevant contexts (Sholihah & Lastariwati, 2020). PBL is highly relevant to STEM education as it enables students to engage in active and profound learning experiences that often involve applying science, technology, engineering, and mathematics concepts to solve problems (Smith et al., 2022). Through PBL, students can develop crucial analytical thinking, problem-solving, and teamwork skills that are essential in STEM fields (Topsakal et al., 2022). PBL also aids students in connecting STEM concepts to the real world, enhancing their learning motivation and developing skills relevant to STEM careers (Salam, 2023). A practical PBL approach in STEM education can enhance students' understanding of scientific concepts and their ability to apply that knowledge in different contexts.

Inspired by various studies, this research investigates the effectiveness of using the STEM-based PBL learning model in improving students' rational thinking abilities at MTs Ma'arif Balong Ponorogo. Specifically, this study aims to: 1) determine the initial rational thinking abilities of the experimental and control class students before the implementation of the learning model, 2) determine whether the STEM-based PBL learning model is more effective in improving students' rational thinking abilities, 3) determine whether there are differences in rational thinking abilities between male and female students, 4) determine whether there is an interaction between the learning model and gender differences in students' rational thinking abilities.

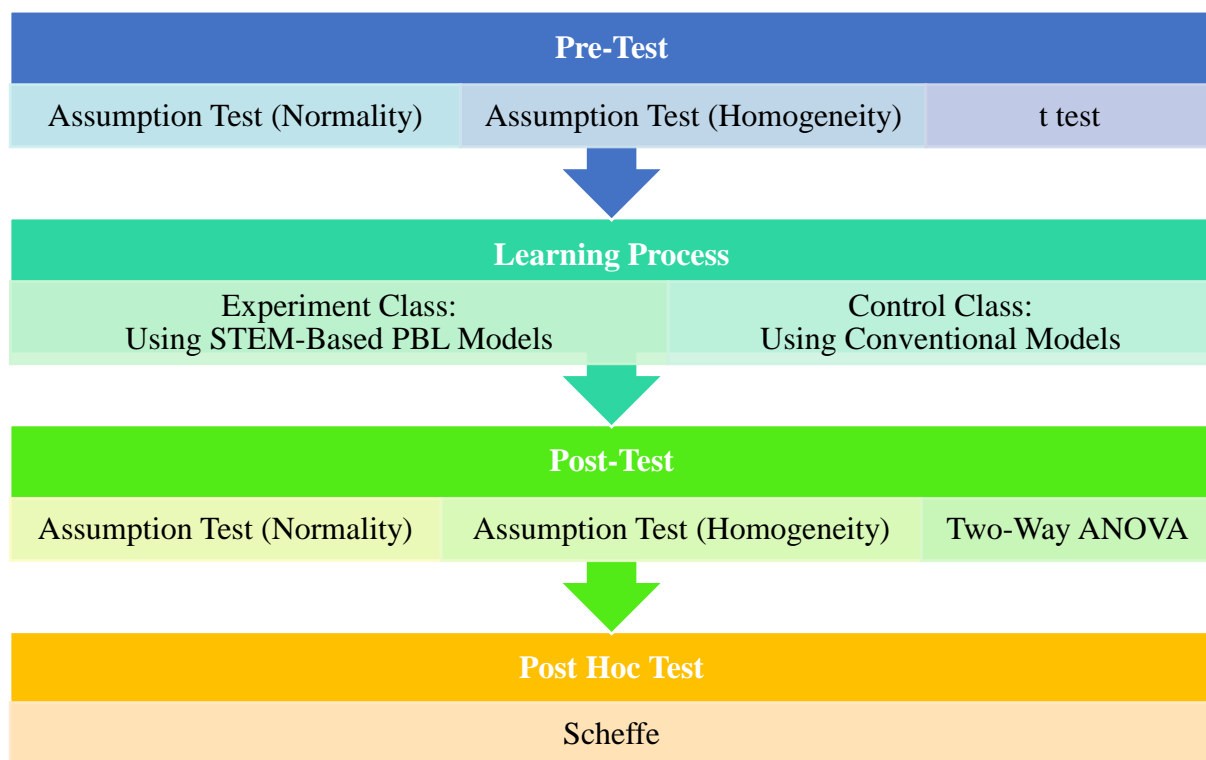
## METHODS

This research is a quantitative study that employs a quasi-experimental method. This method is a research approach similar to a true experiment but with some limitations in controlling variables (Rogers & Revesz, 2020). The quasi-experimental method involves two groups, namely the experimental and control groups, but does not involve randomization in assigning the groups. This study uses a 2 x 2 factorial design because it involves two independent variables, namely the learning model and gender, each of which consists of two categories. The population of this research is all 7th-grade students at MTs Ma'arif Balong. The sampling technique used is cluster random sampling. One class is used as the experimental group, and another as the control group. Data were collected from February 8th, 2021, to February 22nd, 2021. The dependent variable in this study is the rational thinking ability of students. In contrast, the independent variables are the learning model (STEM-based PBL learning and conventional learning) and gender (male and female) of the students. The data collection technique used was a pre-test and post-test on students' rational thinking abilities.

The instrument used to collect data in this research is a pre-test and post-test questionnaire. The instrument created will undergo several tests, including validity and reliability, to ensure the validity of the data before it is distributed to the respondents (Siregar, 2013). Validity testing is conducted through two methods, namely content validity, which is done through validation by a judgment expert, and item validity, which is done using the product-moment correlation. Meanwhile, reliability testing uses the Cronbach Alpha formula (Sürücü & Maslakçi, 2020). The first step in validating the instrument is to conduct an expert validity test. The researcher requested the assistance of two lecturers to check whether the instrument created was valid. The instrument declared valid by the lecturers will then be tested for validity and reliability using SPSS software. This validity and reliability test includes all items, which are 20 questions. Based on the validity test using SPSS software, it is known that all items have a significance value of less than 0.05, indicating that the instrument used is considered valid. The next step is to test the instrument's reliability, which is considered reliable if the value of Cronbach's Alpha is greater than 0.70, while the obtained data is considered unreliable if the value of Cronbach's Alpha is less than 0.70 (Howitt & Cramer, 2017). Based

on the reliability test of the questionnaire instrument, it is known that the value of Cronbach Alpha obtained is 0.916, which is greater than 0.70, indicating that the instrument used is proven to be reliable. After being declared valid and reliable, the instrument is ready to be distributed to the main research respondents.

This research was carried out with the procedure stated in the Figure 1. As stated in Figure 1, the research procedure started with giving pre-test questions to each class, the experimental and control groups. The pre-test questions were given to measure the students' initial ability before giving the learning model. The results were used to test the balance to determine whether the rational thinking ability of the students in both classes before the experiment was the same. Next, the students were taught about environmental pollution. The STEM-based PBL learning model was used in the experimental class, while the conventional or lecture-based learning model was used in the control class. The teaching was carried out according to the syntax of each learning model using environmental pollution material. After completing a series of experimental activities, the students were given post-test questions to determine their rational thinking ability after the experiment.



**Figure 1.** Research procedure

The data analysis technique used in this study consisted of two stages, before and after the experiment. Before the experiment, a balance test was conducted. The balance test was conducted using a t-test, preceded by prerequisite tests that included normality tests using the Kolmogorov-Smirnov test and homogeneity tests using the Bartlett test. Meanwhile, the test after the experiment was a hypothesis test using Two-Way ANOVA. Before conducting the Two-Way ANOVA test, prerequisite tests were carried out, which included normality tests using the Kolmogorov-Smirnov test and homogeneity tests using the Bartlett test. A post hoc test was conducted using Scheffe's multiple comparison tests to follow the Two-Way ANOVA test. Technically, all tests were performed using SPSS 25 software. All data analysis in this study used a significance level of 5%. The null hypothesis ( $H_0$ ) was accepted if the significance value or P-Value was greater than 5%, and the null hypothesis ( $H_0$ ) was rejected if the significance value or P-Value was less than 5% (Irawan, 2014).

## RESULTS AND DISCUSSION

### Results

Before being given treatment, it is necessary to ascertain whether the rational thinking skills of the experimental and control classes are the same. Based on the pre-test and post-test data, the maximum, minimum, mean, median, mode, variance, and standard deviation values are obtained, as listed in Table 1.

**Table 1.** Descriptive statistics of experimental class and control class

Statistics	Experimental		Control	
	Pre-Test	Post-Test	Pre-Test	Post-Test
Min	74.00	73.00	74.00	63.00
Max	78.00	87.00	78.00	80.00
Mean	76.06	80.06	75.81	72.25
Median	76.00	80.00	75.50	72.00
Mode	76.00	83.00	75.00	71.00
Variance	1.26	16.73	1.58	20.73
Standard Deviation	1.12	4.09	1.13	4.55

Furthermore, statistical analysis of inferential tests was carried out based on the results of the pre-test of students' rational thinking skills from the two classes. *First*, prerequisite tests are conducted, which include normality and homogeneity tests. *First*, the normality test is used to determine whether the data is normally distributed or not. Based on the normality test results, it is known that the Kolmogorov-Smirnov test's significance value for the experimental class is 0.058 (greater than 0.05), and for the control class is 0.116 (greater than 0.05). Therefore, the pre-test scores for both the experimental and control classes are normally distributed. *Second*, the homogeneity test ensures whether the two population distributions are homogenous. The significance value of the Bartlett test for the pre-test data is 0.358 (greater than 0.05); hence it can be concluded that the experimental and control classes have homogenous data distributions.

After fulfilling both prerequisites, the balance test was conducted using the t-test. The results of the t-test conducted using SPSS software are presented in Table 2.

**Table 2.** Results of balance test using t-test assisted by SPSS 25

Pre-test Value	t	Sig.
Experimental-Control	0.588	0.561

The Table 2 above indicates that the significance value (P-Value) of the t-test is 0.561 (greater than 0.05); hence it can be concluded that the rational thinking ability of students before treatment between the experimental and control groups is the same. This is supported by the fact that the means of the two groups are not significantly different, with a mean of 76.06 in the experimental group and 75.81 in the control group. Hypothesis testing is performed on the post-test data.

Hypothesis testing was conducted on the post-test data after the experiment. Three stages of tests were carried out, namely prerequisite tests, Two-Way ANOVA tests, and post-ANOVA follow-up tests. The prerequisite test included normality and homogeneity tests. Normality tests were carried out four times: normality tests on each class group and normality tests on each gender group. The significance of the normality test using Lilliefors in the experimental class was 0.200 (greater than 0.05), and in the control class was 0.200 (greater than 0.05), so it can be concluded that the post-test scores of the experimental and control classes, respectively are normally distributed. The significance of the normality test using Lilliefors in male students was 0.145 (greater than 0.05), and in female students was 0.150 (greater than 0.05), so it can be concluded that the post-test scores of male and female students respectively are normally distributed.

Homogeneity tests were conducted twice: homogeneity tests among classes (experiment and control) and groups based on gender (male and female). The significance level of the Bartlett homogeneity test on the post-test results between classes (experiment and control) was

0.926 (greater than 0.05), indicating that the distribution of pre-test data values in both classes is homogeneous. Meanwhile, the significance level of the homogeneity test between genders (male and female) was 0.166 (greater than 0.05); hence it can be concluded that the distribution of pre-test data values between male and female students is homogeneous. After meeting the normality and homogeneity requirements, the Two-Way ANOVA test can be conducted.

The Two-Way ANOVA test was conducted to answer the research hypothesis. The results of the Two-Way ANOVA test using SPSS are listed in Table 3.

**Table 3.** Summary of two-way ANOVA test results of students' rational thinking ability

Source	SS	df	MS	F	Sig.
Learning Model (A)	495.822	1	495.822	30.956	0.000
Gender (B)	26.648	1	26.648	1.664	0.208
Interaction (AB)	86.050	1	86.050	5.372	0.028
Error	448.478	28	16.017		
Total	1050.219	32			

Based on Table 3, it can be concluded as follows. First, for the main effect of rows, which is the learning model (A), a significance value of 0.000 (less than 0.05) was obtained, indicating that there is a significant difference in rational thinking ability between students who learn using the PBL-based STEM learning model and those who use the conventional model. Furthermore, mean, and marginal mean are required to conclude which model is more effective in improving students' rational thinking ability as shown in Table 4. Second, for the main effect of columns, gender (B), a significance value of 0.208 (greater than 0.05) was obtained, indicating that male and female students' rational thinking abilities are equally good. Third, for the interaction effect of the learning model and gender (AB), a significance value of 0.028 (less than 0.05) was obtained, indicating an interaction between the learning model and gender on students' rational thinking ability. Further post-ANOVA tests are needed to determine the specific effects on each group.

**Table 4.** Means and Marginal Means

Learning Model	Gender		Marginal Means
	Male	Female	
STEM-Based PBL	77.500	82.627	80.063
Conventional	72.889	71.429	72.159
Marginal Means	75.194	77.027	

Table 4 shows that the mean rational thinking ability of students who learn using the STEM-based PBL learning model is 80.063, while students who use the conventional model have a mean score of 72.159. The rational thinking ability of students who learn using the STEM-based PBL learning model is better than those who use the conventional model. In other words, the STEM-based PBL learning model is more effective in improving the rational thinking ability of students when compared to the conventional learning model.

The results of the ANOVA test on the interaction effect of the learning model and gender (AB) showed an interaction between the learning model and gender on students' rational thinking ability. Thus a post-ANOVA follow-up test was needed. The results of the post-ANOVA follow-up test using the Scheffe model comparison test are listed in Table 5.

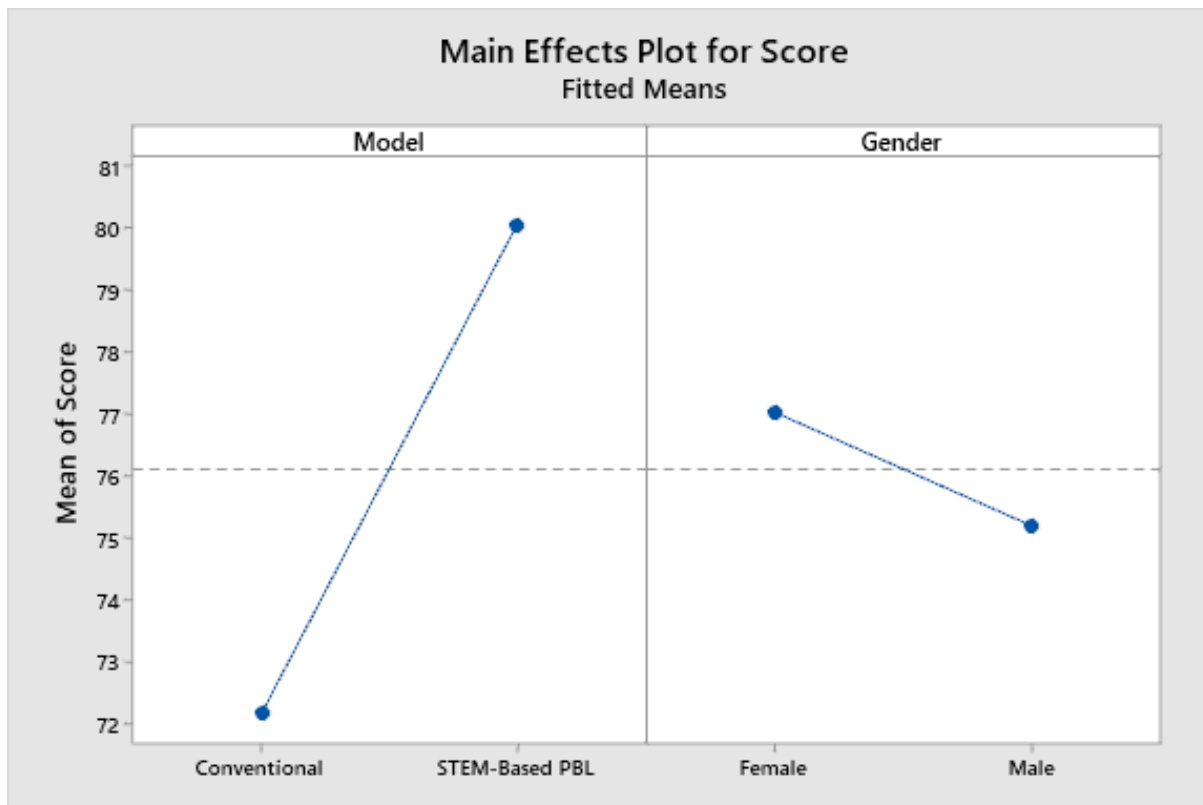
**Table 5.** Summary of scheffe's post hoc comparison test

Kelompok	H <sub>0</sub>	H <sub>1</sub>	F <sub>obs</sub>	Sig.
STEM-Based PBL	$m_{EL} = m_{EP}$	$m_{EL}^1 \ m_{EP}$	6.559	0.016
Conventional	$m_{KL} = m_{KP}$	$m_{KL}^1 \ m_{KP}$	0.532	0.475
Male	$m_{LE} = m_{LK}$	$m_{LE}^1 \ m_{LK}$	5.309	0.025
Female	$m_{PE} = m_{PK}$	$m_{PE}^1 \ m_{PK}$	31.304	0.000

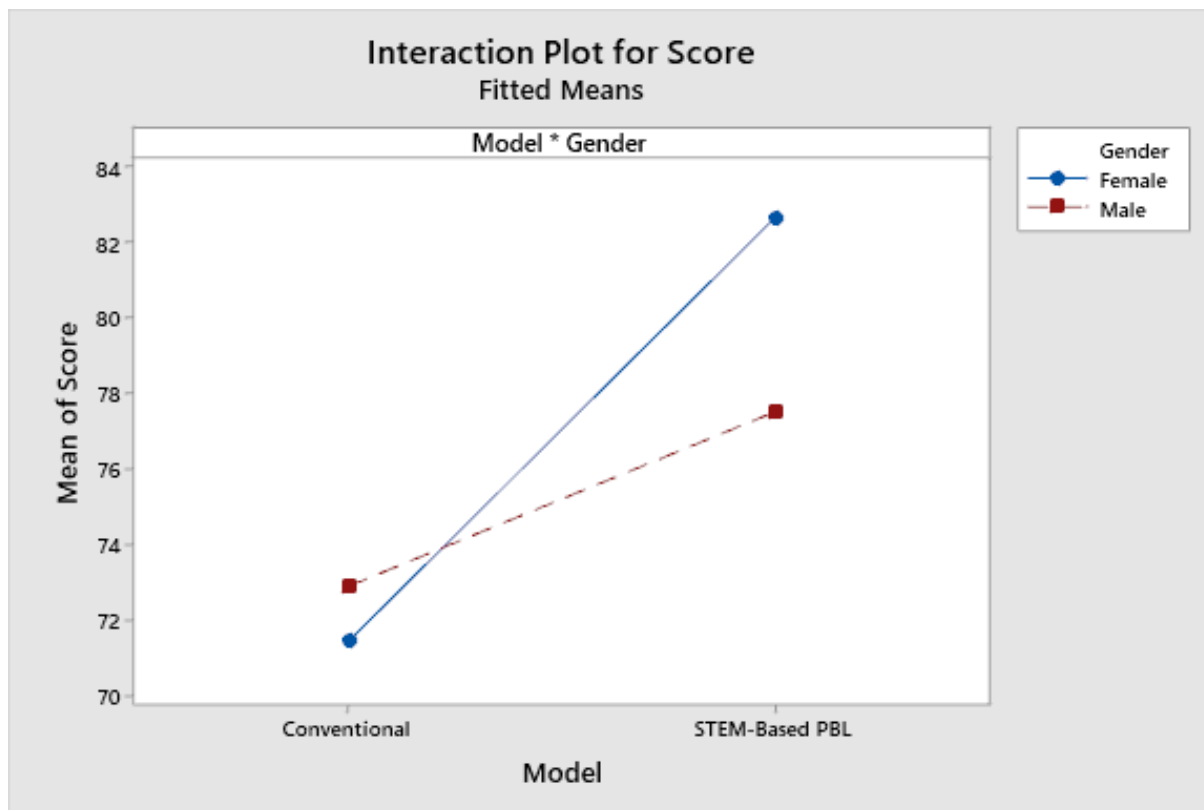
The post hoc Scheffe's multiple comparison test results, as presented in Table 5 above, can be interpreted as follows. *First*, for students who learned using the STEM-Based PBL model, the significance value of the mean comparison between male and female students was

0.016 (less than 0.05). This suggests that there is a significant difference in rational thinking abilities between male and female students who learned using the STEM-Based PBL model. Looking at their means in Table 4, it can be concluded that female students have better rational thinking abilities than male students. *Second*, for students who learned using the conventional model, the significance value of the mean comparison between male and female students was 0.475 (more than 0.05). This suggests no significant difference in rational thinking abilities between male and female students who learned using the conventional model. *Third*, for male students, the significance value of the comparison between the experimental and control groups was 0.025 (less than 0.05). This suggests a significant difference in rational thinking abilities between male students who learned using the STEM-Based PBL model and those who learned using the conventional model. Looking at their means in Table 4, it can be concluded that male students who learned using the STEM-Based PBL model have better rational thinking abilities than those who learned using the conventional model. *Fourth*, for female students, the significance value of the comparison between the experimental and control groups was 0.000 (less than 0.05). This suggests a significant difference in rational thinking abilities between female students who learned using the STEM-Based PBL model and those who learned using the conventional model. Looking at their means in Table 4, it can be concluded that female students who learned using the STEM-Based PBL model have better rational thinking abilities than those who learned using the conventional model.

The main effects of comparing rational thinking abilities between the learning models and genders are presented in Figure 2(a). In contrast, the interaction between learning models and genders on rational thinking abilities is presented in Figure 2(b) below.



(a)



(b)

Figure 2. (a) Main effect plot for score (b) Interaction plot for score

## Discussion

The Problem-Based Learning (PBL) model of learning based on Science, Technology, Engineering, and Mathematics (STEM) can enhance students' rational thinking abilities because, in this model of learning, students are required to solve existing problems and are expected to be proactive in finding the right solution. Additionally, the STEM approach in this learning model combines four aspects of science, technology, engineering, and mathematics, which can broaden students' knowledge in finding the best solution to their problems. The more proficient and active students are in problem-solving, the higher their rational thinking abilities will be (Tseng et al., 2013).

Rational thinking ability is a theoretical quality of the mind. Students' rational thinking abilities encompass four aspects: gathering information, exploring or processing information, problem-solving, and drawing conclusions. Rational thinking is a set of mental activities ranging from simple to complex, including ten skills that underlie rational thinking abilities: memorizing, imagining, classifying, generalizing, comparing, evaluating, analyzing, synthesizing, and concluding (Nurachman & Irawan, 2020).

Students with good rational thinking abilities tend to rely on theoretical thinking styles to respond to everything. People who rely on rational thinking abilities tend to have strong beliefs in their initial decisions to protect personal interests, such as maintaining a good image. Research results explain that rational thinking regulates how far individuals use abstractions, which are general rules guided by analysis and logic in making decisions (De Keersmaecker et al., 2020). Rational thinking ability also refers to a logical and analytical thinking style. Based on this, it shows that individuals with high rational thinking abilities will have stronger logical and analytical thinking, so they tend to understand the reasons and explanations underlying their decisions.

The research findings indicate that the Problem-Based Learning (PBL) model based on STEM influences students' rational thinking abilities. If students' rational thinking abilities



continue to develop, their learning outcomes will also improve. Other studies have also explained that the PBL learning model impacts students' learning outcomes because, in the PBL learning model, students must be more proactive during the learning process. Active involvement of students in learning can bring about new knowledge and experiences for students and cultivate a high level of curiosity toward the material being studied. The more diligent and enthusiastic students are in learning, the higher their thinking skills will be, and the learning outcomes they obtain will also improve.

This study is in line with the research conducted by Handika (2013), who stated that problem-based learning has a better and more significant effect on the mastery of science concepts in terms of the cognitive abilities of elementary school students compared to conventional learning. This study correlates with research conducted by researchers, where there was a significant improvement in students' understanding of the learning material taught, thus developing their thinking skills and obtaining better learning outcomes.

Gender differences in thinking abilities can be seen in the ability to process the left and right brains in each gender. Biologically, there are differences in the brain ability of male and female students to understand STEM-based and problem-based learning (Saputri et al., 2018). Female students tend to be superior in processing information using the left-brain function so that they can be more organized in terms of dressing, and their thinking style is more prominent in verbal learning, which prioritizes the ability to remember, memorize, observe, and conceptualize, as in science and language learning. On the other hand, males are more prominent in processing proper brain functions, in which they are superior in numerical or calculative learning, such as mathematics and physics.

The learning activities that can influence students' rational thinking abilities, viewed from gender differences, are seen from how teachers teach in the classroom and students' participation in helping the learning process become productive and conducive. However, this study has no relationship between gender differences in STEM-based PBL learning and students' rational thinking abilities. The factors that influence the lack of gender differences impact on learning may be due to students' lack of seriousness during learning activities and the educator's ability to condition the classroom is less conducive, thus disrupting other students' learning concentration.

This is in line with the research conducted by Wardani (2018) entitled "The Effectiveness of STEM (Science, Technology, Engineering, and Mathematics) on Understanding Physics Concepts in Terms of Gender Differences of Students," which states that there is no significant influence between the learning approach and gender differences on students' understanding of concepts. This is consistent with research conducted by researchers where there is no significant influence related to gender differences in STEM-based PBL learning that have been taught on students' rational thinking abilities in class VII of MTs Ma'arif Balong.

## CONCLUSION

Based on the results of the analysis and discussion that have been conducted, this research provides several significant contributions to the field of knowledge. *First*, the study reveals that the initial rational thinking ability of the experimental and control group students at MTs Ma'arif Balong is equally good, indicating a balanced starting point. *Second*, the findings demonstrate that the STEM-based PBL model significantly positively impacts students' rational thinking abilities, surpassing the effectiveness of the conventional learning model. This conclusion highlights the value of incorporating the STEM-based PBL model in educational practices to enhance students' rational thinking skills. *Third*, the research indicates no significant difference in rational thinking abilities between male and female students. *Fourth*, there is an interaction between learning models and gender differences in students' rational

thinking abilities. Specifically, female students who learn using the STEM-based PBL model exhibit superior rational thinking abilities compared to male students.

Conversely, no disparity in rational thinking abilities is observed between male and female students when utilizing the conventional model. These findings contribute to a deeper understanding of the impact of learning models and gender on students' rational thinking abilities, providing valuable insights for educators and policymakers. By highlighting the effectiveness of the STEM-based PBL model and shedding light on the gender dimension, this research contributes to advancing the field of education and fostering evidence-based practices for promoting rational thinking skills among seventh-grade students.

## REFERENCES

- Alam, A. (2022). Psychological, Sociocultural, and Biological Elucidations for Gender Gap in STEM Education: A Call for Translation of Research into Evidence-Based Interventions. 95–107. <https://doi.org/10.2991/ahsseh.k.220105.012>
- Al-Qora'n, L. F., Jawarneh, A., & Nganji, J. T. (2023). Toward Creating Software Architects Using Mobile Project-Based Learning Model (Mobile-PBL) for Teaching Software Architecture. *Multimodal Technologies and Interaction*, 7(3), 31. <https://doi.org/10.3390/mti7030031>
- Awalin, N. A., & Ismono, I. (2021). The Implementation of Problem Based Learning Model with STEM (Science, Technology, Engineering, Mathematics) Approach to Train Students' Science Process Skills of XI Graders on Chemical Equilibrium Topic. *INSECTA: Integrative Science Education and Teaching Activity Journal*, 2(1), Article 1. <https://doi.org/10.21154/insecta.v1i2.2496>
- Crompton, H., Bernacki, M., & Greene, J. A. (2020). Psychological Foundations of Emerging Technologies for Teaching and Learning in Higher Education. *Current Opinion in Psychology*, 36, 101–105. <https://doi.org/10.1016/j.copsyc.2020.04.011>
- Dakabesi, D., & Luoise, I. S. Y. (2019). The Effectiveness of Problem-Based Learning Model to Increase the Students' Critical Thinking Skills. *Journal of Education and Learning (EduLearn)*, 13(4), 543–549. <https://doi.org/10.11591/edulearn.v13i4.12940>
- De Keersmaecker, J., Dunning, D., Pennycook, G., Rand, D. G., Sanchez, C., Unkelbach, C., & Roets, A. (2020). Investigating the Robustness of the Illusory Truth Effect Across Individual Differences in Cognitive Ability, Need for Cognitive Closure, and Cognitive Style. *Personality and Social Psychology Bulletin*, 46(2), 204–215. <https://doi.org/10.1177/0146167219853844>
- Handika, I., & Wangid, M. N. (2013). Pengaruh Pembelajaran Berbasis Masalah Terhadap Penguasaan Konsep dan Keterampilan Proses Sains Siswa Kelas V. *Jurnal Prima Edukasia*, 1(1), 85–93.
- Howitt, D., & Cramer, D. (2017). *Understanding Statistics in Psychology with SPSS (Seventh Edition)*. Pearson.
- Ibrahim, M. E., Al-Shahrani, A. M., Abdalla, M. E., Abubaker, I. M., & Mohamed, M. E. (2018). The Effectiveness of Problem-based Learning in Acquisition of Knowledge, Soft Skills During Basic and Preclinical Sciences: Medical Students' Points of View. *Acta Informatica Medica*, 26(2), 119–124. <https://doi.org/10.5455/aim.2018.26.119-124>
- Irawan, E. (2014). *Pengantar Statistika Penelitian Pendidikan*. Yogyakarta: Aura Pustaka.
- Jabarullah, N. H., & Iqbal Hussain, H. (2019). The Effectiveness of Problem-Based Learning in Technical and Vocational Education in Malaysia. *Education+ Training*, 61(5), 552–567. <https://doi.org/10.1108/ET-06-2018-0129>
- Kong, L.-N., Qin, B., Zhou, Y., Mou, S., & Gao, H.-M. (2014). The Effectiveness of Problem-Based Learning on Development of Nursing Students' Critical Thinking: A Systematic

- Review and Meta-Analysis. *International Journal of Nursing Studies*, 51(3), 458–469. <https://doi.org/10.1016/j.ijnurstu.2013.06.009>
- Matsunaga, K., Barnes, M. M., & Saito, E. (2021). Exploring, Negotiating and Responding: International Students' Experiences of Group Work at Australian Universities. *Higher Education*, 81, 989–1006. <https://doi.org/10.1007/s10734-020-00592-5>
- Mulyani, D. F., & Arif, S. (2021). Implementation of Project Based Learning (PJBL) Based on Science, Technology, Engineering and Mathematics (STEM) to Improve Metacognitive Thinking Ability. *INSECTA: Integrative Science Education and Teaching Activity Journal*, 2(1), Article 1. <https://doi.org/10.21154/insecta.v2i1.2931>
- Nair, S. S., Smritika, S. P., & Thomas, K. A. (2020). Revitalizing Education through Problem Based Learning Practices. *Shanlax International Journal of Education*, 9(1), 109–117. <https://doi.org/10.34293/education.v9i1.3436>
- Nasir, M., Cari, C., Sunarno, W., & Rahmawati, F. (2022). The effect of STEM-based guided inquiry on light concept understanding and scientific explanation. *EURASIA Journal of Mathematics, Science and Technology Education*, 18(11), em2175. <https://doi.org/10.29333/ejmste/12499>
- Nida'ul Khairiyah, S. P. (2019). Pendekatan Science, Technology, Engineering Dan Mathematics (STEM). *SPASI MEDIA*.
- Nuayi, A. W., Supartin, S., & Buhungo, T. J. (2018). Stimulation of Pressure on Liquid Concept in Stad Learning Model to Improve Rational Thinking Skills and Learning Outcomes of Student. *Jurnal Pendidikan Fisika Indonesia*, 14(2), 83–91.
- Nurachman, D. E., & Irawan, E. (2020). Effectiveness Of Blended Learning Based On Constructive Feedback In Improving Rational Thingking Ability Of Students. *INSECTA: Integrative Science Education and Teaching Activity Journal*, 1(1), 34–44.
- Putri, E. A., & Fadly, W. (2022). Analysis of Student's Rational Thinking Ability in a Career Perspective in the Field of Science, Technology, Engineering, Mathematics (STEM). *INSECTA: Integrative Science Education and Teaching Activity Journal*, 3(2), Article 2. <https://doi.org/10.21154/insecta.v3i2.5138>
- Rahman, Md. M. (2019). 21<sup>st</sup> Century Skill "Problem Solving": Defining the Concept. *Asian Journal of Interdisciplinary Research*, 2(1), 64–74.
- Rashidov, A. S. (2022). Using of Problem Educational Technologies in the Development of Students'creative and Logical Thinking Skills. *Berlin Studies Transnational Journal of Science and Humanities*, 2(1.5 Pedagogical sciences).
- Rogers, J., & Revesz, A. (2020). *Experimental and quasi-experimental designs*. Routledge.
- Roshayanti, F., Wijayanti, A., & Purnamasari, V. (2022). Model Pembelajaran Berbasis STEAM Berorientasi Life Skills. Penerbit NEM.
- Rusmansyah, R., Yuanita, L., Ibrahim, M., Isnawati, I., & Prahani, B. K. (2019). Innovative Chemistry Learning Model: Improving the Critical Thinking Skill and Self-Efficacy of Pre-Service Chemistry Teachers. *JOTSE: Journal of Technology and Science Education*, 9(1), 59–76.
- Sagala, R., Umam, R., Thahir, A., Saregar, A., & Wardani, I. (2019). The Effectiveness of STEM-Based on Gender Differences: The Impact of Physics Concept Understanding. *European Journal of Educational Research*, 8(3), 753–761.
- Salam, H. (2023). Stem Education: Its Effects on the Quality of Teachers and Students in the 21st Century. *International Conference on Education 2022 (ICE 2022)*, 31–39. [https://doi.org/10.2991/978-2-38476-020-6\\_4](https://doi.org/10.2991/978-2-38476-020-6_4)
- Saputri, R. R., Sugiarti, T., Murtikusuma, R. P., Trapsilasiwi, D., & Yudianto, E. (2018). Analisis kesalahan siswa dalam menyelesaikan soal materi fungsi berdasarkan kriteria watson ditinjau dari perbedaan gender siswa SMP kelas VIII. *Kadikma*, 9(2), 59–68.

- Sholihah, T. M., & Lastariwati, B. (2020). Problem Based Learning to Increase Competence of Critical Thinking and Problem Solving. *Journal of Education and Learning (EduLearn)*, 14(1), 148–154. <https://doi.org/10.11591/edulearn.v14i1.13772>
- Siagan, M. V., Saragih, S., & Sinaga, B. (2019). Development of Learning Materials Oriented on Problem-Based Learning Model to Improve Students' Mathematical Problem Solving Ability and Metacognition Ability. *International Electronic Journal of Mathematics Education*, 14(2), 331–340.
- Siregar, S. (2013). Metode Penelitian Kuantitatif Dilengkap dengan Perbandingan Perhitungan Manual dan SPSS. Prenadaa Media Group.
- Smith, K., Maynard, N., Berry, A., Stephenson, T., Spiteri, T., Corrigan, D., Mansfield, J., Ellerton, P., & Smith, T. (2022). Principles of Problem-Based Learning (PBL) in STEM Education: Using Expert Wisdom and Research to Frame Educational Practice. *Education Sciences*, 12(10), Article 10. <https://doi.org/10.3390/educsci12100728>
- Sundari, R., Ahmed, O. S., Abdurrahman, A., & Herlina, K. (2021). Application of Inquiry Based Learning Model Using STEM Approach to Reduce Students' Intrinsic Cognitive Load. *INSECTA: Integrative Science Education and Teaching Activity Journal*, 2(1), Article 1. <https://doi.org/10.21154/insecta.v2i1.2482>
- Sürücü, L., & Maslakçı, A. (2020). Validity and Reliability in Quantitative Research. *Business & Management Studies: An International Journal*, 8(3), Article 3. <https://doi.org/10.15295/bmij.v8i3.1540>
- Thahir, A., Anwar, C., Saregar, A., Choiriah, L., Susanti, F., & Pricilia, A. (2020). The Effectiveness of STEM Learning: Scientific Attitudes and Students' Conceptual Understanding. *Journal of Physics: Conference Series*, 1467(1), 012008. <https://doi.org/10.1088/1742-6596/1467/1/012008>
- Topsakal, İ., Yalçın, S. A., & Çakır, Z. (2022). The Effect of Problem-based STEM Education on the Students' Critical Thinking Tendencies and Their Perceptions for Problem Solving Skills. *Science Education International*, 33(2), 136–145. <https://doi.org/10.33828/sei.v33.i2.1>
- Tseng, K.-H., Chang, C.-C., Lou, S.-J., & Chen, W.-P. (2013). Attitudes Towards Science, Technology, Engineering and Mathematics (STEM) In A Project-Based Learning (PjBL) Environment. *International Journal of Technology and Design Education*, 23(1), 87–102.
- Tzu-Ling, H. (2019). Gender Differences in High-School Learning Experiences, Motivation, Self-Efficacy, and Career Aspirations Among Taiwanese STEM College Students. *International Journal of Science Education*, 41(13), 1870–1884. <https://doi.org/10.1080/09500693.2019.1645963>
- Wahono, B., Lin, P.-L., & Chang, C.-Y. (2020). Evidence of STEM Enactment Effectiveness in Asian Student Learning Outcomes. *International Journal of STEM Education*, 7, 1–18. <https://doi.org/10.1186/s40594-020-00236-1>
- Wardani, I. (2018). Efektivitas STEM (Science, Technology, Engineering and Mathematics) Terhadap Pemahaman Konsep Fisika Ditinjau dari Perbedaan Gender Peserta didik. UIN Raden Intan Lampung.
- Yang, B., & Mattila, A. S. (2020). How Rational Thinking Style Affects Sales Promotion Effectiveness. *International Journal of Hospitality Management*, 84, 102335. <https://doi.org/10.1016/j.ijhm.2019.102335>
- Zulva, R. (2016). Hubungan Antara Keterampilan Berpikir Rasional Siswa SMA dengan Hasil Belajar dalam Pembelajaran Kooperatif Menggunakan Constructive Feedback. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, 5(1), 61–69. <https://doi.org/10.24042/jpifalbiruni.v5i1.106>