



Received : 13 December 2023

Revised : 24 February 2024

Accepted : 30 March 2024

Publish : 31 March 2024

Page : 132 – 140

Project-Based Learning Resource Innovation to Build Students' Critical Thinking Skills in Basic Teaching of Chromatography

Meilin Simalango^{1*}, Manihar Situmorang²

^{1,2}Chemistry Education Study Program, Universitas Negeri Medan, Medan

*Email: meilinsimalango.4193331026@mhs.unimed.ac.id

Abstract: This study is a Research and Development (R&D) aimed at developing project-based innovative learning resources in the form of E-LKM on the topic of Chromatography with the goal of assessing its effectiveness in improving critical thinking skills and students' learning outcomes. The development method used is the ADDIE model with 3 cycles of implementation stages. The development results indicate that the project-based E-LKM has an average total feasibility score of BSNP = 3.85, categorized as very feasible, and an N-gain score of 0.72, equivalent to a percentage of 72%, indicating high effectiveness. During field trials, there was an increase in the average scores $M4 > M3 > M1$, indicating an improvement in students' abilities in the Chromatography teaching process. Hypothesis testing results show a significant difference between students' learning outcomes before and after using the developed project-based innovative learning resources. Additionally, based on the correlation calculation between critical thinking skills and students' learning outcomes, it was found that there is a significant positive correlation. Thus, it can be concluded that project-based innovative learning resources are effective in improving students' learning outcomes, and there is a correlation between critical thinking skills and students' learning outcomes in the context of teaching chromatography.

Keywords: Electronic Learning Module; Project-Based Learning; Critical Thinking Skills; Chromatography.

INTRODUCTION

Education is one of the most crucial factors in a nation's development efforts. Education is the endeavor to develop the human potential of learners, encompassing physical, mental, and spiritual aspects, so that these potentials become tangible and functional in life's journey. Innovation is defined as an idea, practice, or object considered new by individual. Thus, innovation can be seen as an effort to achieve

specific goal (Susilawati et al., 2020). The principle of 21st century learning states that professors and instructors play the role of facilitators in student-centered learning environments. To create an environment that encourages active student engagement in learning activities, teachers and instructors must be able to develop appropriate strategies, models, and learning media. Facts show that students, especially in science classes, tend to memorize topics, theories,

and principles more than they understand them (Panggabean et al., 2023).

The development of science and technology today has led to the implementation of the Indonesian National Qualifications Framework (KKNI) in higher education, which aims to optimize the development of students' potential (Sutiani et al., 2017). With this curriculum, learning needs to be aligned and juxtaposed with the demand for skills required to work in relevant fields. University courses studied should be pertinent to the expertise needed in the workforce upon completion of the study program. Therefore, learning materials must be packaged attractively to equip learners contextually in understanding the theory and skills required by industries or other jobs in the fields of pharmacy and chemistry (Parulian & Situmorang, 2013). Additionally, learning tends to steer students towards formulas, causing them to become accustomed to memorizing topics without understanding the practical utility of the materials learned. This issue needs to be addressed through the application of innovative project-based learning to cultivate critical thinking skills that can foster the internalization of theory and practice in real-world applications through project implementation (Situmorang et al., 2020).

LITERATURE REVIEW

In Indonesia, national education is designed to empower citizens, guiding them to become capable and proactive individuals ready to face the dynamic challenges of our times. Achieving this vision has led to the implementation of the Indonesian National Qualifications Framework (KKNI) in higher education, aimed at optimizing the development of students' potential (Rati et al., 2017). Aligned with the KKNI, the curriculum in higher education is designed to meet the skills demanded by relevant professional fields. However, the onset of the COVID-19 pandemic has imposed constraints,

particularly on laboratory practical activities due to social distancing policies. This has resulted in a shift towards theory-dominated learning, with limited hands-on experience in analytical chemistry (Sary et al., 2018).

In the digital era, where students increasingly engage with education through technology, the need for innovative learning materials becomes paramount. Proposed as a means to enhance education quality, innovative learning materials are positioned to maximize teaching and learning activities, guiding students from conventional learning styles to more student-centered approaches. This transition is seen as instrumental in deepening their understanding of subject matter and achieving learning competency goals (Martalina et al., 2018).

In conclusion, the term "learning resources" encompasses various interpretations, ranging from a narrow focus on printed materials like books, magazines, and bulletins to a broader perspective. Learning resources can be defined as teaching aids that convey messages through both auditory and visual means, including mediums like radio, television, and hardware devices (Nurlaili, 2018). The incorporation of innovative learning resources with projects proves to be particularly intriguing and challenging, especially in the field of teaching chemistry. These resources offer materials that systematically guide students, whether with or without the presence of instructors and facilitators, enhancing the learning experience (Lumban Gaol & Situmorang, 2022).

In summary, the innovative project-based learning resources actively involve students in the learning process, leading to an enhancement of knowledge and skills applicable to real-life qualitative determination problems. The effectiveness of these resources in promoting critical thinking and improving learning outcomes has been demonstrated. This learning model motivates students to actively engage in the study of analytical chemistry, allowing them to optimize their independent learning styles and attain competence in the field. Furthermore,

the versatility of this learning model makes it applicable to other courses requiring knowledge and skill enhancement, and it can be implemented in both normal and non-normal situations as a strategy for achieving competence (Harahap et al., 2022).

Innovative teaching materials in the form of learning packages are arranged according to the website, packaged attractively, and designed to be easily readable in line with the teacher's development. The innovative learning materials developed are also available in softcopy format for offline learning for teachers who may face difficulty accessing teaching materials online (Situmorang et al., 2022).

Teaching materials are not only in the form of books or worksheets based on print media. Teaching materials based on non-print media can also be used in learning, for example in the form of electronic teaching materials or e-modules. E-Module is one of the digital-based non-print teaching material products that is independently designed to be studied by learners (students). E-Module or electronic module is the electronic version of a printed module that can be read on a computer and designed with the necessary software (Panggabean & Purba, 2021).

Recognizing the need for innovative learning resources in self-directed learning, project-based learning with multimedia is identified as a highly effective approach. This methodology is believed to guide active student learning and has demonstrated success in improving learning outcomes (Sari et al., 2020).

The development of project-based learning, particularly in logical scientific learning, requires special attention in the face of educational transformation. This transformation is associated with imaginative thinking, discovery, and adaptation, involving strategies to address educational challenges. To ensure successful learning transformation, considerations such as hypothetical reasoning, learning reasoning,

and the learning environment must be integral to the development process (Purba & Situmorang, 2015).

Project-based learning is a challenging yet effective method for science students, immersing them in real-world applications of theories, particularly in chemical analysis. Successfully used in science education, especially in teaching chemistry, this approach cultivates skills like problem-solving, investigation, and discovery (Situmorang, 2014). The learning model also improves students' thinking abilities, including synthesis, analysis, and drawing conclusions from experiments. Thus, project-based learning is well-suited for implementing analytical chemistry education. The research aims to enhance student performance by implementing innovative learning materials through projects, fostering independent learning through student-centered activities. This ultimately improves students' competence in the field of chemistry (Samosir et al., 2020).

Acknowledging the transformative potential of project-based learning, (Situmorang et al., 2021), emphasizes the Project-based Learning (PjBL) model as a valuable tool for instructors overseeing transformation. This model places emphasis on efforts and exercises, viewing them as a means to gain perspectives, knowledge, and psychomotor skills. Students are expected to tackle problems by applying exploratory, dissecting, creating, and introducing learning materials based on real experiences (Jusita, 2019). Against this backdrop, our research aims to explore the potential of project-based learning in the field of Analytical Chemistry, specifically focusing on the innovation of learning resources. Titled "Innovation of Project-Based Learning Resources to Build Critical Thinking Skills in Students in the Basic Teaching of Chromatography," our study seeks to contribute valuable insights to the ongoing discourse on effective teaching methodologies in the contemporary educational landscape (Singarimbun et al., 2015).

METHODS

The research employed is the Research and Development (R&D) method, a research approach utilized to produce products with a tested level of effectiveness (Sugiyono, 2018). The development of innovative project-based learning resources follows the R&D method, utilizing the ADDIE development model. The ADDIE model consists of five stages: Analysis, Design, Development, Implementation, and Evaluation.

RESULT AND DISCUSSION

Project-Based Learning Resource Innovation

In conclusion, the development of innovative project-based learning resources in this research followed the systematic and iterative ADDIE development model. The process encompassed three crucial stages: Analysis, Design, and Development.

During the Analysis Stage, a thorough examination was conducted to identify the essential elements that needed to be addressed before developing the learning resources. This included an analysis of the curriculum used in the separation chemistry course at the Department of Chemistry, Universitas Negeri Medan, and an evaluation of various learning resources employed by students in Chromatography teaching within the realm of Separation Chemistry. The outcomes of this analysis, directed the development towards addressing the identified needs, resulting in the creation of a project-based E-module centered on the subject of Chromatography.

Moving on to the Design Stage, meticulous planning and instructional design took place. The development team crafted a draft of the project-based E-module, aligning it with the components of the E-module, project-based learning principles, the analysis of the Separation Chemistry curriculum, and the evaluation of learning resources in the Separation Chemistry learning process. The content of the E-module, drawn from various

relevant sources such as books, journals, and blogs, was compiled and organized. Mini project assignments were created through practical work conducted at the Department of Chemistry, Universitas Negeri Medan. Additionally, project assessments were established through rubrics based on project-based learning criteria, covering the design, implementation, and research aspects.

In summary, the research not only produced a project-based E-module on Chromatography but also demonstrated a comprehensive approach to instructional design and assessment within the context of project-based learning. The culmination of this endeavor is presented in Table 1, encapsulating the description of learning materials, the nature of innovation, and practical examples of project integration within the learning resource. The systematic implementation of the ADDIE model has contributed to the development of a robust and effective educational resource that aligns with the evolving landscape of educational methodologies.

Table 1. Project-Based Learning Resource Description for Basic Chromatography

No	Subtopic	Type of Innovation Integrated into Teaching Material	Project Title
1	Chromatographic Separation Analysis	Separation Chemistry material covering the definition of chromatography, chromatography principles, and its benefits	No project
2	Chromatographic Separation Analysis – Paper	Chemistry material detailing the definition of paper chromatography, working principles, and practical steps in laboratory chromatography using paper	Project 1: Separation of Ink Colors and Metal Ions via Paper Chromatography
3	Chromatographic	Chemistry material explaining the	Project 2:

Separation Analysis - Thin Layer	definition of thin-layer chromatography, methods of separation, principles, and operational steps using thin-layer chromatography in the laboratory	Separation of Green Leaf Substances with Thin-Layer Chromatography
----------------------------------	---	--

thorough and systematic development process ensures the creation of a dynamic and accessible educational resource aligned with contemporary teaching methodologies.

The development of mini-projects for chromatography teaching is guided by considerations to ensure practicality and ease of implementation for students. The criteria for the selection and design of these mini-projects are as follows: 1. **Ease of Implementation:** Mini-projects should be easily executed without imposing a heavy burden on students. 2. **Laboratory Feasibility:** Designed mini-projects should be feasible to conduct within a laboratory setting. 3. **Availability of Natural Materials:** Mini-projects are crafted using readily available natural materials in the surrounding environment. 4. **Alternative Material Options:** Designed mini-projects should offer alternative material options, enhancing flexibility in implementation.

Project for the teaching of chromatography

The mini-projects developed for the project-based learning resource are outlined in Table 2. These projects are carefully curated to align with the outlined criteria, ensuring a seamless integration of practical, accessible, and effective learning experiences for students in the realm of chromatography.

Table 2. Project Descriptions Developed for Basic Chromatography Teaching

No	Project Title	Project Description
1	Separation of Ink Colors and Metal Ions via Paper Chromatography	Students will explore various references related to paper chromatography. In this section, students will present the project, including the tools, materials, and work procedures. They will be guided to identify the colors visible in spots of red, black, and blue liquid ink, and directed to calculate the Rf values for each ink color. Students will create a table based on experimental data, document reactions occurring during the experiment, calculate the percentage levels in the sample, relate the findings to supporting theory, analyze performance and

In conclusion, the Development Stage is a comprehensive process geared towards creating a project-based E-module tailored for effective use. This multifaceted stage comprises two key phases:

a. **Product Development:** In this phase, the E-module is meticulously crafted in alignment with the components outlined in the prior analysis and design stages. The development initiates with the creation of front and back covers using Microsoft Publisher, ensuring harmonization with the designated material. Subsequently, the E-module is fully written in coherence with the previously compiled content. The second step focuses on accentuating the E-module's development, highlighting the designated mini-projects in video format sourced from YouTube. These video projects are seamlessly integrated into the E-module through links and barcodes. The third step involves the strategic design of student tasks for creating mini-projects based on the presented videos. Additionally, it encompasses the completion of other crucial components such as the introduction, table of contents, user guide, learning outcomes, exercise questions, and self-assessment.

b. **Final Stage of Development:** Following the validation process by expert validators, affirming its suitability for chromatography learning, the final stage involves transforming the E-module into an interactive E-module (E-LKM). This transformation facilitates access as a flexible learning resource from any location, achieved through a flipbook maker. With this final step completed, the interactive E-module is prepared for implementation in the learning process at the Department of Chemistry, Universitas Negeri Medan. This

	contributing factors, and draw conclusions.		with correct Indonesian language norms
2	Separation of Green Leaf Substances with Thin-Layer Chromatography	Students will research references related to thin-layer chromatography. In this section, students will outline the project, detailing tools, materials, and procedures. They will be guided to determine the number of compounds in the sample extraction (mustard greens) and calculate the Rf values for mustard greens. Students will create a table based on experimental data, document reactions occurring during the experiment, calculate the percentage levels in the sample, relate the findings to supporting theory, analyze performance and contributing factors, and draw conclusions.	3 Presentation: includes presentation techniques, supporting material presentation, learning presentation 3,86
			4 Graphic: book size (E-module) and book design (E-module) 4,00

Implementation of Learning Resources in Basic Chromatography Teaching

Project-based learning has been implemented in both classes, namely the experimental class using project-based innovative learning resources and the control class using student learning resources. The students' learning outcomes in both treatment groups are summarized in Table 4. From these results, it is evident that innovative learning resources can enhance students' learning outcomes. The project proposal assessment for the student group taught using innovative learning resources in the experimental class ($x=86.61$) is higher compared to the control group ($M=66.28$). It can be stated that project-based innovative learning resources with multimedia are highly effective in improving students' learning outcomes. The learning innovation conducted in this research has enriched the chemistry content with contextual examples and tasks aligned with the university curriculum. The instructional tasks provided in the chemistry learning materials are intended to optimize students' potential for learning and transform the learning process from lecture-centered conventional learning to student-centered learning. The learning activities are expected to equip students with essential skills that will be crucial throughout their education (Sinaga et al., 2019).

Results of Standardization of Innovative Learning Resources

In conclusion, the developed E-module underwent a standardization process in accordance with the criteria set by BSNP, as detailed in Appendix 3. This standardization was carried out by expert validators, consisting of two chemistry lecturers, who utilized a modified BSNP validation questionnaire. The validation process aimed to evaluate the eligibility of the E-module based on four criteria: Core Eligibility, Language Eligibility, Presentation Eligibility, and Graphic Eligibility. The stages of validation included a thorough review of the E-module, subsequent revisions, and a comprehensive assessment. The detailed results of this validation process are presented in Table 3.

Table 3. Standardization Results of Innovative Learning Resources

No	Criteria	Response
1	Content: includes material coverage, accuracy, currency, stimulates curiosity, develops independence, and learning motivation through PjBL (project)	3,84
2	Language: suitability for development, communicative, conformity	3,70

Table 4. Differences in Learning Outcomes between Experimental Class and Control Class

No	Assessment Aspect	Students' Learning Score
1	Pretest	Experimental (n=18): 58.28, Control (n=18): 45.28
2	Posttest	Experimental (n=18): 86.61, Control (n=18): 66.28

CONCLUSION

In conclusion, the data analysis from this study indicates several key findings. Firstly, the development of project-based innovative learning resources for Analytical Chemistry is well-aligned with the KKNI curriculum and project syntax for Basic Chromatography instruction, presenting a visually appealing and adaptable approach for online learning. Furthermore, the implementation of these resources results in increased student engagement, as evidenced by their active involvement in project implementation and a substantial improvement in learning outcomes, reflecting an enhanced comprehension of the subject matter. Moreover, students taught with project-based innovative learning resources demonstrate enhanced critical thinking skills, evident in their adept organization, implementation, and reporting on projects. The study also highlights a significant difference in learning outcomes between students taught with and without innovative learning resources, with the former achieving notably higher scores. Finally, a noteworthy correlation is established between students' critical thinking abilities and their learning outcomes when exposed to innovative learning resources in Basic Chromatography instruction.

REFERENCE

- Harahap, F. Z., Situmorang, M., & Nurfajriani, N. (2022). The Development of Guided Inquiry-Based Learning Resources as a Strategy to Achieve Student Competence in Analytical Chemistry. *AISTEEL*. <https://doi.org/10.4108/eai.20-9-2022.2324794>
- Jusita, M. L. (2019). Implementasi model pembelajaran berbasis proyek (project based learning) untuk meningkatkan aktivitas dan hasil belajar siswa. *Jurnal Teori Dan Praksis Pembelajaran IPS*, 4, 90–95. <https://doi.org/10.17977/um022v4i22019p90>
- Lumban Gaol, H., & Situmorang, M. (2022). Pengembangan Sumber Belajar Inovatif Berbasis Proyek dan Multimedia pada Pengajaran Analisis Kation. *JPSP: Jurnal Penelitian Sains Dan Pendidikan*, 2(2), 136–144. <https://e-journal.iain-palangkaraya.ac.id/index.php/mipa/>
- Martalina, D. S., Situmorang, M., & Sudrajat, A. (2018). The Development of Innovative Learning Material with Integration of Project and Multimedia for the Teaching of Gravimetry. *AISTEEL*, 200, 735–740.
- Nurlaili, N. (2018). Sumber Belajar dan Alat Permainan untuk Pendidikan Anak Usia Dini. *Al Fitrah: Journal Of Early Childhood Islamic Education*, 2(1), 229–241.
- Panggabean, F. T. M., & Purba, J. (2021). Pengembangan E-Modul Terintegrasi Media Berbasis Adobe Flash CS6 Untuk Meningkatkan Kemampuan Pemecahan Masalah Kimia Mahasiswa. *Jurnal Inovasi Pembelajaran Kimia*, 116–122. <https://jurnal.unimed.ac.id/2012/index.php/jipk>
- Panggabean, F. T. M., Silitonga, P. M., Purba, J., Jasmidi, & Purba, R. A. (2023). Analysis Student Motivation and Learning Outcomes by Applying Problem Based Learning and Discovery Learning Models. *Jurnal Inovasi Pembelajaran Kimia*, 5(1), 11–15. <https://jurnal.unimed.ac.id/2012/index.php/jipk>

- Parulian, H. G., & Situmorang, M. (2013). INOVASI PEMBELAJARAN DI DALAM BUKU AJAR KIMIA SMA UNTUK MENINGKATKAN HASIL BELAJAR SISWA. *Jurnal Penelitian Bidang Pendidikan*, 19(2), 67–78.
- Purba, J., & Situmorang, M. (2015). Inovasi Pembelajaran Berbasis Proyek Untuk Meningkatkan Kompetensi Mahasiswa Pada Pengajaran Gugus Fungsi. *SEMIRATA*, 506–513.
- Rati, Ni. W., Kusmaryatni, N., & Rediani, N. (2017). Model Pembelajaran Berbasis Proyek, Kreativitas dan Hasil Belajar Mahasiswa. *Jurnal Pendidikan Indonesia*, 6(1), 60–71.
- Samosir, R. A., Bukit, J., Situmorang, M., & Simorangkir, M. (2020). Implementation of Innovative Learning Material With Project to Improve Students Performance in The Teaching of Complexometry Titration. *PervasiveHealth: Pervasive Computing Technologies for Healthcare*, 1, 375–384. <https://doi.org/10.4108/eai.12-10-2019.2296541>
- Sari, D. P., Sitorus, M., Situmorang, M., & Sudrajat, A. (2020). Implementation of Project-Based Learning Resources With Multimedia to Improve Student Learning Outcomes in Teaching Cation Analysis. *AISTEEL*, 488, 120–126.
- Sary, S. P., Tarigan, S., & Situmorang, M. (2018). Development of Innovative Learning Material with Multimedia to Increase Student Achievement and Motivation in Teaching Acid Base Titration. *AISTEEL*, 200, 422–425.
- Singarimbun, E., Silaban, R., Suyanti, R. D., Jahro, I. S., & Situmorang, M. (2015). Pengembangan Bahan Ajar Kimia Inovatif pada Pokok Bahasan Reduksi dan Oksidasi Berdasarkan Kurikulum 2013 Terintegrasi Pendidikan Karakter. *Jurnal Pendidikan Kimia (JPKim)*, 7(2), 13–20.
<http://jurnal.unimed.ac.id/2012/index.php/jpk>
- Situmorang, M. (2014). Pengembangan Buku Ajar Kimia Sma Melalui Inovasi Pembelajaran Dan Integrasi Pendidikan Karakter Untuk Meningkatkan Hasil Belajar Siswa. *Prosiding Semirata FMIPA Universitas Lampung*, 1(1), 237–246.
- Situmorang, M., Gultom, S., Mansyur, A., Gultom, S., Restu, & Ritonga, W. (2022). Implementation of Learning Innovations to Improve Teacher Competence in Professional Certificate Programs for In-Service Teachers. *International Journal of Instruction*, 15(2), 675–696.
<https://doi.org/10.29333/iji.2022.15237a>
- Situmorang, M., Purba, J., & Silaban, R. (2020). Implementation of an Innovative Learning Resource with Project to Facilitate Active Learning to Improve Students' Performance on Chemistry. *Indian Journal of Pharmaceutical Education and Research*, 54(4), 905–914.
<https://doi.org/10.5530/ijper.54.4.184>
- Situmorang, M., Sinaga, M., Sitorus, M., & Sudrajat, A. (2021). Implementation of Project-based Learning Innovation to Develop Students' Critical Thinking Skills as a Strategy to Achieve Analytical Chemistry Competencies. *Indian Journal of Pharmaceutical Education and Research*, 56(1), S41–S51.
<https://doi.org/10.5530/ijper.56.1s.41>

Susilawati, E., Agustinasari, A., Samsudin, A., & Siahaan, P. (2020). Analisis Tingkat Keterampilan Berpikir Kritis Siswa SMA. *Jurnal Pendidikan Fisika Dan Teknologi*, 6(1), 11–16. <https://doi.org/10.29303/jpft.v6i1.1453>

Sutiani, A., Silalahi, A., & Situmorang, M. (2017). The Development of Innovative Learning Material With Problem Based Approach to Improve Students Competence in The Teaching of Physical Chemistry. *AISTEEL*, 104, 378–382.