JEC | Journal of Educational Chemistry
Journal of Educational Chemistry (5(2), 2023, 69-76)
Website: https://journal.walisongo.ac.id/index.php/jec/index
ISSN 2715-3029 (p) 2685-4880 (e)
DOI: 10.21580/jec.2023.5.2.18426

The Influence of Science, Technology, Engineering, and Mathematics (STEM) Learning Models to Improve Students' Critical Thinking Skills

Tania Avianda Gusman[1], Ruri Vhirgiani Listanty[2]*, Dewiantika Azizah[3]
[1,2,3)]Department of Chemistry Education, Universitas Muhammadiyah Cirebon, Indonesia
*E-mail Corresponding Author: rurivhirgiani24@gmail.com

Abstract

Low learning activity in science students causes a decrease in critical thinking skills. This can be seen from the results of learning redox material under the Kriteria Ketuntasan Minimal (KKM) of 75 in one of the high schools in Cirebon. Therefore, this study aims to improve students' critical thinking skills by using the Science, Technology, Engineering, and Mathematics (STEM) model for redox material in class X IPA MAN 1 Cirebon City. The research method used a Nonequivalent Control Group Design. Sampling was carried out by Purposive sampling consisting of class X IPA 5 as an experimental class and class X IPA 4 as a control class. The instruments used are critical thinking ability tests, observation sheets, and questionnaires. The selection of a sample based on the KKM of a class was revealed from discussions with a chemistry teacher. The development of the T-test obtained a sig value. 0.000 < 0.05 and an n-gain score of 0.71 with the highest category. The results showed improved critical thinking skills after being given STEM learning. Students respond very well to the teaching that has been done using the STEM model. Based on the results of the t-test and N-gain test, it can be concluded that the Science, Technology, Engineering, and Mathematics (STEM) learning model can improve students' critical thinking skills on redox material.

Keywords: critical thinking skills; redox; STEM

Abstrak

Rendahnya keaktifan pembelajaran pada siswa IPA menyebabkan menurunnya keterampilan berpikir kritis. Hal ini terlihat dari hasil belajar pada materi redoks yang dibawah KKM 75 disalah satu SMA kota Cirebon. Oleh karena itu, penelitian ini bertujuan untuk meningkatkan kemampuan berpikir kritis siswa dengan menggunakan model Science, Technology, Engineering, and Mathematics (STEM) padai materi redoks di kelas X IPA MAN 1 Kota Cirebon. Metode penelitian menggunakan desain Nonequivalent Control Group Design. Pengambilan sampel dilakukan dengan Purposive sampling yang terdiri dari kelas X IPA 5 sebagai kelas eksperimen dan kelas X IPA 4 sebagai kelas kontrol. Pemilihan sampel berdasarkan nilai Kriteria Ketuntasan Minimum (KKM) suatu kelas, hal ini terungkap dari hasil diskusi dengan guru kimia. Instrumen yang digunakan adalah tes kemampuan berpikir kritis, lembar observasi, dan angket. Hasil uji-T diperoleh nilai sig. 0,000 < 0,05 dan skor n-gain 0,71 dengan kategori tinggi. Hasil Penelitian menunjukkan peningkatan keterampilan berpikir kritis setelah diberikan pembelajaran STEM. Siswa merespon dengan sangat baik terhadap pembelajaran yang telah dilakukan dengan menggunakan model STEM. Berdasarkan data tersebut, dapat disimpulkan bahwa model pembelajaran Science, Technology, Engineering, and Mathematics (STEM) dapat meningkatkan kemampuan berpikir kritis siswa terhadap materi redoks.

Keywords: berpikir kritis; redoks; STEM

Introduction

The demands of the 21st century require every individual, including learners, to possess skills for navigating the complexities inherent in contemporary life and careers. (Hamidah et al., 2021). One such skills is critical thinking skills. In the 2013 curriculum, students are emphasized in practicing critical thinking skills to solve existing problems. They are expected to not only grasp the subject matter presented by the teacher but also engage with material that involves formulas (Depdikbud, 2014: 52).

Critical thinking emphasizes rational, reasonable, and reflective thinking (Herwanti, 2021). When practicing critical thinking skills, teachers must be able to connect the subject matter to everyday life so that students can better understand the concepts of chemical materials. Ariyatun & Octavianelis (2020) argued that this approach allows learners to grasp and apply the materials to solve problems in their daily social environment.

The role of critical thinking skills has been going in a different direction in the learning experience by students, particularly in chemistry subject, which tend to focus on providing material and practice questions (Gazali et al., 2019). This viewpoint is supported by the results of the PISA (Programs for International Students Assessment) research conducted in 2015, where Indonesia ranked 62nd out of 70 participating countries in terms of students' critical thinking skills (OECD, 2018: 5). One of the reasons is the learning process that accustoms students to only receiving information so that students can only solve problems according to procedural (Gazali et al., 2019).

One of the challenging topics for students to understand is the concept of oxidation-reduction (redox) reactions found in the second semester of class X, this redox material combines both concrete characteristics and abstract concepts, requiring symbolic memorization, understanding, and application, as well as everyday events (Pratiwi et al., 2014).

Solutions that can be used to build scientific attitudes in students' critical thinking skills by using an appropriate learning model and teaching materials (Simatupang et al., 2020). One such learning model that can enhance students' thinking skills and improve the learning process is the Science, Technology, Engineering, and Mathematics (STEM) learning model.

STEM is a learning model designed to instruct students in four key disciplines: science, technology, engineering, and mathematics, with a focus on real life application (Suriti, 2021). One of the teaching materials that can be used for learning to support the 2013 curriculum is the Student Worksheet (LKPD) (Pertiwi et al., 2021). The use of LKPD should be integrated into learning activities to promote student independence and facilitate the development of critical thinking skills (Lestari et al., 2018).

STEM learning equips students with essential skills for the 21st century, including critical thinking, creative thinking, collaboration, communication, and independent learning skills (Trnova & Trna, 2015). In line with Herwanti's research (2021), STEM-based learning can improve students' critical thinking, creative skills, and cognitive abilities on electrochemical cell materials.

With the context of these developments, the primary objective of this study is to investigate the influence of the Science, Technology, Engineering, and Mathematics (STEM) learning model in improving students' critical thinking skills on redox material in class X Science 4 MAN 1 Cirebon City.

Method

This study used an experimental method with Nonequivalent Control Group Design. This research was conducted at MAN 1 Cirebon City. Sampling was carried out through Purposive sampling, which has been discussed in advance with the chemistry teacher based on the highest learning outcomes. This consisted of class X Science 5, comprising 36 students as an experimental class using the Science, Technology, Engineering, and Mathematics (STEM) model and lowest learning outcomes in class X Science 4, which also had 36 students as a control class using the Discovery Learning model.

The research instruments used consisted of three instruments: critical thinking tests, observations, and questionnaires. The test instrument measured the improvement of students' critical thinking skills consisting of 10 essay questions. The test data obtained were statistically tested using prerequisite tests, hypothesis tests (t-tests) and N-gain tests. The observation sheet instrument determined the improvement of students' critical thinking skills after learning. The observational data obtained were categorized as predetermined. The questionnaire sheet was used to determine students' responses to the implemented learning, and Likert scale calculations were employed for this purpose

Result and Discussion

The improvement in students' critical thinking skills can be observed through the results of pretests and posttests, consisting of critical thinking skills test questions that have been verified as valid and reliable. The Pretest and Postest data of the Experimental and Control Classes are presented in Table 1.

Table 1

Pretest and Posttest Results Data Experimental Class and Control Class

	Experimental Class		Control Class	
	Pretest	Posttest	Pretest	Posttest
Minimum value	10	68	5	40
Maximum value	45	90	38	88
Average	24.5	78.50	20.81	68.50

Based on Table 1, the experimental class achieved a higher posttest score of 90 compare tothe control class, which score of 68, resulting in an average score of 78.50. This indicates that STEM learning is more effective in improving Shiva's critical thinking skills. In line with this, Wisudawati (2018) states that students' critical thinking skills can improve after learning with a STEM approach, which can be seen from the increased average pretest and posttest. The pretest and posttest scores obtained from both classes follow a normal distribution and exhibit homogeneity, with obtained sig scores. > 0.05.

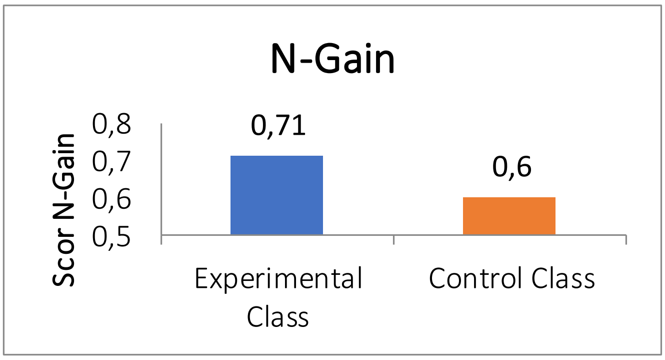
Table 2

Hypothesis Testing (T-Test)

	F	Sig.	T	Df	Sig. (2-tailed)
Equal variances assumed	18,43	0,00	-4,35	0	0,00
Equal variances not assumed			-4,35	52,84	0,00

The T-test was conducted to determine whether the implemented STEM learning model can impact students' critical thinking skills. Based on the t-test results for both classes, Sig. (2-tailed) values of 0.000 were obtained, which is less than 0.05. This indicates a significant influence on students' critical thinking skills in both classes after applying the STEM and Discovery Learning models. Consistent with the research conducted by Sutoyo et al (2019), the t-test result yielded a sig value of 0.000, which is less than 0.05, due to the increase in pretest and post-test results. This demonstrates significant differences in students' critical thinking skills before and after applying the STEM integrated guided inquiry model in chemistry learning.

Figure 1
N-Gain Test Results in Experimental Class and Control Class



The N-Gain test is obtained by calculating the difference between the pretest and posttest scores of students to determine the improvement in their critical thinking skills after learning in experimental and control classes. Based on the results of the N-gain test in the experimental class, a score of 0.71 was obtained in the high category, while the N-gain result in the control class was 0.60, categorized as medium category. This leads to the conclusion that learning using the STEM model can improve students' critical thinking skills to a greater extent than in the control class. Consistent with the research conducted by Ariyatun & Octavianelis (2020), it was found that STEM Integrated Problem Learning can improve students' critical thinking skills, as evidenced by the higher N-gain score in the experimental class compared to the control class, which felt into medium category. This difference may be attributed to the significantly higher average difference between the pretest and posttest in the experimental class compared to the control class.

The second observation aimed to assess the improvement in each of the five critical thinking indicators. Critical thinking skills have five important indicators that can be developed during the learning process (Ennis, 1990). The results of the critical thinking indicator analysis are presented in Tables 4 to 9.

Table 3
Giving a Simple Explanation

	Experimental Class		**Control Class**	
	Pretest	**Posttest**	**Pretest**	**Posttest**
Percentage	27%	79%	26%	67%
Criterion	Weak	Good	Weak	Good

The indicators require students to provide simple explanations, which involve formulating or analyzing problems related to real-life scenario such as acid rain or iron rusting, which are associated with redox reactions. Based on Table 3, analysts experienced an increase in their result after the learning process. In the experimental class, higher results were obtained than in the control class, with a percentage of 79% falling into the good category. According to research by Arini et al. (2021), critical thinking skills can increase when dealing with indicators that necessitate providing simple explanations. This is because students can focus on formulating questions, analyzing arguments, and responding to questions related to colloidal systems.

Table 4
Basic Skill Building Indicators

	Experimental Class		Control Class	
	Pretest	**Posttest**	**Pretest**	**Posttest**
Percentage	26%	78%	26%	70%
Criterion	Weak	Good	Weak	Good

The indicators for developing essential skills require students to observe, consider, and determine the results of decisions found according to facts related to the problem of photosynthesis, thusproving its reduction and oxidation reactions. Based on Table 4, the results of analysts showed improvement after the learning. In the experimental class, higher results were obtained than in the control class, with a percentage of 78% falling into the good category. The results of this research are in line with Khoirunnisa (2020), who states that students' critical thinking skills improve as they are able to assess the accuracy of data through precise procedures, substantiating their understanding of chemical bond material.

Table 5
Concluding

	Experimental Class		Control Class	
	Pretest	**Posttest**	**Pretest**	**Posttest**
Percentage	17%	76%	10%	68%
Criterion	Very weak	Good	Very weak	Good

The concluding indicator requires students to conclude according to experimental data by providing oxidation number calculations to be evidence of the conclusions. Based on Table 5, the results of analysts who have improved after learning are carried out. In the experimental class, higher results were obtained than in the control class, with a percentage of 76% in the good category. These findings are in line with Fujika et al. (2015), which suggests that students' critical thinking skills improve as they are able to infer information and make informed based on critical thinking when considering the information, they have.

Table 6
Giving Further Clarification

	Experimental Class		Control Class	
	Pretest	**Posttest**	**Pretest**	**Posttest**
Percentage	33%	81%	16%	69%
Criterion	Weak	Very good	Very weak	Good

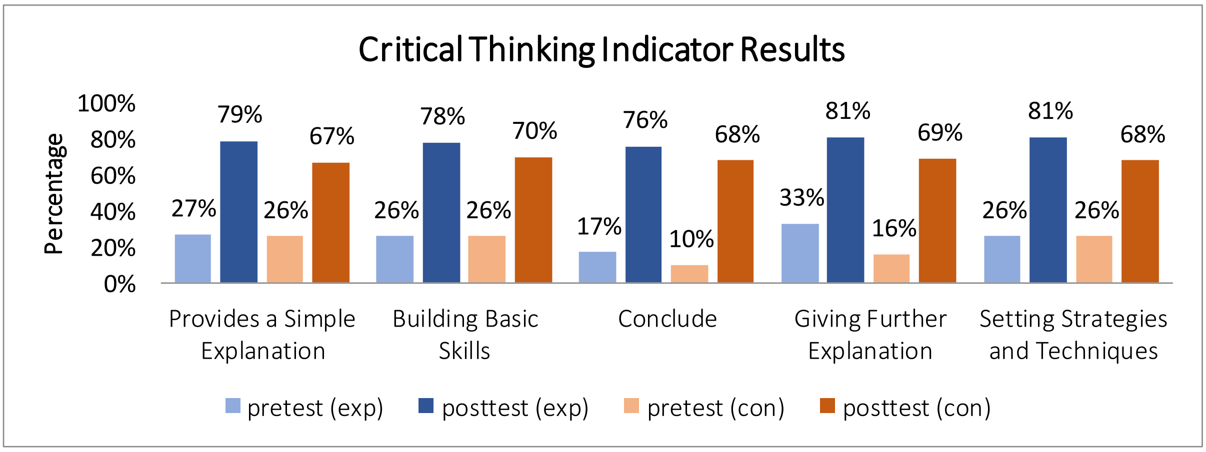
The indicators require further explanation, as students need to test data related to chlorine elements by analyzing and determining factors that are not disproportioned (autoredox). Based on Table 6, analysts showed improvement after the learning process. In the experimental class, higher results were obtained than in the control class, with a percentage of 81% in the very good category. Based on the analysis of Pusparini et al. (2018), this indicator can train students to answer questions correctly to better understand a word's definition.

Table 7
Setting Strategies and Techniques

	Experimental Class		Control Class	
	Pretest	**Posttest**	**Pretest**	**Posttest**
Percentage	26%	81%	26%	68%
Criterion	Weak	Very good	Weak	Good

The indicators set strategies and techniques that require students to find solutions to given problems by logically analyzing redox reactions related to the industrial field. Based on Table 7, analysts demonstrated improvement after the learning process. In the experimental class, higher results were obtained than in the control class, with a percentage of 81% in the very good category. According to Wijayanti & Siswanto (2020) in indicators of managing strategies and techniques, students can practice critical thinking skills with the best action from a problem that exists in the material with rational reasons. In this indicator, there is a STEM step, which is constructing explanations and designing solutions. Critical thinking skills are trained when students can explain problems on redox material in front of the class and provide solutions to these problems.

Figure 2
Results of Calculation of Critical Thinking Indicators in the Experimental Class and Control Class



Based on the results of the analysis, critical thinking skills improved in each indicator after learning. In the control class, the highest critical thinking indicator was found in the basic skill-building indicator, and the lowest indicator was found in providing a simple explanation. In the experimental class, critical thinking indicators reached a very good category on indicators, including providing further explanations and arranging strategies and techniques. in these indicators, students were more active in testing observational data and providing solutions related to problems given about redox material.

The increase in critical thinking indicators in the experimental class and the control class experienced significant differences. The data can be caused due to different learning processes. In experimental classes, STEM learning can make students active because students become the center of learning so that they can find answers to the questions or material taught. in line with Khoiriyah *et al* (2018) hat the learning process carried out is more effective and makes students active in cultivating students' critical thinking skills when compared to the usual learning done by teachers.

In contrast, in the control class, students were less active in the learning process because students find it difficult to solve a problem given by the teacher in the form of pictures. Based on research Rusminiati *et al* (2015) said that Discovery Learning learning makes students think in a limited way because they are only fixated on the problems given by the teacher so that students' critical thinking skills are still lacking, in contrast to students who get problems in a project carried out, students can have the opportunity to think more broadly.

Questionnaires were used to obtain data or descriptions related to students` responses to learning. Likert scale was used to calculate the results of students' responses or opinions on learning that has been done. Based on the results of the Likert scale, student responses in the experimental class reached 87.44%, categorized as very good, in response to the STEM learning model. Meanwhile, the control class received a percentage of 73.36%, categorized as good in response to the Discovery Learning learning model. These response results are in line with Sutoyo *et al* (2019) who reported that students responded positively to integrated STEM learning, with 86.2% showing high satisfaction. This increased motivation led to higher score in critical thinking skills, especially in thermochemical material.

Conclusion

Based on the research results and data analysis, it can be concluded that the Science, Technology, Engineering and Mathematics (STEM) model can improve the thinking skills of grade X Science 5 students at MAN 1 Cirebon City.

References

Arini, N. R., Sabang, S. M., & Diah, A. W. M. 2021. Implementation of Guided Inquiry Learning Model on Colloid Systems to Improve Critical Thinking Ability of Students. *Jurnal Akademika Kimia*, *10*(2), 87–92.

Ariyatun, A., & Octavianelis, D. F. 2020. Pengaruh Model Problem Based Learning Terintegrasi Stem Terhadap Kemampuan Berpikir Kritis Siswa. *JEC: Journal of Educational Chemistry*, *2*(1), 33.

Ennis R H. 1991. *A taxonomy of critical thinking dispositions and abilities In J B Baron & R. J. Sternberg Eds Series of books in psychology Teaching thinking skills*: *Theory and Practice*. New York: Freeman.

Fujika, A., Anggereini, E., & Budiarti, R. S. 2015. Analisis Kemampuan Berpikir Kritis Siswa SMA N 5 Kota Jambi Melalui Pembelajaran Berbasis Masalah Pada Konsep Pencemaran Lingkungan. *BIODIK*, 1(1), 33-47.

Gazali, F., Yusmaita, E., & Ningsih, N. R. 2019. Pengembangan Modul Kimia Berbasis REACT untuk Meningkatkan Keterampilan Staf Pengajar Jurusan Kimia, FMIPA Universitas Negeri Padang. *Jurnal Eksakta Pendidikan (JEP)*, *3*(2), 142–151.

Hamidah, Leny, & Hamid, A. 2021. Analisis Berpikir Kritis dan Hasil Belajar pada Model Project Based Learning dengan Pendekatan Science, Technology, Engineering And Mathematics (STEM) Materi Sel Volta. *JCAE (Journal of Chemistry And Education)*, *4*(3), 101–107.

Khoiriyah, N., Abdurrahman, A., & Wahyudi, I. 2018. Implementasi Pendekatan Pembelajaran STEM untuk Meningkatkan Kemampuan Berpikir Kritis Siswa SMA pada Materi Gelombang Bunyi. *Jurnal Riset Dan Kajian Pendidikan Fisika*, *5*(2), 53-62.

Khoirunnisa, F., & Sabekti, A. W. 2020. Profil Keterampilan Berpikir Kritis Siswa Pada Materi Ikatan Kimia. *Jurnal Pendidikan Kimia Indoensia*, *4*(1), 26–31.

Lestari, D. A. B., Astuti, B., & Darsono, T. 2018. Implementasi LKS Dengan Pendekatan STEM (Science, Technology, Engineering, And Mathematics) Untuk Meningkatkan Kemampuan Berpikir Kritis Siswa. *Jurnal Pendidikan Fisika Dan Teknologi*, *4*(2), 202–207.

OECD. 2009. Learning Mathematics for Life: A View Perspective from PISA. Diakses tanggal 29 November 2018 dari www.oecd.org

Pertiwi, W. J., Solfarina, & Langitasari, I. 2021. Pengembangan Lembar Kerja Peserta Didik (LKPD) Berbasis Etnosains pada Konsep Larutan Elektrolit dan Nonelektrolit. *Jurnal Inovasi Pendidikan Kimia*, *15*(1), 2717–2730.

Pratiwi, Y., Redjeki, T., & Masykuri, M. 2014. Pelaksanaan Model Pembelajaran Problem Based Learning (PBL) Pada Materi Redoks Kelas X SMA Negeri 5 Surakarta Tahun Pelajaran 2013/2014. *Jurnal Pendidikan Kimia Universitas Sebelas Maret*, *3*(3), 40–48.

Pusparini, S. T., Feronika, T., & Bahriah, E. S. 2018. Pengaruh Model Pembelajaran Problem Based Learning (PBL) Terhadap Kemampuan Berpikir Kritis Siswa pada Materi Sistem Koloid. *JRPK: Jurnal Riset Pendidikan Kimia*, *8*(1), 35–42.

Rusminiati, N. N., Karyasa, I. W., & Suardana, I. N. 2015. Dibelajarkan dengan Model Pembelajaran Project Based Learning dan Discovery Learning. *E- Journal Program Pascasarjana Universitas Pendidikan Ganesha Program Studi Pendidikan IPA*, *5*, 1–11.

Simatupang, H., Sianturi, A., & Alwardah, N. 2020. Pengembangan Lkpd Berbasis Pendekatan Science, Technology, Engineering, and Mathematics (STEM) Untuk Menumbuhkan Keterampilanberpikir Kritis Siswa. *Jurnal Pelita Pendidikan*, *7*(4), 170–177.

Suriti, K. M. 2021. Penerapan Model Pembelajaran Berbasis STEM dalam Upaya Meningkatkan Hasil Belajar Kimia Siswa Kelas XI MIPA 4 SMA NEGERI 7 Denpasar Tahun Pelajaran 2019/2020. *Widyadari*, *22*(1), 382–394.

Sutoyo, S., Azizah, U., & Allamin, S. 2019. Effectiveness of the Guided Inquiry Model Integrated with STEM to Improve the Student Critical Thinking Skills in Chemistry Learning. *International Journal of Innovative Science and Research Technology*, *4*(12), 349–353.

Trnova, E., & Trna, J. 2015. Motivational Effectiveness of a Scenario in IBSE. *Procedia-Social and Behavioral Sciences*, *167*, 184–189.

Wijayanti, R., & Siswanto, J. 2020. Profil Kemampuan Berpikir Kritis Siswa SMA pada Materi Sumber-sumber Energi. *Jurnal Penelitian Pembelajaran Fisika*, *11*(1), 109–113.

Wisudawati, A. W. 2018. Science Technology Engineering and Mathematics (STEM) Education Approach against a Microscopic Representation Skill in Atom and Molecule Concept. *International Journal of Chemistry Education Research*, 2(1), 1–5.