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Development of Problem-Based Learning E-Module to Enhance Students' Critical Thinking on Acid-Base Material

Nala Angriani Syalsabila Daulay[1]* and Gulmah Sugiharti[2]

[1,2]*Chemistry Education Study Program, Universitas Negeri Medan, Medan*

**Email*: nalaangria01@gmail.com

***Abstract*:** *Acid-base concepts are often abstract and difficult for students to understand, limiting the development of their critical thinking skills. At SMAS An-Nizam Medan, current learning models have not been fully effective in promoting student engagement or enhancing these skills. This study aims to develop a Problem-Based Learning (PBL) e-module to improve students' critical thinking and to evaluate its validity and practicality. The research uses a Research and Development (R&D) method based on the Borg and Gall model, limited to the seventh stage. The participants consisted of two chemistry lecturers (as media and material experts), one chemistry teacher, and students from Class XI Al-Khawarizmi at SMAS An-Nizam Medan. Data were collected using a questionnaire adapted from BSNP standards. The results showed that the PBL-based e-module was valid, with an average score of 85.75% from material experts, 95.48% from media experts, and 100% from the teacher classified as highly valid. Student responses showed a practicality score of 87.97%, indicating that the module is very practical. In conclusion, the developed PBL-based e-module is valid and practical, making it suitable for use in teaching acid-base chemistry material to support the development of students' critical thinking skills.*

***Keywords*:** *acid base; critical thiking skills; e-module; problem based learning*

INTRODUCTION

School serves as one of the key platforms in the educational sector that plays a significant role in shaping students' character and developing their competencies through learning activities and other related programs within the school environment (Dalimunthe & Ginting, 2022).

Advances in science and technology have opened up enormous opportunities for the development of education globally, including in Indonesia. Advances in information technology require the world of education to continue to innovate and make improvements. In this context, educators are expected to be able to design more engaging learning processes to support students' mastery of 21st-century skills. One of the key factors in the learning process is the availability of learning resources in the form of teaching materials. Teaching materials serve to support teachers in implementing more efficient learning, as well as making it easier for students to understand and master the desired competencies. Therefore, the teaching materials that can be used are those that are easily accessible independently by students (Kimianti & Prasetyo, 2019).

Education is one of the most effective methods for preparing human resources to face the various challenges of the 21st century (Redhana, 2019). The primary focus of education in today's world is on developing strong critical thinking abilities. Those who gain proficiency in these abilities have the capacity to think with reason, react effectively when facing difficulties, and come to sound conclusions about what steps to take. Critical thinking abilities are considered advanced cognitive functions that are crucial in boosting the analytical skills of students (Susilawati et al., 2020). Cultivating and refining cognitive abilities from childhood is crucial to foster a generation equipped to critically analyze and navigate the evolving landscape of our era. The deficiency in critical reasoning skills observed among Indonesian students represents a notable concern that demands careful consideration.

According to the results of the 2019 PISA study, the level of critical thinking skills among students in Indonesia is still relatively low, as indicated by Indonesia's ranking of 71st globally (Tohir, 2019). These results are in line with the findings of a study conducted by (Susilawati et al., 2020) research conducted at SMA 1 Woha revealed that 64% of students were in the low critical thinking skills category, 21% were in the moderate category, and only 15% showed high skills. The results suggest that, overall, Indonesian students' abilities to think critically could be better.

The main challenge in today's formal education system remains the lack of active student engagement. More importantly, the learning process continues to prioritize teachers over students, maintaining a teacher-centered approach that hinders students from developing into independent thinkers through exploratory learning (Sianturi & Panggabean, 2019).

Chemistry is a branch of natural science that focuses on ideas, rules, laws, principles, and theories. It has several distinct characteristics, including: (1) most chemical concepts are abstract in nature, (2) chemical concepts generally represent simplified versions of real-world phenomena, and (3) chemistry concepts are structured in a sequential manner and evolve rapidly (Sutiani & Fayaddah, 2019).

One of the chemistry materials taught in class XI SMA is acid-base. Acid-base is one of the chemistry topics taught at the senior high school level. It serves as a fundamental concept for grasping more advanced materials such as buffer solutions and salt hydrolysis. However, many students find acid-base solutions challenging to comprehend (Ginting & Dibyantini, 2024).

The chemistry material studied covers acids and bases, which is material that is taught in 11th grade high school. This topic is often a hurdle for students because it contains concepts that are not easy to understand. Understanding acids and bases is closely related to everyday life, such as the sour taste of fruit, the use of alkaline substances to relieve heartburn, and the use of lime to neutralize the acidity of agricultural soil (Andriani et al., 2019). Difficulties in learning this material arise due to its complex characteristics, the interrelationship between concepts, the involvement of various calculation processes, and the need for deep and gradual understanding (Sari et al., 2020). This is in line with the opinion (Sari et al., 2020) which states that a large number of students face challenges in learning chemistry because this subject contains many abstract and complex concepts. Therefore, a deep understanding is necessary in order to master the material effectively.

Chemistry is often considered difficult, and many students need innovations to make it easier to understand. One innovation that can be implemented is the use of e-modules or electronic modules. These e-modules aim to support the development of students' critical thinking skills in a more interactive and accessible way. As a digital adaptation of printed modules, e-modules can be accessed via devices such as laptops, tablets, or mobile phones. E-modules are designed systematically so that students develop their learning independently. The material presented in e-modules is arranged to achieve specific learning objectives in a more effective way in digital format, presenting a more interactive, flexible, and efficient learning process (Elvarita et al., 2020). E-modules provide opportunities for students to learn independently and actively develop their knowledge, attitudes, and skills. In addition, e-modules serve to support the development of students' critical thinking skills by connecting relevant information with real-life experiences. Students can independently analyze problems, understand existing concepts, and find solutions to problems they encounter in the learning process (Kartikasari et al., 2021).

One effective learning model for improving students' thinking skills is Problem-Based Learning (PBL). This model can be a solution to overcome various problems in the learning process. PBL emphasizes a student-centered approach, where teachers begin the lesson by introducing a problem and then encourage students to actively find solutions to the problem, either independently or in groups. According to (Saputri, 2020) PBL can develop students' critical analysis skills in identifying and overcoming challenges related to real-life situations.

The description of these problems led researchers to conduct research entitled Development of Problem-Based Learning-Based E-modules to Improve Students' Critical Thinking Skills in Acid-Base Material.

The goal of this research is to develop instructional resources that align with the established curriculum, taking into account the requirements and traits of the students who will be utilizing them most frequently; additionally, it seeks to ascertain how well a PBL-based e-module enhances students' abilities to think critically about acid-base concepts, and to establish whether or not it is workable. (Sugiharti et al., 2024) revealed that well-planned content organization in a module is an effective method to support students in understanding topics more deeply, enabling them to achieve maximum learning outcomes.

METHODS

The type research used was research and development (R&D) with the Borg and Gall development model until seventh stage. (Supriyono, 2022). Follow the steps of the Borg and Gall creation model: (1) gathering information and doing research, (2) creating a plan, (3) making a first version of the revised item, (4) doing initial testing in real-world situations, (5) revising the main product, (6) doing key testing in the field, (7) revising the working product, (8) doing field testing on the working product, (9) revising the final item, (10) sharing and giving out. The study was only done until step (7), which was revising the product that was being used.

This research involved two chemistry lecturers at Universitas Negeri Medan as material and media expert validator, and one chemistry teacher as a material expert validator as well as class XI Al-Khawarizmi at SMAS An-Nizam Medan as many as one class with a total of 30 students.

Data collection techniques in this study were observation, interview, evaluation and comments from expert respondents (two expert lecturers/validators and one teacher) and students' practicality questionnaire on PBL based e-modules that have been developed.

This research instrument consists of an interview sheet for teachers and students, a modified BSNP feasibility questionnaire for material expert validators, media experts and teachers and a practicality questionnaire for students on the use of PBL based acid-base e-modules.

RESULT

The The result of the investigation and enhancement process is an electronic module designed around Problem Based Learning.

This study employs a research and development strategy, utilizing the Borg and Gall development framework, concluding after the seventh phase.

First stage, research and data collection were conducted by interviewing one of the chemistry teachers and students at SMA Swasta An-Nizam Medan with the results that experienced several problems including the school textbook has material that is less in accordance with the level of understanding of high school students, so the teacher makes and compiles its own material that is suitable for study in high school. During learning, students tend to be passive, less involved in discussions, rarely respond or criticize opposing opinions and do not examine deeper information. Information information obtained. Teachers have never created and used e-modules during teaching. Learning still seems monotonous as the learning model used is teacher-centered so that students are easily bored and have difficulty understanding chemistry material.

In the planning stage, the e-module developed using flipbook software is packaged in attractive multimedia. Researchers designed all components of e-module teaching materials, including adjustments to Learning Outcomes (CP), Learning Objectives (TP), and Flow of Learning Objectives (ATP) in accordance with the independent curriculum.

Develop preliminary form of product stage, this stage is done by creating a e-module design. The developed e-module is compiled completely based on module components and several other additions, namely: cover, preface, table of contents, list of images, list of tables, instructions for using e-modules, introduction which includes Learning Outcomes (CP), Learning Objectives (TP), and Flow of Learning Objectives (ATP), concept map, steps of the PBL model, comics, chemistry, acid-base material, examples of problems, learning activities using the PBL model, summary, comprehension test, competency test, answer key, glossary, periodic system of elements, and bibliography. This e-module is made using canva which is then integrated into a pdf flipbook by scanning the qr code or clicking the link https://heyzine.com/flip-book/e2a13baad1.html to make it easier for students to access.

Here are some views of the e-module development results. When opening the e-module for the first time, the cover is displayed and instructions for using the e-module can be seen in Figure 1.

Figure 1. Cover Display and Instructions for Using the E-Module

Based on figure 1, in the image above, there is a display of the e-module cover along with a detailed explanation of the user guide. The usage instructions are divided into five stages, which guide students step by step in using the e-module effectively. These stages are designed to help users navigate the content, understand the learning objectives, engage in problem-based activities, reflect on their understanding, and evaluate their learning outcomes.

There are also learning outcomes, learning objectives, and learning objective flowcharts, which can be seen in Figure 2 as follows.

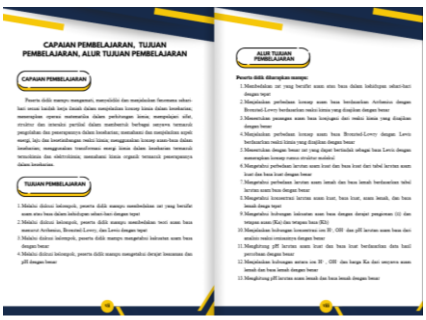

Figure 2. Display of Learning Outcomes, Learning Objectives, and Learning Objective Flow

Based on figure 2, learning outcomes, learning objectives, and learning objective flowcharts act as important references to ensure that the e-module is in line with the curriculum. Learning objectives specify the goals that students need to accomplish, learning objective flowcharts arrange the sequence of learning activities, and learning outcomes describe the ultimate skills or knowledge students should acquire. Combined, these components contribute to a more organized and efficient learning experience.

The next display shows a concept map and the steps of the PBL model, which are used during the learning process. There are five phases of learning activities, which can be seen in Figure 3.

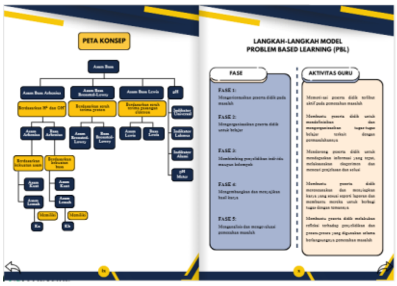

Figure 3. Concept Map Display and PBL Model Steps

Based on figure 3, the concept map display and the steps of the PBL model are very useful in the learning process because they help students understand the thinking process in a visual and systematic way. The five phases in PBL clarifying concepts, defining the problem, brainstorming, self-directed learning, and synthesis are designed to encourage active student participation, enhance critical thinking skills, and foster independence and teamwork.

The next section covers acid-base material, which includes four subsections: acids and bases in everyday life, acid-base theory, acid-base strength, and pH acidity. Each subsection includes a chemistry comic, the material to be studied, learning activities using the PBL model, which includes problems for students to solve in groups, a summary of the material, and at the end, a comprehension test in the form of a QR code that can be clicked to access it, after which students can immediately answer the questions by selecting the correct option. Once the questions are completed, students can immediately submit their answers, and the scores will appear instantly. The interfaces can be seen in Figure 4.

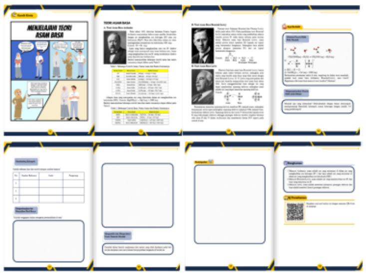

Figure 4. Display of E-Module Development Results

Based on figure 4 preliminary field test stage, at this stage validation was carried out by three groups of assessors: (1) material experts, (2) media experts, and (3) a chemistry teacher. Each expert used a questionnaire based on BSNP standards that included several assessment indicators.

The percentage score for each aspect of validation was calculated using the equation (1):

$$P = \frac{F}{n} x\ 100\% \qquad (1)$$

Where:

- P= percentage of feasibility,
- Total obtained score = sum of all points given by the validator,
- Maximum possible score = number of items × highest likert score (5).

Each questionnaire item was rated on a 5 poin likert scale (1 = strongly disagree, 2 = disagree, 3 = quite agree, 4 = agree, 5 = strongly agree).

Table 1. Material Expert Validation

No	Aspects Assessment	Total Value	Percentage Value	Criteria
1.	Content Feasibility	51	85%	Very Valid
2.	Feasibility Presentation	51	85%	Very Valid
3.	Feasibility Language	51	85%	Very Valid
4.	Feasibility Problem Based Learning	31	88%	Very Valid
	Total	184	85,75%	Very Valid

Based on the table 1, the material validation sheet consisted of 184 items divided into four aspects: (a) content feasibility (12 assessment items) and 51 total value, (b) feasibility presentation (12 assessment items) and 51 total value, (c) feasibility language (12 assessment items) and 51 total value, and (d) feasibility of PBL (7 assessment items) and 31 total value.

The percentage value of the feasibility of content, presentation and language is 85%, the feasibility of PBL is 88% and over all the assessment obtained score was 184 of a maximum of 215 total value, resulting in $P = 85.75\%$, which falls into the "very valid" category.

This means the e-module already meets the content, linguistic, and presentation standards, but some revisions were still recommended, such as improving consistency of typography, increasing the number of higher-order problem items, and ensuring that example questions stimulate critical reasoning.

The result of validation by media expert shown in Table 2.

Table 2. Media Expert Validation

No	Aspects Assessment	Total Value	Percentage Value	Criteria
1.	Aspects Graphics	148	95.48%	Very Valid
	Total	148	95.48%	Very Valid

Based on table 2, the media validation sheet contained 31 items, focusing on aspects such as layout, interactivity, visual integration, and readability. The total score obtained was 148 out of 155, yielding $P = 95.48\%$.

Although categorized as very feasible, the media expert suggested minor revisions, such as correcting typos and adding references in the bibliography to ensure consistency between citations and the reference list.

The validity of the e-module to the teacher was assessed by giving a questionnaire to the teacher. The percentage of the results of the practicality of e-module for teachers can be seen in Table 3.

Table 3. Validity for Teachers

No	Aspects Assessment	Total Value	Percentage Value	Criteria
1.	Content Eligibility Aspect	15	100%	Very Valid
2.	Aspects Feasibility Linguistics	10	100%	Very Valid
3.	Aspects Feasibility Presentation	10	100%	Very Valid
4.	Aspects Feasibility Graphics	20	100%	Very Valid
5.	Aspects Feasibility Effective	10	100%	Very Valid
6.	Aspects Feasibility Efficient	10	100%	Very Valid
7.	Ease of use module	25	100%	Very Valid
	Total	100	100%	Very Valid

Based on table 3 of the e-module practical results sheet, which consists of 100 items divided into seven aspects: (a) content eligibility aspect (3 assessment items) and 15 total value, (b) aspects feasibility linguistics (2 assessment items) 10 total value, (c) aspects feasibility presentation (2 assessment items) 10 total value, and (d) aspects feasibility graphics (4 assessment items) and 20 total value, (e) aspects feasibility effective (2 assessment items) 10 total value, (f) aspects feasibility efficient (2 assessment items) 10 total value, and (g) ease of use module (5 assessment items) 25 total value it can be seen that over all the assessment aspects obtained are 100 with a percentage of 100% so it can be concluded that this e-module is classified as very valid.

Main product revision is the revision stage aims to perfect the e-module which is considered lacking by the validator before being tested. The improved e-modules were then reassessed by the validators. There are several improvements that must be made, among others, material expert validators provide suggestions related to the type of writing used must be consistent, examples of problems and practice questions are more reproduced and questions must be critical thinking. Media expert validators gave suggestions in the form of corrections to writing errors and adding a bibliography to be more in line with what was used. The teacher gave suggestions to add sample problems in activity 4.

The primary stage of the field test involves gathering a practicality evaluation from a group of 30 students, focusing on the e-module instructional resources that have been created. Below are the percentage results illustrating the students' perceptions of the e-module's practicality, which were obtained through a practicality assessment questionnaire administered to the students. An overview of the average percentage of the students' responses is shown in Table 4.

Table 4. Student Practicality of E-Modules

No	Aspects Assessment	Total Value	Percentage Value	Criteria
1.	Language	2	88.33%	Very Practical
2.	Authoring	3	89.10%	Very Practical
3.	Image	2	90%	Very Practical
4.	Material	5	88.13%	Very Practical
5.	Benefits	3	89.32%	Very Practical
	Total	15	87.97%	Very Practical

Based on table 4, the practicality sheet for one student for the e-module consists of 15 items and for 30 students there are 450 items. In this case, to calculate the practicality of students towards the e-module, all student assessments are combined and divided into five aspects: (a) language (2 assessment items) and 265 total value, (b) authoring (3 assessment items) 401 total value, (c) image (2 assessment items) 270 total value, (d) material (5 assessment items) and 661 total value and (e) benefits (3 assessment items) and 420 total value.

The percentage of student practicality, the average score on language is 88.33%, authoring is 89.10%, images are 90%, material 88.13% benefits 89.32% and overall obtained at 87.97% so that it can be categorized as very practical to use when learning using this e-module during learning.

Operational product revision is the last stage of this research is to perfect the product of the field test results, namely the researcher revising the product in the form of e-modules according to the suggestions given by students. Students gave a positive response to the e-module so that it can be used as a student learning resource.

DISCUSSION

This study aimed to develop an electronic module (e-module) based on Problem-Based Learning (PBL) for the topic of acids and bases to enhance students' critical thinking skills at An-Nizam Private Senior High School in Medan. Based on the results of expert and teacher validation, the developed e-module demonstrated a very high level of validity across all evaluation aspects.

The results of the material expert validation showed that the content feasibility, presentation feasibility, language feasibility, and PBL feasibility aspects obtained average scores of 85%, 85%, 85%, and 88%, respectively. The overall average score of 85.75%, categorized as "very valid," indicates that the e-module content has been systematically structured in accordance with the curriculum and effectively facilitates the PBL approach in chemistry learning. This finding aligns with (Asmi et al., 2024), who reported that chemistry e-modules based on PBL were highly valid and effective in fostering students' critical thinking skills.

However, despite the high level of validity, some aspects still require improvement. For instance, the language and presentation aspects, which obtained scores of 85%, could be enhanced by refining the clarity of instructions and sentence structures to make them more communicative and accessible for students with varying academic abilities. In addition, although the PBL aspect received the highest score (88%), further improvements can be made by integrating more contextual and real-life problem scenarios to increase the relevance and meaningfulness of learning.

Validation by media experts yielded an average score of 95.48%, also categorized as "very valid". This result confirms that the visual design, layout, and graphical elements of the e-module effectively support readability and student engagement. Nevertheless, the module could be further improved in terms of interactivity by incorporating features such as instructional videos or interactive quizzz to enhance the independent learning experience.

Meanwhile, teacher validation showed an average score of 100%, categorized as "very valid." This result indicates that teachers found the e-module highly suitable for classroom implementation. However, this perfect score should be interpreted with caution. Possible evaluation bias may exist, as teachers involved in the validation process might share similar perspectives or familiarity with the developed material. To ensure greater objectivity, future studies should involve a larger number of teachers from different schools to obtain more diverse and representative feedback.

The practicality test conducted with students yielded an overall average score of 87.97%, indicating a "very practical" category. The assessment included five aspects: language 88.33%, authoring 89.10%, image 90%, material 88.13%, and benefits 89.32%. These results suggest that students found the e-module easy to use, engaging, and helpful in understanding acid-base concepts more deeply. This finding supports (Abdullah et al., 2021), who reported that a PBL based acid base e-module was highly practical as a supporting medium in chemistry instruction.

The high scores for images and materials indicate that the visualizations and content of the e-module have helped students understand abstract concepts in acid-base materials. However, the integration of text, images, and PBL activities needs to be improved in order to better guide students in the scientific thinking process.

Overall, the findings indicate that the PBL based e-module developed in this study meets the criteria of being valid and practical for use in chemistry learning. Its primary strengths lie in its systematic content organization, attractive design, and alignment with the PBL approach that promotes active student engagement.

Therefore, the developed e-module holds strong potential as an alternative learning medium to enhance students' critical thinking skills, particularly when followed by an effectiveness phase to quantitatively measure its impact on students' learning outcomes.

CONCLUSION

From the research results, it was found that this research successfully developed a Problem-Based Learning (PBL)-based e-module on the topic of acids and bases, which can be accessed at https://heyzine.com/flipbook/e2a13baad1.html, which was designed to improve students' critical thinking skills. This e-module has met the criteria of high validity with an overall average score of 93.74%, as assessed by material experts, media experts, and practical chemistry teachers. Furthermore, this e-module shows a high level of practicality, indicated by an average score of 87.97% from student evaluations. Therefore, this PBL-based acid-base e-module is proven to be valid and practical, making it a very suitable learning resource and is recommended for implementation in chemistry education in schools.

REFERENCE

Abdullah, A., Danial, M., & Anwar, M. (2021). Pengembangan E-Modul Asam Basa Berbasis Problem Based Learning melalui Google Classroom pada Sekolah Menengah Kejuruan (SMK). *CER: Chemistry Education Review, 5*(1), 86–99. https://doi.org/10.26858/cer.v5i1.13315

Andriani, M., Muhali, M., & Dewi, C. A. (2019). Pengembangan Modul Kimia Berbasis Kontekstual Untuk Membangun Pemahaman Konsep Siswa Pada Materi Asam Basa. *Hydrogen: Jurnal Kependidikan Kimia*, *7*(1), 25. https://doi.org/10.33394/hjkk.v7i1.1653

Asmi, A., Silaban, S., & Silaban, R. (2024). Developing An Interactive Chemistry E-module Based on Problem-based Learning to Improve Critical Thinking Skills of High School Students. *Jurnal Paedagogy*, *11*(1), 94. https://doi.org/10.33394/jp.v11i1.9875

Dalimunthe, M., & Ginting, R. J. (2022). Pengembangan Modul Berbasis Problem Based Learning dengan Pendekatan Saintifik pada Materi Asam-Basa. *Jurnal Inovasi Pembelajaran Kimia (Journal Of Innovation in Chemistry Education)*, 4(2), 177–190. https://doi.org/10.24114/jipk.v4i2.38991

Elvarita, A., Iriani, T., & Handoyo, S. S. (2020). Pengembangan Bahan Ajar Tanah Berbasis E-Modul Pada Program Studi Pendidikan Teknik Bangunan, Universitas Negeri Jakarta. *Jurnal PenSil*, *9*(1), 1–7. https://doi.org/10.21009/jpensil.v9i1.11987

Ginting, T. F., & Dibyantini, R. E. (2024). Implementation of an Integrated Project Based Learning Model for Generic Science Skills in Acid-Base Material. *Jurnal Inovasi Pendidikan Kimia (Journal of Innovation in Chemistry Education)*, 6(2), 179-187.

Kimianti, F., & Prasetyo, Z. K. (2019). Pengembangan E-Modul IPA Berbasis Problem Based Learning untuk Meningkatkan Literasi Sains Siswa. *Kwangsan: Jurnal Teknologi Pendidikan*, *7*(2), 91. https://doi.org/10.31800/jtp.kw.v7n2.p91--103

Kartikasari, S., Abudarin, A., & Fatah, A. H. (2021). Pengembangan e-modul pembelajaran mandiri materi senyawa hidrokarbon pada siswa kelas XI SMA Negeri 3 Palangka Raya. *Journal of Environment and Management*, *2*(2), 170–180. https://doi.org/10.37304/jem.v2i2.2946

Redhana, I. W. (2019). Mengembangkan Keterampilan Abad Ke-21 Dalam Pembelajaran Kimia. *Jurnal Inovasi Pendidikan Kimia (Journal of Innovation in Chemistry Education)*, 13(1), 2239–2252. https://doi.org/https://doi.org/10.15294/JIPK.v13i1.17824

Saputri, M. A. (2020). Penerapan Model Pembelajaran Problem Based Learning Untuk Meningkatkan Kemampuan Berpikir Kritis Siswa Kelas V Sekolah Dasar. *Jurnal Pendidikan dan Konseling (JPDK), 2*(1), 92-98.

Sari, M. P., Andromeda, A., & Hardinata, A. (2020). Studi Kesulitan Belajar Mahasiswa Jurusan Pendidikan IPA dalam Mempelajari Sifat Periodik Unsur. *Jurnal Eksakta Pendidikan (JEP)*, *4*(1), 18. https://doi.org/10.24036/jep/vol4-iss1/379

Sianturi, J., & Panggabean, F. T. M. (2019). Implementasi Problem Based Learning (PBL) menggunakan Virtual Dan Real Lab Ditinjau dari Gaya Belajar Untuk Meningkatkan Hasil Belajar Siswa. *Jurnal Inovasi Pembelajaran Kimia (Journal of Innovation in Chemistry Education)*, 1(2), 58–63. https://doi.org/10.24114/jipk.v1i2.15460

Sugiharti, G., Siregar, M. I., Samosir, D., & Anugrah, A. N. (2024). Improving Student's Critical Thinking Ability Using HOTS-Based Modules in Chemistry Learning. *Journal of Ecohumanism*, *3*(4), 118–127. https://doi.org/10.62754/joe.v3i4.3494

Supriyono. (2022). *Research and Development in Education: Borg and Gall Model. Bahan Ajar. Blitar: FKIP Universitas Islam Blitar*. ResearchGate. https://www.researchgate.net/profile/Supriyono-Supriyono-10

Sutiani, A., & Fayaddah, F. (2021). Pengembangan Lembar Kerja Siswa (LKS) Berbasis Model Pembelajaran Inkuiri Terbimbing Pada Materi Termokimia. *Jurnal Inovasi Pembelajaran Kimia (Journal of Innovation in Chemistry Education)*, 3(2), 106–115. https://doi.org/10.24114/jipk.v3i2.28174

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

Tohir, M. (2019). *Hasil PISA Indonesia Tahun 2018 Turun Dibanding Tahun 2015*. Open Science Framework. https://doi.org/10.31219/osf.io/pcjvx