Process Oriented Guided Inquiry Learning (POGIL) Lesson Plans in Physics to enhance 21st-Century Skills

Benigno Ninoy S. Aquino High School (Emil F. Arboleda) and
Philippine Normal University (Marie Paz E. Morales)

Abstract

The study developed POGIL (Process Oriented Guided Inquiry Learning) lesson plans in Physics to enhance junior high school students' 21st-century skills (i.e., problem-solving, collaboration, and adaptability). The ADDIE (analysis, design, development, implementation, and evaluation) model influenced the design and validation of the POGIL lesson. The study employed a descriptive developmental design, incorporating a pretest and posttest approach through self-assessment questionnaires to evaluate the 21st-century skills of 157 conveniently sampled junior high school students. The results revealed that the developed POGIL lesson plans were highly acceptable as rated by purposively selected four experts and four teachers. Furthermore, there was a statistically significant difference between the mean results of the pretest and posttest, indicative of the capability of the developed POGIL lesson plans to enhance 21st-century skills. Utilization of POGIL lesson plans in physics and other subject areas is highly recommended.

Keywords: Inquiry based – learning, constructivism, cooperative learning

INTRODUCTION

A global shift towards a knowledge-based economy where knowledge is one of the vital components of a modern economy transforms the way people live, work, and learn, which requires an expanded set of skills, competencies, and flexibilities (Organization for Economic Cooperation and Development [OECD], 2012). The country's success in the knowledge-based economy depends on the ability of its workforce to respond to new challenges and pursue lifelong learning opportunities (Kefela, 2010). Many employers and educators believe that a new set of skills is required to succeed in this world of new challenges, which requires collaboration, flexibility, and innovation to devise unique and carefully designed solutions (ACTRC, 2015). Thus, education as the path to providing essential skills and knowledge is of central importance to innovation and economic and productive growth to produce a well-educated and highly skilled workforce necessary for success

in the knowledge-based economy (Knowledge Economy Indicators, 2008). In fact, the Asian Development Bank (ADB, 2014) pointed out that in meeting the challenges of a knowledge-based economy through education policies, strategies should be geared towards developing human capital and promoting broad access to skills and competencies such as the capability to learn.

Similarly, international consensus reports that to achieve a knowledge-based economy, a strong foundation in the science education system is a requisite, and it must be anchored on knowledge and innovation (Gluckman, 2010). Hence, education must prepare students to meet these challenges and demands of the workforce. Seemingly, the Partnership for *21st*-Century Skills (P21, 2008) defines the most in-demand three sets of skills in the 21st-Century in achieving a knowledge-based economy: learning and innovation skills, information, media, and technology skills, and life and career skills (Fadel & Trilling, 2012). In fact, the country's education department also recognizes the importance of instilling these skills in learners through various teaching approaches (DepEd, 2019). In this agency, the vision focuses on the responsibility of educators in 21st-century learning to incorporate a healthy balance of knowledge and skills acquisition through engaging learning experiences that bring the real world into the classroom and the classroom into the real world (Hanover Research, 2014). Achieving this balance can be challenging and requires that we adopt new ways of teaching, harness the power of technology for learning, and re-vision words like "classroom," "teacher," "school," and even "student." Thus, this study investigated the use of POGIL in developing 21st-century skills of learners.

POGIL and the 21st-Century Skills

Read literature dictates that problem-based learning (PBL) and inquiry-based learning (IBL) are promising instructional practices to integrate 21st-century skills development in classroom instruction (Bell, 2010; Chu, Reynolds, Notari, Taveres & Lee, 2018). Kuhlthau and colleagues (2015) believed that students acquire 21st-century skills through inquiry processes guided by teachers along the way. Inquiry-based teaching and learning (IBTL) is a learner-centered approach that allows students to gain knowledge by engaging them to formulate questions about a topic, encouraging them to probe and use evidence to find or create solutions to problems, promoting the use of new knowledge in a context that they can relate to, and foster sharing of knowledge with others. In IBTL, teachers or instructors are facilitators of information processing rather than the sole sources of information (SEAMEO, 2016), meaning that attributes of PBL and IBLT may be able to develop 21st-century skills (i.e., problem-solving, collaboration, and adaptability) and may provide an impetus for change in education paradigm.

Within the umbrella of IBTL, POGIL (Process Oriented Guided Inquiry

Learning) is a form of active learning and student-centered teaching strategy that can develop 21st-century skills (Ingersoll, 2015; Kristen et al., 2017; Pogilorg, 2012; Ratti & Power, 2018). Likewise, POGIL lessons scaffold, create high levels of critical thinking and problem-solving skills, and also help impart conceptual clarity, student engagement, and communication through cooperation and reflection (Kode & Cherukuri, 2014). POGIL promotes critical thinking and problem-solving skills aside from improving academic performance (Irwanto et al., 2018). Theoretically, POGIL's success in these aspects of developing *21st*-century skills anchors on cooperative learning, learning cycles, and constructivism, which may induce effective and engaging learning episodes to sustain learning and deepen students' understanding of content and discipline. POGIL activities may promote collaborative learning, critical thinking, and deeper engagement with physics topics, all contributing to improved student performance. Utilizing inquiry-based teaching in physics, like POGIL, can lead to higher achievement scores and help foster growth in mindset through learning.

POGIL in Teaching Physics

The application of POGIL in the sciences has the potential to enhance student learning outcomes significantly. Specifically, most researchers would want to extend their studies on pedagogies and teaching approaches to encompass, explain, and address student difficulties in learning one of the abstract and challenging sciences (Physics). By consensus, the failure of most students in Physics is attributed to a lack of interest, poor problem-solving skills, poor understanding of the concepts in Physics, lack of skill in practical work, and lack of motivation and interest (Assefa et al., 2008; Ornek, 2008). In fact, Onah and Ugwu (2010) identified teaching methodology as one of the predictors of students' performance in Physics.

Teaching the Generation Z poses a significant challenge for Physics educators because students' learning styles often differ from educators' teaching methods. Jones (2012) emphasizes that modern millennial learners "want to engage with the content, not just learn it." Their daily use of modern information technology shapes their motivation to learn, enhancing their creativity and exploration of skills in understanding natural phenomena (Holubova, 2015). Heron and Mceil (2016) reported that to prepare physics students for their 21st-century careers, they must experience an inquiry-based science pedagogical approach where learning experiences involve: 1) Defining problems, 2) planning and carrying out investigations, 3) analyzing and interpreting data, 4) developing and using models, 5) developing explanations and designs based on evidence, 6) applying and using scientific knowledge, and 7) communicating information. Various research studies describe these pedagogical characterizations in POGIL.

POGIL teaching actively develops process skills like critical thinking, problem-solving, and communication by fostering cooperation and reflection—essential attributes and skills for *21st*-century learning (Geiger, 2010). These POGIL features help students become lifelong learners and prepare them to compete more globally (Pogilorg, 2012). However, most POGIL lesson plans emphasize tertiary chemistry and biology teaching and learning (Garoutte & Mahoney, 2015; Trout, 2012). Recent research may evaluate the effectiveness of POGIL to traditional lecture-based education in teaching physics ideas. The findings may suggest that POGIL improves students' conceptual comprehension, problem-solving skills, and information retention. For Student Engagement and Active Learning, POGIL activities may promote collaborative learning, critical thinking, and deeper engagement with physics topics, all contributing to improved student performance. Studies conducted here in the Philippines by Villagonzalo (2014) and Domingo (2014) revealed that POGIL, when used as a teaching approach, enhances the academic performance of Filipino students in chemistry compared with the traditional method. In fact, Domingo (2014) suggested conducting experiments on POGIL instruction in other disciplines since no locally developed POGIL lesson plans are available. Thus, the study focused on developing exemplary POGIL lesson plans for junior high school Physics to enhance the 21st-century skills of the students.

The study theorized that the characteristics of POGIL lessons could develop the 21st-century skills of students who are learning physics (De Galle & Boisselle, 2015; Kussmaul, 2012; Moog & Spencer, 2008). POGIL physics lessons, categorized under inquiry learning, will allow students to construct new knowledge while traversing the three stages: exploration, concept invention, and application, which are believed to develop skills crucial to the demands of industries (Pogilorg, 2012). Students actively engage in activities to master concepts and develop essential learning skills by working in small groups with distinct roles, using carefully designed materials (Moog & Spencer, 2008).

In general, the study aimed to develop exemplary POGIL lesson plans in Physics to enhance the 21st-century skills of Filipino grade 7 students. Specifically, the study sought answers to the following objectives:

1. Identify the level of selected 21st-century skills (problem-solving, collaboration, and adaptability) in Grade 7 students.
2. Design and develop POGIL lesson plans in Physics to develop 21st-century skills (problem-solving, collaboration, and adaptability).
3. Establish content, face validity, and interrater reliability for the developed lesson plans.
4. Determine the effectiveness of the developed POGIL lesson plans to enhance the 21st-century skills of Grade 7 students.

METHODOLOGY

Research Design

The study used descriptive developmental research (DDR), which included observing and describing the behavior of identified participants if they develop 21st-century skills.

Furthermore, the study has four phases (as dictated by the ADDIE framework): 1) analysis and design of the POGIL lessons based on the Prilliman's scaffolding model and assessment questionnaire of the 21st-century skills; 2) development and validation of POGIL lesson plans; 3) implementation of POGIL lesson plans to Grade 7 students; and 4) evaluation of POGIL lessons using students and teachers 21st-century skills assessment questionnaire. Table 1 presents the demographic profile of the respondents.

Table 1. *Demographic Profile of Respondents*

	SECTION A	SECTION B	SECTION C	TOTAL
Male	27	26	26	79
Female	25	27	26	78
Total	52	53	52	157

Table 2. *Summary of Study Stages*

Stages Stages	Participants	Instruments	Data Collection Analysis
	One hundred fifty seven (157) Grade 7 students	21st-Century Skills Assessment adopted with minor revisions from the Career and Technical Education Manual (Washington Public Schools)	Questionnaire (Descriptive statistics)
1 Analysis and Design	Two Grade 7 Science Teachers	Curriculum Guide in Science 7 (Deped)	
	Science Coordinator	POGIL (instructor's Guide by Prilliman's)	
2 Development and Validation	Three Grade 7 Science teachers	Content and face validity tests	POGIL lesson plans in Physics
	Three experts in the field of Physics	Reliability test Inter-rater Reliability	Checklist Questionnaire (Descriptive statistics & Fleiss' kappa coefficient)
3 Implementation	Science Coordinator One hundred fifty seven (157) Grade 7 students	Revised POGIL lesson plans in Physics	POGIL Lesson plans Questionnaire (Descriptive statistics)
4 Evaluation	One hundred fifty seven (157)	21st Century skills Assessment adopted with minor revisions from the Career and Technical Education Manual (Washington Public Schools)	Questionnaire (Descriptive statistics and t-test) 1
	Four science teachers	21st Century Skills Student Assessment Questionnaire	

The ADDIE framework was used in structuring the overall design and evaluation of the POGIL lesson plans. This model is a generic framework that serves as the foundation for most instructional system designs, which represents a guideline for building, training, and performance support tools in five phases: analysis, design, development, implementation, and evaluation (see Figure 6) (Sega, 2006).

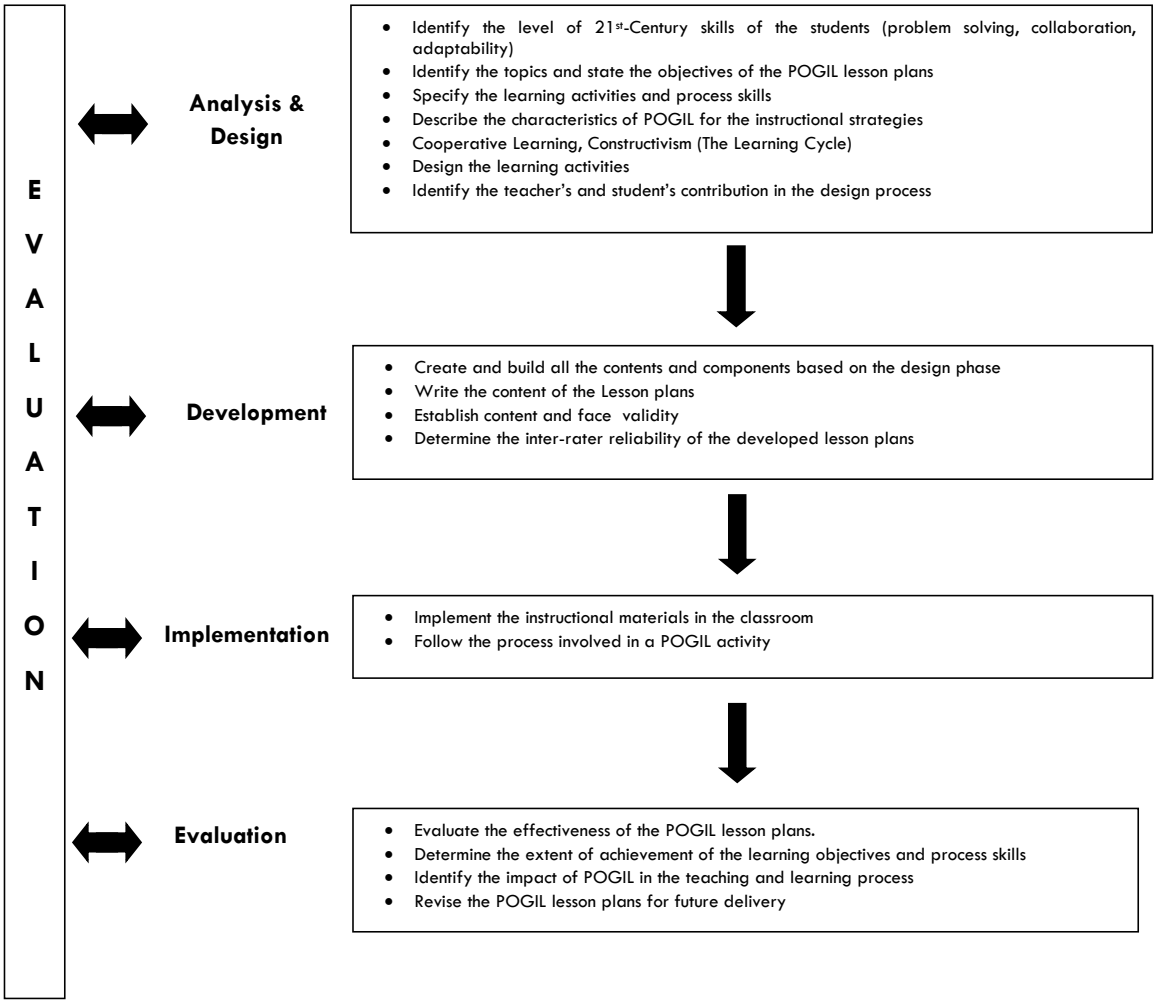

Figure 1. The ADDIE Model of a POGIL Lesson Plan

Participants of the Study

The researchers used convenience sampling techniques to select the study's respondents, selecting three sections of Grade 7 students, equivalent to 157 students, from a government school in Makati City.

Instruments

Need Analysis Questionnaire, Experts and Teacher POGIL Evaluation Questionnaire, and the 21st-Century Skills Student Assessment Questionnaire were the instruments used in this study.

Need Analysis Questionnaire

The researchers adopted a 5-point Likert scale for the need analysis questionnaire from the Career and Technical Education (CTE) Manual (Washington Public School), based on the Partnership for 21st-Century Skills (P21). The proponents chose three specific skills for the questionnaire: problem-solving, collaboration, and adaptability, as these align with the study's nature and objectives. The questionnaire consists of 10 items under the domains of learning and innovation skills and life and career skills. The assessment checklist makes use of a 4-point Likert scale with different scale values and verbal interpretations: strongly agree (4.51–5.00), agree (3.51–4.50), disagree (1.50–2.50), and strongly disagree (1.00–1.50).

The Expert's Assessment Checklist for POGIL Lesson Plans

This 4-point Likert scale evaluation instrument includes two parts: Part I gathered details on the validators' personal information and educational background, and Part II assessed the components of POGIL in terms of content learning objectives, activity structure, learning cycle structure, clarity and flow, process skills goal, cooperative structure, and self-assessment. The questionnaire consists of 22 items under the Content and Process skills domain.

21st-Century Skills Student Assessment Questionnaire

This adopted instrument for 21st-century skills (P21) assessed the 21st-century skills of the students who need POGIL lesson plans. The questionnaire includes Part I for the evaluator's personal and professional background and Part II for the checklist questionnaire that covers 21st-century skills' main domain, standards, and a description for each scale. The questionnaire consists of 7 items under the domains of learning and innovation skills and life and career skills. The criteria were assessed using a four-point scale with different scale values and verbal interpretations: Exceeds standard: 3.25–4.00, Satisfies standard: 2.50–3.24, Approaches standard: 1.75–2.49, and Does not satisfy standard: 1.00–1.74.

Data Gathering Procedure

The researchers observed all requisite details in heeding to all ethical considerations (informed consent, anonymity, request for permission, confidentiality, and security of data collected) in the conduct of the study before the 5-stage procedure.

Analysis phase

In this phase, analyzing the data generated through the assessment of the level of 21st-century skills of Grade 7 students provided important information on the extent to which they had acquired these skills. The results served as inputs for the design phase of the lesson plans.

Design phase

The identified 21st-century skills formed the basis of the lesson plan design in the analysis phase. In this stage, the researchers prepared the final list of topics covered in the lesson plans using the Department of Education's Grade 7 learning competencies (DepEd, 2012), based on Stephen Prilliman's scaffolding model. The Grade 7 science teachers gave formative evaluation through comments and suggestions regarding the content discussed, teaching strategies used, and the elements of POGIL considered.

Development and Validation phase

The researchers developed each lesson plan part based on the Prilliman Scaffolding Model. Content and face validity determine whether the developed lesson plan measures what it has been projected to measure. The identified experts and Grade 7 Science teachers evaluated the first draft of the POGIL lesson plan in the validation phase to establish the content and face validity. Interrater reliability established the internal consistency of the raters in evaluating the lesson plans.

Implementation

The POGIL lesson plans were tried out for two weeks, equivalent to thirty hours. The developed POGIL lesson plans were implemented in the lessons in the third quarter of the school year 2017-2018, specifically on the following topics: motion, speed, velocity, acceleration, properties of waves, electromagnetic waves, properties of light, sound, electricity, and heat.

Evaluation

Semi-structured interviews with students deduced all pertinent information and essential facts in the evaluation stage. The Science Department Head and Grade 7 Science Teachers evaluated the POGIL lesson plans and their implementation using the teacher observation checklist. The 21st-century skills rubric determined if students gained the target skills after implementing the POGIL lesson plans. The students submitted the answered questionnaires after each lesson. Likewise, the science teachers observed and evaluated if the students manifested

21st-century skills. Conducted interviews with the teachers, and the students gathered their insights, comments, and suggestions on the lesson plans. At the same time, the researchers consolidated, analyzed, and presented all the collected data in tables. These data facilitated decision-making about the delivery of instruction and the enhancement of the developed lesson plans.

Data Analysis

The computed mean indicated the level of 21st-century skills among the students based on their responses to a self-assessment survey questionnaire. The standard deviation helped analyze how closely the students' responses aligned with their 21st-century skills. Additionally, a t-test for dependent means was used to determine whether there was a significant difference in the mean scores from pretests and posttests following the implementation of POGIL lesson plans. Qualitative data obtained from interviews verified and justified all the statistical results generated.

RESULTS AND DISCUSSION

This section addresses the previously mentioned questions regarding the development of POGIL lessons, divided into four parts: 1) the level of 21st-century skills among selected Grade 7 students, focusing on problem-solving, collaboration, and adaptability; 2) the design and development process of the POGIL lesson plans; 3) the acceptability of the developed POGIL lesson plans and the degree of consensus among expert evaluations; and 4) the effectiveness of the developed POGIL lesson plans in enhancing 21st-century skills.

I.The Level of Grade 7 students' 21st-Century Skills in Problem-Solving, Collaboration, and Adaptability

21st-century skills are essential to our learners in facing the globally and interconnected world (Koenig, 2011). Table 3 presents the findings for each of the three 21st-century skills previously mentioned and their overall mean ratings.

Table 3. *Level of the 21st-Century Skills of Grade 7 Students*

I. LEARNING AND INNOVATION SKILLS	Total Responses	$\bar{x}$	±SD	Level of 21st-Century Skills
A. Problem solving				
1. I anticipate different kinds of problems in complicated projects.	366	2.33	0.66	Low
2. I think of ways to solve them before they happen.	402	2.56	0.59	Neither high nor low
Overall Total/Average	768	**2.45**	**0.64**	**Disagree**
B. Collaboration				
1. I can communicate openly in my group.	401	2.55	0.62	Neither high nor low
2. I function as an active participant in our group.	358	2.28	0.66	Low
3. I cooperate and show commitment to the group.	388	2.47	0.65	Low
Overall Total/Average	1147	**2.44**	**0.65**	**Disagree**
II. LIFE AND CAREER SKILLS				
C. Adaptability				
1. I can adjust my roles in the group to achieve our objectives	372	**2.37**	**0.63**	Low
2. I work towards the improvement of the group.	376	**2.39**	**0.67**	Low
3. I can work in a group even in a diverse situation.	385	**2.45**	**0.68**	Low
Overall Total/Average	1133	**2.41**	**0.66**	Low
Grand Total/Average		**2.43**	**0.65**	Low

Note: 1.00 – 1.50 strongly disagree (very low), 1.51 – 2.50 Disagree (low), 2.51 – 3.50 neither agree nor disagree (neither high nor low), 3.51 – 4.50 agree (high), 4.51 – 5.00 strongly agree (very high)

Students generally disagreed with the statements pertaining to the identified 21st-century skills categorized as learning and innovation skills (problem-solving and collaboration) and life and career skills (adaptability). They can be said to have a low level of application of the selected 21st-century skills.

Problem-Solving

Table 3 shows that the students possess a low level of problem-solving skills. The students struggle to assess the various options available when facing a problem. Their weakness in problem-solving may be attributed to their difficulty in recognizing and understanding the nature of the problem (OECD, PISA, 2010). Their lack of experience in thinking and analyzing problems is evidence of their weakness in cognitive processing to be able to understand and resolve problem situations (Shute, Wang, Greiff, Zhao, & Moore, 2016). The students also possess a low capacity to engage in cognitive processing to understand

and resolve problem situations where a method of solution is not immediately apparent. It might be that their willingness to engage in such situations is not that high in order to achieve one's potential as a constructive and reflective citizen (OECD, 2012). Reddy and Panacharoensawad (2017) emphasized the importance of this skill in affecting students' performance in physics. The lack of the ability to remember physics formulas and equations and the lack of practice in solving problems cause students to experience difficulty in solving problems.

Collaboration

Collaboration is one of the skills believed to be essential for students to learn in the 21st-century (Kyllonen, 2012). The low level (below the midpoint of the 5-point Likert scale) of collaboration skills of the students based on the mean score reveals that the students are probably anxious to share their ideas during group work. They may have fear communicating with others and can't express themselves comfortably in group discussions. Thus, working cooperatively to accomplish shared learning goals is imperative for the success of the group (Brown & Lara, 2011). Low levels of collaboration skills connote students' irresponsibility for their actions in learning and respecting the abilities and contributions of their peers (Laal, Laal, & Kermanshahi, 2012). According to Lai, DiCerbo, and Foltz (2017), there are varied roles a learner might play in a group setting for collaboration and teamwork performance. The role a person plays in a given context will depend not only on their collaboration skill but also on the roles that other team members play and the task demands.

Adaptability

Adaptability plays a significant role in ensuring successful collaboration within the group. The low adaptability skill of the students implies they had difficulty adjusting to the responsibilities assigned to them. Moreover, they may have had a hard time adjusting to various learning situations that may contribute to the success of the group, which is inevitable since adaptability is one of the most essential skills for learning, work, and citizenship in the 21st-century (Fadel & Trilling, 2012). Adapting to change requires a person to adapt to varied roles, job responsibilities, schedules, and contexts. In addition, adaptability encompasses cognitive, behavioral, and emotional adjustments (Martin, Nejad, Colmar, Liem, & Collie, 2015).

II. The Design and Development of the POGIL lesson plans

The students' low performance in problem-solving, collaboration, and adaptability inspired the researchers to develop POGIL lesson plans in physics to enhance 21st-century skills. The features and POGIL design of the lesson plans give opportunities for the students to apply their problem-solving, collaboration, and adaptability skills.

Table 4. *Components and Features of the POGIL Lesson Plan*

Parts of the Lesson Plan (Learning Cycle)	Scaffolding Model (Prilliman)	21st-Century Skills	POGIL Activity	POGIL Activity Features
Activity Title	Gives the general description of the activity	Collaboration Adaptability	Clear Words/phrases introducing a lesson, to communicate a sense of what the students will be learning	Constructs their own knowledge
Content Objectives	Gives the idea to the students on what they will accomplish	Collaboration Adaptability	Two (2) content learning objectives	Reflects the student's actions when demonstrating understanding of the lesson student - centered
Process Skills	Gives directions on how the students will achieve the content objectives	Collaboration Adaptability	Students' actions to acquire, interpret, and apply knowledge.	Cognitive and affective processes; Critical thinking Teamwork Oral and written Communication Management Problem-solving Information processing Assessment
Prior knowledge	Gives the students the idea of the skills/knowledge they should have to be able to performs the activity	Collaboration Adaptability	Tools/skills needed to accomplish the activity	
Why?	Provide students with context about the activity	Collaboration Adaptability	3-4 sentences providing explanations	Engage, motivate, awaken interest
Model I	Leads the students to develop or better understand the learning objectives	Collaboration Problem-solving Adaptability	Use of a table, a graph, figure, data, examples, terminology, symbols, etc. Contains trends, characteristic, generalizations that are typically explored through the initial questions.	Cooperative learning Work in learning teams Social responsibility Interaction with the facilitator
Exploration Questions	Engages students to become more familiar with the model	Problem-solving Collaboration Adaptability	Deepening of understanding of the concept Critical/Analytical questions	Guided inquiry using the learning cycle Specially designed activities
Read This!	Introduces additional information to understand the model	Collaboration Adaptability	Vocabulary/ concepts/ information	
Concept Invention Question	Constructs their own understanding	Problem-solving Collaboration	Define the vocabulary/concept	Self –regulated skills
Application Question	Uses the concept for different scenarios	Problem-solving Collaboration	The new concept is applied in other situations or contexts to help students generalize its meaning and applicability	Higher order cognitive skills Concept mastery
Extension Questions	Provides challenging questions	Problem-solving Collaboration	Gifted students can work on the extension work while waiting for the other students to finish.	Differentiation
Closure	Summarizes their learning and improves group performance through evaluation	Collaboration	Individual and group Assessment on their roles Reflecting on their progress and assessing their performance.	Individual/Group responsibility Metacognition Positive interdependence

Table 4 shows the researcher integrates 21st-century skills development in the lesson using POGIL. This teaching method focuses on small groups of students engaging in inquiry-based activities and following the learning cycle (Pogilorg, 2012). The framework of the developed POGIL lesson plans was anchored on a learning cycle with two important parts. The first part (content) is subdivided into three subparts (content learning objectives, activity structure, clarity, and flow). The second part is composed of the process skills, which are also clustered into three subparts (process skill goals, cooperative structure, and self-assessment). Inquiry progresses from consideration of some stated material (exploration) through the extension of the material by problem-solving or creative activity (concept formation) to the use of content to solve various kinds of problems (application). These components ensure that the developed lesson plans align with the POGIL activity's elements. These components ensure that the developed lesson plans align with the POGIL activity's elements. The parts of the developed POGIL lesson plan are based on Prilliman's scaffolding model and used scaffolding instruction concepts.

The scaffolding instruction provides a supportive learning environment as the students accomplish the task through the teacher's facilitation. The scaffolds like concept maps, graphic organizers, diagrams, and examples used in the model part of the lesson plan help the students understand the The groups in POGIL follow processes with specific roles, steps, and reports that help students develop process skills found in the lesson plan to encourage individual responsibility and meta-cognition (Kussmaul, 2012). The essential questions are guided inquiry questions to develop the student's problem-solving skills. These features of POGIL activities are distributed within the routine of the lessons to attain a complete and holistic approach to developing 21st-century skills.

III. The Level of Acceptability of the POGIL lesson plans as Evaluated by Experts

Table 5 shows the summary of the evaluation made on the components of the POGIL lesson plans.

Table 5. *Summary of the Evaluation of the Developed POGIL Lesson Plans*

Components of the Learning Materials	$\bar{x}$	±SD	Interpretation	Computed (k) Value	Interpretation	Expert's Comments
Content						
Content Learning Objectives	3.25	0.45	Outstanding	Outstanding	Moderate agreement	Objectives must provide opportunities to develop process skills. Improve consistency between objectives and process skills.
Activity Structure	3.38	0.50	Outstanding	0.33	Fair agreement	Use locally available materials in activities. Revise the concepts and terms used for the lesson. Use an appropriate model in the lessons. Adds more exploratory questions in the lesson.
Clarity and Flow	3.08	0.29	Highly Satisfactory	0.66	Substantial agreement	Improve sentence fragments.
Process Rubric Process Skills						
Process Skills Goal	3.25	0.45	Outstanding	-0.50	Poor agreement	Add more (or explicitly indicate) activities that will address process skills. Add items that prompt students to explain/justify (to address 1st process skill).
Cooperative Structure	3.25	0.45	Outstanding	1.00	Almost Perfect agreement	
Self -Assessment	3.25	0.46	Outstanding	0.51	Moderate agreement	
Grand Total	**3.24**	**0.43**	**Outstanding**	**0.45**	**Moderate agreement**	

In general, Table 5 shows outstanding ratings for content learning objectives, activity structure, clarity and flow, process skill goals, cooperative structure, and self-assessment as per the evaluator's rating. The positive evaluation of the learning objectives denotes that the content objectives constructed by researchers describe the intended outcomes of the lesson and reflect students' actions in demonstrating their understanding. The activity structure of the developed lesson plan follows the learning cycle (exploration, concept invention, and concept application), which is the heart of POGIL activity. Aside from the content objectives, the application and development of at least one of the targeted process skills is explicitly included in the developed lesson plan. The POGIL lesson plans expected the students to work collaboratively in accomplishing the task, which shows positive remarks in the cooperative structure of the lesson plan. The self-assessment and reflection part of the lesson plan is presented meaningfully and interestingly aligned with learning objectives.

Furthermore, the extent of agreement among the experts' evaluations of each component of the learning materials provides a reliability measure of the developed lesson plans. The Fleiss Kappa values computed for the ratings and responses given by science experts indicate the extent of agreement of their ratings on each component of the learning materials (Table 4). In general, most of the components of the lesson plans had a positive degree of agreement except for the process goal, which implies that the evaluators agree that the developed POGIL lesson plans followed the prescribed characteristics of a POGIL learning material. The developed POGIL lesson plan engages students to work together while applying the process skills activated by assigning a specific role for each student to assume (Hanson, 2006; Walker & Warfa, 2017).

On the other hand, modifications were made as per the evaluators' suggestions during the evaluation.

IV. The Effectiveness of the Learning Materials

The effectiveness of the POGIL lesson plans can be determined by comparing the pretest and posttest results and the mean difference results. Table 6 shows the posttest results on the level of students' 21st-century skills in terms of their means after implementing the POGIL lesson plans.

Survey Result of the Pre test and Post Tests of the 21st-Century Skills

Table 6. *Mean Differences between the Pre- and Post-Test Scores on the 21st-Century Skills and the computed t-values and Interpretations*

21st-Century Skills	Pre test		Post Test		Mean Difference	t - value	Interpretation
	$\bar{x}$	±SD	$\bar{x}$	±SD			
I. LEARNING AND INNOVATION SKILLS							
A. Problem Solving	2.33	0.66			1.30		
1. I anticipate different kinds of problems in complicated projects.			3.63	0.58		21.00	With significant difference
2. I think of ways to solve them before they happen.	2.56	0.59	3.99	0.65	1.43		
OVERALL	**2.42**	**0.64**	**3.81**	**0.64**	**1.36**		
B. Collaboration							
1. I can communicate openly in my group.	2.55	0.62	4.21	0.71	1.66		
2. I function as an active participant in our group.	2.28	0.66	4.10	0.63	1.82		
3. I cooperate and show commitment to the group.	2.47	0.65	4.17	0.62	1.70		With significant difference
OVERALL	**2.43**	**0.65**	**4.16**	**0.68**	**1.73**	35.92	
II. LIFE AND CAREER SKILLS							
C. Adaptability							
1. I can adjust my roles in the group to achieve our objectives.	2.37	0.63	4.48	0.53	2.11		
2. I work towards the improvement of the group.	2.39	0.67	4.06	0.66	1.67		With significant difference
3. I can work in a group even in diverse situations.	2.45	0.68	4.09	0.69	1.64	11.89	
OVERALL	**2.41**	**0.66**	**4.21**	**0.66**	**1.80**		
GRAND TOTAL	**2.43**	**0.65**	**4.01**	**0.69**	**1.63**		**With significant difference**

Note: level of significance at a = 0.05

Table 6 shows that the overall mean of the 21st-century skills of the students after the implementation of POGIL lesson plans increases. In general, the ratings given by the students in terms of their 21st-century skills are higher than the midpoint of the scale used. The students' responses had an uneven distribution based on the high standard deviation, which may mean that the students generally had varying responses. However, this result also supports the idea that most students believe they can perform these skills. The 21st-century skills of the students were enhanced, as shown by the mean difference between the pretest and the posttest results. The significant difference in the pretest and posttest of the 21st-century skills means that the POGIL lesson plans significantly enhanced the 21st-century skills of the students.

Adaptability has the highest mean difference among the three 21st-century skills, followed by collaboration and problem-solving, confirming the the data in Table 3. The POGIL activities capably develop the students' process and adaptability skills in a collaborative learning environment (Brown, 2010). One way of providing supportive structures to students in a collaborative learning environment is by assigning roles in group work. Most of the students performed their assigned roles in the POGIL activities. The performance of the group/team depends on how the members perform their roles in the group. Therefore, adaptability plays a crucial role in team effectiveness and cognition (e.g., shared mental models, shared situation awareness, transactive memory) (Uitdewilligen et al., 2010). Most students feel they developed collaboration skills during the POGIL activities. In one of the students' descriptions, he said, "Collaboration, because in collaboration I knew that we needed to participate with someone to answer the questions and finish the activity." The students feel it boosted their self-confidence in dealing with word problems and relational skills in completing group tasks.

Furthermore, they discover their capabilities to take responsibility for their assigned role. In fact, they enjoyed working in teams to accomplish the tasks. The roles most of the students enjoyed in the POGIL activities were those of a manager and spokesperson since these roles gave them opportunities to lead the group, unleash their leadership potential, and enhance their self-esteem (Group Work and Group Assessment, 2013). Some students said, "Being the manager, it's like the leader but in a different way. I push everyone to move and answer." "The role I enjoy the most is being a spokesperson. Being a spokesperson can enhance your self-confidence and can develop your self-esteem." In sum, the collaboration skill POGIL approach promotes student collaboration (De Gale & Bolsell, 2015; Trevathan & Myers, 2013). Students' collaboration skills were evident in the POGIL activities during their interaction, team building, learning, and interest through highly structured group work (Trevathan & Myers, 2013).

Aside from the improved 21st-

century skills of the students, the students and the teachers had other positive feedback based on their assessment of the use of the POGIL lesson plans and the POGIL approach. Most of them answered that they found the new teaching strategy good, interesting, enjoyable, and able to help them quickly understand the lesson. One of the students said, "It's good because the strategy is very helpful. You will learn to be cooperative, and it helps to learn faster because there is seatwork right after discussion." Since the teaching strategy is new to the students, it quickly got their attention. Another comment was, "I find POGIL as a new teaching strategy very interesting and fun because we do activities, and while doing the activities we are developing confidence in saying the answers." The students' participation and attention were also observed during the lesson. "We enjoyed every activity prepared through this program. We can easily comprehend every topic in science. Every student participated and did their best for the group. We improved our talents and skills; we learned how to develop them, especially the confidence and trust in the group and in yourself.".

Most of the students were happy with their experience while doing POGIL activities. When asked, "Did you enjoy learning the lesson using the POGIL teaching strategy? Why?" the students responded, "Yes, because they make teaching even livelier, more interesting, and more persuading." Moreover, other students enjoyed teaching strategy because of the classroom set-up." One student responded, "Yes, because in POGIL, we work as a team, and everyone's ideas are open for discussion."

Various aspects of the POGIL activity make the lesson more manageable for the students. When the students were asked what aspect of the POGIL teaching strategy they found helpful in understanding the lesson, one student responded, "The aspect of the POGIL teaching strategy I find helpful in understanding the lesson is the cooperation, recitation, and being active in POGIL." Furthermore, using the learning materials is critical in helping the students understand the lesson.

This observation is manifested in one of the students' answers: "The test paper or worksheet that they give us, because the worksheet or test paper has some lectures that if we don't understand the activity, we'll just turn our page to see or read the lesson or lecture." Therefore, the students preferred to work in groups and utilize POGIL lesson plans in their learning experience. Numerous studies proved that teamwork in the POGIL approach increases subject understanding and improves educational outcomes (De Gale & Boiselle, 2015; Roller, 2015).

However, the students also needed help dealing with POGIL activities. One of the challenges they encountered was when some members needed to work cooperatively with the group. One student said, "The members, because some of the members are not cooperating and not listening." Instances such as this might have

affected the group and individual performance. Other students saw the time given to them as a hindrance to accomplishing the tasks. One student described his experience with the activity as "time-pressured".

Though problem-solving has the lowest mean gain, the small increment still shows the positive impact of using the POGIL approach, which engages students in collaborative problem-solving situations (Entrepreneurial Adventure Program, 2010). There is a significant difference in the increase of the mean from the pretest to the posttest of the 21st-century skills of the students. The positive outcome can be attributed to the varied activities and problems presented in the POGIL activities, which target the improvement of skills for students to better assimilate concepts in science. POGIL emphasizes the development of problem-solving skills through a transfer of concepts to new situations and context-rich situations (Goodwin et al., 2008).

POGIL teaching strategy can improve the academic performance of the students (Brown, 2010; Hale & Mullen, 2009; & Hein, 2012).

The figure below shows that most students performed well after implementing the POGIL lesson plans based on the formative test mean scores. The result may imply that the students understood and grasped the key concepts and knowledge in physics. The results also suggest that working in a group in POGIL activities increases content mastery compared to traditional lecture instruction (Roller, 2015; Geiger, 2010; Straumanis & Simons, 2008). Furthermore, these characteristics of POGIL may have contributed to the success of enhancing students' performance in this study. It shows the overall performance of the students by comparing the mean score and the highest possible score the students can get on each worksheet. It shows that many students got a mean score of 80% or above compared to the highest possible score in each worksheet, which indicates outstanding performance. This result implies that most students understood the lessons using the POGIL approach. Thus, it can be inferred that the POGIL lesson plans effectively enhanced the students' academic performance.

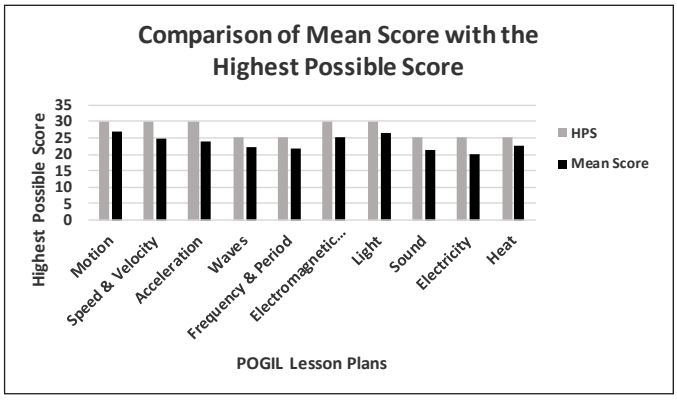

Figure 2. Formative Assessment Results of the POGIL Lesson Plans

Teachers' Comments on the POGIL Lesson Plans

One of the main goals of POGIL is to enhance the teaching pedagogy used to facilitate learning. During the implementation of POGIL, the teachers assessed the effect of the POGIL lesson plans on enhancing the students' 21st-century skills. One teacher observed that "learners work collaboratively in answering their assigned tasks, and they understand the topics very well." Furthermore, some teachers believed in the significant impact of assigning roles to the students, saying, "The students show and perform each role in their group." "They adapt easily to the role assigned to them and take responsibility for it." The teachers assessed that the 21st-century skills of the students exceeded standards with an overall mean of 3.43. They observed that the students manifested skills in problem-solving, collaboration, and adaptability due to using POGIL lesson plans. This result suggests that the POGIL lesson plan is an effective learning material for developing the 21st-century skills of the students (Pogilorg, 2012).

CONCLUSION

This study aimed to develop POGIL lesson plans in physics to enhance 21st-century skills. The lesson plans are considered a few locally developed materials that utilize the POGIL approach in teaching physics aligned with the K-12 curriculum. It enhances 21st-century skills, which prepares the students to compete globally.

The results of the study showed that POGIL lesson plans were effective in enhancing the 21st-century skills of the students, specifically problem-solving, collaboration, and adaptability, based on the increase in the overall mean. The findings also showed that students are more likely to learn in group-learning teams, are responsible for their own learning, and are engaged in student-centered activities, which are the POGIL characteristics anchored on cooperative learning, constructivism, and the learning cycle. Furthermore, the students felt empowered by the collaborative environment provided by POGIL, where they share their ideas, perform their roles, and work together to achieve their goals while developing their process skills.

Thus, integrating the POGIL approach into the lesson plan will help teachers improve their pedagogical skills and develop the 21st-century skills of their students.

RECOMMENDATIONS

The study focuses only on developing three 21st-century skills, namely problem-solving, collaboration, and adaptability, using the POGIL lesson plans, which lasted for two weeks. Thus, additional studies are needed to observe students 21st-century skills for a more extended period. Second, it would be interesting to determine the effect of POGIL lesson plans on other 21st-century skills like critical thinking, communication, and creativity. Further research is needed to compare the results reported in this study using other

inquiry-based approaches. Finally, while students showed a significant difference in 21st-century skills, additional studies should examine the correlation among students' interest in science, their perception of an understanding of science, and their 21st-century skills.

REFERENCES

21st Century Skills in the Philippines. (2015). Retrieved from https://actrc.org/projects/current-projects/21st-century-skills-in-the-philippines/

Assefa, B., Ohijeagbon, O. I., Negash, S., & Melese, G. (2008). Action Research on Enhancing Academic Excellence in a Study Program. Ethiopian Journal of Education and Sciences (3) 71-80. doi:org/10.4314/ejesc.v3i2.42008.

Asian Development Bank. (2014). Innovative Asia: Advancing the Knowledge-Based Economy. Retrieved from https://www.adb.org/sites/default/files/publication/41752/innovative-asia-knowledge-based-economy.pdf

Bell, S. (2010). Project-Based Learning for the 21st Century: Skills for the Future, The

Clearing House: A Journal of Educational Strategies, Issues and Ideas, 83:2, 39-43, DOI: 10.1080/00098650903505415

Brown, P. J. (2010). Process-oriented guided-inquiry learning in an introductory anatomy and physiology course with a diverse student population. Advances in physiology education, 34(3), 150-155.

Brown, L., & Lara, V. (2011). Professional Development Module on Collaborative Learning. El Paso Community College, Texas; USA. Retrieved 5 Nov. 2011.

Chu, S. K. W., Reynolds, R. B., Tavares, N. J., Notari, M., & Lee, C. W. Y. (2021). 21st -century skills development through inquiry-based learning from theory to practice. Springer International Publishing.

De Gale, S., & Boiselle, L. (2015). The Effect of POGIL on Academic Performance and Academic Confidence [Abstract]. Science Education International, 26(1), 56-79. doi:http://files.eric.ed.gov/fulltext/EJ1056455.pdf.

DepEd (2019). Education chief highlights importance of 21st-century skills in PH education system during 3rd EduTECH forum. Retrieved from https://www.deped.gov.ph/2019/02/23/education-chief-highlights-importance-of-21st-century-skills-in-ph-education-system-during-3rd-edutech-forum/

Domingo, J. F. (2015). Utilization of Process Oriented Guided Inquiry Learning (POGIL) toward Achievement in Tertiary Chemistry. In Conference Proceedings. New Perspectives in Science Education 2015.

Fadel, C., & Trilling, B. (2012). Twenty-first century skills and competencies. Encyclopedia of the sciences of learning, 1, 3353-3356.

Garoutte, M. P., & Mahoney, A. B. (2015). Introductory chemistry: A guided inquiry. John Wiley & Sons.

Geiger, M. (2010). Implementing POGIL in allied health chemistry courses: Insights from process education. International Journal of Process Education, 2(1), 19-34.

Gluckman, P. (2011). The wider roles of science and innovation. New Zealand Science Review, 68(1), 49-51.

Goodwin, J. A., Slusher, D. L., Gilbert, T. R., & Hanson, D. (2009). POGIL-IC: An ideal context for developing problem solving skills. In ABSTRACTS OF PAPERS OF THE AMERICAN CHEMICAL SOCIETY (Vol. 237). 1155 16TH ST, NW, WASHINGTON, DC 20036 USA: AMER CHEMICAL SOC.

Group Work and Group Assessment (2013). Retrieved from https://www.utdc.vuw.ac.nz/resources/guidelines/GroupWork.pdf

Hale, D., & Mullen, L. G. (2009). Designing Process-Oriented Guided Inquiry Activities: A New Innovation for Marketing Classes. Marketing Education Review, 19(1), 73–80.

Hanson, D. M. (2006). Instructor's guide to process-oriented guided-inquiry learning. Lisle, IL: Pacific Crest.

Hanover Research (2014). Bringing 21st Century Skill Development to the Forefront of K-12 Education. Retrieved from https://www.hanoverresearch.com/insights-blog/bringing-21st-century-skill-development-to-the-forefront-of-k-12-education

Hein, S. M. (2012). Positive impacts using POGIL in organic chemistry. Journal of Chemical Education, 89(7), 860-864.

Heron, P., & McNeil, L. (2016). Phys21: Preparing Physics Students for 21st-Century Careers. APS. Retrieved from https://www.compadre.org/JTUPP/docs/J-Tupp_Report.pdf

Holubova, R. (2015). How to Motivate Our Students to Study Physics? Universal Journal of Educational Research, 3(10), 727-734.

Ingersoll, R. (2015). Rethinking course design with POGIL. Retrieved from http://ryaningersoll.org/2015/11/29/rethinking-course-design-with-pogil/.

Saputro, A. D., Rohaeti, E., & Prodjosantoso, A. K. (2018). Promoting critical thinking and problem solving skills of Preservice elementary teachers through process-oriented guided-inquiry learning (POGIL). International Journal of Instruction, 11(4), 777-794.

Jones, V. R. (2012). Essentials for Engaged 21st-Century Students. Techniques: Connecting Education and Careers (J3), 87(7), 16-19.

Kefela, G. T. (2010). Knowledge-based economy and society has become a vital commodity to countries. International NGO Journal, 5(7), 160-166.

Knowledge Economy Indicators (2008). Indicators for the Knowledge-Based Economy: Summary Report. Retrieved from https://www.uni-trier.de/fileadmin/fb4/projekte/SurveyStatisticsNet/KEI-WP2-D2.5.pdf

Kode, S., & Cherukuri, J. (2014). Creating a learner centric environment

through POGIL: Our experience in engineering and management education in India. In 2014 IEEE Sixth International Conference on Technology for Education (pp. 72-75). IEEE..

Koenig, J. A. (Ed.). (2011). Assessing 21st-century skills: Summary of a workshop. National Academies Press.

Kristen, K. B., Malinda, W. G., Monica, D., & Kendra, M. (2017). Pedagogical methods and technology used in chemistry secondary education. Modern Chemistry & Applications, 5(3), 223.

Kuhlthau, C. C., Maniotes, L. K., & Caspari, A. K. (2015). Guided inquiry: Learning in the 21st century. Bloomsbury Publishing USA.

Kussmaul, C. (2012). Process oriented guided inquiry learning (POGIL) for computer science. In Proceedings of the 43rd ACM technical symposium on Computer Science Education (pp. 373-378).

Kyllonen, P. C. (2012). Measurement of 21st-century skills within the common core state standards. In Invitational research symposium on technology enhanced assessments (pp. 7-8).

Laal, M., Laal, M., & Kermanshahi, Z. K. (2012). 21st -century learning; learning in collaboration. Procedia-Social and Behavioral Sciences, 47, 1696-1701.

Lai, E., DiCerbo, K., & Foltz, P. (2017). Skills for today: Collaboration. Executive Development, 3(4), 6-12.

Martin, A. J., Nejad, H., Colmar, S., Liem, G. A. D., & Collie, R. J. (2015). The role of adaptability in promoting control and reducing failure dynamics: A mediation model. Learning and Individual Differences, 38, 36-43.

Moog, R.S., & Spencer, J.N. (2008). POGIL: An Overview. ACS Symposium Series, 994(1), 1-13. Retrieved from: https://www.researchgate.net/publication/279406068_POGIL_An_overview

OECD, PISA (2010). Field Trial Problem Solving Framework, Draft Subject to Possible Revision after the Field Trial.

OECD (2012). How does education affect employment rates?. Education at a Glance 2012: Highlights, 30-31.

Onah, D. U., & Ugwu, E. I. (2010). Factors which predict performance in secondary school physics in Ebonyi north educational zone of Ebonyi State, Nigeria. Advances in Applied Science Research, 1(3), 255-258.

Ornek, F., Robinson, W. R., & Haugan, M. P. (2008). What Makes Physics Difficult?. International Journal of Environmental and Science Education, 3(1), 30-34.

Pogilorg. (2012). Process oriented guided inquiry learning. Retrieved from https://pogil.org/what-is-pogil

Ratti, A., & Power, M. (2018). POGIL and reflection: A perfect duo to increase students' performance in a general chemistry course for engineering careers.

Reddy, M., & Panacharoensawad, B. (2017). Students Problem-Solving Difficulties and Implications in Physics: An Empirical Study on Influencing Factors. Journal of Education and Practice, 8(14), 59-62.

Roller, M. C. (2015). Fundamental Nursing: Process-Oriented Guided-Inquiry Learning (POGIL) Research. Journal for leadership and instruction, 14(1), 20-23.

SEAMEO. (2016). Nurturing Critical and Creative Thinkers through Inquiry Based Teaching and Learning in Early Childhood Care and Education. Retrieved from https://www.seameo-innotech.org/wp-content/uploads/2016/10/IBTL.pdf

Shute, V. J., Wang, L., Greiff, S., Zhao, W., & Moore, G. (2016). Measuring problem solving skills via stealth assessment in an engaging video game. Computers in Human Behavior, 63, 106-117.

Straumanis, A., & Simons, E. A. (2008). A multi-institutional assessment of the use of POGIL in Organic Chemistry.

Trout, L. (Ed.). (2012). POGIL activities for AP biology. Flinn Scientific.

Trevathan, J., & Myers, T. (2013). Towards online delivery of process-oriented guided inquiry learning techniques in information technology courses. Journal of Learning Design, 6, 1-11.

Uitdewilligen, S., Waller, M. J., & Zijlstra, F. R. (2010). Team cognition and adaptability in dynamic settings: A review of pertinent work. International review of industrial and organizational psychology, 25.

Villagonzalo, E. C. (2014, March). Process oriented guided inquiry learning: An effective approach in enhancing students' academic performance. In DLSU Research congress (Vol. 2, No. 1, pp. 1-6).

Walker, L., & Warfa, A. R. M. (2017). Process oriented guided inquiry learning (POGIL®) marginally effects student achievement measures but substantially increases the odds of passing a course. PLoS One, 12(10), e0186203.