EDUCENTER

Educenter : Jurnal Ilmiah Pendidikan
Vol 4 No 1 2025
ISSN: 2827-8542 (Print) ISSN: 2827-7988 (Electronic)
Open Access: https://jurnal.arkainstitute.co.id/index.php/educenter/index

The effectiveness of electronic student worksheet based on Process Oriented Guided Inquiry Learning (POGIL)

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Article Info

Article history:
Received October 2nd 2025
Revised November 20th 2025
Accepted December 28th 2025

Keyword:
Effectiveness;
Electronic worksheet;
POGIL;
Chemical calculation

ABSTRACT

This study aims to determine the effectiveness of an electronic student worksheet based on the Process Oriented Guided Inquiry Learning model in improving students learning outcomes on chemical calculation material at an Islamic senior high school. The research applied a quasi experimental approach using a one group design. The participants were students from a science class who learned through an electronic worksheet developed according to the stages of orientation exploration concept invention and application. The learning process emphasized active inquiry collaboration and guided knowledge construction supported by digital media. Data on student learning outcomes were collected through achievement tests. The results indicate a meaningful improvement in students learning outcomes after using the electronic worksheet. This finding shows that the POGIL based electronic worksheet has a strong influence on enhancing students conceptual understanding and problem solving skills. In addition the electronic worksheet facilitates active and collaborative learning while integrating technology into chemistry instruction. The learning materials also incorporate Qur'anic values that support character building alongside scientific understanding. Overall the findings confirm that electronic student worksheets based on Process Oriented Guided Inquiry Learning are effective instructional tools for improving chemistry learning outcomes and supporting holistic student development in digital learning environments.

INTRODUCTION

The 21st century has brought about profound transformations in education, characterized by the integration of technology, data-driven instruction, and a strong emphasis on scientific literacy (Kalyani, 2024; Kurniawan, 2025; Sayadi & Pangandaman, 2025). These changes demand that students acquire not only cognitive knowledge but also a set of higher-order competencies such as creativity, collaboration, critical thinking, and communication. In this context, chemistry education plays an essential role in fostering analytical reasoning and problem-solving abilities. However, many students continue to experience difficulties in understanding abstract and quantitative chemical concepts, particularly those related to chemical calculations, stoichiometry, and mole relationships (Rosa et al., 2022).

The complexity of chemical calculation lies in its dual nature requiring both conceptual understanding and mathematical precision (Kusdayanti et al., 2019). Traditional instructional approaches that emphasize memorization and algorithmic problem solving often fail to promote deep conceptual comprehension (Putriyana et al., 2020). Students tend to focus on obtaining the correct numerical answer rather than understanding the relationships among mass, moles, and particle ratios. Consequently, they develop fragmented and procedural knowledge that hinders their ability to transfer learning to new contexts.

These difficulties are often rooted in teacher-centered instructional methods that limit students' opportunities to actively construct their own understanding. Conventional worksheets that focus solely on procedural exercises fail to engage students in the higher-order thinking processes needed to master chemical calculations. Therefore, the implementation of learning models that prioritize inquiry, student-centered exploration, and guided conceptual construction is essential to improving chemistry learning outcomes.

The use of learning models and media that encourage active and inquiry-based learning is considered a solution to overcome these issues. One of the models proven effective in improving conceptual understanding is the Process Oriented Guided Inquiry Learning (POGIL) model. According to Hanson (2015), POGIL emphasizes a structured inquiry process that allows students to explore concepts actively through discussion, analysis, and reflection while the teacher acts as a facilitator. Learning through POGIL provides opportunities for students to construct their knowledge independently and develop critical and collaborative thinking skills (Aiman et al., 2020; Rambe et al., 2024).

In the context of chemistry learning, integrating POGIL into Electronic Student Worksheets (E-LKPD) can enhance interactivity and accessibility. E-LKPD, according to Ebbini (2023) functions as a medium that guides students through the learning process and provides digital resources to support self-paced learning. Digital worksheets allow teachers to embed videos, animations, and simulations that make abstract chemical concepts more concrete and easier to understand (Mellyzar et al., 2022).

Previous studies have demonstrated the potential of combining inquiry-based approaches and digital media in improving learning outcomes. For instance, Ali & Lestari (2023) found that E-LKPD integrated with inquiry models increases students' motivation, engagement, and conceptual understanding in chemistry. Similarly, Zumronah et al., (2019) concluded that the application of inquiry learning supported by digital tools can significantly enhance students' higher-order thinking skills.

In addition to academic improvement, this study also integrates Qur'anic values into the learning design to foster spiritual and moral awareness among students. The integration of Islamic values into science learning is expected to shape students' scientific attitudes aligned with ethical and religious principles, leading to holistic education that balances intellectual and moral development.

This study also aligns with 21st-century learning principles, which emphasize the integration of digital technology in fostering independent learning, creativity, and collaboration. By utilizing E-LKPDs, students can learn autonomously while still being guided through a structured inquiry process. This approach not only improves cognitive outcomes but also develops essential soft skills such as teamwork, communication, and critical thinking.

Despite these findings, there remains a limited number of empirical studies quantitatively examining the effectiveness of POGIL-based E-LKPD in chemistry—particularly on topics requiring high levels of logical reasoning such as chemical calculations. Many prior studies have focused on descriptive or small-scale applications without statistical validation. Consequently, this research seeks to fill that gap by analyzing the effectiveness of the POGIL-based E-LKPD using inferential statistics (Wilcoxon and N-Gain tests).

Therefore, this study aims to empirically examine the effectiveness of the POGIL-based E-LKPD in enhancing students' learning outcomes in chemical calculation material. The findings are expected to provide valuable insights for chemistry educators seeking to adopt innovative, inquiry-based digital learning strategies to promote deeper conceptual understanding and student engagement.

RESEARCH METHODS

Research Design

This research employed a quasi-experimental design with a one-group pretest–posttest approach to measure the effectiveness of the E-LKPD based on the POGIL model in improving students' learning outcomes on chemical calculation material. The study was conducted at MA Bintan during the 2025/2026 academic year involving 40 students of class X MIA.

The experimental procedure consisted of three main stages. First, a pretest was administered prior to the intervention to measure students' initial understanding of the subject matter. This was followed by the treatment stage, in which the POGIL-based electronic student worksheet (E-LKPD)

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was implemented during the learning process. Finally, a posttest was administered after the intervention to evaluate improvements in students' mastery of the concepts learned.

The POGIL learning syntax implemented in the E-LKPD followed four core phases:

Table 1. The POGIL Learning Syntax

Phase	Learning Activity	Student Role
Orientation	Introduction of learning objectives and problem situations	Receive guidance and motivation
Exploration	Students perform guided activities to explore chemical calculation concepts	Observe, discuss, and collect data
Concept Invention	Students formulate and construct new concepts	Analyze, interpret, and summarize
Application	Students apply newly learned concepts to solve contextual problems	Solve problems independently and collaboratively

Research Instruments

The main instrument used was a learning outcomes test consisting of 20 multiple-choice items designed to measure students' conceptual understanding and problem-solving ability in chemical calculations. The instrument's validity was confirmed through expert judgment, while reliability was tested using the Cronbach Alpha coefficient, resulting in a reliability value of 0.87, categorized as high reliability.

Additional data were obtained from observation sheets to monitor students' activity during the learning process and to qualitatively describe engagement and collaboration patterns.

Data Analysis Techniques

Data were analyzed using both quantitative and qualitative approaches. Quantitative analysis began with a normality test conducted using the Shapiro–Wilk method to determine whether the data were normally distributed. Subsequently, a homogeneity test was performed using Levene's test to assess the equality of variances. Since the data did not meet the assumption of normal distribution, the effectiveness of the treatment was analyzed using the Wilcoxon Signed-Rank Test.

RESULTS AND DISCUSSION

The statistical results indicate that the POGIL-based E-LKPD significantly improved students' mastery of chemical calculation concepts. The large effect size ($r = 0.84$) suggests that the learning model and media combination contributed substantially to learning gains. This aligns with Muchtar & Firmansyah (2015), who reported that scientific and inquiry-based approaches improve learning outcomes and higher-order thinking skills.

Table 2. Students' Learning Outcomes Before Using the POGIL-based E-LKPD

Interval	Frequency	Percentage
80,0 – 100	0	0%
60,0 - 79,9	6	15%
40,0 - 59,9	22	55%
20,0 - 39,9	12	30%
0 - 19,9	0	0%

Table 2 shows that before using the POGIL-based E-LKPD, most students' learning outcomes were in the medium category (55%), and 30% were in the low category, showing limited understanding of chemical calculation material.

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Table 3. Students' Learning Outcomes After Using the POGIL-based E-LKPD

Interval	Frequency	Percentage
80,0 – 100	18	45%
60,0 - 79,9	20	50%
40,0 - 59,9	2	5%
20,0 - 39,9	0	0%
0 - 19,9	0	0%

Table 3 shows a significant improvement in students' performance after the implementation of the POGIL-based E-LKPD. A total of 95% of students achieved high and very high scores, while only 5% remained in the medium category.

Table 4. Statistical Test of E-LKPD Effectiveness

Statistical Test	Value	Interpretation
Z (Wilcoxon Signed-Rank Test)	-5,330	45%
Asymp. Sig. (2-tailed)	< 0.001	Data are significantly different
Effect Size (r)	0,84	Large effect (Cohen, 1988)

Table 4 confirms that the POGIL-based E-LKPD had a significant and strong impact on improving students' learning outcomes. The large effect size indicates that the intervention effectively enhanced conceptual understanding and overall learning achievement.

Qualitative observation showed that students were more engaged and enthusiastic during the learning process. They collaborated actively in solving problems, discussed findings, and demonstrated better conceptual comprehension. The electronic format of the worksheet also provided easier access to resources and visual aids that supported inquiry learning.

Moreover, the integration of Qur'anic values in learning encouraged students to connect scientific understanding with ethical and spiritual reflection, supporting holistic education that aligns science with faith.

The descriptive statistics of students' pretest and posttest scores are presented below.

Table 5. Comparison of Pretest and Posttest Scores

Variable	N	Minimum	Maximum	Mean	Std. Deviation
Pretest	40	40	75	52,35	8,47
Posttest	40	70	95	81,70	6,82

The figure shows a substantial increase in mean scores from 52.35 to 81.70, indicating improved student understanding after the implementation of the POGIL-based E-LKPD.

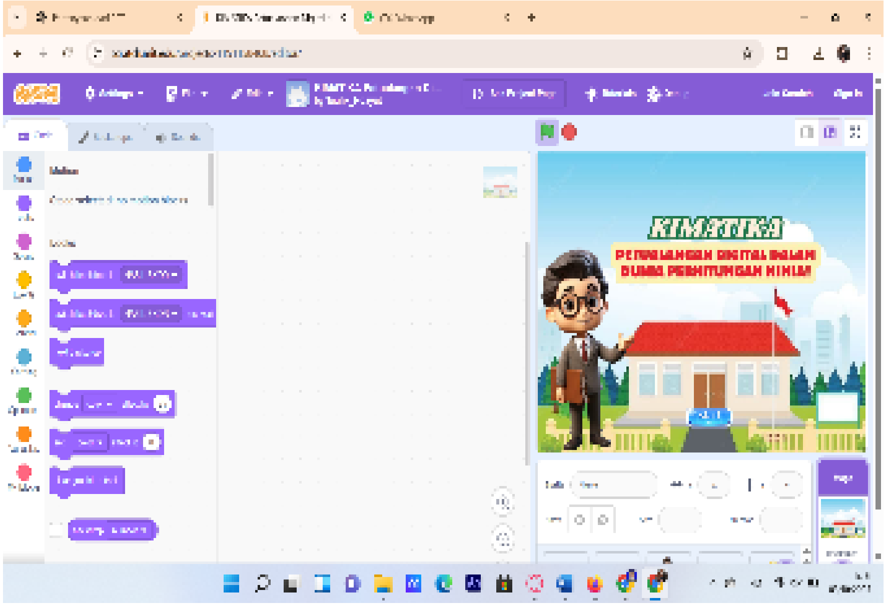
Table 6. The results of the normality and homogeneity tests are summarized

Test Type	Statistic	Sig. (p)	Interpretation
Shapiro–Wilk (Pretest)	0.925	0.021	Data not normal
Shapiro–Wilk (Posttest)	0.903	0.015	Data not normal
Levene's Test	2.674	0.109	Homogeneous variance

The Shapiro–Wilk test results (Sig < 0.05) indicate non-normal data distribution. Therefore, non-parametric analysis using the Wilcoxon Signed-Rank Test was applied. The Levene's test showed p > 0.05, indicating homogeneous variance between pretest and posttest scores.

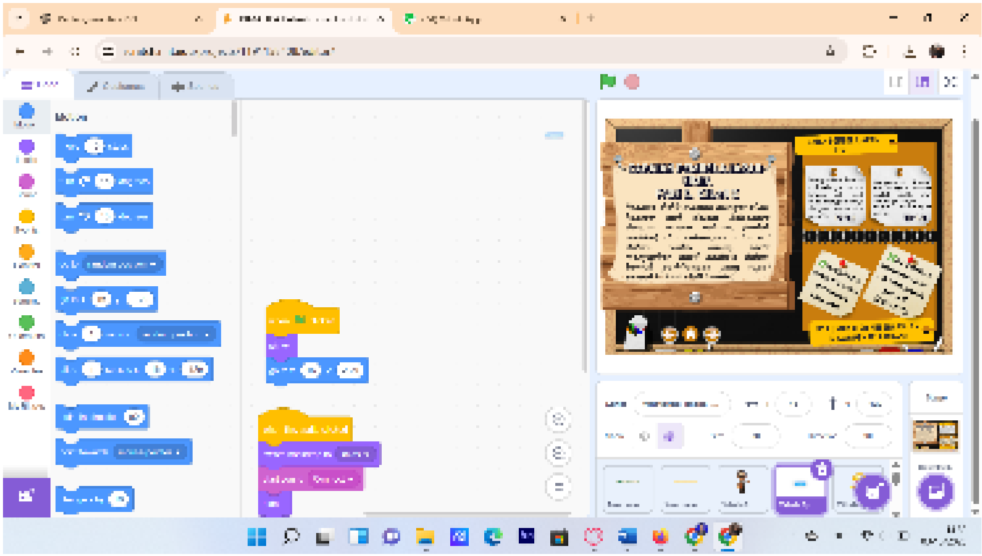
The statistical findings demonstrate that implementing the POGIL-based E-LKPD substantially improves students' learning outcomes. This aligns with the constructivist theory emphasizing student engagement through guided inquiry. The large effect size confirms that integrating POGIL phases into digital worksheets promotes active learning, collaboration, and conceptual understanding.

Development Results of the POGIL-Based E-LKPD Using Scratch on Chemical Calculation Material.



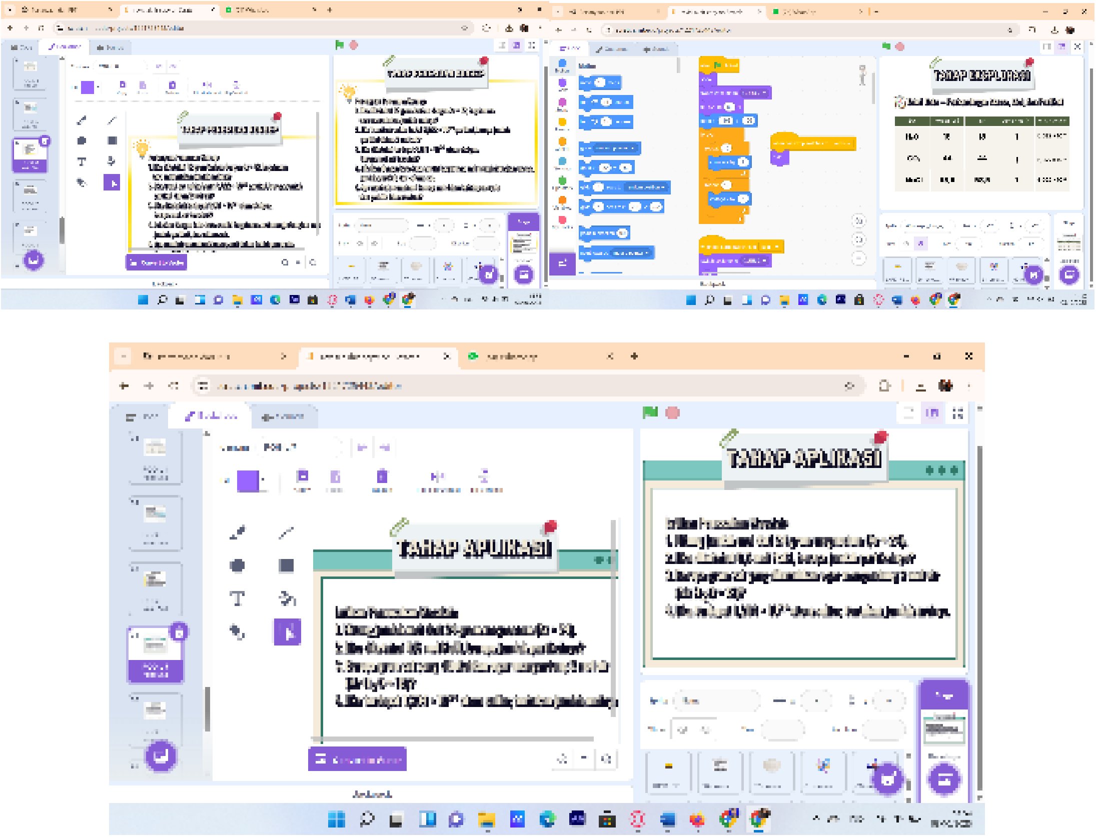
Picture 1. Cover

The initial display presents the media title “KIMATIKA: A Digital Chemistry Adventure with a Virtual Teacher.” The design utilizes a customized backdrop and sprite representing a teacher character. This opening screen visually introduces students to the theme of the learning media. The transition to the next page is activated by pressing the Start button.



Picture 2. Learning Objectives and Achievement Indicators

This page functions to communicate the learning objectives and expected outcomes to students. It helps learners understand the competencies they are expected to achieve and serves as a reference point throughout the lesson. This ensures that students are aware of the learning goals while engaging with the POGIL-based E-LKPD activities.



Picture 3. POGIL Learning Steps

This section outlines the POGIL learning syntax integrated into classroom activities. Each session includes the essential stages of orientation, exploration, concept invention, and application. Through these steps, students engage in guided discovery and problem-solving processes that strengthen their conceptual understanding and teamwork

Students were observed to engage more actively in group discussions, question formulation, and reflection activities. The electronic format made the learning process more interactive through embedded visual and multimedia aids, which helped clarify abstract chemical relationships such as mole ratios and stoichiometric conversions.

This result is consistent with Antonio & Prudente (2024), Putri & Rahayu (2023), Ozila & Zen (2023) and Yamwongsri & Chen (2025), who found that inquiry-based digital learning improves both engagement and higher-order thinking skills. The digital POGIL environment provided immediate feedback and visual representation, fostering a more student-centered and technology-driven learning experience.

Additionally, integrating digital worksheets with inquiry learning supports 21st-century education competencies, including collaboration, problem-solving, and digital literacy (Winarko, 2024; Yulia et al., 2021). The structured guidance within POGIL enabled students to independently explore concepts while maintaining a clear learning trajectory a balance between autonomy and structure crucial for scientific reasoning development.

The findings of this study strengthen the theoretical foundation of constructivist learning, which emphasizes that meaningful understanding is achieved through active inquiry, interaction, and reflection. The significant improvement in students' mastery of chemical calculation concepts demonstrates that the integration of POGIL syntax within an electronic learning environment is not only theoretically sound but also practically effective. This result is particularly important for chemistry learning at the senior high school level, especially for chemical calculation material that is often perceived as abstract and difficult. Through guided inquiry stages embedded in the POGIL-based E-LKPD, students were able to actively construct knowledge, explore relationships among concepts, and

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apply mathematical reasoning in a structured manner. For faith-based schools, the integration of Qur'anic values further enriches the learning process by connecting scientific understanding with ethical and spiritual reflection, thereby supporting holistic education that balances cognitive, affective, and spiritual development.

From a pedagogical perspective, this research contributes to the growing body of literature on the digital transformation of instructional materials by demonstrating that inquiry-oriented strategies remain effective when mediated by technology. The POGIL-based E-LKPD provides teachers with a flexible and structured tool to facilitate guided inquiry, increase student participation, and promote deeper understanding of complex chemical concepts. For schools, especially those seeking to align instruction with 21st-century learning goals, this model offers a scalable and sustainable approach to improving instructional quality, fostering collaboration, problem-solving skills, and digital literacy among students. The positive qualitative findings, such as increased engagement, collaboration, and enthusiasm, further support the practical value of implementing digital inquiry-based learning in chemistry classrooms.

Despite these promising results, several limitations must be acknowledged. This study involved a limited sample size from a single class and employed a one-group pretest–posttest design without a control group, which restricts the generalizability of the findings and limits comparative conclusions with other learning models. Additionally, the focus of the study was confined to chemical calculation material, and long-term effects such as learning retention, development of higher-order thinking skills, and changes in students' scientific attitudes were not examined. Therefore, future research is recommended to involve larger and more diverse samples, apply experimental designs with control groups, and extend the implementation of the POGIL-based E-LKPD to other chemistry topics and grade levels. Further studies may also explore the integration of this model with other digital learning platforms or AI-assisted systems to support more adaptive and personalized learning experiences, as well as to investigate its long-term impact on students' cognitive, affective, and spiritual development, particularly in faith-based educational settings.

CONCLUSION

The findings of this research conclude that the Electronic Student Worksheet (E-LKPD) based on the Process Oriented Guided Inquiry Learning (POGIL) model is highly effective in improving students' learning outcomes in chemical calculation material. The statistical analysis through the Wilcoxon Signed-Rank Test showed a significant difference ($Z = -5.330$; $p < 0.001$) between pretest and posttest scores, and the calculated effect size ($r = 0.84$) falls into the large category, demonstrating the strong influence of the treatment.

The implementation of the POGIL-based E-LKPD was not only effective in raising students' academic performance but also succeeded in fostering active participation, collaboration, and critical thinking. It allowed students to explore scientific concepts independently and interactively, aligning with the principles of 21st-century learning. Furthermore, by integrating Qur'anic values, this learning model nurtured students' moral awareness and reflective thinking, contributing to the formation of scientific character and spiritual sensitivity.

For educators, the findings imply that E-LKPD-based POGIL can serve as a model of technology-integrated inquiry learning that enhances engagement and understanding in complex subjects such as chemistry. Future research is recommended to apply this model to different chemistry topics, investigate its long-term impact on higher-order thinking, and explore its implementation in varied educational contexts to strengthen both cognitive and affective learning outcomes.

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