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The Influence of Process-Oriented Guided Inquiry Learning on Eleventh Grade Students' Chemical Literacy

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Abstract

This study is driven by Indonesia's low scientific literacy, as indicated by its PISA score. The deficiency in chemical literacy is attributed to the ineffective and limited application of learning models. Its objective is to assess the impact of the Process-Oriented Guided Inquiry Learning (POGIL) model on students' chemical literacy regarding salt hydrolysis. Conducted in May 2023 at a public high school in Jakarta, the study employed a quasi-experimental design, randomly assigning two sample classes, XI MIPA-1 as the experimental group and XI MIPA-3 as the control group, using the flipping coin method. Each class comprised 36 students. The chemical literacy assessment utilized multiple-choice tests, and data analysis was performed via t-test. The findings demonstrated that POGIL positively influenced students' chemical literacy in salt hydrolysis among grade 11 students, suggesting its effectiveness in enhancing chemical literacy. Consequently, it is suggested that educators adopt the POGIL model to improve students' chemistry literacy across various chemistry topics based on these results.

Keywords: *Inquiry Learning, POGIL, Chemical Literacy, Salt Hydrolysis*

INTRODUCTION

In the 21st century, education has witnessed numerous advancements in knowledge. Scientific literacy serves as a crucial pathway toward achieving scientific and technological advancements, as well as ensuring economic sustainability within the realm of science education (Oludipe & Awokoy, 2010). Miller (2010) defines literacy as the basic capacity to comprehend and articulate phenomena in straightforward terms, alongside the skills of reading and writing essential for engaging in societal participation and communication.

Chemical literacy holds significant importance as it influences reasoning abilities and contributes to civil, social, and individual decision-making processes when confronting situations in real-world scientific and technological settings (Dori et al., 2018; Pabuccu & Erduran, 2016). Researchers have emphasized the significance of integrating chemistry into daily life to transform abstract chemical concepts into tangible ones, thus enhancing comprehension (Pabuccu & Erduran, 2016; Sevian et al., 2018).

According to the 2018 Program for International Student Assessment (PISA) report, the literacy level of students in Indonesia is notably low. Indonesia's PISA score for 2018 indicates a concerning situation, falling below the global average literacy score (OECD, 2019). Specifically, Indonesia ranks 74th out of 79 countries based on the 2018 PISA score. The country achieves a score of 371, placing 74th in reading ability, a score of 379 in 73rd position in mathematics ability, and a score of 396 in 71st position in science ability (OECD, 2019).

Previous studies also reported that chemical literacy needs to be improved (Cigdemolu & Geban, 2015; Vogelzang et al., 2020). Low literacy skills caused bad for the nation. One of them is the spread of incorrect information because the information obtained is not read carefully. Low literacy also affects the low ability to communicate, solve problems, think critically, and make decisions (Thummathong & Thathong, 2018). One way to increase student's chemistry literacy is changing by teacher-centered learning (lectures) into student-centered learning. One teaching method that can be applied to improve student's chemical literacy is Process-Oriented Guided Inquiry Learning (POGIL).

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Research conducted by Idul and Caro (2022) in the Philippines indicates that students who engage with Process Oriented Guided Inquiry Learning (POGIL) achieve satisfactory academic outcomes and demonstrate proficient mastery of science process skills. Similarly, a study conducted in the US by Mata (2022) revealed that POGIL serves as an effective instructional strategy for enhancing chemistry final exam scores. Furthermore, research by Beck and Miller (2022) suggests that POGIL actively involves students in scientific practice.

Chemistry, ften regarded as an abstract discipline, explores the structure, properties, and transformations of substances, comprising three fundamental aspects: product, process, and attitude (Cigdemoglua & Geban, 2015; Taber, 2013). As per the Curriculum 2013 implemented in Indonesia, in the context of salt hydrolysis, students are expected to analyze the properties and categories of hydrolyzed salt solutions. Hence, proficient chemical literacy skills are crucial for acquiring knowledge in the form of facts, concepts, or principles, thereby enabling students to bolster these competencies.

LITERATURE REVIEW

Chemical Literacy

Chemical literacy is a component of scientific literacy (Mozeika & Bilbokaite, 2010). In this study, the definition of chemical literacy is informed by two primary theoretical frameworks derived from Bybee (1997) concerning the conceptualization of scientific literacy. The first framework, proposed by Shwartz et al. (2006), offers a comprehensive perspective on chemical literacy, drawing from input from scientists, educators, and high school chemistry instructors. The second framework is based on the PISA approach to scientific literacy, as outlined by Cigdemoglu et al. (2017).

According to Shwartz et al. (2006), chemical literacy refers to an individual's capacity to grasp fundamental chemistry concepts. As defined by PISA, chemical literacy entails the ability to apply scientific knowledge, pose inquiries, and reach conclusions based on available evidence and data to make informed decisions regarding natural phenomena and human interactions (OECD, 2019). Scientific literacy, as interpreted by Ratcliffe & Millar (2009), encompasses understanding scientific concepts and principles, comprehension of the scientific inquiry process and the nature of resultant knowledge, recognition of the societal context's impact on scientific endeavors, and acknowledgment of the influence of scientific ideas and practices on everyday life and personal and societal decision-making.

The measurement of students' chemical literacy involves assessing their proficiency across interrelated dimensions of scientific literacy. Drawing from the 2018 PISA framework, scientific literacy encompasses three key dimensions or aspects. The first aspect is context, which entails understanding science and technology to elucidate global, local, and personal phenomena, both present and historical. The second aspect is competence, which involves the ability to scientifically explain phenomena, assess and design scientific investigations, and interpret data and evidence scientifically. The third aspect is knowledge, which encompasses understanding facts, concepts, and explanatory theories underlying scientific knowledge. This includes natural and technological knowledge (content), procedural knowledge regarding how ideas are generated, and epistemic knowledge concerning the rationale behind procedural choices.

Process Oriented Guided Inquiry Learning (POGIL)

POGIL, grounded in Vygotsky's social constructivist theory and Piaget's perspective on learning, is a student-centered instructional approach centered around group work. Its aim is to foster a collective understanding of a subject by emphasizing activities tailored to develop or reinforce skills, ideas, and concepts (Joshi & Lau, 2021). According to Hanson (2014), POGIL facilitates learning through group interaction, with a focus on conceptual development, skill acquisition, and application in real-life contexts. Moog and Spencer (2008) characterize POGIL as a research-based, student-centered pedagogical strategy that draws on cognitive development, cooperative learning, and instructional design principles. POGIL prioritizes the cultivation of process skills such as information management, critical thinking, problem-solving, communication, teamwork, organization, and self-assessment (Nadelson, 2009).

In POGIL, the learning process follows a structured learning cycle comprising three phases: exploration, concept discovery, and application (Hanson, 2014). During the exploratory phase, students are encouraged to bridge their existing knowledge with new information. The concept discovery phase involves active group work where students articulate their understanding of observed patterns and relationships. This phase, termed term recognition, involves the introduction of new terminology by the teacher once students have identified patterns. Finally, the application phase focuses on applying newly acquired knowledge in practical scenarios, problem-solving tasks, and research situations (Hanson, 2014).

In the POGIL learning approach, students assume greater responsibility compared to the teacher. They are encouraged to rely on their critical thinking skills rather than memorization, fostering improved study habits and positive peer relationships (Nadelson, 2009). Within this model, students are assigned specific roles and responsibilities, including managers or group leaders, presenters or spokespersons, recorders or note-takers, and reflectors or strategy analysts (Hanson, 2014). Despite the student-centered nature of POGIL, the teacher's role remains essential. In POGIL, the teacher acts as a leader, monitor, facilitator, and evaluator, providing guidance and support throughout the learning process

Research Question

The study aimed to examine the impact of Process-Oriented Guided Inquiry Learning (POGIL) on the chemical literacy of eleventh-grade students regarding the subject of salt hydrolysis. Consequently, the research problem was formulated as follows: "Does the implementation of Process-Oriented Guided Inquiry Learning (POGIL) have a significant effect on students' chemical literacy regarding salt hydrolysis?"

METHODOLOGY

Research Design

This study adopted a quantitative approach with a quasi-experimental design employing a nonequivalent control group design. The nonequivalent control group design was chosen to assess the effectiveness of the POGIL learning model on students' chemical literacy. Quasi-experimental design involves multiple sample groups that are not randomly assigned, with one group receiving a specific treatment while the other acts as a control (Cresswell, 2012). In this study, the experimental group (EG) was exposed to the POGIL, while the control group (CG) utilized the think-pair-share cooperative learning method.

Participants

Participants were 72 students of class XI at SMAN 85 Jakarta. Samples were taken using simple random sampling technique. Two classes were randomly selected, namely XI MIPA-1 and XI MIPA-3 at a public high school in Jakarta, Indonesia. Determination of class groups through flipping coins or throwing coins. The EG was XI MIPA-1 with 36 students (14 boys and 22 girls) and the CG was XI MIPA-3 with 36 students (14 boys and 22 girls) with an age range of 16-18 years.

Instrument

he research instrument employed in this study was a multiple-choice type of chemical literacy test comprising 20 questions, each offering 5 answer choices. Scoring for this test was straightforward: correct answers received a score of 1 (one), while incorrect responses were scored as 0 (zero) for each item. This objective test item was designed to gauge students' chemical literacy levels. The construction of the research instrument was guided by Competency Achievement Indicators related to the salt hydrolysis topic and aligned with the aspects of chemical literacy, specifically context, competence, and knowledge as outlined in the PISA 2018 framework. The chemical literacy test underwent validation and empirical testing, followed by an examination of its reliability. Reliability analysis was conducted using the Kuder-Richardson (KR-20) formula. Based on the calculation, r_{ii} value was 0.827. The coefficient reliability of the test was around 0.70-0.89 and it is included in the high category (Kurtz & Mayo, 2012). The minimum score that can be obtained is 0 and the maximum score is 20. The instrument was completed within 60 minutes.

Procedure

The research was conducted in 3 meetings, each meeting lasting 180 minutes. The research was started by giving a pretest to the EG and CG. Then the POGIL was applied to the EG and the think pair share cooperative learning to the CG. After learning, a posttest was carried out in the EG and CG to determine the level of chemical literacy after treatment.

POGIL learning in the EG consisted of three phases. In the exploration phase, students form small groups of 3-4 people and determine their respective roles in the study group. Next, students read, study the questions, and discuss to answer the questions in the POGIL student worksheet on salt hydrolysis. In the concept discovery phase, students compare the data from the discussion with prior knowledge. Then, students analyze the relationship between answers to obtain a concept. The concepts that have been found are then written on the POGIL student worksheet. At the application phase, students carry out simple experiments or answer questions on the POGIL student worksheet in groups. These questions aim to apply the concepts students have acquired. Then students convey the results of their discussions and respond to each other. During the lesson, if there are difficulties students are allowed to ask questions to the teacher.

In the CG, the first phase of TPS cooperative learning is think. At this phase, students answer trigger questions from the teacher, which is followed by listening and hearing the explanation of the material by the teacher. Furthermore, students work on questions on student worksheet individually. In the pairing phase, students in pairs discuss the results of the worksheet answers that have been done. In the share phase share, students present the results of their discussions and respond to each other.

Data Analysis

The data collected underwent processing and analysis to determine whether there were disparities in the chemical literacy levels of students in the EG and CG. Parametric statistics, specifically the *t*-test, were employed for data analysis using SPSS 25 software. The *t*-test aimed to ascertain whether there was a statistically significant difference between the means of the two groups, utilizing parametric data derived from random samples with a normal distribution (Cohen et al., 2007). Both independent *t*-tests and paired *t*-tests were utilized in this study. Before conducting the *t*-test, prerequisite tests were conducted, including the normality test using the Kolmogorov-Smirnov test and homogeneity test using the Levene test. If the data exhibited normal distribution and homogeneity (sig > 0.05), the *t*-test could be applied. In addition to the *t*-test, Cohen's *d* effect size calculations were performed to determine the relationship, difference, or effect of a variable on other variables within the study. The resulting effect size was compared with Cohen's *d* effect size table, which categorizes effect sizes as follows: 0.00-0.20 (weak effect), 0.21-0.50 (moderate effect), 0.51-1.00 (strong effect), and > 1.00 (very strong effect) (Cohen et al., 2007).

RESULTS

Based on the results of the independent *t*-test as shown in Table 1, the significance value for the pretest is 0.272, indicating that it exceeds 0.05. Thus, it can be concluded that the null hypothesis (Ho) is accepted. Consequently, the pretest results for students in both the EG and CG did not demonstrate a statistically significant gap in their chemical literacy prior to the treatment. Furthermore, the calculated *t*-value is less than the critical *t*-value, with 1.07 being smaller than 1.994. This indicates that there is no significant discrepancy between the average pretest scores in the EG and CG.

Table 1. Results of independent *t*-test on chemical literacy

Indicator		Group	N	M	SD	*t*	Sig.
Pretest	Explain phenomena scientifically	EG	36	3.17	1.384	0.588	0.559
		CG	36	2.97	1.424		
	Evaluating and designing scientific investigations	EG	36	3.06	1.413	1.829	0.072
		CG	36	2.53	1.000		
	Interpret data and evidence scientifically	EG	36	3.11	1.348	0.609	0.544
		CG	36	2.92	1.360		
	All Indicators	EG	36	8.86	1.869	1.107	0.272
		CG	36	8.42	1.519		

	Indicator	Group	N	M	SD	*t*	Sig.
Posttest	Explain phenomena scientifically	EG	36	10.61	1.871	5.486	0.000
		CG	36	8.47	1.404		
	Evaluating and designing scientific investigations	EG	36	3.06	0.754	2.778	0.007
		CG	36	2.42	1.156		
	Interpret data and evidence scientifically	EG	36	2.44	0.773	2.591	0.012
		CG	36	1.97	0.774		
	All Indicators	EG	36	16.11	2.148	6.997	0.000
		CG	36	12.86	1.775		

In the independent *t*-test for the posttest, a significance value of 0.000 was obtained, indicating that the significance value was below 0.05. Therefore, it was concluded that the null hypothesis (Ho) was rejected. Consequently, the results of the posttest for students in both the EG and CG indicated a significant gap in their chemical literacy after the treatment. Additionally, the calculated *t*-value was greater than the critical *t*-value, with 6.997 being larger than 1.994. This indicates that there is indeed a difference in the average posttest scores between the EG and CG.

Table 2. Results of paired *t*-test on chemical literacy

Indicator	Group	Different		*t*	Sig.	Cohen's *d*
		M	SD			
Explain phenomena scientifically	EG	4.806	1.880	-15.341	0.000	2.71
	CG	2.944	1.638	-10.787	0.000	2.03
Evaluating and designing scientific investigations	EG	1.333	1.095	-7.303	0.000	1.56
	CG	0.750	1.519	-2.963	0.005	0.74
Interpret data and evidence scientifically	EG	1.111	1.326	-5.027	0.000	1.28
	CG	0.750	0.967	-4.652	0.000	0.95
All Indicators	EG	7.250	1.204	-36.125	0.000	3.60
	CG	4.444	0.969	-27.509	0.000	2.69

Table 2 displays the significance values of the paired *t*-test in both the EG and CG, with values of 0.000 for the EG and 0.001 for the CG. Since these values are less than 0.05, the null hypothesis (Ho) is rejected, indicating a significant increase in students' chemical literacy after learning about salt hydrolysis. Moreover, the calculated *t*-values are greater than 2.030, specifically 36.125 for the EG and 27.509 for the CG. Furthermore, the Cohen's *d* value for the EG is 3.60, while for the CG it is 2.69. The Cohen's *d* value in the EG is higher than in the CG and is considered high. Consequently, it can be inferred that the implementation of the POGIL has a very substantial impact on students' chemical literacy in the topic of salt hydrolysis.

DISCUSSION

The study has examined the impact of the POGIL on 11th grade students' chemical literacy regarding salt hydrolysis. Results indicated that in the EG, average student scores increased from pretest to posttest following the implementation of the POGIL. This suggests that POGIL has a beneficial influence on students' chemistry learning specifically concerning salt hydrolysis. These findings are consistent with those of Wen et al. (2020), who demonstrated that inquiry-based learning can enhance students' scientific literacy. Additionally, the research by DeMatteo (2019) also supports these findings, indicating that the combination of the POGIL and flipped classroom models positively impacts chemistry education.

In the independent pretest data test, the result was that before being given treatment, the two classes had the same initial chemical literacy. In addition, the results of the pretest showed that conventional learning had not been able to improve students' chemical literacy skills. Research conducted by Vogelzang (2020), shows that learning that tends to be teacher-centered is not enough to increase students' chemical literacy.

During the treatment, students in the EG were taught using the POGIL method, while those in the CG were instructed using cooperative learning. Statistical analysis revealed an improvement in students' chemical literacy scores in both the EG and CG, indicating a positive effect of both instructional models on students' chemical literacy regarding salt hydrolysis. However, the increase in scores observed in the EG was greater. Additionally, the calculation of effect size indicated that POGIL had a strong effect on enhancing students' chemical literacy. These findings are consistent with research conducted by Moore et al. (2015), which suggested that team-based learning and POGIL, especially when utilizing iPads, offer students opportunities to develop and apply literacy skills effectively.

Chemical literacy is assessed through competency aspects and content knowledge. Competency aspects include explaining phenomena scientifically, evaluating and designing scientific investigations, and interpreting data and evidence scientifically. In all three indicators, the implementation of the POGIL model in the EG demonstrated more significant improvement in students' chemical literacy skills compared to the CG. This aligns with the findings of research by Walker and Warfa (2017), indicating that POGIL offers opportunities to enhance process skills such as observation, investigation, and inference, thereby reducing the risk of academic underachievement in science. Similarly, Gormally et al. (2009) demonstrated that learning through inquiry-based laboratory instructions enhances scientific literacy and science skills, further supporting the effectiveness of POGIL in improving chemical literacy.

The knowledge content aspect, focusing on salt hydrolysis, encompasses six indicators representing competency achievement in this material. Implementation of the POGIL model has shown significant improvement in students' abilities across these indicators. For instance, in indicators such as determining the color of litmus paper and identifying characteristics of salt solutions, students demonstrated the ability to articulate phenomena with concrete explanations or evidence drawn from theory or prior learning (Jam et al., 2011). When analyzing characteristics, types, and equations of salt hydrolysis reactions, students exhibited critical thinking skills in identifying ions involved in the hydrolysis process. Additionally, in the pH calculation indicator, students demonstrated proficiency in mathematical abilities. These findings resonate with research by Chatila and Sweid (2020), indicating that guided inquiry significantly fosters the development of all aspects of scientific literacy.

The observed higher increase in chemical literacy scores among students in the EG can be attributed to their use of the POGIL learning model. POGIL learning provides students with valuable opportunities to develop crucial processing skills such as time management, self-assessment, communication, teamwork, problem-solving, and reasoning (Vishnumolakala et al., 2017). By actively involving students in the learning process, the POGIL model guides them to construct their own knowledge (Şen & Yılmaz, 2015). This aligns with the findings of Aiman and Hasyda (2020), who demonstrated that POGIL learning supplemented with realia media has a more significant impact on students' scientific literacy compared to those receiving expository learning. Additionally, Chu et al. (2011) asserted that a collaborative teaching approach incorporating inquiry project-based learning can effectively enhance student literacy.

Improving students' chemical literacy is feasible because the learning process directly engages them in seeking information, discovering concepts, and applying these concepts. When students seek information, they participate in reading activities, a fundamental aspect of literacy. Miller (2010) defines literacy as the basic ability to comprehend and articulate phenomena using clear language, as well as the capacity to read and write for participation and communication. In the process of discovering concepts, students must employ analytical and critical thinking skills to address questions. Artuz and Roble (2021) illustrate that POGIL motivates students to actively engage in learning activities, fostering enhancements in communication, critical thinking, analysis, and problem-solving. Improved analytical skills and critical thinking contribute to enhanced literacy skills. Critical thinking, as a form of literacy, enables individuals to critically engage with content by seeking evidence to support claims and evaluating valid arguments (Machete & Turpin, 2020). Furthermore, in applying concepts, students tackle questions by applying the concepts they have acquired. Activities within the POGIL learning framework, such as information seeking, processing, analysis, problem-solving, and communication, contribute to the development of scientific process literacy (Soltis et al., 2015). The research findings of Jin and Bierma (2013) indicate that POGIL learning in applied science courses leads to an improvement in scientific literacy.

Students' increased chemical literacy is expected to improve argumentation, critical thinking, and decision making. According to research by Dori et al. (2018), chemical literacy is necessary because it has an impact on reasoning skills, and plays a role in civil, social, and individual decision-making processes to deal with situations that may be encountered in real-life scientific and technological contexts. Sutiani's findings (2021), also show that inquiry-based learning with scientific literacy can elevate students' critical thinking skills.

Based on the explanation provided, it can be concluded that the application of the POGIL model has a positive impact on students' chemical literacy, particularly in salt hydrolysis material. This is due to the fact that POGIL activities engage students in various literacy activities such as reading, writing, and communicating. Moreover, the implementation of POGIL activities facilitates the development of science process skills, problem-solving abilities, critical thinking, and communication, all of which are integral components of chemical literacy.

CONCLUSION

Based on the research results, it can be concluded that the average value of students' chemical literacy in the pretest for the EG was 8.86 (SD=1.869), while for the CG it was 8.42 (SD=1.519). In the posttest, the average chemical literacy of students in the EG increased to 16.11 (SD=2.148), whereas in the CG it rose to 12.86 (SD=1.775). The most significant improvement in the EG was observed in the competency aspect, particularly in the indicators of interpreting data and scientific evidence. Regarding content knowledge, notable enhancement was seen in the indicator of the salt hydrolysis reaction equation. These findings suggest that POGIL has a substantial influence on augmenting students' chemical literacy skills concerning salt hydrolysis. This is attributed to the involvement of students in literacy activities within POGIL learning activities. This is further supported by the Cohen's *d* value of 3.60 for the EG and 2.69 for the CG. With a higher Cohen's *d* value for the EG, indicating a stronger influence, it is evident that POGIL is effective in enhancing students' chemical literacy.

SUGGESTIONS

This research encountered several limitations that need to be addressed. Firstly, the study utilized a limited sample size, with only two classes totaling 72 students. Consequently, the findings may not be fully representative of the wider population. Future research should aim to include a larger number of samples and expand the scope to enhance the generalizability of the results. Secondly, time constraints restricted the duration of the study, allowing for only three relatively short sessions to evaluate the effectiveness of the new learning model. To address this limitation, future researchers should consider extending the duration of the learning intervention. This would enable all stages in the POGIL model to be implemented optimally, providing a more comprehensive assessment of its efficacy. Furthermore, this study focused specifically on the effect of POGIL on students' chemistry literacy in the context of salt hydrolysis. Future research endeavors could explore the application of POGIL in other chemistry learning topics or across different subjects. This would offer a more holistic understanding of the impact of POGIL across various educational domains.

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