HYDROGEN
JURNAL KEPENDIDIKAN KIMIA
https://e-journal.undikma.ac.id/index.php/hydrogen/index

August 2026, 14(4)
e-ISSN: 2656-3061
p-ISSN: 2338-6487
pp. 864-872

Development of a Process-Oriented Guided Inquiry Learning (POGIL)- Based Learning Module on Buffer Solutions for Grade XI Senior High School Students

Adilla Putri Ramadhani & Elvy Rahmi Mawarnis*
Department of Chemistry Education, Faculty of Tarbiyah and Teacher Training, Mahmud Yunus State Islamic University Batusangkar, Jl. Jendral Sudirman No. 137, Sumatera Barat, Indonesia
*Corresponding Author e-mail: elvyrahmimawarnis@gmail.com

Article History
Received: 30-06-2026
Revised: 09-08-2026
Published: 31-08-2026

Keywords: Buffer Solution Learning; Module; 4-D; POGIL; Chemistry Education.

Abstract
This study developed a Process-Oriented Guided Inquiry Learning (POGIL)-based printed learning module on buffer solutions for Grade XI senior high school students. The novelty of this study lies in the development of a printed self-instructional POGIL-based module on buffer solutions. This study employed a Research and Development (R&D) approach using the 4-D development model (Define, Design, Develop, and limited Dissemination). Data were collected through expert validation and practicality testing involving Grade XI students and a chemistry teacher. The validation results indicated that the module achieved a material validity score of 83% (Highly valid), a language validity score of 100% (Highly valid), and a construction/graphical validity score of 76% (valid). The practicality test conducted with students yielded a score of 84%, indicating that the module was very practical. In addition, interviews with the chemistry teacher confirmed that the module was practical and efficient for classroom implementation. These findings indicate that the developed module is valid, practical, and suitable for use as an instructional material to support both classroom learning and students' independent learning.

How to Cite: Ramadhani, A. P., & Mawarnis, E. R. (2026). Development of a Process-Oriented Guided Inquiry Learning (POGIL)- Based Learning Module on Buffer Solutions for Grade XI Senior High School Students. *Hydrogen: Jurnal Kependidikan Kimia*, *14*(4), 864-872. https://doi.org/10.33394/hjkk.v14i4.21598

https://doi.org/10.33394/hjkk.v14i4.21598

This is an open-access article under the CC-BY-SA License.

INTRODUCTION

Chemistry is one of the essential subjects in education because it helps develop students' thinking abilities and creativity. However, many students still encounter difficulties in learning chemistry. This is because many chemical concepts are abstract and complex, requiring a deep understanding for students to master them effectively (Priliyanti et al., 2021). This situation leads some students to experience difficulties in comprehending chemical concepts and connecting them to phenomena observed in everyday life.

The success of the learning process is supported by the availability of instructional materials that are aligned with students' characteristics and learning objectives. Instructional materials are systematically organized learning resources, including information, tools, and texts, designed to help students achieve the expected competencies and support the implementation of the learning process (Dafit & Mustika, 2021). According to research conducted by Manurung et al., (2023), instructional materials are designed to achieve the expected goals, namely the comprehensive mastery of competencies or subcompetencies. For educators and students, instructional materials play a crucial role as a guide in achieving the established learning objectives.

According to Erna, maria & Aminullah, (2020), chemistry concepts are generally abstract and therefore require appropriate instructional materials to facilitate students' understanding. However, classroom instruction still relies heavily on textbooks as the primary learning resource. Although some schools have implemented

Copyright ©Authors

internet-based practice exercises, their utilization remains limited due to the insufficient availability of supporting devices. Moreover, these exercises generally consist only of assignments and problem-solving activities without incorporating interactive learning experiences. As a result, the delivery of abstract chemistry concepts has not been optimized, since not all students possess the same ability to comprehend material presented in printed textbooks, particularly those with low reading motivation. This finding is consistent with the study by Safitri & Sari, (2022), which reported that the use of textbooks as the primary learning resource tends to reduce students' interest in learning because the materials are presented in a monotonous manner and are relatively difficult to understand. Furthermore, textbooks are less effective for independent learning, as students still require direct explanations from teachers to fully understand the learning content.

The problems described above are consistent with those identified through interviews and classroom observations conducted at one senior high school. The findings revealed that students experience difficulties in understanding abstract chemistry concepts and often give up when faced with complex chemistry problems. Classroom instruction remains predominantly teacher-centered, with the learning process relying heavily on textbooks as the primary instructional resource. Although the textbooks used are aligned with the Merdeka Curriculum, students still struggle to understand abstract concepts because the materials are presented in a less engaging manner and are supported by limited illustrations. Interviews with chemistry teachers further indicated that students frequently encounter difficulties in solving complex chemistry problems, as reflected in their daily assessment scores, which have not yet met the Learning Objective Achievement Criteria (KKTP).

Based on these conditions, one potential solution to address these challenges is the use of learning modules. A learning module is an instructional material designed to support students' independent learning (*self-instructional*). Well-designed modules can promote active student engagement and facilitate a deeper understanding of chemistry concepts (Ramadani et al., 2020). According to Famulaqih & Lukman, (2024), demonstrated that learning modules enable students to read, understand, and explore knowledge independently. Therefore, the development of self-instructional learning modules represents a relevant approach to supporting contemporary learning, particularly in situations where interaction between teachers and students is limited.

One learning model that can be integrated into instructional modules is Process-Oriented Guided Inquiry Learning (POGIL). This model combines guided inquiry and cooperative learning, placing students at the center of the learning process (V. W. Putri & Gazali, 2021). The characteristics and learning stages of the POGIL model enable students to actively construct knowledge independently. This model also enhances critical thinking, conceptual understanding, and problem-solving skills, while the teacher acts as a facilitator and mediator throughout the learning process. The implementation of the POGIL model guides students in a more structured way in solving problems, thereby enhancing their understanding of the concepts being learned (Sari et al., 2020).

The topic selected by the researcher in the development of this instructional module is buffer solutions. Buffer solutions are one of the topics in chemistry that are considered abstract. This concept involves abstract aspects of acid–base reactions, the understanding of buffer solutions, pH calculation, and applied aspects related to the function of buffer solutions in everyday lifeNevertheless, students' understanding of the buffer solution concept remains limited. Despite this, buffer solutions are a fundamental concept that serves as the basis for learning other topics in chemistry. Difficulties in understanding this basic material may affect students' mastery of subsequent concepts (Awwalin & Nugroho, 2024).

Previous studies have demonstrated that Process-Oriented Guided Inquiry Learning (POGIL)-based electronic modules (e-modules) are effective in improving students' conceptual understanding and higher-order thinking skills. In addition, these e-modules can serve as valuable resources for independent learning (Cahyaningrum et al., 2017; Simangunsong & Purba, 2025). However, most previous studies have focused on the development of digital instructional materials in the form of e-modules, while limited attention has been given to the

development of printed self-instructional modules that fully integrate the POGIL learning cycle, particularly on the topic of buffer solutions. Therefore, the development of a printed POGIL-based module remains relevant and necessary to support students' independent learning across diverse educational contexts.

Based on the foregoing discussion, this study aims to evaluate the validity and practicality of a Process-Oriented Guided Inquiry Learning (POGIL)-based learning module on the topic of buffer solutions. Unlike previous studies, which have predominantly focused on developing POGIL-based e-modules for various chemistry topics, the module developed in this study is a printed self-instructional module specifically designed to facilitate independent learning through structured inquiry activities that fully integrate the POGIL learning cycle. The module is expected to serve as an effective alternative instructional material for schools where printed learning resources remain the primary source of instruction, enabling students to construct their own understanding of concepts with reduced dependence on direct teacher guidance.

METHOD

This study employed a Research and Development (R&D) approach to develop a Process-Oriented Guided Inquiry Learning (POGIL)-based learning module on the topic of buffer solutions for senior high school students using the 4-D development model, which includes the *Define*, *Design*, *Develop*, and *Limited Dissemination* stages. The research was conducted at SMAN 1 Batusangkar and involved 35 Grade XI.F.4 students and one chemistry teacher. Participants were recruited through purposive sampling based on the relevance of the buffer solution topic and the chemistry teacher's recommendation.

Product validation was carried out by three expert validators consisting of a content expert, who was a Chemistry Education lecturer; a language expert, who was an Indonesian Language Education lecturer; and a media expert, who was a Chemistry Education lecturer. The research instruments consisted of expert validation sheets, student response questionnaires, and a teacher interview guide. The validation sheets and questionnaires used a four-point Likert scale ranging from strongly disagree to strongly agree. The validation assessed three aspects: content appropriateness, language, and graphical/construction quality. Meanwhile, the student response questionnaire assessed ease of use, time efficiency, and benefits.

Define Stage

The define stage was the initial phase of this study, aimed at analyzing the main problems and learning needs in chemistry instruction. This stage involved classroom observations and interviews with a chemistry teacher at SMAN 1 Batusangkar. The analysis was conducted in several stages, namely front-end analysis to determine the learning conditions in the school as well as the needs of teachers and students in the learning process, followed by material analysis, and learning objective analysis.

Design Stage

This design phase involves planning the product to be developed. The objective is to create a preliminary design for the product. This phase includes designing learning modules, starting with the selection of instructional materials and formats, and creating a preliminary design. In addition, this stage also involves designing research instruments, which consist of a learning module validation sheet, a validity instrument validation test sheet, a practicality response questionnaire, and a practicality questionnaire validation test sheet for the learning module.

Develop Stage

The develop stage was conducted to evaluate the validity and practicality of the developed learning module. At this stage, the module was revised based on the validators' feedback to ensure its quality and suitability for classroom use. The evaluation was carried out by four experts covering three aspects: content appropriateness, language, and graphical design. The evaluation results served as the basis for revising and improving the module. Afterward, a limited field trial was conducted to assess the practicality of the learning modules. The trial involved students in Class XI.F.4 at SMAN 1 Batusangkar. Data on practicality was collected through student response questionnaires and supplemented by interviews with teachers. This practicality assessment covered ease of use, time efficiency, and benefits.

Limited Disseminate Stage

The limited dissemination stage involved the

limited distribution of the revised learning module. The module was provided to chemistry teachers and students at SMAN 1 Batusangkar as instructional material for the buffer solution topic. This stage was conducted only within the research setting to evaluate the module's usefulness and suitability before broader implementation.

Data Collection and Analysis

Data were collected through expert validation sheets, student response questionnaires, and interviews with a chemistry teacher. The quantitative data were analyzed to determine the validity and practicality of the module, while the qualitative data obtained from the validators' feedback and teacher interviews were analyzed descriptively to support the interpretation of the findings and the refinement of the developed product. The percentage was calculated using the following formula:

$$\text{Percentage} = \frac{\Sigma \text{ score of each item}}{\text{max score of each item}} \times 100\%$$

Table 1 Summerizes the Data Collection Instruments and Analysis Techniques Applied in This Study

Score Interval	Criteria
< 20%	Not valid/practical
21-20%	Less valid/ practical
41-60%	Fairly valid/practical
61-80%	Valid/practical
81-100%	Highly valid/practical

Source: (Mufida et al., 2022)

RESULTS AND DISCUSSION

Define Stage

The front-end analysis revealed that chemistry instruction at the research school was still largely teacher-centered. The learning process was dominated by lectures, note-taking, problem-solving exercises, and whiteboard-based explanations. These findings indicate that the learning process has not yet encouraged active student participation or fostered the critical, collaborative, and creative thinking skills required for 21st-century learning. As a result, the teacher remains the central figure in the classroom, while students tend to receive information passively rather than actively engaging in the learning process (Mutaqin et al., 2025).

The analysis of instructional materials further showed that the textbooks used in class had not fully supported students' learning needs. Although the textbooks were aligned with the curriculum, their monotonous presentation and relatively complex language made them less engaging and less effective for independent learning. As a result, students still relied heavily on teacher explanations to understand chemistry concepts. This finding supports the results reported by Cahyaningrum et al., (2017), who stated that effective instructional materials should be systematically designed and presented in an engaging manner to better support the learning process. Systematically designed teaching materials help students learn the content in a gradual and organized manner, making it easier for them to achieve the expected competencies.

These findings highlight the need to develop a learning module that promotes independent learning, encourages active student engagement, and enhances students' understanding of chemistry concepts. Therefore, the results of the define stage became the basis for developing a POGIL-based learning module on buffer solution material.

Design Stage

The second stage is the learning module. This stage included the selection of instructional materials, format development, preparation of the initial module draft, and the development of research instruments, including validation sheets and practicality questionnaires. The POGIL-based learning module was designed in accordance with the Learning Outcomes (*Capaian Pembelajaran* / CP) and Learning Objectives (*Tujuan Pembelajaran* / TP) specified in the Merdeka Curriculum, ensuring that its content and learning activities were aligned with curriculum requirements. The topic selected for this module was buffer solutions, as it requires conceptual understanding and problem-solving processes that are well suited to the characteristics of the Process Oriented Guided Inquiry Learning (POGIL) approach. This finding is consistent with Famulaqih & Lukman, (2024), who reported that learning modules can facilitate students in reading, understanding, and independently exploring knowledge.

Furthermore, the module was structured into several main components, namely an introduction, instructions for use, learning outcomes, learning objectives, concept maps, POGIL-based learning activities, evaluation tasks, a glossary, and references. This structure reflects the concept of a learning module as a comprehensive instructional unit consisting of a systematic

sequence of learning activities designed to help students achieve the intended learning objectives (Famulaqih & Lukman, 2024).

The learning module was designed using Canva. This initial design represented the preliminary version of the product prior to the validation and revision stages. The initial design of the developed module is presented below.

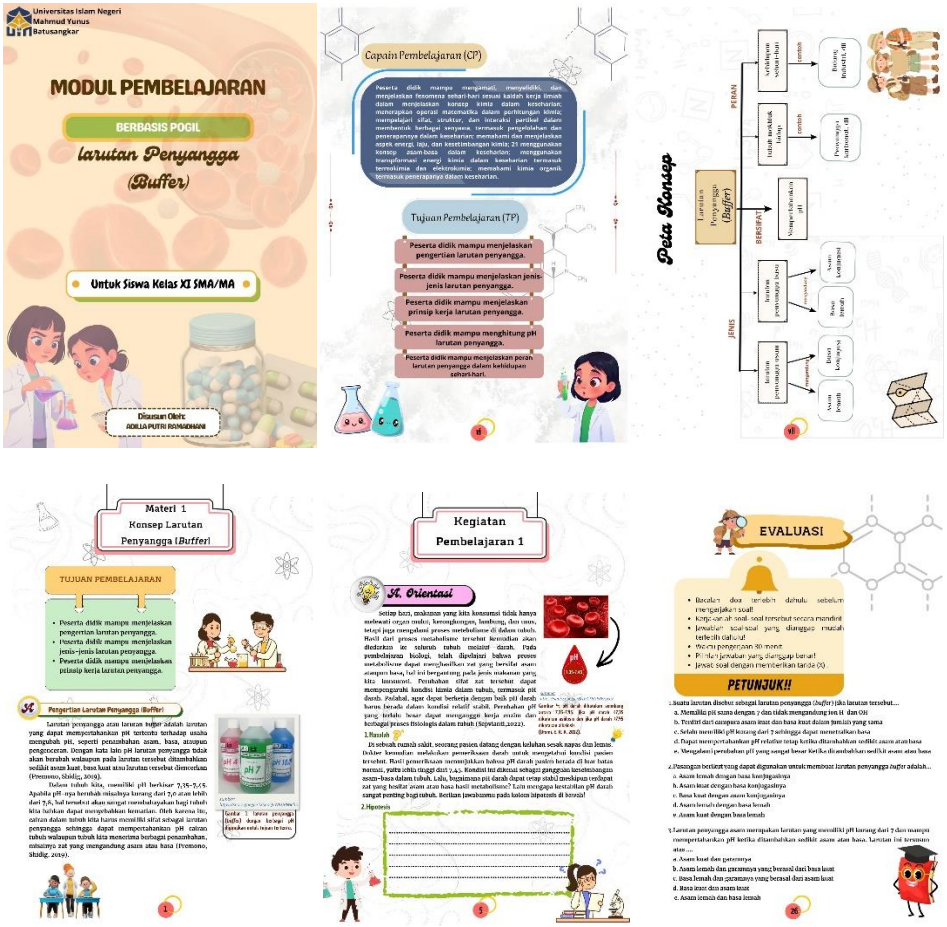


Figure 1 Design of a Learning Module based on Process Oriented Guided Inquiry Learning (POGIL) on The Topic of Buffer Solutions

Figure 1 presents the Process-Oriented Guided Inquiry Learning (POGIL)-based learning module on buffer solutions developed through the define and design stages. The module was designed as a self-instructional learning material to help students independently discover and understand the concepts of buffer solutions.

Develop Stage

Validation Stage

The validity of the developed learning module was evaluated by three expert validators who assessed the aspects of content, language, and construction/graphics. The validation results indicated that the developed learning module met the validity criteria across all assessed aspects, demonstrating its suitability for use in the learning process. A summary of the validation results for the Process-Oriented Guided Inquiry Learning (POGIL)-based learning module on buf-fer solutions is presented in Table 2.

Table 2 Results of validation the Process Oriented Guided Inquiry Learning (POGIL)-based learning module on buffer solution material

Validation Aspects	Score	Criteria
Aspects of content	83%	Highly valid
Aspects of language	100%	Highly valid
Aspects of construction/ graphics	76%	Valid
Total	86%	Highly valid

The results of the material validation indicated that the content appropriateness aspect of the learning module achieved a score of 83%, which was categorized as highly valid. This indicates that the Process Oriented Guided Inquiry Learning (POGIL)-based learning module on buffer solution material fulfilled all indicators of content feasibility and presentation feasibility. In addition the module content was systematically organized according to the learning phases of the

Process-Oriented Guided Inquiry Learning (POGIL) model. A good learning module is one that is aligned with the curriculum, including the appropriateness of the material, the suitability of the developed content with the characteristics and developmental level of senior high school students, and its relevance to students' learning needs. The instructional materials should also be supported by accurate facts, concepts, and principles relevant to the topic (Azhari et al., 2024).

The language validation results indicated that the language appropriateness aspect achieved a score of 100%, which was categorized as highly valid. The findings indicate that the developed learning module met all the criteria assessed in the language validation. These criteria included clarity, communicativeness, suitability for students' characteristics, and compliance with standard Indonesian language conventions. The language used in the module was grammatically appropriate and consistent with proper Indonesian usage. In addition, the information presented in the module was clear, unambiguous, and conveyed in an effective and efficient manner. The writing style of the module also adopted a conversational tone, as if directly addressing the reader, thereby creating a more familiar atmosphere and giving the impression of two-way communication (Azhari et al., 2024).

The results of the validity test for the construction/graphical feasibility aspect showed a percentage of 76%, which was categorized as valid. This indicates that the developed learning module met all indicators assessed in the construction feasibility validation, including module size, cover design, and content layout. Therefore, the module was considered to be in accordance with the standards for instructional material development and was able to enhance both readability and visual attractiveness for students. The module was designed with an appealing layout and visuals that were easy to understand. Furthermore, an appropriate visual presentation can support students' interest and motivation in learning, making them feel more comfortable and better assisted in accessing the material. The use of fonts, colors, image placement, and the presentation of information were also consistent with the principles of effective instructional design and did not create confusion for students (Amalia et al., 2025).

The overall validation score of 86% indicates that the module possesses strong content accuracy, clear language, and an appropriate graphical design. This finding answers the first research question, demonstrating that the Process Oriented Guided Inquiry Learning (POGIL)-based learning module on buffer solution material has a highly high level of validity for use in chemistry learning. This result suggests that the module is not only feasible for classroom use but also capable of supporting students' independent learning through well-structured and understandable learning activities.

Practicality Stage

The practicality evaluation of the *Process-Oriented Guided Inquiry Learning* (POGIL)-based learning module on buffer solutions involved 35 students and one chemistry teacher. Data were collected through student response questionnaires and an interview with the chemistry teacher. The practicality assessment covered ease of use, language, time efficiency, graphical design, and usefulness. A summary of the students' practicality evaluation results is presented in Table 3.

Table 3 Results of practicality the Process Oriented Guided Inquiry Learning (POGIL)-based learning module on buffer solution material

No	Practicality Aspects	Score	Criteria
1	Ease uf use	84%	Highly Practical
2	Efficiency of time	83%	Highly Practical
3	Benefits	84%	Highly Practical
	Total	84%	Highly Practical

Based on the students' practicality test, the learning module obtained a score of 84%, which was categorized as highly practical. The responses from 35 students supported this result, as they considered the module easy to use, efficient in terms of learning time, and beneficial in the learning process. The students also reported that the module helped them understand buffer solution concepts more quickly and increased their active participation in learning. This finding is in line with the study conducted by Yani & Yerimadesi, (2023), which found that modules designed with structured learning activities, images, tables, worked examples, exercises, explanatory materials, and key guiding questions

that are easy to understand can assist students in learning chemistry more effectively. The ease-of-use aspect is closely related to the clarity of the language, the suitability of the material, and the accessibility of the examples provided in the module. In addition, the time allocation in the module was considered effective and efficient because the learning materials were systematically organized according to students' learning pace. In terms of usefulness, the module was found to support students in understanding the concepts being studied, increase their learning motivation, and guide them in constructing concepts independently.

Based on the interview results with the chemistry teacher regarding the practicality of the learning module, the POGIL-based module on buffer solutions was considered practical and suitable for use in the learning process. The teacher's positive response indicates that the module can function as a practical instructional aid in classroom implementation. Because the activities are already organized according to the POGIL learning cycle and aligned with the Learning Outcomes and Learning Objectives, the teacher can focus more on facilitating discussion and guiding inquiry rather than repeatedly explaining basic concepts. This finding is consistent with Natalia, (2021), who reported that a well-developed learning module can help teachers provide clearer and more accurate explanations of the concepts being taught. The practicality of a developed product can therefore be seen from the results of its use by the intended users.

Regarding the language aspect, the chemistry teacher stated that the language used in the developed learning module was simple and easy for students to understand. The information presented in the module was also considered clear and free from ambiguity. As a result, students could study the module more easily because its linguistic components, including the form and size of the text, were sufficiently readable and did not create confusion. In terms of time efficiency, the teacher explained that the module had been designed in accordance with the allocated instructional time and that the material was presented in a focused and well-organized manner, making it more effective and practical to use. This is supported by D. S. Putri et al., (2025), who stated that learning modules allow students to learn according to their own pace, improve time efficiency, and maximize understanding of the material. From the teacher's perspective, the use of the module also helped reduce the need for repeated explanations, thereby supporting the role of the teacher as a *guide on the side* in active learning. In terms of the construction/graphical aspect, the teacher noted that the design of the module was relevant, attractive, and systematically as well as communicatively presented.

These findings are in line with Sagita et al., (2017), who stated that instructional materials serve as a guide for both teachers and students in directing learning activities. In addition, learning modules support a more structured, independent, and comprehensive learning process, thereby improving the quality of learning and students' learning outcomes. Overall, the practicality test of the Process Oriented Guided Inquiry Learning (POGIL)-based learning module obtained a score of 84% demonstrates that students were able to use the module easily and efficiently during learning activities. This finding indicates that the module's organization, instructions, and learning tasks were sufficiently clear to guide students through the POGIL learning process without excessive dependence on teacher explanation.

Disseminate Stage

In this study, the development process was carried out up to the limited dissemination stage after the module had been validated and found to be practical. The dissemination was limited to the school where the research was conducted, namely SMAN 1 Batusangkar. The targets of this limited dissemination were Grade XI students and chemistry teachers. the limited dissemination received positive responses from the teacher and students However, the developed Process Oriented Guided Inquiry Learning (POGIL)-based learning module was still implemented only in one class. Therefore, Although dissemination was limited to one class at SMAN 1 Batusangkar, the positive validity and practicality results indicate that the module has potential for broader implementation. Nevertheless, wider trials involving different schools and larger samples are needed to obtain stronger evidence regarding its effectiveness and generalizability.

CONCLUSION

This study successfully developed a Process-Oriented Guided Inquiry Learning (POGIL)-based learning module on buffer solutions. The

expert validation results showed a validity level of 86%, indicating that the module met the criteria for content appropriateness, language quality, and graphical design. The practicality test also yielded a score of 84%, demonstrating that the module is highly practical and easy to use in classroom instruction. In addition, the interview with the chemistry teacher revealed positive feedback regarding the implementation of the module in the classroom. Therefore, the developed module can be considered valid and practical as instructional material to support chemistry learning and enhance students' independent learning.

This study was limited to testing the validity and practicality of the developed module. Nevertheless, the findings may serve as a reference for teachers in developing innovative learning practices. Overall, this study contributes to the development of instructional materials in chemistry education. Future research is recommended to examine the effectiveness of the module through broader implementation involving larger sample sizes and diverse educational contexts.

RECOMMENDATION

Future research is recommended to examine the effectiveness of the Process-Oriented Guided Inquiry Learning (POGIL)-based learning module in improving students' learning outcomes, conceptual understanding, and critical thinking skills through experimental studies involving larger sample sizes and multiple schools. In addition, the development of POGIL-based learning modules can be extended to other Grade XI chemistry topics to broaden their application in chemistry education.

BIBLIOGRAPHY

Amalia, M., Kurnia, N. C., Aulia, S., Rasyid, Y., & Satria, D. (2025). Pengembangan Modul Pembelajaran Teks Berita Berbasis Saintifik untuk Siswa Kelas XI SMA Negeri 7 Sarolangun. *Jurnal Studi Guru Dan Pembelajaran*, *8*(3), 2235–2245. https://doi.org/10.30605/jsgp.8.3.2025.7544

Awwalin, U. B., & Nugroho, D. E. (2024). Identifikasi miskonsepsi siswa menggunakan tes diagnostik five-tier pada materi larutan penyangga. *Science Education and Development Journal Archives*, *2*(1), 20–29. https://doi.org/10.59923/sendja.v2i1.79

Azhari, N., Fitriani, V., & Safitri, E. (2024). Validitas Modul Pembelajaran Biologi Materi Jaringan Pada Tumbuhan Kelas XI. IPA MAN 1 Solok Selatan. *Jurnal Pendidikan, Sains Dan Teknologi (JPST)*, *3*(1), 139–143. https://doi.org/10.47233/jpst.v3i1.1546

Cahyaningrum, R. D., Nurjayadi, M., & Rahman, A. (2017). Pengembangan E-Module Kimia Berbasis Pogil (Process Oriented Guided Inquiry Learning) Pada Materi Reaksi Reduksi-Oksidasi Sebagai Sumber Belajar Siswa. *Jurnal Riset Pendidikan Kimia*, *7*(1), 59–65. https://doi.org/10.21009/JRPK.071.07

Dafit, F., & Mustika, D. (2021). Pengembangan Bahan Ajar Membaca Berbasis Higher Order Thinking Skills pada Siswa Sekolah Dasar. *Edukatif : Jurnal Ilmu Pendidikan*, *3*(6), 4889–4903. https://doi.org/10.31004/edukatif.v3i6.1565

Erna, maria, H., & Aminullah, R. (2020). Validitas Bahan Ajar Kimia Pada Materi ikatan Kimia Berbasis Exe-Learning untuk Sekolah Tingkat Atas/Sederajat. *Jurnal Pendidikan Kimia Universitas Riau*, *3*(2), 65–76. https://doi.org/10.33578/jpk-unri.v3i2.7784

Famulaqih, S., & Lukman, A. (2024). Pengembangan Bahan Ajar Modul Pembelajaran. *Karakter : Jurnal Riset Ilmu Pendidikan Islam*, *1*(2), 84–99. https://doi.org/10.61132/karakter.v1i2.156

Manurung, J. P., Haloho, B., & Napitu, U. (2023). Mengembangkan Bahan Ajar Dalam Pembelajaran Ilmu Pengetahuan Sosial (IPS) di SD. *Jurnal Pendidikan Mandala*, *8*(2), 676–683. https://doi.org/10.58258/jupe.v8i2.5596

Mufida, L., Subandowo, M., & Gunawan, W. (2022). Pengembangan e-modul kimia pada materi struktur atom untuk meningkatkan hasil belajar. *JIPI (Jurnal Ilmiah Penelitian Dan Pembelajaran Informatika)*, *07*(01), 138–146. https://doi.org/10.29100/jipi.v7i1.2498

Mutaqin, D. Z., Nursilah, N., Murojab, M., & Purwanti, N. Y. (2025). Pembelajaran Berpusat Pada Guru (Teacher Center Learning). *Jurnal Magister Pendidikan Agama Islam*, *01*(02), 95–104. https://doi.org/https://journal.attaqwa.ac.id/index.php/Istajadda/article/view/92

Natalia, D. (2021). Praktikalitas Modul Pembelajaran Biologi Berbasis Studi Kasus Pada Materi Ekosistem Untuk Siswa Sma Kelas X. *Al-Jahiz: Journal of Biology Education Research*, *2*(1), 52–60. https://doi.org/10.32332/al-jahiz.v2i1.3389

Priliyanti, A., Muderawan, I. W., & Maryam, S. (2021). Analisis Kesulitan Belajar Siswa Dalam Mempelajari Kimia Kelas Xi. *Jurnal Pendidikan Kimia Undiksha*, *5*(1), 11–18. https://doi.org/10.23887/jjpk.v5i1.32402

Putri, D. S., Rasyid, M. Al, & Sari, D. A. (2025). Validitas Dan Praktikalitas Modul Kesetimbangan Kimia Berbasis Discovery Learning Untuk Melatih Keterampilan Berpikir Kritis. *(IJI) Indonesia Journal of Intellectual Publication*, *5*(3), 322–328. https://doi.org/10.51577/ijipublication.v5i3.742

Putri, V. W., & Gazali, F. (2021). Studi Literatur Model Pembelajaran POGIL untuk Meningkatkan Hasil

Belajar Peserta Didik pada Pembelajaran Kimia. *Ranah Research : Journal of Multidisciplinary Research and Development*, *3*(2), 61–66. https://doi.org/10.38035/rrj.v3i2.363

Ramadani, R., Ramlawati, & Arsyad, M. (2020). Pengembangan Modul Pembelajaran Kimia Berbasis Augmented Reality. *Chemistry Education Review*, *3*(2), 152–162. https://doi.org/10.26858/cer.v3i2.13315

Safitri, R., & Sari, M. (2022). Pengembangan E-Modul Kimia Berbasis Sets (Science , Environment , Technology , And Society) Untuk Siswa Sman 1 Kecamatan Payakumbuh. *Journal of Chemistry Education and Integration*, *1*(1), 9–15. https://doi.org/: 10.24014/jcei.v1i1.16245

Sagita, R., Azra, F., & Azhar, M. (2017). Pengembangan Modul Konsep Mol Berbasis Inkuiri Terstruktur dengan Penekanan Pada Interkoneksi Tiga Level Representasi Kimia Untuk Kelas X SMA. *Jurnal Eksakta Pendidikan (JEP)*, *1*(2), 25–32. https://doi.org/10.24036/jep.v1i2.48

Sari, D. Y., Widiyowati, I. I., & Kusumawardani, R. (2020). Pengaruh model pembelajaran POGIL dengan metode praktikum terhadap kemampuan kognitif siswa pada materi kelarutan dan hasil kali kelarutan. *Bivalen: Chemical Studies Journal*, *3*(2), 33–35. https://doi.org/10.30872/bcsj.v3i2.445

Simangunsong, G. B. A., & Purba, J. P. (2025). Development E-Module of Process Oriented Guided Inquiry Learning on Thermochemistry. *Jurnal Inovasi Pembelajaran Kimia*, *7*(2), 205–213. https://doi.org/10.24114/jipk.v7i2.66456

Yani, S. H., & Yerimadesi, Y. (2023). Validitas dan Praktikalitas Modul Reaksi Kimia Berbasis Guided Discovery Learning Terintegrasi Etnosains untuk Fase E SMA. *Jurnal Pendidikan MIPA*, *13*(56), 436–444. https://doi.org/10.37630/jpm.v13i2.986