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POGIL and the Microbiome

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Abstract

POGIL, or process-oriented guided inquiry learning, is a pedagogical technique created over thirty years ago to enhance student engagement. POGIL is a student-centered approach that improves students' learning and professional skills. POGIL activities incorporate the classic learning model with recurrent actions of exploration, concept invention, and application to encourage student inquiry. The microbiome represents the total collection of microbes associated with living organisms in distinct locations. The balance of microorganisms at the population level impacts an organism's health and disease disposition. Enrichment or reduction of specific bacteria, viruses, and fungi in the human population accurately predicts normal or abnormal physiological functions. There is a lack of literature regarding POGIL and microbiome sciences. Thus, this article will elucidate the advantages of developing and integrating microbiome-focused POGIL assignments in institutions of higher learning. The development of additional POGIL activities will improve the understanding of microbiome concepts and experiments designed to explore the composition and functions of the microbiome in various plant and animal ecosystems. Additional educational research on the effects of POGIL activities on student outcomes will boost acceptance of this collaborative learning technique

Keywords: POGIL; Microbiome; Active Learning; Dysbiosis; Pedagogy

1. Introduction

Chemistry educators introduced process-oriented guided inquiry learning (POGIL) to improve students' understanding of chemistry concepts to reduce failure and attrition rates [1-2]. POGIL is a student-centered teaching and learning method that involves forming student groups that work collaboratively in the classroom to solve problems and discover insights into course content [3-4]. POGIL falls under the umbrella of active learning pedagogy because students are active in the learning process. Active learning vastly differs from traditional learning schemes in which students are considered passive learners. In active learning environments, students dominate communication time, and the instructor serves as a guide or coach. During POGIL exercises, the instructor typically provides helpful or corrective information to student groups that require assistance. Active learning is accomplished in POGIL by assigning students roles during the learning process. POGIL activities also promote student collaboration during class and, over time, reduce student reliance on the instructor to unravel conceptual misconceptions. The learning cycle is a pedagogical model that supports active learning during the instructional period. The learning cycle is associated with the constructivist learning theory, which encourages students to build solid conceptual foundations [5-6]. The learning cycle proceeds through three major phases: exploration, concept invention, and application. Other learning cycle models contain five or seven stages; however, most POGIL activities utilize the three-tenet model for simplicity.

The process-oriented components of POGIL refer to workforce-specific skills that students acquire during POGIL completion. One meaningful aspect of POGIL is that process skills are essential for all science, technology, engineering, and math (STEM) majors and all STEM or STEM-related careers. Process skills typically include communication, collaboration, management, critical thinking, problem-solving, information assimilation, evaluation, and conflict

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resolution. These process skills and many other competencies are highly desirable to employers [7]. Based on the reported student outcomes, the infusion of POGIL in the curriculum enhances key metrics such as retention, academic success, engagement, career preparation, motivation, and learning. POGIL utilizes guided inquiry learning to teach conceptual information that is paramount for future success. The guided inquiry framework is a teaching and learning procedure in which the instructor uses a series of developmental, progressively more probing, or challenging questions designed to help students build themes, observe relationships, and organize knowledge. Typically, instructors utilize Bloom's taxonomy to create appropriate questions for a deeper understanding of course terms, concepts, and theories. Bloom's taxonomy is a hierarchical system categorizing learning outcomes grouped into either lower-order thinking skills or higher-order thinking skills [8]. The guided inquiry teaching and learning scaffolding technique also motivates students to ask questions to aid in the discovery of new conceptual connections.

Various POGIL activities exist for many disciplines found in college science departments, most notably chemistry, anatomy and physiology, biology, and even microbiology [9-10]. De Gale and Boisselle demonstrated that organic chemistry POGIL activities were sufficient to enhance academic confidence in undergraduates [11]. This finding was determined using a pre-test and post-test design and is significant because improving student confidence is an ongoing goal in STEM departments. The researchers also examined academic performance by comparing summative assessments of students engaged in traditional teaching methods and students taught using POGIL, but the results were mixed and inconclusive. Using summative assessments to study the effect of learning techniques on grades or academic performance is not always reliable. A more trustworthy strategy is to use both formative and summative assessments to analyze the impact of pedagogical methods on academic success. Recently, researchers finalized a thirty-five-year longitudinal study analyzing final grades in general chemistry courses. For approximately half of the study years, students learned chemistry using traditional methods, and for the other remaining years of the study, students participated in POGIL protocols. Statistical analysis indicated significant positive improvements in grades for the POGIL students, suggesting that using POGIL throughout STEM departments may be a valuable strategy to help students academically and reduce attrition rates [12]. POGIL works well in a student-centered active learning environment for undergraduate programs (SCALE-UP), although recent qualitative research demonstrates mixed student viewpoints to SCALE-UP classrooms [13-14].

2. Microbiome POGIL Development

Classically designed POGIL exercises all have similar components. POGIL components are associated with the main stages of the learning cycle model (e.g., exploration, concept invention, application). Many POGIL exercises in biology include a model that facilitates the exploration phase and a series of questions that aid concept invention and the application phases. Numerous exciting microbiome concepts may serve as a promising topic for POGIL construction. Construct microbiome POGIL exercises to enhance student understanding of essential topics such as the scientific method, microbiome research equipment, biodiversity, microbial ecology, biotechnology, dysbiosis, diversity indices, plant and animal microbiomes, and microbiome research methods. Design POGIL microbiome exercises to increase comprehension of microbiome research pioneers and contemporaries in the field, elucidate unanswered microbiome research questions, and discuss ethical considerations. For example, instructors may design a microbiome POGIL exercise that examines the difference between 16S rRNA gene sequencing and shotgun metagenomic sequencing. Following the microbiome POGIL, students would be expected to demonstrate an understanding of the similarities and differences in the two gene sequencing strategies, explain the limitations of each microbiome sequencing approach, and develop controlled experimental protocols using both technologies.

In another example, microbiome POGIL exercises could address student comprehension of homeostasis and dysbiosis in the human gastrointestinal tract. Following the microbiome POGIL, students would be expected to explain the difference between the terms dysbiosis and homeostasis, identify diseased and healthy microbiomes from illustrations and experimental data, explain the transition from homeostasis to dysbiosis in human digestive organs, explain how family pedigree, lifestyle, and diet affect the transition, describe the fecal microbiota transplant method to treat patients with *Clostridioides difficile* infections, and develop an experiment to determine the bacterial species that are more abundant during human disease. In a third example, microbiome POGIL exercises could explore biodiversity and the standard statistical biodiversity characterizations employed in microbial ecology. Following the microbiome POGIL, students would be expected to explain the conceptual divergence between alpha, beta, and gamma diversity and calculate alpha, beta, and gamma diversity using experimental data.

3. Conclusion

Developing a curriculum focused on preparing undergraduates for the job space is paramount. STEM educators constantly refine and utilize pedagogy that allows students to learn relevant skills and acquire essential knowledge for employment. These STEM employability skills represent the hard and soft skills required to get hired and maintain employment during turbulent periods [15-17]. Since the turn of the century, science educators have looked to infuse more active learning strategies into the classroom. Data supports more positive student perceptions in active learning classroom environments. Unlike passive learning, active learning requires that all students participate in the activity. Passive learning settings often overlook unmotivated students who may need more time to record lecture notes, comprehend lecture material, or complete assessments. POGIL is a unique teaching student-centered technique that focuses on higher-order thinking skills but also creates a job-like atmosphere in the classroom that requires students to work in groups, compile discipline-specific information, and present information subjected to critical examination. Additionally, the format of POGIL allows all students to absorb information at an acceptable pace that allows for better assimilation of problematic concepts. Instructors can also enhance POGIL activities to improve student productivity by modifying classroom architecture and improving classroom management policies. STEM departments may opt for circular desks, interactive smart boards, and dry eraser boards for each student group.

A rudimentary bibliometric investigation using the keywords POGIL and microbiome in major databases (e.g., PubMed, ERIC, JStor) led to relatively few retrieved results, which provided evidence that the development of more microbiome POGIL activities and the investigation of their impact on learning and career self-efficacy may be beneficial. POGIL is a multifaceted process that involves the creation of student "jobs" during the activity, as mentioned earlier (e.g., manager, recorder, presenter, reflector). The specific tasks of each POGIL group member must be clearly articulated and understood before the start of the POGIL exercise to increase efficiency and enhance assignment goals. Rubrics and a job description document must be created and utilized during the instructional period to keep group members on track. Overall, the collaborative learning approach represented in POGIL activities is aligned with real-world work experience, often involving several teams working together to accomplish company goals. Pairing POGIL with traditional bench or field laboratories combines guided inquiry and hands-on learning and may amplify student learning outcomes. Additionally, pairing POGIL activities with virtual labs or virtual reality laboratories may have the same beneficial effect. Virtual reality allows students to visualize better and manipulate biological organisms and structures in an immersive environment to reinforce understanding. Future research on the impact of POGIL exercises on microbiome science comprehension may increase awareness of this active learning strategy's effectiveness in improving student engagement and professional outcomes related to microbiology, molecular biology, ecology, and bioinformatics fields. POGIL educational research must also explore faculty perceptions to resolve the benefits of this student-centered pedagogical technique.

Compliance with ethical standards

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