UNESA Journal of Chemical Education *ISSN: 2252-9454*
Vol. 14, No. 3, pp. 220–226, September 2025

IMPACT OF PROCESS-ORIENTED GUIDED INQUIRY LEARNING (POGIL)WITH THE CONTEXTUAL TEACHING AND LEARNING (CTL) BASED APPROACH IN IMPROVING STUDENTS' SCIENCE LITERACY ON BUFFER SOLUTION MATERIAL

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Abstract

This study aims to investigate the effect of Process-Oriented Guided Inquiry Learning (POGIL) combined with the Contextual Teaching and Learning (CTL) approach on improving students' scientific literacy in the context of buffer solution material. The research was conducted using Classroom Action Research (CAR) involving 32 eleventh-grade students from SMA Laboratorium UM Malang. Scientific literacy was assessed through post-tests at the end of each cycle using PISA-based instruments, along with observation sheets, interview guides, and reflection journals. Each test cycle included five items measuring three literacy aspects: explaining scientific phenomena, interpreting scientific data, and evaluating and designing scientific investigations. The results showed that the average scientific literacy score increased from 65.94% in Cycle 1 to 84.17% in Cycle 2. The greatest improvement occurred in the aspect of evaluating and designing investigations, with an increase of 29.37 points. Additionally, the implementation level of the POGIL-CTL model rose from 83.5% to 91%, indicating enhanced instructional effectiveness. These findings demonstrate that CTL-based POGIL learning can improve students' scientific literacy, particularly in applying scientific processes and contextual understanding.
Keywords: class action research, POGIL, CTL, buffer solutions

INTRODUCTION

Scientific literacy plays a crucial role in the decision-making process based on data about science-related phenomena, such as health and environmental issues. Explaining scientific phenomena requires more than just the ability to remember and use theories. The analysis of scientific explanations also requires an understanding of how the knowledge was obtained and the level of confidence in the scientific statements. With scientific literacy, students are taught to research, evaluate, and utilize scientific information to make decisions and take action [1].

Based on the initial observations, it is evident that students struggle to explain the phenomenon scientifically. Students are hindered in making scientific predictions based on the results of literature searches. These difficulties reflect the students' limited scientific literacy, which implies a restricted understanding of scientific concepts and limitations in science-based decision-making [1]. Therefore, a learning strategy is needed that can improve the level of scientific literacy of students.

Scientific literacy encompasses three key competencies: the ability to explain a phenomenon scientifically, the ability to develop and evaluate designs for scientific investigations, and the ability to interpret scientific data and evidence critically [2].

To enhance students' scientific literacy, one pedagogical approach that can be employed is Process-Oriented Guided Inquiry Learning (POGIL), which emphasizes structured, collaborative exploration and critical thinking within a guided inquiry framework [3]. POGIL consists of three stages of learning, namely exploration, concept formation, and concept application [4]. The implementation of POGIL shows an increase in students' scientific literacy skills [4,5].

The improvement of students' scientific literacy skills is also shown in the application of Contextual Teaching and Learning (CTL), especially when combined with guided inquiry [6]. Through CTL, theoretical knowledge can be connected with its application in real-world practice [7].

The selection of buffer solutions as the topic in this study is based on its potential to represent various aspects of scientific literacy, including content knowledge, scientific competence, and real-world context. Previous research shows that students tend to perform well in recognizing scientific terms, but their ability to use and apply scientific knowledge in a meaningful and contextual manner remains limited. In one study, students’ nominal literacy scores reached 83.33%, while scores for functional, conceptual, and multidimensional literacy were considerably lower, particularly in the multidimensional aspect, which scored only 28.49 % [8]. Another study found that although the average scientific literacy score on buffer systems reached 74.61%, the high result was influenced by the academic level of the respondents and the assessment being conducted in a summative context, suggesting the need for more inclusive and process-based learning strategies [2]. These findings highlight that buffer solutions, due to their abstract concepts and real-life applications, are suitable materials for developing scientific literacy. Furthermore, according to the latest PISA 2022 report, only 34% of Indonesian students reached the baseline level of proficiency in science, which is far below the OECD average of 76. This means that a majority of students are still unable to apply basic scientific concepts to everyday contexts [9]. These conditions highlight the urgency to implement structured, inquiry-based, and contextually relevant learning models, such as the POGIL with CTL approach, to foster meaningful improvement in students’ scientific literacy.

METHODS

The research is a Classroom Action Research (CAR), which is a descriptive, quantitative study. The subjects of the research are 32 students from Senior High School Labschool UM class XI MIPA 5, who have heterogeneous abilities. The object of the study is the science literacy of students. The stages of the research used are initial exploration, planning, implementation and observation, and reflection [10].

In the initial exploration stage, the problems that occur in schools are identified through the observation of learning activities and interviews with teachers and students. The planning stage involves preparing research instruments and learning tools. During the implementation and observation stage, innovative learning is introduced in the classroom, and observations of the learning process are conducted, accompanied by tests to assess students' scientific literacy.

The next stage involves reflecting on research activities. The results of reflection are presented in the form of obstacles encountered during the research, as well as improvements and follow-up for the next cycle. The cycle of action research will end when the science literacy improves as expected and reaches 75% in each aspect. The POGIL syntax used is Orientation, Exploration, Concept Formation, Application, and Closing [11].

The data collection instruments used in this study include learning activity observation sheets, interview sheets, PISA framework-based test questions that measure aspects of science literacy, teacher reflection journals, and student reflection journals.

The technique for collecting scientific literacy data was obtained through a post-test administered individually to students at the end of each cycle. The scientific literacy test instruments used in this study were adapted from previous research [2,12–14], and had previously undergone validity testing by the original authors. Therefore, the items were considered valid and suitable for measuring the intended aspects of scientific literacy. Minor adjustments were made to align the instruments with the students' context in this study.

The reliability of the test instruments was measured separately for Cycle 1 and Cycle 2, with each cycle consisting of five test items. Reliability testing was conducted using Cronbach's Alpha with a sample of 32 students. The reliability coefficient for the Cycle 1 instrument was 0.475, indicating moderate reliability, while the Cycle 2 instrument showed a very high reliability with a coefficient of 0.997.

The test items were designed to assess three core aspects: explaining scientific phenomena, interpreting scientific data and evidence, and evaluating and designing scientific investigations. Each item was constructed to reflect real-life contexts aligned with the CTL approach and structured through the POGIL learning model.

The scientific literacy scores obtained from students' post-tests were converted into percentages to standardize the results and facilitate comparison across different aspects and cycles. The percentage score for each aspect was calculated by dividing the total score achieved by students for that aspect by the maximum possible score, then multiplying by 100.

To avoid measurement bias caused by students memorizing test items or answers, this study did not use a pretest-posttest design. Instead, post-tests were administered only at the end of each cycle, using different sets of questions for Cycle 1 and Cycle 2. This approach ensured that students had no prior exposure to the test items, thereby minimizing recall bias and enhancing the validity of the results.

Observation sheets were used to assess the implementation of the POGIL-CTL learning stages during classroom activities. In Cycle 1, the observation instrument consisted of 24 items in Meeting 1 and 14 items in Meeting 2. In Cycle 2, it included 11 items in Meeting 1 and 13 items in Meeting 2. These items covered indicators of the learning phases, including orientation, exploration, concept formation, application, and closing. The observation was conducted using a scale to determine the percentage of implementation.

Interview guidelines and reflection journals were used to gather qualitative data from both teachers and students regarding their perceptions of the learning process, obstacles encountered, and suggestions for improvement. These data were used to support the interpretation of the quantitative findings and guide revisions for the subsequent learning cycle.

RESULTS AND DISCUSSIONS

The implementation results, as presented in Table 1, show that POGIL with CTL-based approach was carried out with an implementation rate of 83.5% in Cycle 1 and 91% in Cycle 2. The POGIL syntax used is Orientation, Exploration, Concept Formation, Application, and Closing [11].

Table 1. Learning Implementation

Meeting	Cycle 1	Cycle 2
1^{st}	82%	97%
2^{nd}	85%	85%
Average	83,5%	91%

In Cycle 1, the Orientation, Exploration, and Concept Formation stages were completed during Meeting 1. The Concept Formation stage was continued at Meeting 2, followed by the Application and Exploration stages.

At the first meeting, a buffer solution practicum was conducted, and several observations were made that became the subject of reflection. At the Exploration stage, the teacher did not demonstrate the practicum work steps at the beginning of the stage, which caused students to have difficulty following the work steps listed in the student worksheets. Practical errors also occurred because students misinterpreted the observation table in the student worksheets. This shows the need to improve students' procedural knowledge [1]. The absence of information regarding the pH indicator trajectory in the student worksheets made it difficult for students to interpret the data. The inactivity of some group members indicated that the dynamics of group work were not optimal and that there was a need for fairer and more participatory role facilitation.

The second meeting in Cycle 1 focused on discussing the results of the practicum. The seating arrangement of 6 people in each group made the classroom atmosphere too crowded and less conducive, so it needed to be adjusted. The Closing Stage, which includes learning reflections on the student worksheets, needs to be improved to be more detailed and focused, such as by adding guiding questions to help students effectively convey their learning reflections. Based on the results of the Cycle 1 reflection, students found the chemistry learning to be quite interesting, but the pace was perceived as too fast. Several students suggested increasing the duration of group activities.

In Cycle 2, the Orientation, Exploration, and Concept Formation stages were completed during Meeting 1. The Concept Formation stage was then continued at Meeting 2, which was followed by the Application and Exploration stages.
In the Exploration stage, improvements were made based on Cycle 1 reflections regarding the need to enhance students' procedural abilities, specifically by adding steps for working on questions that contain dots, which students can fill in to determine the pH of buffer solutions. Some students still require guidance in the form of teacher explanations on how to work through the steps for determining the pH of buffer solutions. Due to time constraints, the concept formation stage was assigned at home and discussed at the next meeting.

At the 2nd meeting, improvements were made to the learning process based on reflection on Cycle 1, namely by forming learning groups with a maximum of 4 members to maximize the role of group members in class and providing continuous practice questions that require all group members to finish working on one question first before the group can continue working on the next question. In this activity, all groups worked in an orderly manner without accessing the internet. In addition, two students who often fell asleep in class during the previous activities played an active role in the group activities of this cycle.

Table 2. Science Literacy Ability Test Results

Aspects of Scientific Literacy	Cycle 1 (%)	Cycle 2 (%)
Explaining phenomena scientifically	68	90
Interpreting data scientifically	71	75
Evaluating and designing scientific investigations	58	88
Average	66	84

There was an increase in students' science literacy from Cycle 1 to Cycle 2 by 18%. This is directly proportional to the rise in the implementation of learning with the POGIL model in Cycle 2, which indicates that the implementation of POGIL can improve students' science literacy skills [3]. This improvement is reflected in the results of Cycle I and II tests, which cover three main aspects: explaining phenomena scientifically, interpreting data and scientific evidence, and evaluating and designing scientific investigations. The improvement in students' scientific literacy from 66% in Cycle 1 to 84% in Cycle 2 represents an increase of 18 percentage points.

Among the three aspects of scientific literacy assessed, the most substantial improvement was observed in evaluating and designing scientific investigations, which rose by 29 points (from 58% to 87%). This finding highlights the effectiveness of the POGIL structure, particularly the exploration and concept formation stages, in fostering students' investigative thinking and procedural understanding.

The ability to explain phenomena scientifically also improved, increasing by 22 points (from 68% to 90%). This increase reflects the role of the CTL approach in contextualizing learning, helping students connect theoretical content to real-world situations.

Meanwhile, the aspect of interpreting scientific data showed a more modest improvement of 4 points (from 71% to 75%). This indicates that while progress was made, students may still require additional scaffolding or strategy training to strengthen their skills in analyzing and interpreting data.

In parallel, the implementation rate of the POGIL-CTL learning model increased from 83.5% in Cycle 1 to 91% in Cycle 2. This 7.5-point rise in instructional implementation is consistent with the improved student outcomes, suggesting that greater fidelity in applying the learning model contributed to enhanced scientific literacy performance.

In Cycle 1, the average score of students' scientific literacy was 66% with the highest score in the aspect of interpreting scientific data (71%) and the lowest score in the aspect of evaluating and designing scientific investigations (58%). This indicates that in the early stages of implementation, students still lack procedural knowledge related to scientific investigations.

To address this issue, several improvements were implemented in Cycle 2. The student worksheets were revised to include more explicit instructions and guided questions that helped students plan and carry out investigations more systematically. Contextual problems were added to help students connect procedural steps with real-life situations. In addition, teacher facilitation was strengthened by providing more structured scaffolding during group discussions and offering direct feedback as students engaged in learning activities. As a result, students in Cycle 2 demonstrated greater accuracy in conducting investigations and improved ability to explain the reasoning behind their answers.

These improvements are consistent with findings from previous studies that highlight students' challenges in applying scientific knowledge through procedures. Preliminary research reported that students' functional and conceptual literacy, which reflect procedural understanding, were still in the moderate category with scores of 57.67% and 59.07%, respectively [8]. This indicates that although students may understand scientific terms or concepts, they often face difficulties when applying them in practice. Similarly, previous research found that while students attained relatively high average scores in scientific literacy on buffer solution material, the results were influenced by the academic level of participants and the use of conventional teaching methods, which did not provide sufficient focus on procedural skills [2]. These findings support the effectiveness of structured, inquiry-based, and contextually relevant learning approaches such as those implemented in Cycle 2 to enhance students' procedural knowledge as an essential component of scientific literacy.

In Cycle 2, the learning process was implemented in the same class subject as Cycle 1 but with slightly different materials. Cycle 1 was about the definition, principles, and components of buffer solutions. Cycle 2 materials are the continuation of Cycle 1 materials, which were pH calculations of buffer solutions.

The implementation of learning increased to 91%, accompanied by a rise in students' scientific literacy achievement to 84%. The most growth occurred in the aspect of evaluating and designing scientific investigations, which increased by 29% from Cycle 1 to Cycle 2. This aspect is influenced by the POGIL learning structure that allows students to build scientific understanding through stages of exploration and concept formation gradually and through well-facilitated collaboration [3].

The aspect of explaining phenomena scientifically also increased from 68% to 90%. This increase indicates the influence of the CTL approach in linking learning materials to real-world contexts so that students can construct an understanding of buffer solutions through their context in everyday life [15]. Improvements in interpreting scientific data indicate a strengthening of students' ability to understand and analyze data.

Several improvements were made in Cycle 2 based on the challenges identified during Cycle 1. To address students' procedural difficulties in conducting experiments, the teacher provided more detailed demonstrations and added guided steps in the worksheets. The layout and content of the worksheets were revised to clarify observation tables and include pH indicator guidance. To enhance group collaboration, group sizes were reduced from six to four members, and tasks were structured to promote equitable participation. Time management was also adjusted by assigning certain activities, such as concept formation, as homework for further discussion in class. Additionally, the classroom layout was modified to create a more conducive learning environment. These changes contributed to more effective learning activities in Cycle 2, as reflected in both improved implementation levels and student outcomes.

CONCLUSION

Based on the results and discussion, it can be concluded that the implementation of CTL-based POGIL learning has a positive effect on improving students' scientific literacy in buffer solution material. The students' average scientific literacy score increased from 66% in Cycle 1 to 84% in Cycle 2, with the most notable improvement found in evaluating and designing scientific investigations. This indicates that the combination of structured inquiry through POGIL and contextual learning through CTL effectively enhances students' scientific reasoning and understanding. For future research, it is recommended to apply the CTL-based POGIL model to other chemistry topics or different levels of education to examine its broader applicability.

ACKNOWLEDGEMENTS

We want to thank the Teacher Professional Education Study Program (PPG) of the Postgraduate School, State University of Malang, for funding this activity.

REFERENCE

1. OECD. 2023. PISA 2025 Science Framework (Second Draft). England: Oxford University Press.
2. Muntholib, M., Yusnaini, M. L., Khusmawardani, E., Sa'dila, R., Joharmawan, R., and Yahmin, Y. 2023. Analysis of Eleventh Graders' Scientific Literacy on Buffer. *AIP Conference Proceedings*, Vol. 2569.
3. Puspitasari, P. A., Hastuti, B., and Mulyani, B. 2024. Impacts of The POGIL Learning Model Combined With a SETS Approach on Chemical Literacy and Science Process Skills in The Context of Buffer Solutions. *JKPK (Jurnal Kimia dan Pendidikan Kimia)*, Vol. 9, No. 1, pp. 171–184.
4. Yennita, Astriawati, F., and Jumiarni, D. 2024. Process Oriented Guided Inquiry Learning (POGIL): Its Effectiveness in Increasing Students' Scientific Literacy Skills in Plant Physiology Course. *Bioeduscience*, Vol. 8, No. 1, pp. 104–115.
5. Muntholib, M., Anggraeni, D. P., Zaroh, I., Utomo, Y., and Yahmin, Y. 2023. The Effect of POGIL instruction on Students' Chemical Literacy in Electrolyte and Nonelectrolyte Solution. *AIP Publishing*, Vol. 2569, pp. 030017-1–030017-6.
6. Milanto, S., Suprapto, N., and Budiyanto, M. 2023. Effectiveness of Contextual Learning Using the Guided Inquiry Approach to Improve Students' Scientific

Literacy Ability. *Jurnal Penelitian Pendidikan IPA*, Vol. 9, No. 1, pp. 444–448.

7. Picardal, M. T., and Sanchez, J. M. P. 2022. Effectiveness of Contextualization in Science Instruction to Enhance Science Literacy in the Philippines: A Meta-Analysis. *International Journal of Learning, Teaching and Educational Research*, Vol. 21, No. 1, pp. 140–156.

8. Yudha, S., Simorangkir, M., and Nurfajriani, N. 2023. Analysis of Science Literacy of XI Class Students In Buffer Solution Materials. *Journal of Learning Improvement and Lesson Study*, Vol. 3, No. 2, pp. 1–6.

9. OECD. 2023. PISA 2022 Results Indonesia. *Factsheets*, 1–9. https://www.oecd.org/publication/pisa-2022-results/country-notes/malaysia-1dbe2061/. Accessed February 2, 2025.

10. Kemmis, S., McTaggart, R., and Nixon, R. 2014. *The Action Research Planner, 3rd edn*. New York: Springer.

11. Hainun, H., Haeruddin, H., and Basir, A. 2022. Literature Review: Model Process Oriented Guided Inquiry Learning (POGIL) Pada Pembelajaran Matematika. *Primatika : Jurnal Pendidikan Matematika*, Vol. 11, No. 1, pp. 61–70.

12. Faiza, N. I. 2021. *Pengembangan Perangkat Pembelajaran Kimia Berbasis Learning Cycle 7E untuk Meningkatkan Kemampuan Literasi Kimia dan Sikap Ilmiah Peserta Didik SMA pada Materi Larutan Penyangga*. Yogyakarta: Universitas Negeri Yogyakarta.

13. Dewi, R. 2024. *Analisis Kemampuan Literasi Sains Siswa Kelas XI pada Materi Larutan Penyangga Berdasarkan Gaya Belajar Siswa*. Yogyakarta: Universitas Negeri Yogyakarta.

14. Yusmaita, E., Anthonio, L. G., and Rivaldo, I. 2021. Chemical Literacy Test Instrument Designing on Buffer Topic using Model of Educational Reconstruction (MER). *Journal of Physics: Conference Series*, Vol. 1788, No. 012044, pp. 1–7.

15. Yani, F., and Hasibuan, V. U. 2023. Pengaruh Pendekatan Contextual Teaching and Learning (CTL) Terhadap Motivasi dan Kemampun Literasi Sains Untuk Peserta didik. *INNOVATIVE: Journal Of Social Science Research*, Vol. 3, No. 7, pp. 3362–3371.