Jupiter: Jurnal Pendidikan Terapan
Homepage : https://journal.diginus.id/jupiter/index
Email: jurnalpendidikanterapan@gmail.com

p-ISSN : 2985-3214; e-ISSN : 2964-3171
Jupiter, Vol. 4, No. 5, November 2026
Page 488-494

Enhancing University Students' Critical Thinking Skills through STEM-Based Macromolecule E-Module

Irfandi[1*], Kiprah Piawi[2], Nofri Yuhelman[3]
[1,2]Universitas Islam Kuantan Singingi, Teluk Kuantan, Riau, Indonesia
[3]Universitas Negeri Padang, Padang, Sumatera Barat, Indonesia

ARTICLE INFO

Article history:
Submitted: September 17, 2026
Final Revised: October 06, 2026
Accepted: October 16, 2026
Published: November 21, 2026

Keywords:
Chemistry; Critical Thinking; Electronic; Module; Organic

ABSTRACT

Technology-assisted learning enables teachers and students to explore the material flexibly and efficiently. One such technological application in education is the use of e-modules. To optimize the effectiveness of e-module material delivery, it is essential to integrate it with a STEM-based pedagogical approach. Through STEM integration, students are able to find a solution to a problem. The present study aims to examine the enhancement of university students' critical thinking skills in the macromolecules through STEM-based e-modules. The sample in this study consists of fourth-semester students of Universitas Islam Kuantan Singingi enrolled in the Organic Chemistry II course selected using purposive sampling. The research method is Quasi Experiment designing Lesson Study in two cycles. The stages of Lesson Study are plan, do, and see. At the end of each cycle, the learning evaluation was conducted using test instruments aligned with critical thinking skills. The STEM-based e-module is considered effective if the evaluation results meet the effectiveness indicators, specifically when the n-gain value criterion is achieved. Findings reveal that there is an improvement in students' critical thinking skills from 0.23 with a low category in cycle 1 to 0.464 with a moderate category in cycle 2. Thus, the STEM-based macromolecule e-module increases students' critical thinking skills. Through e-modules, students can study independently and build their knowledge effectively.

Doi: https://doi.org/10.61255/jupiter.v4i5.2121

INTRODUCTION

Integrating technology into learning is a 21st century challenge in Indonesia (Febrianti et al., 2023). The role of technology in learning can enhance students' interaction with instructional content, creating more engaging and in-depth learning experiences. The technological utilization is also able to improve the quality of education (Salsabila & Agustian, 2024), making learning more relevant to students' needs and more dynamic. Technology-based learning further enables teachers and learners to access diverse educational resources flexibly and efficiently (Azzahra & Suherlin, 2022). Moreover, technology plays a significant role in clarifying abstract concepts and providing experiential learning opportunities through technology-based applications (Adawiyah et al., 2021). Several abstract materials that can be facilitated through technology can include chemistry learning materials.

Chemistry encompasses abstract concepts and involves three levels of chemical representation, commonly referred to as the chemistry triangle or multiple representations (K. V Sari & Ulianas, 2021). This often leads to a lack of interest and motivation among students, and those who may feel compelled to rely on others or their teachers in the learning process (Sukmawati, 2019). The difficulties encountered by students in studying chemistry include challenges in understanding concepts, completing tasks of numerical calculations, and operating laboratory equipment. These obstacles contribute to students' fear and perception that chemistry is difficult to comprehend, resulting in passive participation during learning activities.

Based on findings from several schools and higher education institutions, including Universitas Islam Kuantan Singingi, the main problem of chemistry learning is the availability of quality learning resources. High-quality and innovative learning resources can produce high-quality learning outcomes (Sariati et al., 1858). Macromolecules is one of the chemistry topics that students tend not to be interested in. Macromolecule is a topic that a number of students perceive as relatively easy due to its theoretical nature; however, in reality, it requires in-depth analytical skills to understand properly (Irfandi et al., 2023). Hence, the solution is to provide learning resources through e-modules.

According to Laili et al., 2019) e-modules serve as learning resources that can assess students' skills and the intensity of their independent study. An e-module not only contains learning material but also incorporates methods and evaluation tasks designed to foster students' interest in learning. Learning through modules requires

students to be active in the learning process, engaging in various activities that encourage active participation (W. P. Sari & Montessori, 2021). E-modules as learning resources contribute not merely to students' learning motivation (Putri & Purmadi, 2020), but also addresses learning challenges such as learning outcomes and student misconceptions (Irfandi et al., 2022). In chemistry education, e-modules have proven effective in reducing student fatigue during class. The success is also seen in students' problem-solving skills (Mahendra et al., 2023). The effectiveness of e-modules in learning is further enhanced when the material is contextualized to students' daily lives and oriented toward project-based learning. One essential step in creating engaging learning materials is integrating STEM.

The STEM approach is an educational method designed to train learners in solving problems related to the teaching and learning process involving students (Santosa et al., 2021). By this approach, students become more motivated and actively participate in learning activities, enhancing their understanding of science and engaging in classroom discussions. students become more motivated and actively engaged, with enhancements in science content and participation during discussions (Karahan et al., 2015). The use of STEM-based e-modules has been shown to enhance students' creative thinking from Cycle I to Cycle II at 18% on statistics materials (Ferdiani & Pranyata, 2022). In addition, STEM-based e-modules are able to increase students' learning outcomes and characters (Agung et al., 2021). STEM is a learning method that enables students to deepen their understanding and enhance their skills (Fatma, 2021). One essential skill that can be strengthened through STEM-integrated learning material is critical thinking.

Critical thinking skill is an crucial element of individual growth in today's information and knowledge age. Analytical ability is a mental process for gaining understanding and knowledge, as well as the capacity to find solutions and formulate conclusions (Umam, 2018). It can guide individuals to generate new ideas or perspectives as solutions to problems. Through this process, individuals are trained to articulate opinions or ideas in a rational and relevant manner (Irwan et al., 2019). The purpose of critical thinking skills is to examine an opinion or idea, which includes making judgements or considerations based on the proposed argument (Irwan et al., 2019). As stated by Ennis (2011), Classifying indicators of critical thinking activity into the following five main categories which, in practice, may be integrated into a single activity or treated as separate indicators: providing clear explanations, developing basic skills, drawing conclusions, offering further explanations, and formulating strategies and techniques. Previous relevant studies have examined the effectiveness of using STEM-based e-modules on critical thinking skills, but have not specifically focused on the topic of macromolecules at the university level. Thus, implementing e-modules is crucial to enhancing students' critical thinking skills on macromolecule material. Through critical thinking skills, students are expected to easily resolve problems encountered during the learning process.

METHOD

The research method used in the present study is Quasi Experiment designing Lesson Study in the Organic Chemistry II course. The research scheme with each cycle can be illustrated in Figure 1.

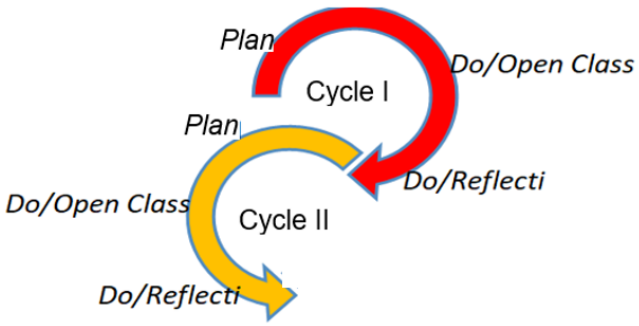

Figure 1. Research Scheme of Lesson Study (Huang et al., 2019)

Stages conducted in this research are Plan, Do, and See (2 cycles). The STEM-based Plan stage covers problem identification, review of prior learning experience, syllabus preparation, and pretest. The Do stage consists of the implementation and observation of the learning process. The See stage involves reviewing, evaluating, or reflecting on the learning process that has taken place.

The population involved all active students in the Chemistry Education Study Program at Universitas Islam Kuantan Singingi. The sample consisted of fourth-semester students currently studying macromolecular learning material in the Organic Chemistry II selected using purposive sampling. Data collection technique was carried out in a post-test in the form of essay questions designed to assess students' critical thinking skills after learning with

STEM-based e-modules. The critical thinking indicators that were adopted from Ennis (2011) can be described as follows:

Table 1. Indicators of Critical Thinking Skills

Stages	Indicators of Critical Thinking Skills	Descriptions
1	Elementary Clarification	1. Focusing questions
		2. Analyzing arguments
2	Basic Support	3. Considering the quality of learning resources
		4. Considering observation results
3	Inference	5. Making inferences
		6. Analyzing inference result
4	Advanced Clarification	7. Making a term definition
		8. Identifying assumption
5	Strategies and Tactics	9. Determining further steps
		10. Collaborating with others

A STEM-based e-module is effective if it meets the effectiveness and n-gain score. The higher N-Gain score achieved by students is the result of the essay questions on critical thinking aspects. To determine whether the increase in score falls into the high, medium, or low, a normalized N-Gain score or (<g>) is calculated. To calculate (<g>), a formula adopted from Hake (1999) can be presented as follows:

$$< g >= \frac{\text{Posttest} - \text{pretest}}{\text{Max Score} - \text{pretest}}$$

To indicate whether gain scores are high or low, the normalized gain scores are categorized as set out in Table 2 as follows.

Table 2. Interpretation of Normalized Gain score (<g>) (Widoyoko, 2012)

Nu.	<g>	Criteria
1	(<g>) > 0.7	High
2	0.3 ≤ (<g>) < 0.7	Medium
3	(<g>) < 0.3	Low

RESULTS

a. Plan in Cycle 1

The implementation stage began with the plan. In this preparatory stage, administrative arrangements related to the research were conducted. Activities in the plan phase include discussions regarding the learning tools commonly used by lecturers in teaching, preparing teaching and learning materials and mastery of content and establishing deeper connections between the material and real-world contexts. During this planning stage, a pre-test is also administered to assess students' initial understanding of the topic of macromolecules.

b. Do in Cycle 1

The subsequent stage is 'Do' to conduct the teaching and learning activities using STEM-based e-modules. This implementation stage was conducted to observe improvements in students' critical thinking skills after engaging with the STEM-based e-modules. The learning process using STEM-based e-modules guides students to actively participate in learning through a structured sequence of stages.

c. See in Cycle 1

After completing Cycle 1, a reflection was conducted to obtain suggestions and improvements. The recommendations from Cycle 1 include:

1) The problem-formulation stage requires greater organization by the lecturer so that students can more easily understand the issues presented.
2) Supporting facilities need to be prepared thoroughly and adequately, as lecturer involvement remains relatively dominant.
3) Students demonstrated limited participation in discussions during the exploration analysis stages.
4) The synthesis and implementation stages require more time to be carried out effectively.

d. Plan in Cycle 2

Activity conducted in the Plan stage of Cycle 2 focuses on improving the implementation of the STEM-based e-modules based on the results of previous reflection. Improvements include a more dominant role for lecturers in the learning process specifically by providing greater guidance to facilitate student discussion and communication

as well as preparing learning support resources before the session begins. During the planning stage of Cycle 2, a pre-test was also administered to assess the students' initial understanding of the macromolecule material for that cycle.

e. Do in Cycle 2

The "Do" phase in Cycle 2 was more effective than in Cycle 1 because the lecturer did not dominate the instruction, allowing students to engage in productive discussions. Students were able to work through the module by following the stages of the STEM approach. This process effectively fostered students' skills in communication, collaboration, and critical thinking. The execution of the 'Do' phase is illustrated in Figure 2.



Figure 2. Implementation of Do in Cycle 1

f. See in Cycle 2

After implementing Cycle 2, the reflection result reveals that the using STEM-based e-modules on macromolecular content was successfully applied and could be extended to another chemistry content. Each cycle of the lesson study began with a pre-test and concluded with a post-test to measure improvements in students' critical thinking skills. The pre-test and post-test results of using STEM-based e-modules on macromolecular content reveal differences between Cycle 1 and Cycle 2. Final analysis of the post-test data on students' critical thinking skills in each cycle indicates differences, with the average score in Cycle 2 being higher than that in Cycle 1. The mean pre-test and post-test scores for each cycle are presented in Table 3.

Table 3. Normalized N-Gain Score (<g>)

Cycle	N-Gain Score Mean	Criteria
1	0.23	Low
2	0.464	Medium

The finding is relevant to Karnia et al. (2022), who conducted an innovation of STEM-integrated Chemistry learning development with a validity level of 94%. Maximizing the use of STEM in conjunction with technology-enhanced learning can improve the quality of instruction (Erna et al., 2021). Research findings indicate that science learning tools, including e-modules, enable students to engage in active learning and enhance higher-order thinking skills (HOTS), such as critical thinking abilities (Uswatun & Rohaeti, 2015). These are also consistent with (Ahdhianto et al., 2024), who demonstrated that the use of e-modules is effective in enhancing students' critical thinking skills.

DISCUSSION

Findings reveal that STEM-based e-modules were effective in enhancing students' critical thinking skills. This is consistent with (Setiadi & Kurniawan, 2018), who emphasize that educators today must bring innovation and creativity into learning activities to align with the characteristics and needs of the current generation of learners. By utilizing e-modules, educators can encourage students to participate actively in the learning process, comprehend the material, and provide innovative learning experiences. The e-modules developed were equipped with clear usage instructions. Modules designed with well-structured explanations can obtain practical evaluations (Basaroh et al., 2020). As teaching materials, the modules were designed systematically and coherently, with an understandable language. This aims to make students grasp the content according to their knowledge level and age, enabling them to learn independently without requiring teacher assistance.

In addition, the improvement in students' critical thinking skills was influenced by the integration of the STEM approach within the e-module. It is relevant to (Tseng et al., 2013), who stated that integrating STEM into learning can have a positive impact on critical thinking skills. Similarly, (Gandi et al., 2021) reported that STEM-based learning integration can enhance students' critical thinking skills.

CONCLUSION

The STEM-based macromolecule e-module proved effective in enhancing students' critical thinking skills. The findings revealed an increase in critical thinking from Cycle 1 (0.23, low category) to Cycle 2 (0.464, medium category). These results underscore the importance of employing technology-based teaching materials in contemporary learning, given the rapid pace of technological development. Through e-modules, students are able to learn independently and construct knowledge effectively. Integrating STEM into e-modules also has a positive impact on the development of critical thinking skills, as STEM enables students to engage in higher-order thinking by combining science, technology, engineering, and mathematics.

REFERENCE

Adawiyah, R., Robbia, A. Z., Jariah, A., Syukur, A., & Jamaluddin, J. (2021). Innovation in Chemistry Learning Videos as a Solution for Learning Media during the Covid-19 Pandemic at MAN 2 Bima. *Jurnal Ilmiah Profesi Pendidikan*, *6*(2), 175–181. https://doi.org/10.29303/jipp.v6i2.185

Agung, I. D. G., Suardana, I. N., & Rapi, N. K. (2021). STEM-PjBL-Based Science E-Module Oriented toward Character Education to Improve Students' Learning Outcomes. *JURNAL IMIAH PENDIDIKAN DAN PEMBELAJARAN*, *6*(1), 120–133. http://dx.doi.org/10.23887/jipp.v6i1

Ahdhianto, E., Masula, S., Thohir, M. A., & Khotimah, K. (2024). Development of PBL-based e-modules to improve problem-solving and critical thinking skills of elementary school students. *Jurnal Math Educator Nusantara*, *10*(1), 167–178. http://ojs.unpkediri.ac.id/index.php/matematika

Azzahra, F., & Suherlin, A. (2022). Utilization of 3D Digital Media in Chemical Bonding Material Viewed through the Levels of Chemical Representation and Visuospatial Intelligence. *Prosiding Seminar Nasional Pendidikan Kimia*, *1*(1), 96–102. https://proceedings.radenfatah.ac.id/index.php/snpk/article/view/58

Basaroh, A. S., Muhdhar, M. H. I. Al, Prasetyo, T. I., Sumberartha, I. W., Mardiyanti, L., & Fanani, Z. (2020). Development of an E-Module Based on the Experiential Nature Exploration (EJAS) Model for the Plantae Topic. *Jurnal Pendidikan Biologi*, *12*(1), 30–39. https://doi.org/10.17977/um052v12i1p30-39.

Ennis, R. . (2011). *The Nature of Critical Thinking: An Outline of Critical Thinking Dispositions and Abilities.* University of Illinois Last Revised.

Erna, M., Ellfizar, E., & Dewi, C. A. (2021). The Development of E-Worksheet Using Kvisoft Flipbook Maker Software Based on Lesson Study to Improve Teacher ' s Critical Thinking Ability. *International Journal of Interactive Mobile Technologies (IJIM)*, *15*(1), 39–55. https://doi.org/10.3991/ijim.v15i01.15679

Fatma, H. (2021). Students' Creativity in Biotechnology Learning Using STEAM-Based PjBL. *Pedagonal : Jurnal Ilmiah Pendidikan*, *5*(1), 7–14. https://doi.org/10.33751/pedagonal.v5i1.2574

Febrianti, I., Tuffahati, J., Rifai, A., Affandi, R. H., Pradita, S., Akmalia, R., & Siahaan, A. (2023). The Effect of Information Technology in Educational Planning Management to Enhance Educational Efficiency. *AoEJ: Academy of Education Journal*, *14*(2), 506–522. https://doi.org/10.47200/aoej.v14i2.1763

Ferdiani, R. D., & Pranyata, Y. I. P. (2022). STEM-PjBL-Based E-Module to Enhance Creative Thinking Skill during Covid-19 Pandemic. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *11*(3), 1875–1885. https://doi.org/10.24127/ajpm.v11i3.5141

Gandi, A. S. K., Haryani, S., & Setiawan, D. (2021). The Effect of Project-Based Learning Integrated STEM Toward Critical Thinking Skill. *Journal of Primary Education*, *10*(1), 18–23. https://journal.unnes.ac.id/sju/index.php/jpe/article/view/3382%0A5/14147

Hake, R. R. (1999). *Analyzing Change/Gain Scores*. Dept of Physics Indiana University.

Huang, R., A, T., & Ponte, J. P. da. (2019). *Theory and practices of lesson study in mathematics: An international perspective*. Springer. https://doi.org/10.1007/978-3-030-04031-4

Irfandi, I., Murwindra, R., Musdani, D., Apriwanda, W., & Hanri, C. (2022). Identification and analysis of student's misconceptions using three-tier multiple choice diagnostic instruments on thermochemistry topic. *International Journal of Education and Curriculum Application*, *5*(3), 306–316. https://doi.org/10.31764/ijeca.v5i3.11613

Irfandi, I., Musdansi, D. P., Murwindra, R., Chandra, M. F., & Rini, R. (2023). A Needs Analysis for the Development of STEM-Based Electronic Student Worksheets on Macromolecules. *EDUCATIONAL INSIGHTS*, *1*(2), 69–74. https://doi.org/10.58557/eduinsights.vxix

Irwan, I., Maridi, M., & Dwiastuti, S. (2019). Developing guided inquiry-based ecosystem module to improve students' critical thinking skills. *Jurnal Pendidikan Biologi Indonesia*, *5*(1), 51–60. https://doi.org/DOI: 10.22219/jpbi.v5i1.7287

Karahan, E., Bilici, S. C., & Ünal, A. (2015). Integration of Media Design Processes in Science, Technology, Engineering, and Mathematics (STEM) Education. *Eurasian Journal of Educational Research*, *15*((60)), 221–240. https://doi.org/10.14689/ejer.2015.60.15

Laili, I., Ganefri, G., & Usmeldi, U. (2019). Effectiveness of Developing a Project-Based Learning E-Module in

the Electrical Motor Installation Subject. *Jurnal Ilmiah Pendidikan dan Pembelajaran*, *3*(3), 306–315. https://doi.org/10.23887/jipp.v3i3.21840

Mahendra, M. R., Enawaty, E., Junanto, T., Muharini, R., & Lestari, I. (2023). Effectiveness of Using a Problem-Based Learning Chemistry E-Module to enhance Students' Problem Skills in Thermochemistry. *Journal of The Indonesian Society of Integrated Chemistry*, *15*(2), 120–127. https://doi.org/10.22437/jisic.v15i2.27826

Putri, M. A., & Purmadi, A. (2020). The Effect of Sigil-Based E-Module Learning Media on Students' Learning Motivation in the Graphic Design Subject. *Jurnal Teknologi Pendidikan: Jurnal Penelitian Dan Pengembangan Pembelajaran*, *5*(2), 174–180. https://doi.org/10.33394/JTP.V5I2.3073

Salsabila, U. H., & Agustian, N. (2024). The Role of Educational Technology in Learning. *SENTRI: Jurnal Riset Ilmiah*, *3*(7), 3257–3262. https://doi.org/10.55681/sentri.v3i7.3115

Santosa, T. A., Razak, A., Lufri, Zulyusri, Fradila, E., & Arsih, F. (2021). Meta-analysis: The effect of STEM-based teaching materials on ecology learning. *Journal of Digital Learning and Education*, *1*(1), 1–9. https://doi.org/10.52562/jdle.v1i01.24

Sari, K. V, & Ulianas, A. (2021). A Literature Review on the Use of Chemistry Triangle-Oriented Teaching Materials in Chemistry Topics and Their Impact on Student Learning Outcomes. *Journal of Multidicsiplinary Research and Development*, *3*(2), 13–19. https://doi.org/10.38035/rrj.v3i2.365

Sari, W. P., & Montessori, M. (2021). Enhancing Elementary Students' Creative Thinking Skills through Thematic Learning Modules. *Jurnal Basicedu*, *5*(6), 5275–5279. https://doi.org/10.31004/basicedu.v5i6.1527

Sariati, N. K., Suardana, I. N., & Wiratini, N. M. (1858). Analysis of Grade XI Students' Learning Difficulties in Chemistry Regarding Buffer Solutions. *Jurnal Ilmiah Pendidikan Dan Pembelajaran*, *4*(April 2020), 86–97. https://doi.org/10.23887/jipp.v4i1.15469

Setiadi, H. W., & Kurniawan, J. (2018). Development of Interactive Learning Media Based on Macromedia Authorware 7.0 to Facilitate English Concept Comprehension and Learning Interest. *Elementary School: Jurnal Pendidikan Dan Pembelajaran Ke-SD-An*, *5*(1), 88–94. https://doi.org/10.31316/esjurnal.v5i1.602

Sukmawati, W. (2019). Analysis of Students' Macroscopic, Microscopic, and Symbolic Levels in Understanding Electrochemistry. *Jurnal Inovasi Pendidikan IPA*, *5*(2), 195–204. https://doi.org/10.21831/jipi.v5i2.27517

Tseng, K., Chang, C., Lou, S., & Chen, W. (2013). Attitudes towards science, technology, engineering and mathematics (STEM) in a project-based learning (PjBL) environment. *International Journal of Technology and Design Education*, *23*(87), 87–102. https://doi.org/10.1007/s10798-011-9160-x

Umam, K. (2018). Improving Students' Mathematical Critical Thinking Skills Through Reciprocal Teaching. *Jurnal Pendidikan Matematika Indonesia*, *2*(2), 57–61. http://dx.doi.org/10.26737/jpmi.v3i2.807

Uswatun, D. A., & Rohaeti, E. (2015). Inquiry-Based Science Learning Materials to Enhance Students' Critical Thinking Skills and Scientific Attitude. *Jurnal Inovasi Pendidikan IPA*, *1*(2), 138–152. https://doi.org/10.21831/jipi.v1i2.7498

Widoyoko, E. P. (2012). *Techniques for Developing Research Instruments*. Pustaka Pelajar.

ACKNOWLEDGEMENT

The authors would like to express their gratitude to Universitas Islam Kuantan Singingi through LPPMDI for providing financial support for this research via the 2026 Internal Grant.

AUTHOR CONTRIBUTION STATEMENT

II contributed to the research from the initial to the final stages, KP contributed to the development of research instruments, and NY contributed to editing the research outputs.

AI DISCLOSURE STATEMENT

The author used AI to translate and paraphrase this research article. Subsequently, the author analyzed the research findings and their relevance to the identified articles. The author bears full responsibility for the accuracy, integrity, and content of this article.

***Irfandi (Corresponding Author)**
Department of Chemistry Education, Universitas Islam Kuantan Singingi,
Jl. Gatot Subroto KM 7, Kebun Nenas, Jake, Teluk Kuantan, Kabupaten Kuantan Singingi, Riau
Email: irfandi@uniks.ac.id

Kiprah Piawi
Department of Chemistry Education, Universitas Islam Kuantan Singingi,
Jl. Gatot Subroto KM 7, Kebun Nenas, Jake, Teluk Kuantan, Kabupaten Kuantan Singingi, Riau
Email: kiprahpiawi@gmail.com

Nofri Yuhelman
Department of Chemistry Education, Universitas Negeri Padang,
Jalan Prof. Dr. Hamka, Air Tawar Barat, Kecamatan Padang Utara, Kota Padang, Sumatera Barat
Email: nofriyuhelman@unp.ac.id