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Process-Oriented Guided-Inquiry Learning in Saudi Secondary School Chemistry Instruction

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Abstract

Students' perceptions of the Process-Oriented Guided Inquiry Learning (POGIL) approach in Saudi Arabian public secondary school chemistry classes was investigated. The sample comprised 189 Grade 10 students (male and female) from four schools in the northern and southern regions. Student-centered (POGIL) and teacher-focused chemistry teaching approaches were applied using the same instructional materials to randomly selected gendered experimental and control groups over a four-week period in winter 2018. Results from analyzing *What is Happening in This Class?* (WIHIC) data revealed that POGIL helped students more actively engage in the classroom thus enabling them to perceive their chemistry learning experience as positive and academically effective. POGIL also improved students' affective traits such as cohesiveness and personal relevance. There were no gendered differences in overall WIHIC scores. Results suggest that (a) POGIL mitigates the impact of borrowing education curricula and policies from Western countries and (b) Saudi pre-service and inservice teachers should receive POGIL training because POGIL works in the Saudi educational context.

Keywords: Process-Oriented Guided Inquiry Learning (POGIL), secondary science education, chemistry, Saudi Arabia, gendered differences

INTRODUCTION

Education in the Arab world has a traditional value in preserving culture (G-Mrabet, 2012). But as the learning and teaching of science transforms, there is a widening gap between traditional science teaching, long established in Arab education, and the so-called Western way of science instruction evolved from constructivism. Under the influence of globalization, students' academic performance across the world has become an issue. Saudi students' performance in science in international assessments, such as the Trends in International Mathematics and Science Study (TIMSS), has recently attracted the attention of global educators. TIMSS assesses students' problem-solving skills in math and science (International Association for Educational Advancement [IEA], 2019). With less-than-optimal results, the effectiveness of Saudi's traditional teaching of science is being scrutinized.

To offset the disappointing TIMMS results, the Saudi education authority looked to a student-centred approach to science teaching, which has been developed and instituted in the West. With insights gained, new Saudi science curricula has been introduced, and schools and teachers have been directed to follow them, because the value of science education is paramount in the midst of attempting to actualize the goals set in Saudi's current national development plan, *Vision 2030*. This serves as a roadmap for converting Saudi's oil-dependent economy into a knowledge-based economy (Kingdom of Saudi Arabia [KSA], 2016).

Despite the optimism of switching from the traditional teacher-centred science education to something more current, including a student-centred approach, many doubt the preparedness of Saudi teachers and students alike. Among many complex issues, gendered education in Saudi Arabia is the norm. In such a context, the success of transitioning across the board to a student-centred approach such as Process-

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Contribution to the literature

- The study makes a notable contribution to knowledge, because little research exists about the compatibility between the instruction methods adopted from Western countries and Saudi Arabia's teacher-centred educational setting. Global educators interested in gathering solid evidence to prove the effectiveness of the student-centred approach to science learning should find our Saudi-based results useful especially for comparative studies related to POGIL and chemistry and science education.
- Results further justify recommending that Saudi science teacher education programs and professional in-service initiatives provide an orientation and training in POGIL (and other constructivist, inquiry-based approaches).
- Constructivist science curricula (such as POGIL) will help ensure that Saudi students gain life-long skills necessary for success at the tertiary level and in the workforce (e.g., cooperation, time management, critical and creative thinking). POGIL-oriented science instruction would help the KSA evolve to a knowledge-based economy supported with strong, collaborative problem solvers and innovate, analytical thinkers.

Oriented Guided-Inquiry Learning (POGIL) (to be discussed) may take longer and require joint-effort and collaboration among stakeholders to achieve. Respecting this scholastic, gendered context, this study looked at how secondary school students perceived such new teaching and learning approaches in science education in the modern Saudi Arabia. It is anticipated that results can serve as an indicator of whether this new endeavour is likely to succeed.

BACKGROUND

Rather than preserving culture, education in Saudi Arabia is now being viewed as a foundation of economic development and social change (G-Mrabet, 2012). Arab policymakers thus face the dilemma of reconciling modern values with national, traditional values (Bahgat, 1999). Traditionally, the KSA education system has been dominated by chalk-talk methods of instruction that focus on the teachers, rote learning, memorization and mastery of content (Alrwathi, Almazroa, Alahmed, Scantbly, & Alshaye, 2014; Treagust et al., 2018).

In the science education realm, concerns have arisen about whether this practice will compromise students' ability to develop deep understandings of and appreciation for science and how this might impact striving for *Vision 2030*. As noted, Saudi's traditional science education is now being criticized because of students' low TIMSS results (Alghamdi, 2013). As a case in point, Al-Harbi (2013) reported that Saudi secondary students were ill-equipped with scientific skills and knowledge, especially in areas requiring higher-level cognition.

In addition to low TIMSS scores, Saudi's traditional science teaching approach is being criticized for other reasons. Cognitive psychologists assert that (a) the learning process is personal and different for every student and (b) students' academic experiences are in close relationship with the learning process (Bruner & Haste, 1987). In Arab Gulf countries, including Saudi Arabia, Litvin (2010) found that a vast distance existed between science teachers and students, because the Saudi teaching process is teacher-centred; students were passive participants in the education process. As a result, Saudi science students expected their teachers to explain 'how to do' rather than 'how to learn.' Not surprisingly, many Saudi students found their science classes boring and impractical (Kind, Barmby, & Jones, 2007).

Pedretti (1999) further affirmed that Saudi science students were dealing with an excessive amount of information and required to master, memorize and apply any new knowledge gained in the real world. The latter application was compromised, because they had not been taught how to learn outside the classroom, and what they learned in the classroom may not have personal relevance. Teaching science differently seems expedient in this scenario with POGIL being one such approach (to be discussed).

Moreover, Aydarova (2013) questioned whether Saudi *teachers* were to blame for Saudi students' low TIMSS performance. As a result of holding one of the lowest achievement scores for TIMSS-listed countries (IEA, 2019), SA has recently increased its interest in different aspects of science and mathematics education in local schools (Hamdan, 2005). In particular, the Saudi government said it regarded science educators' professional development (PD) a national priority, arguing that it should be the main research focus in education for forthcoming years (Alshamrani, 2012). Although Wiseman and Al-Bakr (2012) argued that the Gulf countries (including SA) needed to increase teacher quality to improve students' science academic achievement, other issues surely come into play including the pedagogies embedded in the curricula. This assertion serves as a segue to a discussion of the Western-developed student-centered pedagogies now embraced in Saudi Arabia in rhetoric if not in practice.

The new imported student-centred Saudi science curriculum emphasizes the *understanding* of concepts rather than just memorization. A student-centred pedagogy is a new approach in Saudi science teaching and learning (Smith & Abouammoh, 2013), meaning POGIL will be new as well. The Western-imported curriculum is based on constructivist learning practices, which emphasize the development of critical thinking and problem-solving skills. Despite the potential to improve Saudi TIMSS scores and help the nation move toward the goals of *Vision 2030*, it is not clear if these practices are applicable in the Saudi educational context nor whether teachers and students are ready for this pedagogical change (Alghamdi Hamdan & Al-Salouli, 2013; Smith & Abouammoh, 2013).

Context-wise, what is happening now in Saudi Arabia? Arab science education is changing, because educational leaders are following the pattern set by other nations that are borrowing and adopting curricula developed elsewhere into their existing educational system (Guo, 2007). A prevalent ongoing practice is for non-Western countries to adopt Western curricula grounded in constructivist and inquiry-based pedagogical practices (Treagust et al., 2018).

The conventional memorization, rote learning, teacher-oriented science instruction used in the Gulf nations, by its very nature, eschews comprehension, critical thinking, problem solving and analysis (Alrwathi et al., 2014; Al-Sadaawi, 2007). This was perpetuated by centralizing the science curriculum development process with curriculum implementation taking place via the top-down approach. In this context, the Ministry of Education (MoE) has translated British and American science curricula and textbooks into Arabic (Alghamdi Hamdan & Al-Salouli, 2013; Guo, 2007) and implemented them in the Saudi educational system. These borrowed curricula tend to use a student-centred pedagogy, which is problematic for any Saudi science educators who tend to adopt teacher-centred approaches in delivering science education.

To compound matters, besides the imported Saudi curricular pedagogical framework, numerous science textbooks used in SA are exact copies of Western versions despite being used in a different educational system. Science teaching in SA tends to rely heavily on traditional teaching practices and the content of imported, prescribed textbooks. Saudi science teachers also possess broad discretion in deciding whether to employ active-learning methodologies and engage students in scientific inquiry (student-centered) often opting for the teacher-oriented lecture style and lab experiments instead (Alhammad, 2015; Hamdan, 2006).

Al-Harbi's (2013) scholarship validates the assertion that Arab traditional science teaching focuses on memorisation instead of information processing and analysis, which is now an intent of the newly adopted curriculum propagated by the Saudi educational authority. Considering that Arab countries are introducing policies to become knowledge-based economies (KSA, 2016), necessary educational reform, pedagogical advancements and curricular development in all subjects and disciplines must be implemented, especially in science education, because scientific knowledge helps meet human basic needs, improve living standards and inspire technological and scientific innovation and progress. All and more are required for nation building and achieving *Vision 2030* (KSA, 2016).

That said, Aydarova (2013) examined the implementation of borrowed educational policies in Saudi education and found that local culture and context have a modifying effect over the transferred curriculum (i.e., borrowed from Western nations, Guo, 2007). By this, Aydarova (2013) meant that people on the ground can thwart the student-centered intent of the borrowed curriculum. This finding and other threads of this argument for student-centered science curricula in Saudi Arabia support the need for this study. While some science education scholars are convinced that both learners and curriculum development initiatives in non-Western countries will benefit from embracing a constructivist pedagogy (Cobern, 1996), this should not be taken for granted.

This study takes on this issue given Saudi Arabia's newly adopted constructivist science curriculum, including high school chemistry. Actually, we wanted to examine a particular pedagogical innovation namely POGIL. Of interest is how this student-centred approach plays out in the Saudi educational context that is deeply entrenched in a teacher-oriented pedagogy. Will POGIL work in Saudi Arabia? We are also convinced that insights from how science is taught in a gendered society will be meaningful for other nations who experience gender disparity in their educational settings (Buchmann, DiPrete, & McDaniel, 2008). Therefore, gaining insights into male and female Saudi science students' perceptions of POGIL was an integral part of this study.

LITERATURE REVIEW

Constructivism is "an approach to learning that holds that… people actively construct or make their own knowledge and that reality is determined by the experiences of the learner" (Elliott, Kratochwill, Littlefield Coo, & Travers, 2000, p. 256). With this philosophical paradigm as a backdrop, pedagogies that place learners in the centre of the teaching and learning process have come into being including POGIL. POGIL is widely adopted in the teaching of science, in particular chemistry. However, this student-centred approach is relatively new to Saudi teachers and students. The deep-rooted tradition of science education in the Arab world is teacher-oriented and possibly compounded by gendered education. Science students have their own perceptions of the change in the mode of learning: switching from traditionist to constructivist learning.

Furthermore, in Saudi Arabia, the relationship between gendered-based differences and education is complex creating issues in science education, attitudes toward science education, and chemistry teaching.

Educational Philosophy of Social Constructivism

Teaching methods and the ways in which students best form their own knowledge and understandings have evolved over time due to technological advancements and paradigm shifts (Barak, 2017). Science educators and scholars have recognized the importance of constructivism as far back as the mid-eighties (Atwater, 1996). Since then, social constructivist ways of knowing have been emerging in educational reform strategies specifically in the ways in which pre-service teachers are trained and educated (Jost, 1999).

Imel (2000) explained that, from a social constructivist approach, what students learn is coupled with their life experiences and contexts and is constructed by them, not the teachers. This learning is anchored in real-life situations and problems. The knowledge gained is inseparable from the contexts and activities within which it was developed. Interactions with others are a major factor influencing what is learned and how learning takes place (see also Atwater, 1996).

"POGIL … is built on a platform of social constructivism (De Gale & Boisselle, 2015, p. 59) in that students learn chemistry while interacting with other people in the learning environment. The creation of new knowledge about chemistry is "aided by cooperative social interactions" (De Gale & Boisselle, 2015, p. 60). Together, students actively develop new knowledge, so they can understand and apply chemistry concepts and methods in class and in real life (De Gale & Boisselle, 2015; Eberlein et al., 2008).

Process-Oriented Guided Inquiry Learning (POGIL)

In the mid-1990s, the National Science Foundation (NSF) in the United States suggested that pedagogy should change to focus on students rather than teachers (Zgraggen, 2018). This suggestion prompted some higher education science teachers to devise novel teaching approaches that could substitute traditional, teacher-centred ones. This led to the development of POGIL (Eberlein et al., 2008), which is a student-centred, group-learning instructional strategy and philosophy first developed in 1994 (Brown, 2015).

Its intent is to facilitate the instruction of content and important process skills at the same time (Treagust et al., 2018). Drawing on constructivism, inquiry- and collaboration-based learning, POGIL promotes active student involvement in organising and comprehending the knowledge that they themselves generate (Şen, Yılmaz & Geban, 2016). Unlike the conventional sage-on-the stage teacher-centred approach, POGIL is based on the principle of interactivity with careful thought processing, idea elaboration, comprehension refinement, skill implementation, progress reflection, and performance evaluation (Moog et al., 2009).

When applying POGIL, teachers do not transmit knowledge; rather, they facilitate students acquiring it on their own by exploring the supplied data or information through collaboration on tasks with peers in small groups (Brown, 2015; Spencer & Moog, 2008). To enable in-depth comprehension of course material whilst at the same time fostering advanced cognitive skills, POGIL learning tasks concentrate on key science concepts *and* cognitive processes. Although originally designed for science (Brown, 2015), POGIL can also be applied in other disciplines (Zgraggen, 2018).

POGIL's Usefulness in Secondary School Chemistry

Comparative assessment of the POGIL approach with conventional instruction has suggested that POGIL has high efficiency as a teaching method especially in the natural sciences, including chemistry (Brown, 2015; Mauer, 2014). POGIL allows a great deal of flexibility in the roles that students can assume. They can be manager, recorder, presenter/spokesperson, reflector, strategy analyst, technician, encourager, and significant figure checker (Treagust et al., 2018). In chemistry, POGIL integrates assisted investigation and collaboration-based learning thereby enabling students to be active participants in the educational process (Bransford et al., 2000; Brown, 2015).

Barthlow and Watson (2014) examined POGIL's efficacy by comparing it with conventional lecture instruction in high school chemistry with special attention to its ability to minimise alternative interpretations about the particulate character of matter. POGIL was found to excel at this task evident through higher post-test scores for both sexes and four ethnic groups (African American, Hispanic, Asian and Caucasian). Villagonzalo (2014) reported similar results with the POGIL approach accounting for more than 50% of score discrepancies.

Şen et al. (2015) compared POGIL to traditional teacher-focused chemistry instruction to determine which method most benefitted the self-regulated learning skills of Turkish 11th grade students. POGIL enhanced several skills: the mastery approach, task value, learning-belief management, learning and performance self-efficiency, critical thinking, assistance request, peer learning, metacognitive self-regulation, effort management, and management of study time and setting. In another study, Şen et al. (2016) reported that, compared to conventional instruction, POGIL was more effective in helping Turkish grade 11 students grasp electrochemistry concepts and correct any of their misinterpretations.

Using a theoretical model based on culturally pertinent teaching practice and social constructivism in instruction and learning, Treagust et al. (2018) sought to make POGIL a teaching method of cultural relevance in Qatar. They found that delivery of well-structured learning materials within a POGIL strategy led to better chemistry learning perceptions among 10th grade science students than the traditional teaching approach. They also highlighted the importance of students actively participating in the classroom to enhance not only how they perceived chemistry learning but also how they performed academically. Moreover, POGIL was found to enhance several *affective* traits: student cohesiveness, participation, and collaboration through role-based active discussions within small groups.

Zgraggen (2018) examined American secondary students' performance in chemistry by contrasting POGIL against an Independently Developed Guided-Inquiry Method (InDGIM). The latter is a guided inquiry method (GIM) developed and implemented by Zgraggen himself over 15 years and then tested in his doctoral research. He concluded that he absence of statistically different results is clear evidence of the effectiveness of a constructivist oriented GIM strategy when teaching chemistry including POGIL.

Students' Perceptions of Constructivist Learning

In addition to the curriculum itself, both teacher quality and gender-based differences affect students' interest in and attitudes toward science (Osborne, Smith, & Collins, 2003). An attitude is a positive or negative disposition toward something while interest involves paying attention to it. Interest tends to influence attitude (Tranter & Warn, 2008), in that "the strength of a person's attitude is [their] interest … An interest [is] an activated attitude" (Rummel, 1981, Section 6.3). Over the past 50 years, studies have confirmed that "girls and boys have different interests and attitudes toward studying science and different perceptions of scientists and science careers" (Jones, Howe, & Rua, 2000, p. 180-181; see also Ormerod & Duckworth, 1975).

Although some researchers found no significant differences in students' attitudes toward science education (Selim & Shrigley, 1983), others have disagreed, many from a gendered perspective. To illustrate, researchers determined that students' interest in science started to decrease at the age of 11 with the lowest interest between the ages of 11 and 14 (Jones et al., 2000; Osborne et al., 2003). Boys were more inclined to have a positive attitude toward science than girls (George, 2000). However, boys' interest dropped faster than girls'. Interest increased for both boys and girls *if* they had extra-curricular activities such as visiting science centres (Jarvis & Pell, 2002). Such visits also had a positive effect on overall academic performance (Kousa, Kavonius, & Akseka, 2018).

Some factors are crucial for increasing students' interests in sciences (aside from gender): activity-based exercises; parent and peer encouragement; the classroom environment (e.g., engagement, relationships with classmates, teaching strategies); extra-curricular activities; and quality science teaching (Freedman, 2002; Papanastasiou & Papanastasiou, 2004; Said, Summers, Abd-El-Khalick, & Wang, 2016). Some social factors dramatically affected girls' interest in and attitudes toward science especially hands-on experiences and social interactions in school settings (Al-Dahmash, Mansour, Alshamrani, & Almohi, 2016; Dawson, 2000). The international Relevance of Science Education (ROSE) project showed that relevancy to daily life is also a key factor in science interest (Busch, 2005).

Chase, Pakhira, and Stains (2013) reported that using POGIL in a chemistry class led students to score higher on emotional satisfaction learning chemistry and lower on anxiety than the control group. That said, POGIL did not significantly change respondents' attitude toward chemistry as a subject matter but it did affect their attitude toward the skills used by chemists. Also, POGIL-taught students measured higher on interest in chemistry than the control group. With little research on this topic, they conjectured that, at this point in time, "the extent of the impact of POGIL on students' attitude toward chemistry is unclear" (p. 410).

Regarding the link between POGIL and students' interest in chemistry, Walker and Warfa (2017) reported that "POGIL reduced the risk of failing a [chemistry] course by 38% while standard lectures increased the risk of failure by 59%" (p. 12). They concluded that using POGIL would stimulate an interest in chemistry thereby improving retention rates in university classes. The same could hold for high school. Students might retain an interest in chemistry if taught using POGIL.

Gender-Based Issues and Science Teaching and Learning in Saudi Schools

As noted, complex relationships exist between (a) gender and science education, (b) gender and students' attitude toward science in the Saudi context, and (c) gender and chemistry teaching.

Gender and science education. In some countries, the issue is students' lack of interest in the science discipline (regardless of sex) while other nations face the issue of equal gendered access to educational science opportunities (Boujaoude & Gholam, 2014). Generally, gender is an essential factor when evaluating students' interests in science courses (Potvin & Hasni, 2014). This interest in science is closely related to several factors: further studies, scientific activities, contexts where science topics are applied for students, students' perceiving science achievements as their own, the application of different teaching methods, and appreciating the level of difficulty for teachers (Badri et al., 2017; Trumper, 2006). These studies reported that male students were more interested in science than female ones. However, this may not be the case in the KSA, because more than half of all higher education science students are women (KSA, 2016). A principal goal of science education is to bridge the gender gap (Biklen & Pollard, 2001), which may be a challenge in a gendered society like Saudi Arabia, where boys and girls attend different schools with different educational cultures.

Gendered science attitudes in Saudi schools. Indeed, Mayr (2015) believed that schools have "the power to foster particular kinds of identities to suit their purposes" (p. 755). Schools function to shape students, and often different expectations are set respectively for males and females. Silfver (2019) cautioned that certain gender group expectations can limit students' behaviours and choices. Also, gendered expressions of thoughts are different and dependent on culture, which is perpetuated at schools. This difference is primarily felt in cultures where genders are expected to act differently (i.e., have a different level of independence) like in Arab cultures. In such situations, to shape the interests and attitudes of boys and girls toward favouring science, different sexes (genders) might need to be taught differently (Silfver, 2019).

Regrettably, unequal treatment for females in Saudi Arabia remains embedded in the education system; some believe that science education reforms need to place more emphasis on female students' perceptions of science (Hamdan, 2005). Despite this disparity, Arab women still pursue studies in science after completing high school; in 2020, they hold nearly half of all the available places at the university level. This despite that secondary school education is not free from impediments (e.g., culture, religious factors, gendered social perceptions) that can prevent women from transitioning to higher education and pursuing scientific careers. In this context, effective learning of science in high school (including chemistry) is thus paramount.

Gender gap and chemistry teaching. Although many studies have focused on students' attitudes toward science (see earlier sub-section), few have focused on chemistry in particular (Kahveci, 2015a, b). Research shows those attitudes as shaped by academic achievement and performance, and gender bias. Respectively, among secondary students, higher academic achievement correlated with high interest in and a positive attitude toward chemistry (Brandriet, Xu, Bretza, & Lewis, 2011; Kan & Akbas, 2006).

Gender bias exists in chemistry manifested in gendered curricula and images in textbooks and resources. To illustrate, Kousa et al. (2018) reported that Finnish chemistry books included more men than women in chemistry experiments. There was also sexist language and activities with not-so-positive descriptions of females. Similar results for chemistry educational resources were obtained in other countries: Australia (Lee & Collins, 2009), Greece (Dimopoulos, Koulaidis, & Sklaveniti, 2005), Jamaica (Whiteley, 2007) and the United States (Brandriet et al., 2011). This issue is a concern, because Saudi Arabia has recently translated and implemented Western-developed curricula and textbooks, which likely contain gendered images and messages. The use of such learning materials while implementing POGIL could be problematic.

RESEARCH PROBLEM AND QUESTIONS

The science curricula implemented in Western nations are often transplanted into non-Western ones (Guo, 2007), as is the current situation in Saudi Arabia. This has recently led to an attendant recommended change in approach in the Saudi education system from teacher-centred rote learning to a constructivism-based strategy with an emphasis on students' engagement, inquiry, analysis, research and problem solving (Alaudan, 2015). Students must possess problem-solving skills to learn chemistry, but problem solving is no easy task and is frequently a source of irritation for students (Valdez & Bungihan, 2019). Indeed, Chemistry is among the most challenging science subjects because of its complexity (Avargil, 2019).

Saudi teaching practitioners are attempting to implement the new, imported science curricula while struggling to deal with the chalk-talk teacher-focused methods that dominate the Saudi educational system. Respecting their struggle, the current study explored the use of POGIL as a student-centred instructional approach for 10th grade chemistry students within the Saudi educational context. It sought students' perceptions of their learning experience. The effect of POGIL on secondary school students' science learning experience has not been empirically investigated so far, especially in chemistry (Treagust et al., 2018; Zgraggen, 2018). Although POGIL encourages students to actively engage in the educational process (Şen et al., 2016), the compatibility between this Western approach and the Saudi educational system has not been extensively explored (Treagust et al., 2018). Will POGIL work in the KSA? To that end, two research questions framed this study:

1. How do Saudi secondary students perceive their learning prior to and following exposure to student-focused POGIL in a chemistry course? Does this perception differ from students taught using the conventional teacher-oriented approach?
2. Do Saudi male and female secondary students perceive their chemistry learning prior to and following exposure to POGIL differently?

As a caveat, per the research questions' focus on perceptions, "perception is closely related to attitudes" (Pickens, 2005, p. 53). By understanding how students *see* (perceive) a learning experience, teachers are in a better position to facilitate a productive and effective learning environment. Insights about perception can be used to change students' attitudes, which is important, because their receptiveness to learning stimuli is influenced by their attitudes (Pickens, 2005); in this case, attitudes toward POGIL versus teacher-centred pedagogies. Studies have recently shown a significant positive correlation between students' perceptions of and their attitudes toward natural science (Kurniawan, Darmaji, Putri, Jannah, & Puspitasari, 2019).

METHODOLOGY AND PROCEDURES

As an overview, using a quantitative experimental research design, Saudi Grade 10 chemistry experimental groups were exposed to POGIL while control groups were taught using conventional teacher-focused teaching strategies that are commonly used in the KSA. Before and following this intervention, the *What is Happening in This Class* (WIHIC) instrument was administered as a pre- and post-test to discern any statistically significant differences in perception of the science learning experience.

Sample Frame

Using convenience sampling (i.e., known and accessible to the researchers), two schools were selected for the study with one in the northern Al-Jouf Province and another in the Aseer Province near the Red Sea in the southwest. Both schools were equipped with similar science laboratory tools, instruments and textbooks, and the teachers involved held similar qualifications, experience levels and taught the mandatory MoE science curriculum.

Within the two schools in each region, each school containing several Grade 10 chemistry classes, the classes taught by the POGIL-trained teacher were automatically part of the study with the control classes taught by a teacher who agreed to participate with his or her class. The final sample frame comprised: of 60 boys students in the experimental and 44 were in the control group at the Al-Jouf location. At the Abha location, 54 girls were in the experimental group with 31 girls in the control group.

Although the Saudi national educational authority (MoE) manages all public independent schools, the local education authorities in the two regions (i.e., Al-Jouf and Aseer) approved the study before it was conducted.

Intervention

In fall 2018, each of the two researchers first trained a teacher how to use the POGIL strategy (i.e., two teachers in total, one from each school). They were taught about Hanson's (2014) recommended learning cycle sequence: (a) orientation, (b) exploration, (c) concept formation, (d) application and (e) closure. POGIL-informed instruction especially focuses on exploration to help students develop and deepen their conceptual understandings. "In this phase, students have the opportunity to propose, question, and test hypotheses in an attempt to explain or understand the exploration presented to them. The intent is to have the students encounter questions or complexities that they cannot resolve with their accustomed way of thinking" (Hanson, 2014. p. 5) (see also Eberlein et al., 2008).

To successfully facilitate the crucial exploration phase, teachers were taught to prepare a file for students that included a set of tasks to complete that are informed by POGIL philosophy and procedures (adopted from Hanson, 2014) (see Figure 1). It represents a set of heuristics, which are simple rules, procedures or sequenced processes designed to help students explore unfamiliar content and discover/find solutions and answers in the course of their learning process. Heuristic is Greek *heurema*, 'discover.'

In winter, 2018, all 104 students received chemistry instruction in Arabic over a four-week period with teachers meeting students twice a week for one hour each time. All teachers used identical teaching materials; students were just taught differently. The experimental group (one class at the boy's school and one class at the girl's school) comprised 60 students and was taught by the POGIL-trained teacher at the respective school. The control group (one class at the boy's school and one class at the girl's school) comprised 40 students who were taught by two teachers not trained in POGIL.

Data Collection Instrument

Students' perceptions of their science learning experiences were measured using the *What is Happening in This Class* (WIHIC) instrument (Chionh & Fraser, 1998). This tool is highly useful for gaining insights into what students think about what is going on in the class and how they perceive their learning setting (Fraser, 1998). It has been used in various countries at different levels of education, and its reliability and validity have been confirmed (Emilov & Tafrova-Gergorova, 2016).

Emilov and Tafrova-Gergorova (2016) further clarified that WIHIC captures information about a range of topics (subscales) that include but are not limited to (a) student cohesiveness, (b) teacher support, (c) student involvement, (d) cooperation, (e) equity, (f) investigation and (g) task orientation. *Student cohesiveness* is about the level of support and amiability that students showed one another. *Teacher support* refers to the level of assistance provided by the teachers. *Student involvement* is concerned with students' classroom participation and engagement with peers in exploring ideas and dealing with problems. *Cooperation* refers to collaboration among students and teamwork involvement. *Equity* is about teachers' fair treatment of the students and provision of the same chances to take part in discussions while *investigation* is concerned with formulation of solutions

- Give the learning activity a title
- Tell students why they are learning this material
- List the learning objectives
- Outline criteria to be used to measure achievement of desired learning outcomes
- Specify any prior skills or knowledge needed for the learning activity
- List essential resources to complete the activity
- Identify and define key terminology
- Compile and share any information needed for the activity
- List any tasks or plans that must be completed to meet learning objectives
- Provide models, representations or methodologies for what is to be learned
- Pose key questions to guide the execution of aforementioned tasks or plan. These questions should entice students to explore, process information, judge resources, stimulate their thinking and construct new understandings
- Direct students to practice using their new knowledge (gained from answering the key questions) in simple situations and familiar contexts
- Extend level of difficulty by directing students to use knowledge in new contexts so they can practice transference, synthesis and integration
- Help learners engage in research by prompting them to explore new situations and create unique knowledge aside from information provided
- Get students to share their overall results with peers to be validated and assessed
- Prompt students to engage in reflection on what they learned and how and on how well they mastered the material
- Guide students through a self-assessment of their own learning (done well, could improve)

Figure 1. Students' POGIL-related activity template adopted in the study (adapted from Hanson, 2014)

to problems through empirical work; and *task orientation* is about students' awareness of learning aims and scheduled tasks. (see Chionh & Fraser, 1998).

This study employed a modified version of the original WIHIC instrument. The instrument herein excluded both the tasks and investigation subscales (Chionh & Fraser, 1998). In their stead, three others were included: (a) *personal relevance* - relevance of classroom learning to their daily life, (b) *enjoyment of chemistry lesson* - perceived significance of guided peer and group learning for content comprehension and (c) *academic efficiency* - effective and correct use of concepts when understanding chemistry.

Five chemistry education specialists (i.e., an expert panel of judges) inspected the modified version to ensure its validity. The tool was subsequently amended using their feedback. The expert panel of judges ultimately affirmed the addition of these three subscales (i.e., an aspect of content-related instrument validity) (Berk, 1990). Each item in the instrument was rated using a 5-point Likert scale ranging from 'Almost Never,' 'Seldom,'

'Sometimes,' 'Often,' and 'Almost Always.' The internal consistency based on Cronbach's Alpha was high ranging from 0.88 to 0.947 (see Table 1). This is an acceptable stability factor, as it indicates the viability of the tool to achieve the study's objectives.

Data Collection

The WIHIC instrument was administered to the students as a pre- and post-test in winter 2018. The second author administered the instrument both times in Al-Jouf, and the first author's graduate student did the same in Abha. All students completed the WIHIC on both occasions meaning before and after the intervention. Both students and teachers were assured confidentiality.

Table 1. Measurement of WIHIC subscale internal consistency based on Cronbach's Alpha

Subscale	No of Items	Cronbach's Alpha
Student Cohesiveness	8	0.88
Teacher Support	8	0.894
Involvement	8	0.924
Cooperation	8	0.907
Equity	8	0.915
Personal Relevance	8	0.898
Enjoyment of Chemistry Lesson	8	0.947
Academic Efficiency	8	0.908

Data Analysis

The WIHIC questionnaire data collected in this study underwent descriptive analysis (frequency, mean and standard deviation) and inferential statistical analysis for the pre- and post-test results (paired t-tests and Cohen's d effect size values) (Cohen, 1988).

RESULTS

The first research question was intended to determine students' perceptions of what happened in class per the WIHIC subscales (see Table 1). Apart from the Personal Relevance and Enjoyment of Chemistry two subscales, the experimental and control groups did not differ significantly in WIHIC subscale pre-test scores. The discrepancy was inclined toward the control groups.

On the other hand, significant differences in Student Cohesiveness, Cooperation, and Personal Relevance were revealed in the post-test with differences inclined

Table 2. Independent sample t-test with WIHIC subscales pre- and post-test

WIHIC subscales	Pre-test POGIL vs non - POGIL		Post -test POGIL vs non - POGIL	
	t	df	t	df
Student cohesiveness	1.48	96	2.02**	109
Teacher support	1.03	96	0.952	109
Involvement	1.69	96	1.92	109
Cooperation	1.80	96	2.17**	109
Equity	1.74	96	1.70	109
Personal Relevance	2.33**	96	2.28**	109
Enjoyment of Chem. Lessons	2.26**	96	1.87	109
Academic efficiency	1.51	96	1.64	109

Table 3. Descriptive and effect size statistics for pre- and post-test WIHIC

WIHIC subscales	POGIL group				*t* value	Effect size (d)	Non - POGIL group				*t* value	Effect size (d)[a]
	Pre-test (n =)		Post- test (n =)				Pre-test (n =)		Post- test (n =)			
	Mean	SD	Mean	SD			Mean	SD	Mean	SD		
Student cohesiveness	3.12	0.83	3.93	0.66	5.96**	0.42	3.38	0.86	3.75	0.89	2.19**	0.16
Teacher support	3.40	0.98	3.66	0.89	1.34	0.04	3.60	0.96	3.48	0.88	0.561	0.007
Involvement	2.70	0.96	3.33	0.96	3.24**	0.18	2.99	1.01	3.02	1.03	0.140	0.00
Cooperation	2.76	1.00	3.61	1.00	4.42**	0.29	3.07	1.02	3.31	1.09	1.02	0.02
Equity	3.33	1.01	3.90	0.71	3.15**	0.17	3.58	0.94	3.62	0.92	0.197	0.00
Personal Relevance	2.86	0.90	3.45	0.88	3.11**	0.16	3.22	0.98	3.05	0.91	0.902	0.02
Enjoyment of Chem. Lessons	3.13	1.26	3.25	1.18	0.530	0.001	3.60	0.94	2.68	1.25	4.14**	0.28
Academic efficiency	2.95	1.09	3.33	0.98	2.28**	0.12	3.18	0.92	3.07	1.19	0.508	0.006
Total score	24.23	6.29	28.45	4.89	3.74**	0.22	26.63	5.75	25.97	6.62	0.538	0.007

[a] Range of Cohen's d (Cohen 1988): small effect (0.20-0.30); medium (0.40-0.70); large (0.80 and above)
*P<0.05; **P<0.01

Table 4. The results of descriptive and effect size statistics for post-test WIHIC

WIHIC subscales	Post POGIL				*t* value	Sig.
	Male students		Female students			
	M	SD	M	SD		
Student cohesiveness	31.86	5.33	30.23	6.00	1.30	.197
Teacher support	28.74	6.10	30.74	7.3	1.25	.216
Involvement	26.86	7.71	29.30	6.9	1.45	.151
Cooperation	29.25	6.7	29.03	6.2	.146	.884
Equity	31.23	5.5	31.97	7.2	.532	.596
Personal Relevance	27.71	6.9	29.03	6.8	.853	.396
Enjoyment of Chem. Lessons	25.81	9.2	31.09	8.1	2.66**	.009
Academic efficiency	27.08	7.3	33.29	6.3	3.96**	.000
Total score	228.54	38.7	244.68	37.9	1.86	.066

*P<0.05; **P<0.01

toward the experimental groups (see Table 2). This result suggests that, unlike students exposed to teacher-centred chemistry instruction, those receiving POGIL perceived their chemistry learning more favourably as measured by WIHIC.

The experimental groups differed significantly in the pre- and post-test mean scores for every WIHIC subscale apart from Teacher Support. By contrast, the control groups differed significantly in the pre- and post-test mean scores on only two WIHIC subscales: Student Cohesiveness, and Enjoyment of Chemistry Lessons (see Table 3). Again, these results intimate that POGIL was making a difference in Saudi Grade 10 chemistry classes.

Regarding the second research question concerned with gendered differences, male and female students did not differ significantly overall *or* in any WIHIC subscale in how they perceived their chemistry learning except for Enjoyment of Chemistry Lessons, and Academic Efficiency in which the performance of female students exceeded that of males (see Table 4).

DISCUSSION

Research Question One: Students' Perception of Chemistry Learning Experience

Few studies have addressed the issue of the compatibility of teaching methods adopted from Western countries with the Saudi educational setting (Treagust et al., 2018). This study demonstrated the effectiveness of POGIL in encouraging Saudi male and female Grade 10 chemistry students to actively participate in the classroom and thus enhance their perceptions of learning chemistry. Emilov and Tafrova-Gergorova (2016) similarly reported that student-focused teaching resulted in high WIHIC scores among high school chemistry students. Also, in our study, Saudi science students of both sexes benefitted from POGIL.

Our results corroborate Şen et al.'s (2016) findings that, compared to teacher-oriented instruction, POGIL was more effective in helping students assimilate scientific concepts. Furthermore, our study results are consistent with Treagust et al.'s (2018) Qatar study, where students exposed to POGIL perceived their chemistry learning more favourably and performed better academically due to actively participating in the classroom. Similarly, our results supported Villagonzalo's (2014) argument that POGIL had greater effectiveness than conventional instruction in improving students' academic performance; POGIL students in our study scored significantly higher on Academic Effectiveness.

The statistically significant results in Table 3 can be explained in terms of POGIL affording students chances to (a) familiarise themselves with one another and collaborate during activities (Student Cohesiveness), (b) debate and critically think about the questions provided in worksheets (Involvement), (c) work as part of small groups where each member had a particular role (Cooperation), (d) realise the relevance of classroom learning to their daily life (Personal Relevance) and (e) experience and value the significance of guided peer learning for content comprehension (Enjoyment of Chemistry Lessons). These benefits mirror Hanson's (2014) anticipated efficacy of the exploratory nature of the POGIL approach.

Indeed, these are all well-recognized and expected benefits of POGIL-oriented science instruction (Bransford et al., 2000; Busch, 2005; Zgraggen, 2018). POGIL worked in our Saudi setting. Our results contradicted Kind et al.'s (2007) earlier findings that all Saudi students found their science classes boring and irrelevant. Like our Saudi-based study results, Treagust et al. (2018) reported that other Arabian students (Qatar) exposed to POGIL enjoyed their chemistry lessons more than those not exposed to POGIL. A meta-analysis of 11 international studies revealed similar results (den Brok, Telli, Cakiroglu, Taconis, & Tekkaya, 2010). Others have also reported that student engagement with science and their relationships with classmates (e.g., classroom environment) increased students' interest in and enjoyment of chemistry (Freedman, 2002; Papanastasiou & Papanastasiou, 2004). And although in a university setting, Hale and Mullen (2009) also reported that students in a POGIL class (relative to a control group) gained a greater sense of responsibility for their learning.

On the other hand, no statistically significant results were found for two WIHIC subscales: Teacher Support (i.e., level of assistance to students while they are learning), and Enjoyment of Chemistry Lessons (see Table 3). POGIL expects students to be self-directed with the teacher acting in a facilitator role (Hanson, 2014). This result could be explained by ingrained constraints imposed by the teacher-centred approach on Saudi teachers who were trying to adopt an unfamiliar facilitator position (Teacher Support) (Alrwathi et al., 2014; Treagust et al., 2018). Although not statistically significant, it seems that POGIL training did not always ensure teachers could provide the support needed to students engaging with inquiry-based learning. Overall means scores in the 3 range (sometimes) support this supposition. Ah-Weher (2004) reported that teachers whose approach was not inline with the constructivist philosophy became more positive after they received training in these methods. This outcome implies that unless teachers' perceptions of constructivism (e.g. POGIL) change, they will sustain the pervasive teacher-centered approach, which has been shown to not resonate well with Saudi science students (Kind et al., 2007).

Also, Saudi students traditionally lack experience with and appreciation for the significance of guided peer learning for content comprehension, which could affect their Enjoyment of Chemistry Lessons, where they were expected to engage with each other. And, rote learning and lecture-style teaching might have socialized students to not expect enjoyment in chemistry class. This apparently deeply entrenched mind set (i.e., learn 'how to do' instead of 'how to learn') is reinforced by Saudi's educational system's focus on the teacher with passive student involvement (Alrwathi et al., 2014; Treagust et al., 2018).

Results suggest that even an approach like POGIL, which provides opportunities for students who are disengaged from science to actually engage with science at a deeper level, was not enough to breach this pedagogical wall on these two subscales. But there is hope. Science students' perceptions of constructivist learning environments significantly affects their science achievement (Boz, Yerdelen-Damar, & Belge-Can, 2018). Fakayode (2014) noted that once they become used to it, chemistry students come to prefer guided-inquiry methods. But researchers have cautioned that the relationship between deep learning and constructivist learning is complex and cannot be assumed (Gijbels, Segers, & Struyf, 2008).

Per Table 3, the post-test POGIL groups differed significantly on Student Cohesiveness, Cooperation, and Personal Relevance with this reflecting the positive impact of POGIL. POGIL-taught science students had the chance to acquaint themselves with one another (Student Cohesiveness), tackle tasks together in small groups where everyone had a particular part to play (Cooperation) and determine the usefulness of classroom learning to their daily life (Personal Relevance). These students were at least ready to set aside the sit-at-a-desk-facing-forward mind set and embrace connecting with their peers and finding personal relevance in what they were learning.

Results further indicate that POGIL augmented several *affective* traits in these Saudi secondary chemistry students deemed to include Student Cohesiveness, Participation, Cooperation and Collaboration, and Personal Relevance. den Brok et al. (2010) also reported high and statistically different scores on both Student Cohesiveness and Cooperation. Treagust et al. (2018) also reported *affective* benefits attributing them to role-based active discussions within small groups. Paying attention to *affect* when using POGIL is important, because "on the basis of constructivism in science education, affect has emerged as an important aspect of learning, inseparable from cognition [just harder to measure]" (Rahayu, 2015, p. 29). When reporting mathematics affect as measured by TIMSS, Ghasemi and Burley (2019) commented on whether students liked math, had confidence in being able to do math, and thought mathematics was important (has value). It would be interesting for future studies to do the same for chemistry affect in Saudi Arabia relative to POGIL.

Research Question Two: Gendered Differences

Regarding the overall WIHIC score, Saudi male and female Grade 10 chemistry students achieved similar results meaning no gendered differences. Two reasons for such similarity might be (a) their shared background and cultural effects and (b) the use of the same teaching resources for all students (i.e., not gender tailored). That said, other factors might challenge this result. For instance, every Saudi public independent school is under the auspice of the MoE, meaning differences in the socialisation of the two sexes are likely translated into dissimilarities between male and female students. This possibility suggests an expectation of gendered differences for WIHIC scores, which we did not find.

Per our results, Barthlow (2011) reported comparable findings in that American students of both sexes exposed to both types of instruction did not differ significantly regarding alternative interpretations of particle theory in secondary chemistry. Similarly, Zgraggen (2018) reported no statistically significant differences among American students (regardless of sex) exposed to POGIL and InDGIM both guided-inquiry methods. From another perspective, our result is surprising given the gender bias currently inherent in Saudi chemistry curricula and resources (e.g., Brandriet et al., 2011; Kousa et al., 2018; Lee & Collins, 2009). Both the conventional and POGIL strategies employed in this investigation used the same gendered resources. De facto, this result speaks to the power of the POGIL approach in that it might have circumvented such gendered influence.

Saudi male and female Grade 10 chemistry students differed significantly on only two subscales: Enjoyment of Chemistry Lessons, and Academic Efficiency with girls scoring highest (see Table 4). Both enjoying the chemistry lesson and perceiving that it helped them better understand concepts could be construed as an interest in science, which is usually higher for boys than girls (Bilken & Pollard, 2001). Our contradictory result suggests that this norm did not manifest in Saudi Arabia. Gender segregation might impact interaction at the entire class level (Howe, 1997) and in small-group discussions (Mercer & Littleton, 2007). In the 2015 TIMSS results, Saudi Grade 8 girls outperformed boys by 55 scale points (IEA, 2019). And in 2020, more than half of all Saudi university science students are women, intimating an enjoyment of science, including chemistry. This phenomenon merits further investigation, because gender and culture deeply shape attitudes toward science (Osborne et al., 2003).

From another perspective, both male and female Saudi students had similar outcomes with both teaching approaches (experimental and control groups). This result implies that it should not matter which approach is used from a gendered perspective, *but* it *does* matter from a student-learning perspective. If both approaches work, but POGIL offers richer educational benefits, it makes sense to switch from conventional teacher-centered to student-centred approaches for the science curriculum. Per Treagust et al.'s (2018) concern, this Western-created approach (POGIL) seemed to work very well in the Saudi educational context, meaning our study added significantly to the literature.

Pragmatic implications arise as well. Although Saudi students have been socialized to the teacher-focused, rote learning, memorization approach, the student-centred, constructivist POGIL approach still resonated with them. This means changing the teaching and learning culture in Saudi may not be as hard as expected (Alghamdi, 2013), because POGIL worked. Results may even imply that POGIL mitigates the impact of borrowing education curricula and policies from Western countries. Nonetheless, the MoE is encouraged to develop culturally relevant and sensitive Saudi-oriented science textbooks and resources that reconcile Saudi values with modern science (Aydarova, 2013; Bahgat, 1999; Guo, 2017).

On a final note, interests tend to influence attitudes (Tranter & Warn, 2008), and attitudes toward science are affected by gender (Osborne et al., 2003). This study measured students' perceptions of learning science through POGIL. There were no gendered differences in Saudi Grade 10 chemistry students as far as *what they perceived was going on in the class* (i.e., WIHIC) whether it was taught using POGIL or teacher-centered methods. Girls did not differ from boys in their perceptions. This result somewhat contradicts Al-Dahmash et al. (2016) and Dawson's (2000) aligned findings of dramatically increased *interest* in science for girls *if* instructions involved peer collaboration and social settings (fostered using POGIL).

To elaborate, once people perceive something (e.g., a POGIL classroom), they selectively interpret it using their attitudes and interests (Pickens, 2005). Fully expecting, but not finding, gendered differences in the Saudi educational context (Hamdan, 2005) vis-à-vis the implementation of POGIL prompts the recommendation that future studies should investigate different approaches to capturing this dynamic in Arab-world secondary science classes. Women's *interest* in science seems to be strong in Saudi Arabia, and a positive *attitude* (with resultant behaviour) needs to be fostered if KSA education is to continue to enrich economic development and social change (G-Mrabet, 2012; KSA, 2016). Sustained *interest* in science is a national benefit. This can begin with further research on secondary students' gendered perceptions of chemistry pedagogy in the KSA.

Limitations

Respecting Aydarova's (2013) assertion that local culture and context can thwart the implementation of imported curricula, future studies in the Saudi context could sample all schools from the same region to offset this influence, which the researchers had deemed minimal in this study, because teachers in all regions of Saudi Arabia teach the mandated MoE chemistry curriculum, just differently. This study focused on students' perceptions of POGIL; future research could examine Saudi teachers' perceptions of using POGIL. Given the imbalanced representation of students in the experimental group and control group (reflecting a limitation of convenience sampling), future studies should ensure a more balanced research design.

CONCLUSION

Saudi Arabia has translated British and American science curricula and textbooks into Arabic and implemented these student-centred, constructivist pedagogies in the KSA. This policy decision created challenges for Saudi educators delivering the curricula, because they tend to understand science education as teacher oriented. The student-centred approach is a very new practice in the Saudi context (Smith & Abouammoh, 2013). This study strove to discern students' perceptions of what is happening in the classroom when two very different pedagogical approaches were used to teach high school chemistry.

Results confirmed that compatibility can exist when using POGIL (as measured using WIHIC) despite entrenched gendered differences in Saudi's educational system. Contrary to Silfver's (2019) assumption, results suggest that different sexes do not need to be taught science differently in Saudi Arabia, *if* POGIL is used. And the anticipated modifying effect of the Saudi educational setting on borrowed science education curricula (Aydarova, 2013) was not observed *when* POGIL was implemented.

The study makes a notable contribution to knowledge, because little research exists about the compatibility between the instruction methods adopted from Western countries and Saudi Arabia's teacher-centred educational setting (Treagust et al., 2018). Global educators interested in gathering solid evidence to prove the effectiveness of the student-centred approach to science learning should find our Saudi-based results useful especially for comparative studies related to POGIL and chemistry and science education.

Results further justify recommending that Saudi science teacher education programs and professional in-service initiatives provide an orientation to asnd training in POGIL (and other constructivist, inquiry-based approaches). This strategy could address science teachers' struggles with delivering a borrowed curriculum and respect the Saudi government's earlier prioritization of and commitment to science teachers' PD (Alshamrani, 2012).

Finally, constructivist science curricula (such as POGIL) will help ensure that Saudi students gain life-long skills necessary for success at the tertiary level and in the workforce (e.g., cooperation, time management, critical and creative thinking). POGIL-oriented science instruction would help the KSA evolve to a knowledge-based economy supported with strong, collaborative problem solvers and innovate, analytical thinkers.

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