Research Article

Review of Chemistry Learning Strategy Based on Process Oriented Guided Inquiry Learning (POGIL)

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Abstract.
This study aimed to review the application of Process Oriented Guided Inquiry Learning (POGIL) in chemistry learning strategies by analysing reputable international journal documents between 2012 and 2022. The method used was a literature study with 47 articles on POGIL-based chemistry learning strategies. The results of the analysis showed that POGIL-based chemistry learning strategies applied to college students and high school students can improve learning achievement, self-efficacy, critical thinking, problem-solving, science processing skills, representational abilities, multiple intelligences and other skills. The chemical study materials were about basic chemistry, organic chemistry, physical chemistry, biochemistry and inorganic chemistry. In addition, several researchers used the POGIL syntax at different stages from the original idea of Moog and Spencer because the design of POGIL activities adapted to the skills to be improved. Furthermore, there are limitations to the application of POGIL-based chemistry learning strategies, which require more time to implement.

Keywords: POGIL, chemistry, learning strategies

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1. INTRODUCTION

POGIL is a process-oriented strategy in which students work in small groups to engage with carefully designed activities. These activities focus on core concepts and encourage a deep understanding of the subject matter while also developing higher-order skills such as critical thinking, problem solving, and communication through collaboration and reflection [1]. The structure of POGIL is based on social constructivist learning theory and therefore engages students to develop their conceptual understanding collaboratively [2]. The design of POGIL activities is based on a learning cycle that involves "critical thinking questions" which are characterized as (1) Exploration (answering directed questions), (2) Concept discovery (constructing ideas), and (3) Application (applying ideas to new contexts) [3].

POGIL classrooms differ from traditional classrooms in that the instructor acts as a facilitator and students take a more active role in learning new concepts. Students are encouraged to engage in discussion of questions and concepts; they then internalize these concepts and manipulate and modify them to apply them in various contexts [4]. There is no one right way to implement POGIL, but there are four core characteristics that must be present in order for an implementation to be considered as POGIL including, (1) Students are expected to work collaboratively in groups of three or four people, (2) Activities used students are specially designed for POGIL implementation and follow the learning cycle process, (3) Students work on activities during class time with the presence of the instructor, (4) Teachers act more as facilitators of student, not as lecturers [4].

Seven process skills can be developed in a POGIL learning environment when using well-designed POGIL activities: communication, teamwork, management, information processing, critical thinking, problem solving, and assessment (especially self-assessment). That is, POGIL materials are designed to develop transferable skills in a content learning context, with one or two process skills targets in a well-designed POGIL activity [5].

There are not many explicit reports on the application review of the POGIL strategy especially in chemistry learning. The lack of literature on reviews of the application of POGIL-based chemistry learning strategies is one of the obstacles for educators in overcoming obstacles to the application of POGIL activities. This statement is in line with Rodriguez [6] who stated that POGIL-based instruction supports student learning better than the traditional approaches. Nevertheless, universities have been slow to move away from instructor centered teaching methods, this happens due to obstacles that have not been addressed, one of which is the lack of review literature application of chemistry learning strategies. Therefore, there is a need for a literature review study on the use of POGIL-based chemistry learning strategies. With the information from the literature review can assist educators in designing and implementing learning strategies. This article is the latest article that reviews the application of the POGIL learning strategy especially in chemistry by describing and reviewing the existing literature, affecting what skills can be improved, modified POGIL syntax to help improve these skills, and limitations in implementing the POGIL strategies. The purpose of writing this article is to review the application of POGIL-based chemistry learning strategies through the analysis of reputable international journal documents between 2012 – 2022.

2. RESEARCH METHOD

In this study, we investigate and analyze articles between the years 2012 – 2022 that have been published to obtain data on the application of POGIL-based chemistry learning strategies. To obtain data, several steps were taken, namely collecting relevant articles, identifying articles, and analyzing the identification of the articles. Article collection is done by searching through a digital database search on Google Scholar regarding POGIL-based learning strategies, where the publishers of the articles sought are such as the American Chemical Society (ACS), SpringerLink, ERIC, Royal Society of Chemistry and others. In a google Scholar search, it is done by typing keywords such as POGIL-based chemistry learning strategy, POGIL implementation, POGIL influence in chemistry learning, and Process Oriented Guided Inquiry Learning (POGIL). In searching for relevant articles, there are criteria used in article selection, namely article publishers must be Scopus indexed, the subject in the article is high school and college students, articles published between 2012 and 2022, and must be within the scope of chemistry learning. After collecting articles, 60 articles related to POGIL learning strategies were obtained, after screening the contents of the articles, 47 articles related to POGIL-based chemistry learning strategies were obtained. The articles obtained were identified and analyzed. Each article is identified by a title, then viewed from the abstract to the results obtained. Based on the identification of the articles, several points were obtained as the focus of article review analysis, namely the influence of the application of POGIL-based chemistry learning strategies, modification of POGIL syntax to help improve the skills obtained from the application of POGIL-based chemistry learning strategies, as well as limitations in the application of POGIL-based chemistry learning strategies.

3. RESULT AND DISCUSSION

In this study, we will summarize and discuss POGIL-based chemistry learning strategies from 2012 to 2022. Based on the 47 articles we have reviewed, we identify the effect of applying POGIL-based chemistry learning strategies, then research using POGIL syntax with different stages. from the original idea of Moog and Spencer [7]. Simonson which generally consists of three stages, namely exploration, concept formation and application, this is because the design of POGIL activities adapts to the skills to be improved, in addition it is found that there are limitations in the use of POGIL-based learning.

3.1. Chemistry Topic

In the articles studied, the chemistry topics taught in the application of POGIL-based chemistry learning strategies are divided into several main topics, namely basic chemistry, organic chemistry, physical chemistry, biochemistry, and inorganic chemistry. The main topic of chemistry that is widely discussed in implementing the POGIL strategy is basic chemistry, which is divided into several materials, namely electrochemistry, chemical bonds, hydrocarbon compounds, solubility equilibrium, reaction rates, thermochemistry, mole concepts, hydrolyzing salts. Table 1, presents the chemistry topics taught in the application of POGIL-based chemistry learning strategies contained in the article.

Table 1: Topics of chemistry taught in the application of POGIL-based chemistry learning strategies.

Chemistry Topics	**References**
Basic chemistry	(1, 2, 3, 5, 7, 10, 14, 15, 19, 21, 25, 30, 33, 34, 37, 38, 39, 40, 41, 42, 43, 45, 46, 48)
Organic chemistry	(8, 9, 10, 11, 12, 13, 16, 29, 32 , 47)
Physical chemistry	(6, 7, 17, 23, 24, 28, 35, 36, 44)
Biochemistry	(4, 7, 11, 27)
Inorganic chemistry	(18, 20)

3.2. Research Subject

The research subjects in the application of this POGIL-based chemistry learning strategy are college students and high school students who are mostly applied to college students as shown in Table 2.

Table 2: Research subjects.

Research Subject	**References**
College student	(4, 6, 7, 8, 9, 10, 11, 12, 13, 16, 17, 20, 23, 24, 25, 27, 28, 29, 32, 35, 36, 40, 41, 42, 43, 44, 46, 47)
High school student	(1, 2, 3, 5, 14, 15, 19, 21, 30, 33, 34, 37, 38, 39, 45)

Results of implementing POGIL-based chemistry learning strategies

There is a relationship between student achievement and the method used [8] which in this study used POGIL-based learning strategies. Table 1 summarizes the results of the review of several articles after implementing the POGIL-based learning strategy. Based on the results of the analysis, POGIL - based chemistry learning strategies can improve student achievement and some skills. A total of 26 of 47 articles reported that the results of implementing POGIL-based learning strategies were to improve learning achievement. 11 articles report that the POGIL strategy can improve students'. The test results are used to see the increase in students' conceptual understanding [9]. The other three articles are known to be able to overcome students' misconceptions. Two articles discuss how the POGIL strategy can examine how the class coordinates macroscopic, submicroscopic, and symbolic representation levels through class discourse [10] and the result is that the POGIL strategy can improve students' representational skills. Judging from the effect of students in their arguments [11]. In addition to cognitive, affective skills such as students' self-confidence (Self Efficacy) are proven to be improved through reports from 6 articles. The application of the POGIL strategy can also improve collaborative abilities among students , which is summarized in 3 articles. Furthermore, improving skills in problem solving [12–14], process skills [5, 15–18], communication [1], critical thinking [1, 19–23], and improving argumentation skills [4, 11, 24, 25]. Improving scientific literacy [26] and information literacy [14], multiple intelligence [6] as well as two articles that apply the POGIL strategy to improve these strategies to suit students, such as to serve novice students in the context of academic development programs [27]. Table 3. Presents the results obtained after implementing the POGIL-based chemistry learning strategy.

3.3. Modification of POGIL Syntax

POGIL syntax generally consists of three stages, namely exploration, concept formation and application. However, there were 12 review articles whose syntax was modified for additional activities outside the three general stages, in order to support the achievement of learning achievement goals or skills to be improved. Modification of syntax in improving learning achievement is carried out in several ways namely students work through at least two learning cycles in which they make predictions, collect data, model data, and discuss their meaning [28], The modified version is different from other studies in that each lecture starts with approx. about five slides of content before students are divided into small groups to work on a POGIL-style activity [1], In addition, another POGIL implementation in the classroom uses hybrid POGIL, which is defined as a combination of the POGIL method (1/2 of weekly class time) and a more conventional lecture format (sometimes with half lecture and half POGIL on the same day, and sometimes full POGIL

Table 3: The results of implementing POGIL-based chemistry learning strategies.

Influence Obtained	References
Improve learning achievement	(1, 2, 4, 5, 7, 10, 11, 12, 13, 16, 17, 19, 21, 27, 28, 29, 31, 32, 34, 38, 40, 43, 44, 46, 47, 48)
Improve conceptual understanding	(4, 5, 9, 16, 18, 25, 27, 28, 33, 34, 47)
Overcoming misconceptions	(1, 5, 33)
Improve representational skills	(6, 35)
Improve self-confidence	(10, 12, 27, 39, 41, 42)
Improve problem solving	(13, 15, 20)
skills Improve collaborative	(2, 20, 34)
skills Improve process	(1, 8, 32, 43, 44)
skills Improve communication	(46)
skills Improve critical thinking skills	(2, 14, 34, 37, 45, 46)
Improve argument skills	(23, 24, 35, 36)
Improve scientific	(3)
literacy Improve information literacy	(20)
Improving multiple intelligence	(30)
Improving POGIL strategies to be better and needs of students	(25, 26)

sessions), following the model by Perry and Wright. Meanwhile, the POGIL routines set in the classroom were adapted from the work of Vishnumolakala to suit the researchers' institutional constraints. And every POGIL stage is accompanied by using a quick clicker quiz and after that the instructor will provide feedback [29]. In line with the increase in learning achievement, the understanding of students' concepts also increases. There are three articles that modify POGIL syntax to improve concept understanding, namely by changing 100% of lecture activities to apply POGIL and combining it with clicker quizzes, think-pair-share, and lecture PowerPoints that function as templates [30]. In another article, the flow of POGIL activities was modified according to the suggestions of workshop participants starting from arranging activities that were not long-winded, changing the order of several questions in the activity, and removing some content from the activity information section [31]. Another article reviews the modification of POGIL syntax by applying the heuristics of science writing in the laboratory and also updating the activity section of the course to allow the implementation of POGIL activities based on the model presented by Minderhout and Loertsher, this is done to improve students' science process skills [17] while other articles modify it by making minor procedural adjustments from time to time [16]. In order to improve argumentation skills, the strategies applied will be chosen by the instructors, determined by their experience implementing POGIL, the constraints of their learning environment, and their teaching philosophy [4]. In addition, to increase the confidence of students. The POGIL syntax intervention was modified according to the learning environment of the institution as shown in Figure 1, which is an illustration of how POGIL is organized [32]. The modified approach utilizes mini-lecture presentations with small group activities in workshop sessions.

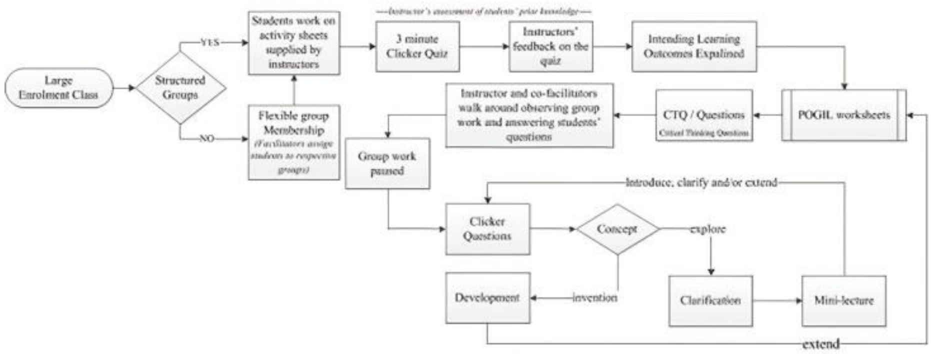

Figure 1: Application of POGIL in the first year undergraduate chemistry class. [32].

3.4. Limitations of POGIL-based Chemistry Learning Strategies

The limitations found in the application of POGIL-based chemistry learning strategies that have been analyzed in 47 research articles are limitations as stated by Conway [33] guided inquiry such as the POGIL strategy requires changes in course content, because this technique requires more time for students to learn Theory. These techniques cover somewhat less material but are more in-depth. It is physically impossible to cover the same amount of material using guided inquiry as it is using the lecture method. This is in line with the statement of Rege [34], when they first heard about POGIL, many instructors were interested in this strategy and could see the benefits, but they were worried that the speed of the material covered would be much slower in POGIL courses than in lecture-based in general. The limitations of applying different POGIL strategies were found through one of the challenges of the POGIL class: students' knowledge gaps and wrong ideas were often seen by teachers and peers. Students are reluctant to make mistakes in class, so it is important for teachers to set the right way early on in which mistakes should be seen as a normal part of the learning process. Another limitation of the POGIL strategy by Hein [35] stated that an area of concern in implementing POGIL is that it caters students to low achieving. The findings show that fewer students scored lower in chemistry courses; more students can score above average or average. This makes sense because students would get the most out of such an approach.

Furthermore, the limitations of the application of POGIL were found in high schools in Qatar [36] where the application of POGIL was selective in terms of curriculum content.

Communicating, and applying concepts. The most of students answered correctly on predicting question as many as 81% of 211 students. While the the students rarely answered correctly on applying the concept question, only 24% of 211 students answered correctly.

4. CONCLUSION

In an effort to bring abstract chemistry topics into a concrete and understandable form, chemistry instructors use a variety of models to explain complex science topics. To address the problems inherent in the subject of inquiry, science educators have turned to inquiry process-oriented mentoring (POGIL). In the POGIL learning cycle students work in small cooperative study groups. Based on the results of this study, the application of POGIL-based chemistry learning strategies had the most effect on increasing learning achievement, which was reported by 26 articles out of 47 articles analyzed. through an analysis of reputable international journal documents between 2012 – 2022. In addition, we found 12 analytical articles that modify the POGIL syntax. In general, modifications and corrections are made in accordance with the views obtained (on the basis of student feedback and researcher observations) and adapted to the needs of students in order to achieve learning objectives. Another modification is the integration of the POGIL strategy with other activities that can support learning. Furthermore, regarding the limitations of the application of the POGIL learning strategy, the most impactful in terms of time is because guided inquiry such as the POGIL strategy requires changes in course content which requires more time for students to learn the material. This statement is in line with Rege, et al, they are worried that the speed of the material discussed will be much slower in the POGIL course.

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