JPPIPA 11(4) (2025)

Jurnal Penelitian Pendidikan IPA

http://jppipa.unram.ac.id/index.php/jppipa/index

Validity of Science Module Based on Problem Based Learning Multiple Representations to Improve Students' Higher Level Thinking Skills on the Topic of Acid-Base

Siti Sholikhah[1], Sentot Budi Rahardjo[2*], Bowo Sugiharto[3]

[1] Science Education, Universitas Sebelas Maret, Surakarta, Indonesia.
[2] Chemistry, Universitas Sebelas Maret, Surakarta, Indonesia.
[3] Biology Education, Universitas Sebelas Maret, Surakarta, Indonesia.

Received: December 27 2024
Revised: March 10, 2025
Accepted: April 25, 2025
Published: April 30, 2025

Corresponding Author:
Sentot Budi Rahardjo
sentotbr@staff.uns.ac.id

DOI: 10.29303/jppipa.v11i4.10837

Abstract: The background of this research is the use of learning resources that have not been effective in improving students' higher-order thinking skills. This study aims to develop a science module, analyze its validity, feasibility, and effectiveness on higher order thinking skills. This research type of research and development (R&D) uses the 4D development model according to Thiagarajan (Define, Design, Develop, Disseminate). The science module was validated by six validators. The effectiveness of the module is seen from the increase in the students' higher order thinking skills test scores from 36 student. Validity was analyzed using Aiken's V, while effectiveness was analyzed with N-Gain. In the validation level, the learning material expert validator obtained a score of 0.91 with the category "valid", the presentation expert validator obtained a score of 0.88 with the category "valid", the linguist validation obtained a score of 0.91 with the category "valid", and the graphic expert validation obtained a score of 0.88 with the category "valid". A feasibility value of 79.8 by teachers with a feasible category. The effectiveness results show that the module has an effect on students' higher order thinking skills as evidenced by the N-Gain score of the experimental class of 0,63 with a fairly effective category while the N-Gain score of the control class is 0,55 with a less effective category. Thus, the developed e-module is declared valid, feasible, and effective.

Keywords: Acid-base; HOTs; Problem based learning; Science module

Introduction

The advancement of information and technology in the 21st century demands an improvement in the quality of education. To prepare quality education, it is necessary to improve the ability of one of them is the ability of higher order thinking skills (HOTS) (Jihannita et al., 2023). Ahmad et al. (2018) state that HOTS is a thinking skill that combines critical analysis, creativity, and problem-solving skills. HOTS has been deemed essential in learning because it has helped students understand the concepts more deeply and has developed critical, analytical, and creative thinking skills needed to understand science concepts (Boeren & Íñiguez-Berrozpe, 2022). Through HOTS, students have not only passively understood science concepts but have also learned to analyze, evaluate, and create new knowledge (Wu et al., 2024).

Jansen & Möller (2022) have suggested that students with more HOTS tend to have achieved higher levels of achievement in science learning. They have been able to perform more in-depth information analysis, critically evaluate arguments, and create creative solutions to scientific problems. Similarly,

How to Cite:
Sholikhah, S., Rahardjo, S. B., & Sugiharto, B. (2025). Validity of Science Module Based on Problem Based Learning Multiple Representations to Improve Students' Higher Level Thinking Skills on the Topic of Acid-Base. *Jurnal Penelitian Pendidikan IPA*, *11*(4), 811-820. https://doi.org/10.29303/jppipa.v11i4.10837

research Bulut et al. (2024) has suggested that learning designed to develop HOTS, such as problem-solving, inquiry, and reflective thinking, has positively affected students' understanding of science concepts.

Based on the results of the science literacy survey issued by PISA in 2022, Indonesia was ranked 67th out of 81 countries listed in the survey (OECD, 2022) with a score of 383. Because the majority of PISA questions are at the C4-C6 level, PISA results can be used as a benchmark for how well a country's students understand HOTS (Jamaluddin et al., 2019). This shows that Indonesia is in a low position and this condition is very concerning (Arafah et al., 2021). To improve students' higher-order thinking skills, student-centered active and constructivist learning models and strategies are needed (Mayasari et al., 2016).

Learning models that have promoted HOTS in science learning have focused on creating a learning environment that encourages students to think critically, analytically, and creatively. One effective model has been PBL (Affandy et al., 2024). The main principles of PBL have involved challenging authentic problems, giving students autonomy in solving problems, and emphasizing collaboration and reflection (Hidajat, 2023). Allowing students to develop HOTS such as analysis, evaluation, and creation, as they have had to face complex challenges that have required creative problem-solving (Kwangmuang et al., 2021). Furthermore, PBL has also been supported by deep mastery of science concepts, as students have been actively involved in investigating those concepts in the context of real-world relevant problems (Wan Husin et al., 2016).

PBL has been proven to be a practical approach to enhancing these HOTS (Helsy et al., 2017). However, the PBL model also has some areas for improvement and difficulties in its implementation. Understanding natural science principles and applying those concepts in solving problems has often been a challenge for many students (Kusumawardani & Aminatun, 2024). Students often need help internalizing natural science theories and applying them in the context of real-world situations. There is a need for cognitive assistance for students who have difficulty in understanding science phenomena on chemistry topics. Cognitive assistance makes it easier for students to understand the problems presented and find solutions so that it will be easier to understand concepts when they have a good understanding of representation (Sundaygara & Gaharin, 2017). Thus cognitive assistance is needed in the form of multiple representation methods.

The success of students in learning chemistry is characterized by the ability to solve problems using three levels of chemical representations (macroscopic, submicroscopic, and symbolic), known as multiple representations (Rizal & Aini, 2023). Multiple representation-based learning builds a more profound understanding and helps understand abstract concepts to be concrete (Hasbullah et al., 2019). Students need to have a thorough understanding of multiple representations to avoid conceptual errors (Kapici, 2023). Facts in the field show that many students cannot use three chemical representations to explain a phenomenon (Safitri et al., 2019). Students have difficulty understanding chemical material, one of which is acid-base material (Meutia et al., 2021).

Acid-base phenomena are easily found in everyday life, but this material has a high level of conceptual difficulty (Azizah et al., 2022). This material includes several subjects, including the concept of acid-base and its strength and equilibrium in solution. An example of conceptual errors that often occur in this material is that students often identify acids with corrosive properties, even though there are weak acids such as citric acid in oranges or vinegar that are not harmful to the skin (Jusniar et al., 2024).

This misconception can occur because students find it difficult due to the lack of learning visualization at the submicroscopic level of chemical representation in using images of molecules or ions to explain phenomena that cannot be seen with the naked eye, such as the chemical reaction of a solution (Rizal & Aini, 2023). To distinguish the acidity of a solution can be done by experiment, where students observe the difference in the flame of the lamp and the bubbles produced (macroscopic), understand the movement and state of ions, electrons, water molecules, molecules of a substance in solution or in a conducting wire (submicroscopic), and write it in the form of a reaction equation (symbolic). These three levels of representation need to be well understood in order to avoid misconceptions and be able to solve problems appropriately (Alighiri et al., 2018).

The results of the needs analysis show that the main learning resources used by teachers during the learning process are chemistry textbooks. There has never been a problem-based analysis of the chemistry textbooks used. The books are selected only based on completeness, use of simple language, and conformity with the curriculum. This shows that teachers only focus on the content of the material and do not prioritize contextuality, so the approach used in helping students solve problems is less structured. Teachers stated that they usually rely on textbooks to deliver the material and the questions given during the exams are usually still at the C1-C3 level.. In addition, there are no questions that help strengthen students' HOTS in the textbooks used. Therefore, all teachers stated the need to develop a problem based learning-multiple representation module to improve students' HOTS skills.

The findings of the problem require a learning resource solution that does not only provide one-way information. However, learning resources must also describe phenomena in the form of real-world problems using macroscopic, submicroscopic, and symbolic representations. The combination of problem-based learning models and multiple representations (PBL-MR) on acid-base material is a new offer in science learning in improving students' higher order thinking skills on acid-base material. Therefore, this study aims to develop a PBL-MR science module on acid-base material, analyze the validity, feasibility, and effectiveness of the developed module.

Method

This type of research is known as development research (R&D), which aims to define, design, develop, and disseminate. The subjects of this research were UNS chemistry lecturers and chemistry teachers as validators. The students who were used as research subjects were students of class XII IPA SMAN 1 Ngemplak.

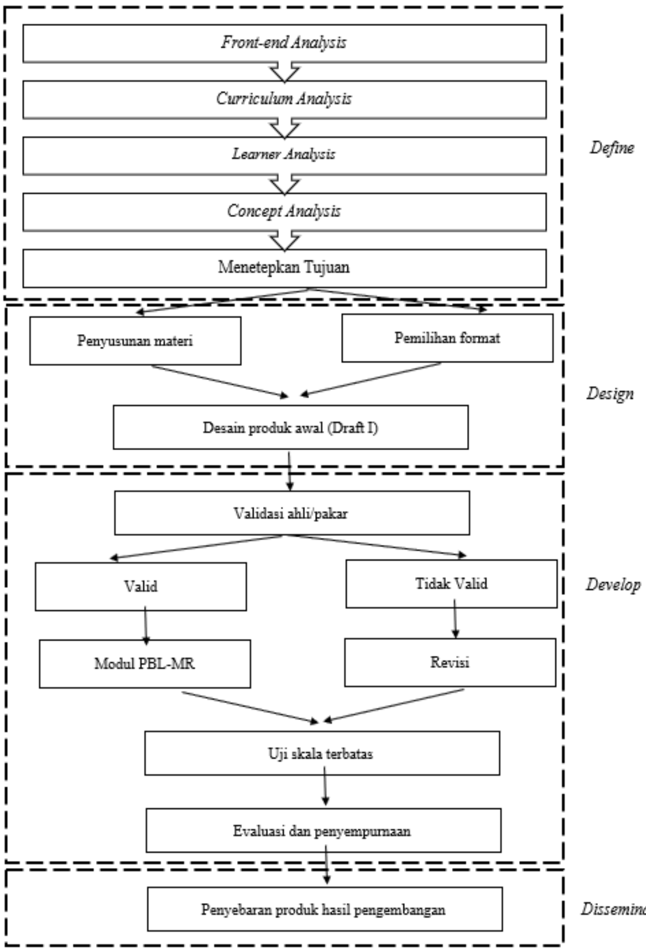

Figure 1. 4D development model procedures

The module was developed using 4D's development model which consists of four main stages; define, design, develop, and disseminate. 4D's stages can be seen in Figure 1.

Define

This stage includes defining the product to be developed and its definitions and specifications. This stage consists of an initial-end analysis, namely problem analysis to analyze alternatives that can be developed to solve problems, learner analysis, task analysis, concept analysis. problem analysis, learner analysis, task analysis, concept analysis. This stage is carried out by conducting literature studies on books, journals, and other references.

Design

The design stage is the stage of designing the module grids to be developed. This stage is carried out after analyzing the learning material and determining the objectives to be achieved. At this stage, the visuals of the module are designed, the form of activities in the module adjusts the syntax of the selected learning model, and determines the assessment instruments to be developed. The result of this stage is the initial draft of the module.

Development

The development stage is the stage of developing the module product and evaluation instrument based on the question grid that has been designed. After that, the module product is validated by experts and then the module is revised based on input from the validators. After the module is revised, a feasibility test of the developed module is carried out by implementing it in a small-scale trial.

Disseminate

This dissemination stage is the stage of using the developed science module. Module validation is carried out by giving a score of 1 - 5 on each item with the aspects measured, namely material validation, presentation, language, and graphics.

$$V = \frac{\Sigma s}{[n(c-1)]} \quad (1)$$

With: s = r-lo, V = Rater agreement index, lo = Lowest validity assessment number (in this case = 1), c = Highest validity assessment number (in this case = 5), n = Number of raters.

Aiken's V value coefficient ranges from 0-1. If the result obtained is close to 1, the higher the validity value. Conversely, if the result obtained is close to 0, then the validity is getting lower (Aiken, 1985).

The assessment of high-level thinking skills consisting of critical thinking essay tests and problem solving was given to the experimental class and the control class to assess the effectiveness of the module. The experimental class used modules that had been valid and feasible in learning, while the control class used existing teaching materials at school.

Tests were given before and after the lesson. Pre-test and post-test result were analyzed using the N-Gain formula to see the effectiveness of modules in improving higher order thinking skills. The N-gain formula is shown in the Equation 2.

$$\mathrm{N-Gain} = \frac{\text{Posttest score} - \text{Pretest score}}{\text{Max score} - \text{Pretest score}} \quad (2)$$

Based on the results obtained, the categories can be grouped based on Table 1.

Table 1. Interpretation of N-Gain

N-Gain score	Category
< 40	Ineffective
40-55	Less effective
56-75	Moderately effective
>76	Effective

Result and Discussion

This study developed a PBL-MR-based module on the topic of acid-base using the Thiagarajan model, which consists of four stages, namely:

Define stage

In the defining stage, teacher needs analysis was conducted to reveal the teacher's needs for the availability of science learning modules. In addition, the teacher needs analysis revealed the implementation of science learning, especially the implementation of problem based learning-multiple representation. The results of the teacher needs analysis are presented in Table 2.

The needs analysis was not only conducted on teachers, but also on students. Just like the teacher's needs analysis, students were also given a questionnaire to reveal the problems experienced by students during the science learning process. In addition, unstructured interviews were also conducted with some students.

Table 2. Teacher Needs Analysis Results

Question indicator	%
There are difficulties in delivering acid-base material	66.7
Application of problem-based learning	33.3
Application of learning with various representations	0
Providing HOTS questions on acid-base material	0
The need for learning resources that can improve students' HOTS	100

The results of the student needs analysis are presented in Table 3. The next step is to analyze the tasks that have been carried out by analyzing the questions given by the teacher. The results of the analysis show that the types of assessment instruments used by chemistry teachers include multiple choice questions with five distractors, and short form/essay. The Bloom's Taxonomy cognitive domain that can be seen from the daily test questions made by the teacher is at the C1-C3 level.

Continued with the analysis of the chemistry material chosen for the development of HOTS questions is acid-base. The selection of this material is based on the low student learning outcomes at SMAN 1 Ngemplak on acid-base material. Pebrianti et al. (2024) explained that acid and base materials are conceptually dense and require integration of understanding from many areas of introductory chemistry. In addition, the acid-base concept emphasizes two components, namely algorithmic and conceptual. Algorithmic is found in determining the concentration of acid-base solutions, pH or pOH, finding Ka and Kb, and percent ionization. Conceptual includes an explanation of various acid-base phenomena in life. The acid-base learning process should be contextual, creative, and critical to explore deeper knowledge. However, in its implementation, students are less involved in building higher-order thinking skills (Ningsih & Kamaludin, 2023).

Table 3. Student Needs Analysis Results

Question indicator	%
There are limitations in the textbooks provided by the school	66.7
There are difficulties in understanding the topic of acid-base with the chemistry book used and the method applied by the teacher	33.3
Application of problem-based learning	100
The need for learning resources that help students understand the concept of acid-base better	100

Design Stage

The second stage in the 4D model is design. In this design stage, a design is carried out to create a problem-based learning module with predetermined material. At this stage, the module scenario is compiled along with an attractive module design. Learning in the science module is delivered through the syntax of a problem-based learning model that contains multiple representations to improve students' HOTS. The integration of problem-based learning syntax with activities in the module can be seen in Table 4.

The module content section contains a concept map, learner outcomes as indicators, and learning activities such as table 4 which are adapted to the PBL syntax. In general, the material in this module is organized into four main sections: 1) acid-base indicators, 2) acid-base concepts, 3) Kw, pH, and pOH concepts, and 4) Acid-Base Strength. The closing part of the module consists of evaluation questions, a bibliography, a glossary, and a back cover.

Table 4. Learning Activities in Module

Syntax PBL	Activities in the module
Orienting students to the problem	Problem orientation through the presentation of phenomena in daily life
Organizing students to learn	Group formation and formulate the problems encountered in the orientation stage
Guiding individual and group investigations	Search for references to answer the formulation of problems made/ conduct experiments to answer problems
Develop and present work	Presenting the results of the discussion
Analyze and evaluate the problem solving process	Rechecking answers and summarizing the results of the discussion

Development Stage

The development stage in this study includes the results of module validation by validators. After the validation was carried out, the suggestions and input obtained were then used as guidelines for revising the initial module product.

Material expert validation

The complete material expert validation results are shown in Table 5. Based on the validator's assessment for all material components, the material validity results obtained an average Aiken V value of 0.91 with a valid category. Modules designed with feasible criteria from the aspects of content and suitability of the PBL model are beneficial for learners to build problem-solving, independent investigation, critical thinking decision-making, and active involvement of learners (Orulebaja et al., 2021; Distrik et al., 2022).

Table 5. Module Validation Results by Material Experts

Assessment aspect	Item	V	Criteria
Material Coverage	1, 2, 3	0.89	Valid
Factual Accuracy	4, 5	0.96	Valid
Current & Relevant	6, 7	0.88	Valid
Does not contain racial, intellectual property, bias, and pornographic content.	8	0.92	Valid
Training, Assignment, and Assessment as per assessment demands	9	0.92	Valid
Develops Thinking skills	10	0.91	Valid
Average		0.91	Valid

Presentation Expert Validation

The complete presentation component validation results are shown in Table 6.

Table 6. Module Validation Results by Presentation Experts

Assessment aspect	Item	V	Criteria
Presentation technique	1, 2, 3, 4	0.88	Valid
Supporting material presentation	5, 6, 7, 8	0.90	Valid
Presentation of learning	9, 10, 11	0.88	Valid
Completeness of presentation	12, 13, 14	0.88	Valid
Average		0.88	Valid

Based on the validator's assessment for all presentation components in the module that has been developed, the results of the validity of the presentation obtained an average Aiken's V value of 0.88 with a valid category. The results of expert validation on the presentation component show that the acid-base science module has been well presented to meet the feasibility of support, technique, and completeness of presentation (Arigiyati et al., 2019).

Linguist Expert Validation

The complete language component validation results are shown in Table 7. Based on the validator's assessment for all language components, the results of language validity obtained an average Aiken's V value of 0.92 with a valid category. This shows that the problem-based learning-multiple representation-based science module on the topic of acid-base developed has been following the rules of good and correct Indonesian language, straightforward, coherent thinking flow, dialogical and interactive, designed following the students' level of development (Rahayu et al., 2023).

Table 7. Module Validation Results by Language Experts

Assessment aspect	Item	V	Criteria
Readability	1, 2, 3, 4	0.84	Valid
Straightforward	5, 6, 7	0.91	Valid
Coherent flow of thought	8	0.81	Valid
Dialogical & interactive	9, 10	1	Valid
Appropriateness to learner development	11, 12	0.90	Valid
Appropriateness with language rules	13, 14, 15, 16	0.96	Valid
Consistency in the use of terms	17	1	Valid
Average		0.92	Valid

Graphic Expert Validation

The complete presentation component validation results are shown in Table 8. Based on the validator's assessment for all components of the graphics presentation on the module that has been developed, the results of the validity of graphics obtained an average Aiken's V value of 0.88 with a valid category. This shows that the problem-based learning-multiple representation-based science module on the topic of acid-base developed has an apparent font size, cover display, and overall attractive module content (Kautsari et al., 2023).

Table 8. Module Validation Results by Graphic Experts

Assessment aspect	Items	V	Criteria
Module size	1, 2	0.94	Valid
Module cover design	3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16 ,17, 18	0.84	Valid
Module content design	19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47	0.85	Valid
Average		0.88	Valid

The recapitulation results of the module validation on the four aspects by the validator can be seen in Table 9. Based on the assessment of all validators on the four aspects of the assessment, the average value of Aiken V value is 0.89 with valid criteria, so the developed module is declared valid and suitable for use as a learning resource. The feasibility test of material, presentation, language, and graphics is an essential part of the development of teaching materials because it can help and facilitate students in understanding teaching materials (Pramudiyanti et al., 2023).

Table 9. Module Validity Result

Component	V	Criteria
Material	0.91	Valid
Presentation	0.88	Valid
Language	0.92	Valid
Graphics	0.88	Valid
Average	0.89	Valid

In addition to validating the module with an assessment score, the validator also provided comments and suggestions for improving the draft module. Revisions made to the draft module are in the form of repairing low-resolution images that look broken, typing errors, ineffective sentence structure, and adding image captions.

Next, small group trials were conducted with six students. This small group trial used a readability questionnaire. The results of the small group trial analysis can be seen in Table 10.

Table 10. Results of the Small Group Trial Analysis

Component	% Average	Criteria
Attractiveness	79.3	Feasible
Readability	76.7	Feasible
Display	79	Feasible

The small group trial was conducted on the module by six students who had different ability levels, namely high, medium, and low ability levels. There were three aspects carried out in the small group readability test, namely the attractiveness aspect, the readability aspect, and the display aspect with an average score of 79.3 with a good category. This means that the material presented in the module is presented in an interesting way and can increase students' interest in learning (Damayanti & Perdana, 2023).

In the readability aspect, the average score is 76.7 with a good category. This shows that the module can be read clearly and easily understood by students (Lafifa et al., 2023). In the display aspect, the average score is 0.79 with a good category. This shows that the selection of images, tables, and colors in the module is appropriate (Aldilla & Usmeldi, 2024).

The Desseminate Stage

The goal of the module is to improve students' higher thinking skills. A higher-order thinking skills test with eight analytical questions is given to evaluate critical thinking and four essay questions to evaluate problem solving. Test were given to the experimental and control groups both before (pre-test) and after (post-test) the lesson.

With a maximum score of 54, the pre-test scores for the two courses were comparable: 36 for the experimental class and 36 for the control class. The average score for the experimental class was 40, while the average score for the control class was 35. With a maximum score of 92, the experimental and control class post-test outcomes were 78 and 71, respectively.

The post-test socre is significantly higher than the pre-test score. This happens because Students typically receive instruction or training that greatly expands their knowledge and abilities. Research indicates, for instance, that gamified learning interventions can raise student motivation and academic accomplishment, both of which are correlated with improved post-test results (Stratton, 2019).

To determine the effectiveness, the N-Gain formula was used. From the N-Gain analysis, the results obtained were 0.63 for the experimental class which was included in the moderately effective category and 0.55 for the control class which was included in the less effective category. Students who used the problem-based learning module-multiple representations on acid-base material had a greater N-Gain percentage compared to students who did not use the module (Putri et al., 2024). Table 11 displays the N-Gain analysis's findings.

Table 11. N Gain Analysis Result

Class	N-Gain	Criteria
Experiment	0.63	Moderately effective
Control	0.55	Less effective

Students' use of instructional resources created especially for problem based learning is credited with this efficacy. Students that participate in problem-based learning must work together with other students to solve challenges, which can improve their higher order thinking skills (Taufiqurrahman et al., 2025).

This final stage also involved disseminate the module to 3 chemistry teachers. The scores given by the teachers at this stage are presented in Table 12.

Table 12. Teachers' Responses to Module Feasibility

Component	% Average	Criteria
Self-instruction	79	Feasible
Self-contained	80	Feasible
Stand alone	80	Feasible
Adaptive	73	Feasible
User friendly	87	Feasible
Average	79.8	Feasible

Based on the teacher's response to the five aspects of the assessment, an average percentage of 79.8 was obtained with a decent category. This shows that the developed module meets the eligibility criteria for learning resources. A decent module must meet the criteria of self-instruction, self contained, stand alone, adaptive, and (5) user friendly (Herdiana et al., 2022).

Conclusion

A problem based learning-multiple representation (PBL-MR) science module has been developed to improve higher order level thinking skills in acid-base material with a 4D development model, where this model consists of the stages of define, design, develop, and disseminate. The designed problem-based learning-multiple representation module has been proven valid, feasible, and successful in improving students' high order thinking skills, according to research that has been conducted. Science learning using a PBL-MR science module on acid-base material can be used as a reference for further research.

Acknowledgments

The authors would like to thank the supervisors, validators, chemistry teachers and students of class XII IPA SMA Negeri 1 Ngemplak who have helped in this research.

Author Contributions

Conceptualization, S.S., S. B. R., B.S.; methodology, S.S.; validation, S. B. R. and B.S.; formal analysis, S.S., S. B. R, B.S.; investigation, S.S.; resources, S.S., S. B. R., B.S.; data curation, S.S., S. B. R., B.S.: writing—original draft preparation, S.S.; writing—review and editing, S. B. R., B.S.; visualization, S.S., S. B. R., B.S. All authors have read and agreed to the published version of the manuscript.

Funding

This research received no external funding.

Conflicts of Interest

The authors reported no potential conflict of interest.

References

Affandy, H., Sunarno, W., Suryana, R., & Harjana. (2024). Integrating Creative Pedagogy into Problem-Based Learning: The Effects on Higher Order Thinking Skills in Science Education. *Thinking Skills and Creativity*, *53*, 1–17. https://doi.org/10.1016/j.tsc.2024.101575

Ahmad, S., Prahmana, R. C., Kenedi, A., Helsa, Y., Arianil, Y., & Zainil, M. (2018). The instruments of higher order thinking skills. *Journal of Physics: Conference Series*, *943*(1), 1–8. https://doi.org/10.1088/1742-6596/943/1/012053

Aiken, L. R. (1985). Three coefficients for analyzing the reliability and validity of ratings, educational and psychological measurument. *Educational and Psychological Measurement*, *45*(1), 131–142. https://doi.org/10.1177/0013164485451012

Aldilla, E., & Usmeldi. (2024). Validity and Practicality of the Physics E-Module Based on the Orientation, Identify, Discussion, Decision, and Engage in Behavior Model to Improve Students' 21st Century Skills. *Jurnal Penelitian Pendidikan IPA*, *10*(8), 5768–5774. https://doi.org/10.29303/jppipa.v10i8.7719

Alighiri, D., Drastisianti, A., & Susilaningsih, E. (2018). Pemahaman Konsep Siswa Materi Larutan Penyangga Dalam Pembelajaran Multiple Representasi. *Jurnal Inovasi Pendidikan Kimia*, *12*(2), 2192–2200. https://doi.org/10.24815/jpsi.v6i1.10745

Arafah, K., Amin, B. D., Sari, S. S., & Hakim, A. (2021). The Development of Higher Order-Thinking Skills (HOTS) Instrument Assessment in Physics Study. *Journal of Physics: Conference Series*, *1899*(1), 1–8. https://doi.org/10.1088/1742-6596/1899/1/012140

Arigiyati, T. A., Kusmanto, B., & Widodo, S. A. (2019). Validasi Instrumen Modul Komputasi Matematika. *Jurnal Riset Pendidikan Dan Inovasi Pembelajaran Matematika (JRPIPM)*, *2*(1), 23–29. https://doi.org/10.26740/jrpipm.v2n1.p023-029

Boeren, E., & Íñiguez-Berrozpe, T. (2022). Unpacking PIAAC's Cognitive Skills Measurements Through Engagement with Bloom's Taxonomy. *Studies in Educational Evaluation*, *73*(101151), 1–9. https://doi.org/10.1016/j.stueduc.2022.101151

Bulut, A. C., & Aktamis, H. (2024). Investigating the Effects of Creative Educational Modules Blended with Cognitive Research Trust (CoRT) Techniques and Problem Based Learning (PBL) on Students' Scientific Creativity Skills and Perceptions in Science Education. *Thinking Skills and Creativity*, *51*(101471), 1–22. https://doi.org/10.1016/j.tsc.2024.101471

Damayanti, D. S., & Perdana, P. I. (2023). Pengembangan E-Modul Pembelajaran Tematik (EMOTIK) Berbasis Flipbook pada Tema 8 Subtema 1 Kelas V di Sekolah Dasar. *Jurnal Basicedu*, *7*(5), 2886–2897. https://doi.org/10.31004/basicedu.v7i5.5932

Distrik, I. W., Setiawan, W., & Ertikanto, C. (2022). Building Physics Concept Understanding and Problem-Solving Ability in Online Learning Through Concept Attainment Model. *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, *11*(1), 141–150. https://doi.org/10.24042/jipfalbiruni.v11i1.11775

Hasbullah, H., Halim, A., & Yusrizal, Y. (2019). Penerapan Pendekatan Multi Representasi Terhadap Pemahaman Konsep Gerak Lurus. *Jurnal IPA & Pembelajaran IPA*, *2*(2), 69–74. https://doi.org/10.24815/jipi.v2i2.11621

Helsy, I., Maryamah, Farida, I., & Ramdhani, M. A. (2017). Volta-Based Cells Materials Chemical Multiple Representation to Improve Ability of Student Representation. *Journal of Physics: Conference Series*, *895*(1), 1–5. https://doi.org/10.1088/1742-6596/895/1/012010

Herdiana, L. E., Sunarno, W., & Indrowati, M. (2022). Feasibility of Inquiry-Based Science E-Module Guided by Material Interaction of Living Beings with Environmental Learning Resources to Improve Science Literacy. *Jurnal Penelitian Pendidikan IPA*, *8*(6), 2697–2704. https://doi.org/10.29303/jppipa.v8i6.2023

Hidajat, F. A. (2023). A Comparison Between Problem-Based Conventional Learning and Creative Problem-Based Learning on Self-Regulation Skills: Experimental Study. *Heliyon*, *9*(9), 1–12. https://doi.org/10.1016/j.heliyon.2023.e19512

Jamaluddin, J., Andayani, Y., & Purwoko, A. A. (2019). Pelatihan Penyusunan Instrumen Keterampilan Berpikir Tingkat Tinggi Bagi Pendidik Mata Pelajaran IPA SMP Di Kota Mataram. *Jurnal Pengabdian Magister Pendidikan IPA*, *1*(1), 79–85. https://doi.org/10.29303/jpmpi.v1i1.223

Jansen, T., & Möller, J. (2022). Teacher Judgments in School Exams: Influences Of Students' Lower-Order-Thinking Skills on The Assessment of Students' Higher-Order-Thinking Skills. *Teaching and Teacher Education*, *111*(103616), 1–10. https://doi.org/10.1016/j.tate.2021.103616

Jihannita, J., Prasetyo, Z. K., & Wilujeng, I. (2023). How to Prepare HOTS to Face the 21st Century? *Jurnal Penelitian Pendidikan IPA*, *9*(8), 486–492. https://doi.org/10.29303/jppipa.v9i8.2847

Jusniar, Sakinah, Z., & Sentot, K. (2024). Effectiveness of Problem-Based Learning to Improve Critical Thinking Ability of Chemistry Students on Acid-Base Material. *Jurnal Penelitian Pendidikan IPA*, *10*(9), 6464–6472. https://doi.org/10.29303/jppipa.v10i9.8434

Kapici, H. O. (2023). From Symbolic Representation to Submicroscopic One: Preservice Science Teachers' Struggle with Chemical Representation Levels in Chemistry. *International Journal of Research in Education and Science*, *9*(1), 134–147. https://doi.org/10.46328/ijres.3122

Kautsari, M., Hairida, H., Masriani, M., Rasmawan, R., & Ulfah, M. (2023). Pengembangan E-Modul Berbasis Problem Based Learning pada Materi Zat Adiktif. *Edukatif : Jurnal Ilmu Pendidikan*, *4*(6), 8116–

8130. https://doi.org/10.31004/edukatif.v4i6.3850

Kusumawardani, W., & Aminatun, T. (2024). PBL in Blended Learning Design to Increase Critical Thinking and Problem-Solving Skills. *Jurnal Penelitian Pendidikan IPA*, *10*(6), 3303–3308. https://doi.org/10.29303/jppipa.v10i6.7052

Kwangmuang, P., Jarutkamolpong, S., Sangboonraung, W., & Daungtod, S. (2021). The Development of Learning Innovation to Enhance Higher Order Thinking Skills for Students in Thailand Junior High Schools. *Heliyon*, *7*(6), 1–13. https://doi.org/10.1016/j.heliyon.2021.e07309

Lafifa, F., Rosana, D., Jumadi, J., Suyanta, S., Nurohman, S., & Astuti, S. R. D. (2023). Effect of Using Interactive Electronic Module with Contextual Approach on Students Learning Motivation on Conductor and Insulator Materials. *Jurnal Penelitian Pendidikan IPA*, *9*(9), 6734–6741. https://doi.org/10.29303/jppipa.v9i9.3354

Mayasari, T., Kadarohman, A., Rusdiana, D., & Kaniawati, I. (2016). Apakah Model Pembelajaran Problem Based Learning Dan Project Based Learning Mampu Melatihkan Keterampilan Abad 21? *Jurnal Pendidikan Fisika Dan Keilmuan (JPFK)*, *2*(1), 48. https://doi.org/10.25273/jpfk.v2i1.24

Meutia, F., Nurdin, N., & Winarni, S. (2021). Development of e-Student Worksheets Based on Multiple Representations of Factors Affecting Reaction Rates. *Jurnal Penelitian Pendidikan IPA*, *7*(2), 129–136. https://doi.org/10.29303/jppipa.v7i2.533

Ningsih, N. R., & Kamaludin, A. (2023). Development of Higher Order Thinking Skills-Based Assessment Instrument on Acid-Base Materials in High School. *Jurnal Penelitian Pendidikan IPA*, *9*(1), 13–19. https://doi.org/10.29303/jppipa.v9i1.1457

OECD. (2022). PISA 2022 Results (Volume III): Creative Minds, Creative Schools, PISA. *Factsheets*, *I*, 1–9. Retrieved from https://www.oecd-ilibrary.org/education/pisa-2022-results-volume-i_53f23881-en%0Ahttps://www.oecd.org/publication/pisa-2022-results/country-notes/germany-1a2cf137/

Orulebaja, Y. T., Owolabi, O. L., & Akintoye, H. (2021). Effects of Multiple representations and Problem-solving learning strategies on Physics students' problem-solving abilities. *International Journal for Innovation Education and Research*, *9*(4), 350–365. https://doi.org/10.31686/ijier.vol9.iss4.3045

Pebrianti, P., Andromeda, Yerimadesi, Hardeli, & Suryani, O. (2024). Development of the Acid-Base Module Based on Problem Based Learning with Ethnochemisty to Improve Students Science Literacy Ability. *Jurnal Penelitian Pendidikan IPA*, *10*(8), 4634–4640. https://doi.org/10.29303/jppipa.v10i8.8582

Pramudiyanti, P., Pratiwi, W. O., Armansyah, A., Rohman, F., Putri, I. Y., & Ariani, D. (2023). PBL-Based Student Worksheet to Improve Critical Thinking Ability in Science Learning in Elementary Schools. *Indonesian Journal of Science and Mathematics Education*, *6*(1), 109–124. https://doi.org/10.24042/ijsme.v6i1.17187

Putri, H. S., Oktavia, B., Yerimadesi, & Alizar. (2024). Development of E-Module Acid-Base Based on Problem Based Learning Oriented Chemo-Entrepreneurship to Improve Student's Critical Thinking Skills. *Jurnal Penelitian Pendidikan IPA*, *10*(7), 4033–4039. https://doi.org/10.29303/jppipa.v10i7.7943

Rahayu, M., Aima, Z., & Juwita, R. (2023). Validitas E-Modul Berbasis Android Menggunakan Sigil Software pada Materi Peluang. *Plusminus: Jurnal Pendidikan Matematika*, *3*(2), 265–276. https://doi.org/10.31980/plusminus.v3i2.1342

Rizal, D. A. P., & Aini, F. Q. (2023). Development of an assessment instrument to evaluate the concepts of chemical equilibrium at macroscopic, sub-microscopic, and symbolic representation levels using the rasch model. *Jurnal Pijar Mipa*, *18*(2), 208–218. https://doi.org/10.29303/jpm.v18i2.4720

Safitri, N. C., Nursaadah, E., & Wijayanti, I. E. (2019). Analisis Multipel Representasi Kimia Siswa pada Konsep Laju Reaksi. *EduChemia (Jurnal Kimia Dan Pendidikan)*, *4*(1), 1. https://doi.org/10.30870/educhemia.v4i1.5023

Stratton, S. J. (2019). Quasi-Experimental Design (Pre-Test and Post-Test Studies) in Prehospital and Disaster Research. *Prehospital and Disaster Medicine*, *34*(6), 573–574. https://doi.org/10.1017/S1049023X19005053

Sundaygara, C., & Gaharin, D. (2017). Pengaruh Multiple Representation pada Pembelajaran Berbasis Masalah Terhadap Penguasaan Konsep Fisika Dasar II Mahasiswa Fisika. *Momentum: Physics Education Journal*, *1*(2), 111. https://doi.org/10.21067/mpej.v1i2.1863

Taufiqurrahman, Fathonah, S., Ahmadi, F., Arsyad, A. A., & Rahman, S. (2025). Problem-Based Learning Model Assisted by Interactive Media to Improve Students Higher Order Thinking Skills (HOTS). *Jurnal Penelitian Pendidikan IPA*, *11*(1), 1234–1243. https://doi.org/10.29303/jppipa.v11i1.6649

Wan Husin, W. N. F., Mohamad Arsad, N., Othman, O., Halim, L., Rasul, M. S., Osman, K., & Iksan, Z. (2016). Fostering Students' 21st Century Skills Through Project Oriented Problem Based Learning

(POPBL) in Integrated Stem Education Program. *Asia-Pacific Forum on Science Learning and Teaching*, *17*(1), 1–19. https://doi.org/10.1016/j.chb.2016.05.038

Wu, T. T., Sari, N. A. R. M., & Huang, Y. M. (2024). Integrating Extended Formative Assessment in Flipped Jigsaw Learning: Promoting Learning Engagement and Higher-Order Thinking Skills in International Business Education Context. *International Journal of Management Education*, *22*(1), 1–14. https://doi.org/10.1016/j.ijme.2024.100930