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Process-Oriented Guided Inquiry Learning (POGIL) as a Culturally Relevant Pedagogy (CRP) in Qatar: a Perspective from Grade 10 Chemistry Classes

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Abstract Educational reforms in Qatar have seen the implementation of inquiry-based learning and other student-centred pedagogies. However, there have been few efforts to investigate how these adopted western pedagogies are aligned with the high context culture of Qatar. The study presented in this article highlights the implementation of a student-centred intervention called Process-Oriented Guided Inquiry Learning (POGIL) in selected independent Arabic

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government schools in Qatar. The study followed a theoretical framework composed of culturally relevant pedagogical practice and social constructivism in teaching and learning. A mixed method research design involving experimental and comparison groups was utilised. Carefully structured learning materials when implemented systematically in a POGIL intervention helped Grade 10 science students improve their perceptions of chemistry learning measured from pre- and post-tests as measured by the What Is Happening In this Class (WIHIC) questionnaire and school-administered achievement test. The study further provided school-based mentoring and professional development opportunities for teachers in the region. Significantly, POGIL was found to be adaptable in the Arabic context.

Keywords Qatar · POGIL · POGIL in high schools · Science education · Chemistry education · Culturally relevant pedagogy · Student-centred learning · Active learning · What Is Happening In this Class

Introduction

Qatar's heavy investments in educational reforms and innovations have led to an increase in the number of teachers, academic performance of students (Organisation for Economic Co-operation and Development-OECD 2013) and infra-structural facilities including several international educational institutions from secondary to tertiary levels (Mansour and Al-Shamrani 2015). The academic engagement of students especially in the school education sector is influenced by changes in the curricula (Author 2016a, b; Zellman et al. 2009). The science curriculum standards that are a result of the education reform are internationally benchmarked and reflect Qatari values and culture. Contrary to this, there has been a growing concern that traditional methods of instruction and assessment have contributed to students' declining interest and attitudes toward the study of mathematics and science, and their low tertiary-level enrolment in STEM disciplines (Said et al. 2016). In a recent qualitative study involving science coordinators' and teachers' views of science education reforms in Qatar, Said et al. (2016) had identified several factors that impeded students' achievement in science. These included—didactic teaching methods, inadequate curriculum resources, lack of parent and family support, students' lack of self-efficacy, and the few opportunities for teachers' professional training. The Said et al. study recommended that schools need to regulate factors like teaching methods, learning strategies and resources to facilitate the acquisition of knowledge by students as autonomous learners. In conclusion, the study sought a consolidated effort by school coordinators, teachers and students to recognise *alternative teaching and learning approaches* such as inquiry that make students more self-directed in their learning and improve their science achievement. It is evident from the literature that thoroughly planned pedagogical implementations are vital to the needs of students and teachers engaged in inquiry-based approaches in science (Weimer 2013).

An analysis of Qatar's PISA results for 15-year olds has shown that the local national students have poorer performance when compared to their expatriate peers (Areepattamannil 2012). Thus, it would be of interest to see if a student-centred approach such as POGIL can help diminish this gap. Indeed, there is emerging research to suggest that, from a cultural perspective, student-centred techniques and cooperative group work may better match the learning styles of Arab students in Qatar (Lemke-Westcott and Johnson 2013).

Culture and learning are inherently intertwined and inseparable. The major concern of the imported curricula, education systems and technologies in the Gulf region is their suitability to the local culture, students' learning styles and needs. For example, in the case of Qatar, where instruction in some secondary schools is made in Arabic, more research is needed to examine if the *Western pedagogical practices* and learning materials when undertaken in the official Arabic language are correspondingly effective. According to Rostron (2009), imported pedagogical practices that are not deeply rooted into students' cultural beliefs may jeopardise their study habits and critical thinking. In his article focusing on intercultural perspectives on liberal art education in Qatar, Rostron exemplified instructional practices followed by *Western faculty* in Education City institutions and by teachers in the Qatari school system. The culturally non-superimposable instructional strategies followed in these educational settings led to an assumption that there is little pedagogical similarity of approaches between post-secondary and secondary institutions. The lack of such similarity can pose an academic challenge to many of the aspiring secondary students intending to pursue their post-secondary education in the western post-secondary institutions in Qatar. The essence of any culturally relevant instructional approach is to offer students the opportunities to develop twenty-first century skills thereby empowering them to take control of their own academic development (Ladson-Billings 1992, 2001).

A culturally oriented curriculum promotes students' motivational levels thereby enabling students to develop a deeper understanding of science (Abrams et al. 2013). Culturally relevant instructional practices (CRP) are socially mediated learning processes facilitating students' cultural and linguistic experiences (Durden et al. 2015). The vast majority of the literature on CRP focuses on either students' learning or teachers' instruction in culturally diverse educational settings. However, the cultural appropriateness of constructivist pedagogies imported from the West needs to be examined for their suitability in a non-Western context (Baker and Taylor 1995). The cultural pertinence of adopted instructional practices in a specific educational context such as Qatar may be viewed in terms of learners' needs, interests, values, their perceptions, communication styles and expected learning outcomes (Smith and Ayers 2006).

Based on the available evidence in support of the perceived cognitive developmental lag between Arab and Western students, Bart et al. (1987) have advocated for increased research oriented toward the development of culturally appropriate educational practices that can prepare Qatari students both academically and professionally. The notion of chalk-talk teacher-centeredness within Qatar's education system is often regarded as a challenge to many innovative practitioners. The study presented in this article refers to a pedagogical intervention developed and used in Grade 10 chemistry classes in accordance with the curricular and cultural contexts of Qatar.

POGIL

POGIL (Process-Oriented Guided Inquiry Learning) is a student-centred instructional strategy that provides opportunities, simultaneously to teach both content and key process skills. The philosophical foundations of POGIL involve an interactive process of thinking carefully, discussing ideas, refining understanding, practicing skills, reflecting on progress and assessing performance (Moog et al. 2009). Teaching within a POGIL paradigm, teachers facilitate learning rather than serve as a source of information, and students work in small self-managed groups on activities to explore concepts by examining the data or information provided in the course (Spencer and Moog 2008).

In a POGIL class, students work in groups of three or four with a flexible membership. The teachers allow students to switch the groups at the start of the semester, and switching becomes less frequent as the semester progresses. Roles are assigned to students where they can often change to a new one. Typical POGIL roles are as follows: Manager, Recorder, Presenter or Spokesperson and Reflector or Strategy Analyst. Additional roles such as Technician, Encourager and Significant Figure Checker are made available depending on the nature of the POGIL activity. Numerous studies have reported the pedagogical implications of POGIL on students' academic achievement (Straumanis and Simons 2008), conceptual understanding (Minderhout and Loertscher 2007) and their attitudes and science learning experience in post-secondary education settings (Vishnumolakala et al. 2017). However, research on POGIL implementations impacting students' learning in secondary settings (high schools) is yet to emerge.

POGIL as a Culturally Relevant Pedagogy

A vast majority of the research relating to development and implementation of Process-Oriented Guided Inquiry Learning (POGIL) in science education has aroused from western cultural and educational contexts. There is a dearth of information in the literature on the *localization* of such innovative pedagogies especially in the Gulf educational landscape where numerous reform efforts were successfully undertaken both at secondary and tertiary levels. Research on western pedagogical approaches underpinning the aspects of cultural dimension is desired for the Gulf society because the purpose of education therein is to preserve and transmit traditional culture. Reviewing the research on the effect of culture on the learning of science in non-Western countries, Baker and Taylor (1995) concluded that cultural and linguistic backgrounds have a significant effect on students' ways of knowing and learning science and personal construction of meaning. Therefore, POGIL learning materials that are carefully structured in accordance with a culturally oriented curriculum can bridge the students' cultural and linguistic backgrounds. In this article, we describe the utilisation, implementation, impact and appropriateness of POGIL within the educational and cultural context of Qatar.

Exploring the Effectiveness and Students' Perceptions of POGIL

Researchers have developed and used several instruments to study the impact of POGIL on tertiary students' cognitive and affective characteristics, including the particulate nature of matter assessment 2-ParNoMA2 (Barthlow and Watson 2014), students assessment of their learning gains–SALG (Canelas et al. 2017; Seymour 2002; Vishnumolakala et al. 2016) and chemistry attitudes and experiences questionnaire–CAEQ (Dalgety and Coll 2006; Vishnumolakala et al. 2017). Owing to the non-availability of the above-mentioned studies related to POGIL in the secondary educational levels, the researchers derived inspiration from earlier studies where educational innovations were effectively explored and evaluated using What Is Happening In this Class (WIHIC) (Martin-Dunlop and Fraser 2008; Wolf and Fraser 2008) and students' achievement in school-based assessment. More information on WIHIC is available in the research design section.

Research Questions

The objective of this research—to determine the effectiveness of Process-Oriented Guided Inquiry Learning (POGIL) in two Qatari high schools—was guided by the following research questions:

1. What steps were taken to adapt POGIL intervention to ensure that it is culturally relevant to the Qatari context?
2. How was culturally relevant POGIL perceived in Grade 10 science classes?
3. What are students' perceptions of their learning before and after POGIL instruction?
4. How effective is POGIL in meeting the expected learning outcomes of Year 10 chemistry curriculum standards?

Perspectives (or) Theoretical Framework

High-Context Culture for Learning The independent schools governed by the Ministry of Education (MOE) in Qatar are structurally prepared in terms of availability of technology, digital learning and organisation of classrooms to facilitate students' group work but have never experienced home-grown cultural pedagogies (Prowse and Goddard 2010). Western pedagogical innovations have since been adopted at various educational settings which necessitate systematic research on their effectiveness. Theorising culturally relevant pedagogy, Ladson-Billings (1995) proposed three criteria for successful teaching practice: student achievement, cultural competence and development of critical consciousness. For an educational context such as Qatar, a culturally relevant pedagogy built on the academic and cultural strength of students is desired to prepare its citizens toward meeting the challenges of a knowledge-driven economy.

Research has shown that students from high-cultural contexts learn better when they are immersed in learning environments that facilitate peer interaction (Hamdan 2014). The collectivist cultural orientation of Qataris enables them to easily work in small groups and report their findings to the class as groups (Prowse and Goddard 2010). This kind of learning environment is ideally suited because it recognises group values, group roles and group decisions. Furthermore, the curriculum standards devised by MOE when delivered using innovative pedagogies across all disciplines may provide academic opportunities for Qataris to excel on par with their peers from advanced education systems across the globe.

Teaching-Learning Process The theoretical foundations for small group active learning pedagogy such as POGIL were identified by Cole et al. (2012) from Vygotsky's social constructivism, which views the origin of knowledge construction as being the social interaction of people where interactions involve sharing, comparing and debating among learners. Vygotsky's (1978) sociocultural theory of learning accentuates the supportive guidance of peers and mentors for the development of higher-order functions and independent competence.

Curriculum Framework The intended, implemented, perceived and achieved curriculum framework proposed by Treagust (1986) has been utilised to identify relevant curricular topics suitable for POGIL implementation (as *intended curriculum*); prepare POGIL worksheets that can be adequately contextualised to Qatari school system (as *implemented curriculum*); visualise students' perception of POGIL experience (as *perceived curriculum*); and investigate students' attainment of expected learning outcomes (*achieved curriculum*).

Research Design

The research design consisted of a post-positivist paradigm using experimental and comparison groups with data collected using mixed methods (Creswell 2003). The research was approved by the institutional review board at Cornell University located on Education City campus in Qatar and the MOE recommended two independent Arabic schools located in Doha to participate in the study.

Curriculum

Secondary education in Qatar lasts for 6 years. The first 3 years comprise *preparatory/intermediate/junior secondary stage* (Grades 7 to 9) and the last 3 years constitute *secondary stage* (Grades 10 to 12). The school curriculum in Qatar is tailored in accordance with the type of education catered by the institution. The schools are of three categories—general, technical or commercial and religious. Students at the end of *secondary/higher secondary/pre-university stage* appear for General or Specialised Secondary Certificate Examination depending on the chosen stream. Increasingly, inquiry-based instruction is gaining momentum in Qatar's secondary science classes as a result of curriculum reforms; however, in a study that examined science education reforms in Qatar, Said (2016) reported on the existence of ongoing challenges like students' motivation and their self-efficacy, curriculum resources and teachers' professional development.

Several curriculum standards (see Table 1 for a short list) of the Grade 10 Qatari chemistry curriculum were chosen because students traditionally have struggled to fully master the concepts and the teachers of this grade group were often new to chemistry and needed extra support. The teachers who participated in this study had attended a day-long POGIL workshop and one of the co-authors had systematically mentored their POGIL implementations over one semester at the selected government independent schools.

Participants

The *student sample* comprised 122 students from two male Arabic government independent schools taught by four male teachers who delivered the same chemistry content. The language of instruction in these schools is Arabic. As a governing body of all Arabic government independent schools in Qatar, the MOE's approval was mandatory for conducting any educational research including this research that was conducted in two independent schools. Male students ($n = 66$) from four classes (referred to here as the POGIL group) were engaged in small group interactive learning as per the POGIL teaching-learning philosophy using POGIL activity worksheets whereas students representing other classes ($n = 56$) had no POGIL-style interactions (referred to here as non-POGIL groups) and did not use POGIL activity worksheets.

Table 1 Sample of MOE curriculum standards and POGIL activities

Curriculum standard		Learning outcome	POGIL activity
18.11	Understand the importance of recycling products such as metals and plastics and of designing products to make recycling easier.	Set up recycling operations in school with assistance from Friends of the Environment.	Semester 1: POGIL Activity: Recycling products
22.9	Recognise the many functions of the oceans in regulating climate	Compare the specific heat capacity and the specific latent heat of water with that of other liquids to demonstrate the effectiveness of the oceans as energy sinks and energy sources to the atmosphere. Study the effect of major ocean circulations (e.g. the North Atlantic Gyre and the Benguela Current) on the climate of contingent continents.	Semester 1: POGIL Activity: How oceans regulate the climate

The *teacher sample* comprised four male Arabic expatriate high school teachers who have been employed by the MOE for over 3 years and who had gained approval from the MOE authorities to become trained and implement the student-centred teaching intervention in their classes.

Instruments

Data sources included the following: (1) students' responses to *What Is Happening In this Class* (WIHIC), (2) researchers' observation of POGIL intervention in chemistry classes and (3) semi-structured interviews with teachers. The Arabic version of WIHIC (Afari et al. 2013) was adapted and administered to students before (pre-test) and after (post-test) POGIL instruction. Students in non-POGIL classes also completed the pre- and post-WIHIC where the content was traditionally delivered by the teachers. The original English versions of WIHIC survey were developed and validated by Aldridge et al. (1999). The Arabic version of the WIHIC instrument had 64 items organised into eight eight-item subscales—*student cohesiveness, cooperation, academic efficacy, personal relevance, enjoyment of mathematics classes* and *involvement.* In their study, Afari et al. used WIHIC instrument in mathematics classes; for the purpose of this study, the subscale *enjoyment of mathematics* was modified as *enjoyment of chemistry* to make items suitable for chemistry learning context. Cronbach's alpha values for the subscale *enjoyment of chemistry* (0.91 for POGIL group; 0.85 for Non-POGIL group) indicate the reliability of the obtained data (Cohen 1988). Similarly, the Cronbach's alpha values of other subscales ranged from: 0.87 to 0.93 for POGIL group and 0.85 to 0.93 for Non-POGIL groups.

The rationale for the selection of WIHIC instrument is based on three reasons: (1) the instrument is suitable for student-centred instructional practice at secondary levels, (2) availability of a validated Arabic version suitable to Qatari context and (3) robustness and reliability of WIHIC subscales acquired from cross-national validation studies.

The school-based end-of-semester assessment scores for the curriculum standards covered by POGIL lessons, shared by teachers, were used to explore the trends in students' achievement of the standards. The POGIL worksheets included content relating to curriculum standards: recycling of plastics, papers and heavy metals (18.11); release of undesired gases into the atmosphere (22.2); and functions of the oceans in regulating the climate (22.9) (for the third standard also, see Table 1).

Qualitative approaches to observation of POGIL classes provide rich, descriptive information about teachers' practices and students' experiences in classrooms. Researchers' field notes included observed information on aspects like teacher's facilitation of small-group POGI|L interactions, delivery of content and students' efforts on the development of process skills and conceptual knowledge. Additionally, semi-structured interviews conducted in English with the aid of a bilingual (Arabic and English) research officer were used to investigate teachers' reflections and their pedagogical development. The interview data were transcribed by the research officer and further qualitative analysis was performed using QSR NVivo software (Bazeley and Jackson 2013).

Mentoring and Observation

The science education researchers involved in this study were fully qualified teachers experienced in staff mentoring and fostering pedagogical change in science classrooms. With the support of the research team, the Grade 10 science teachers who attended the POGIL workshop implemented POGIL in their high school science lesson environment and the co-authors mentored them in identifying any perceived barriers. The teachers' implementation of POGIL activities was also observed by three of the researchers (authors of this article) who were also experienced POGIL practitioners. The POGIL classes at the two schools were observed once a week. The observations allowed the education research officer to support each of the teachers to reflect on their lessons after implementation and consider any changes to be made to improve the delivery of the lessons next time. Feedback was obtained from the teachers who implemented POGIL at the government independent schools and also teacher participants who attended the POGIL workshop at a teaching and learning forum held in Qatar. At this forum, two teachers who taught POGILs as part of the project presented the results of the POGIL vs non-POGIL intervention.

Findings

The results are presented in accordance with the curriculum framework utilised in this study. The results for research question #1 correspond to the *intended* and *implemented* aspects of the POGIL paradigm; whereas research questions #2 and #3 reflect the *perceived* aspects of POGIL, respectively. The *perceived* component of POGIL implementation constituted: students' quantitative responses to the items of WIHIC, researchers' class-observation notes and semi-structured interviews with teachers. For non-POGIL classes, the teachers followed a traditional method of instruction; hence, the qualitative data were not available for these groups.

POGIL Interventions in Arabic

The contents of this subsection deal with the outcome of the first research question undertaken in the study—What steps were taken to adapt POGIL intervention to ensure it is culturally relevant to the Qatari context? The contextualization of POGIL in Grade 10 chemistry course is illustrated in Fig. 1. Firstly, the POGIL practitioners with an intention to explore and test POGIL in Qatari secondary schools approached the MOE which have responded by identifying two Arabic government independent schools located in Doha. Secondly, the secondary teachers and head of chemistry departments aspiring to try POGIL in their classes were invited to attend a 1-day introductory POGIL workshop conducted by practitioners from Qatar and Australia. Following the feedback from the MOE subject co-ordinators and school-based teacher-coordinators, the relevant curriculum standards in Grade 10 chemistry were identified (see Table 1) as appropriate content for POGIL implementation.

Thirdly, a total of 4 POGIL lessons (see Appendix for a sample POGIL activity) were prepared following the MOE's curriculum standards, and these learning materials were thoroughly moderated by MOE science specialists and POGIL practitioners in chemistry at institutions in Qatar and Australia who were co-authors of this research. The translation of POGIL materials was developed through a collaborative process between Arabic translators and reviewers (school teachers) who are bilingual and familiar with the chemistry/science terminology at secondary level. This process ensured the accuracy and adequacy of the POGIL materials into Arabic (Brislin 1970; Su and Parham 2002). The mentoring and observation by science education researchers, as described in subsection on research design, helped teachers to strengthen their classroom practice of POGIL. The effort of making POGIL a culturally relevant pedagogical practice consistently enforces the practice of including students' first language in the school program and in classroom interactions stipulated by Osborne (1996).

The following transcripts, derived from semi-structured interviews, indicate teachers' preparedness to adopt POGIL into their classes:

> "I will try to connect this strategy with the book, I mean the original book which means that this will include the same content of the book but in a different way so in case that the book doesn't represent the information to the student in a good way, this strategy will do the job and deliver the information in an easy way so that all students will understand it" (MT1)

Commenting on the quality of POGIL materials and the need for professional support, a teacher who participated in the intervention said:

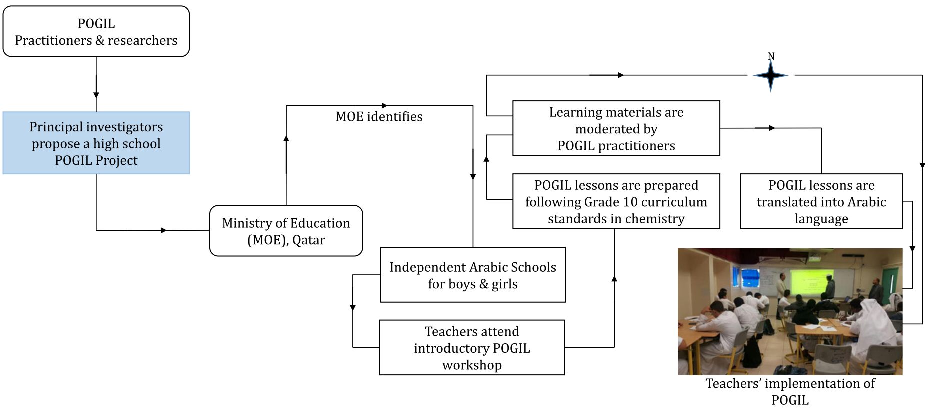

Fig. 1 An approach to culturally relevant POGIL implementation

> “It’s not only me (teacher) who is excited, the students are as well. I feel these are good materials to be used as a base to build on. As much we give them they will give us back (MT2).

Another teacher emphasised the need for motivating the students and simultaneously making them realise that small group interaction successfully leads to learning when they are engaged.

> “Sure as it is a new idea I tried to convince the students that it’s a good one. They were thinking that we were acting because we have visitors but I told them. You actually learned so I think the first and last barrier we faced is the psychological one, that they weren’t able to believe that we finished the lesson within the time period” (MT3)

Students’ Learning in a Culturally Relevant POGIL

The research question #2—How was culturally relevant POGIL perceived in Grade 10 science classes?—was used as a viewing lens to explore and understand students’ learning of chemistry content in POGIL classes. The contents of researchers’ general classroom observation notes were classified into five categories: general class environment, lesson design and POGIL implementation, content, group working and teacher reflection on lesson. Each is discussed below.

General Classroom Environment

Researchers’ observations on general characteristics of organisation of classroom environment prior to POGIL lessons are included in this section. Aspects like students’ general behaviour, their formation as POGIL groups at the start of the class and teachers’ initial preparation for the facilitation of POGIL are presented.

> Mr O divided his students into groups of 4 and 3. The roles were assigned quickly: manager, presenter, recorder, and reflector. All students were Qataris. Tables and chairs were very well arranged in the class to facilitate group work. Students in this class were very responsible, quiet, well behaved and were serious about learning. No talking or moving around without permission was noticed in this class. (O1)

> Mr MY divided his students into groups of 4 and 3. Most of the students in the classroom were Qataris. Tables and chairs were well organised. The students showed responsibility, good discipline and interest to learn. (O2)

The above observations from two lessons in two different schools indicate a similar approach adapted by the teachers in setting up their classroom and structuring of groups. The students’ behaviour truly represented the cultural characteristics of Qatar. Contrary to these, when teachers were inadequately prepared, their POGIL implementations may not yield the desired outcomes. For example, in the case of Mr. N and Mr. R, who are considered to be good POGIL facilitators, their class organisation needed improvement to ensure that full advantage could be made of the POGIL activities.

> Mr N divided his students into 2 groups of 4 and 2 groups of 3. Students wore badges representing their role (manager, presenter, recorder, and reflector) in POGIL groups. The tables and chairs were not well organised. The discipline in the class was of a concern as students were chatty and moved around the classroom without permission. (O1)

> Mr R did not seem to have prepared the students for this first POGIL class. Students were not behaving well. Students sat in straight rows throughout the class. (O2)

Lesson Design and POGIL Implementation

This category was intended to explain (1) the relevance of POGIL activities to the curriculum standards and resources used in the classroom (i.e., textbooks) and (2) teachers' facilitation of POGIL in the classroom.

> The content of the activity was very closely related to the material in the book as requested by the teachers at the school. A few divergent questions were challenging and demanded additional thought process from students. Mr Y was well prepared and he was happy with the content and its effectiveness towards meeting the expected learning outcomes for the curriculum standard 17.9 [Allotropy]. (O2)

> The activity on Allotropy is harder than the earlier topic on writing equations with symbols for simple reactions. The teacher moved around the class encouraging students to participate in active discussions. The groups functioned very well. The activity seemed to be very relevant to the chosen curriculum standard. (O1)

The above snippets from researchers' classroom observations of POGIL implementations indicate the appropriateness of activities and teacher facilitated learner-centred classroom environment.

Classroom Culture

Information presented in this section is related to the observed interactive behaviours of students in POGIL classes. Researchers observed how students are performing the prescribed group roles. The quality of discussions and students' understanding of concepts were also observed by the researchers.

> The class was very interactive and organized. The students were very well behaved, engaged and they seemed to like the activity and its questions. (O1)

> The teacher was patient with the students, group roles were encouraged. Students were well behaved and sought to meet the learning outcomes. The teacher could have randomly selected students to report on their responses to questions. (O2)

> Some students seemed to be involved in the activity and accepting the new POGIL pedagogy in their chemistry lesson. However, other students had an opposite attitude

> toward this strategy. They seemed to refuse to study, get involved, perform group roles, and work cooperatively in the class. (O2)

The above excerpts highlight students' motivational levels in POGIL classes. Teachers emphasised group work repeatedly to ensure that students stay on the task. Several factors were ascribed as reasons for variations in students' motivational level, such as timing of class, presence of observers and physical orientation of the classroom.

Reflection on Lesson

The teachers' perceptions of their POGIL implementation are considered as an important contributor to the success of inquiry-based instructional initiatives in Qatari schools. At the end of the class, teachers were invited to share their classroom experiences. The following observations provide opportunities for improving POGIL implementation in Grade 10 chemistry classes:

> Improvement needs to be made on several aspects: discipline, students' involvement, random assignment of students to groups, re-organisation of classroom furniture to support group activity. (O1)

> Overall, as a first lesson, the class was very good. The students were well engaged and they seem to like the fact that they now have roles to play in their chemistry lesson. (O2)

> Improvements were definitely made compared to the first lesson. More planning and improvements need to be made. Students' discipline and their involvement were definitely much better. (O1)

To make POGIL more culturally relevant in Qatari context, regular interaction between school teachers and POGIL experts seemed highly beneficial.

Effectiveness of POGIL

The effectiveness of POGIL is answered by Research Questions #3 and #4. The former research question was aimed at exploring students' perceptions, whereas the latter research question was aimed at investigating students' achievement. Two approaches were used to answer Research Question #3, What are the students' perceptions of their learning before and after POGIL instruction? Firstly, the responses of students' from experimental and comparison groups to the items of WIHIC were analysed. Later, the impact of the intervention on students' perceptions of their learning within the experimental group was gauged by comparing pre and post-test mean scores of WIHIC. The results of descriptive statistics, paired sample *t* tests and Cohen's *d* (Cohen 1988) effect size values for pre- and post-WIHIC subscales in POGIL and non-POGIL classes are shown in Table 2. The students in the experimental and comparison groups appeared to have homogeneous perceptions about their learning of chemistry as there is no significant mean difference in their pre-test WIHIC scores. Eventually, in the POGIL group, the post-test WIHIC scores were higher than the non-POGIL group for all subscales.

The effect size for student cohesiveness, cooperation, academic efficacy, personal relevance, enjoyment of chemistry classes and involvement ranged from 0.31 to 0.51 (medium) in

Table 2 Pre- and post-test WIHIC (Year 10 boys): descriptive and effect size statistics

WIHIC subscales	POGIL group				*t value* (two-tailed)	Effect size (*d*)	Non-POGIL Group				*t* value (two-tailed)	Effect size (d^a)
	Pre-test ($n = 66$)		Post-test ($n = 66$)				Pre-test ($n = 56$)		Post-test ($n = 53$)			
	Mean	SD	Mean	SD			Mean	SD	Mean	SD		
Student cohesiveness	4.07	0.65	4.25	0.52	2.08*	0.31	4.28	0.51	4.02	0.59	2.44*	− 0.47
Teacher support	3.68	0.83	3.81	0.91	1.00	0.15	3.64	0.87	3.69	0.85	0.11	0.06
Involvement	3.42	0.83	3.81	0.68	3.02**	0.51	3.27	0.69	3.49	0.77	1.56	0.30
Cooperation	3.75	0.70	4.00	0.66	2.33*	0.36	3.75	0.79	3.54	0.67	1.55	− 0.28
Equity	3.88	0.77	4.06	0.78	1.24	0.23	3.78	0.74	3.83	0.93	0.20	0.06
Personal relevance	3.55	0.83	3.89	0.72	2.71**	0.44	3.39	0.80	3.60	0.73	1.25	0.27
Enjoyment of chemistry lessons	3.36	1.20	3.90	0.93	2.95**	0.50	3.24	1.00	3.43	0.84	1.09	0.20
Academic efficacy	3.51	1.04	3.88	0.80	2.73**	0.40	3.41	0.85	3.75	0.86	1.97	0.39

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

* $p < 0.05$; ** $p < 0.01$

POGIL classes indicating that students have positive perceptions about their learning as compared to non-POGIL group.

For a better understanding of the impact of POGIL, students' perceptions of their learning before and after the POGIL intervention were compared (see Table 2). The post-test mean scores for all subscales of WIHIC were generally higher than pre-test scores. The paired sample *t* test results were statistically significant indicating the positive impact of POGIL on students' perception of their learning. Teacher support appeared to have a minimal impact due to the fact that POGIL emphasises student centeredness rather than a teacher-focused activity. A small effect size for equity indicates that the POGIL group work fitted well with the students' conceptions of what was equitable about their usual learning experiences of sharing responsibilities.

An independent sample *t* test was conducted for each subscale to identify statistically significant differences between experimental and comparison groups. As shown in Table 3, students' responses to the subscales of student cohesiveness, involvement, cooperation, personal relevance and enjoyment of chemistry lessons were statistically significant. These statistically significant results may have resulted due to the availability of opportunities for POGIL students to know each other and work collectively on tasks (*student cohesiveness*); actively discuss (*involvement*) while answering critical thinking questions given in the worksheet (see Appendix); engage as co-operative small groups with assigned roles (*cooperation*); identify what they learn in class is relevant to their everyday life (*personal relevance*); and experience and appreciate the importance of guided peer-learning in understanding the content (*enjoyment of chemistry lessons*).

In contrast, the non-significant independent *t* test scores for the subscales *teacher support* and *academic efficacy* may have resulted due to the restricted nature of teacher's role as a facilitator, and students' were unable to self-evaluate their learning gains. Students' perception of their improvement in academic efficacy is revealed from their achievement scores in end-of-semester assessment.

For answering Research Question #4, the students' achievement scores for the identified curriculum standards (18.11, 22.2 and 22.9) on the school-based end-of-semester assessment test were utilised, and the results are presented in Table 4.

The POGIL cohort's achievement is generally higher than non-POGIL cohort for all curriculum standards and is statistically significant. The effect sizes (Cohen 1988) ranged from 0.27 to 0.31. POGIL appeared to be effective in improving students' achievement

Table 3 Independent sample *t* test results: pre- and post-WIHIC subscales

WIHIC subscales	Pre-test POGIL vs non-POGIL		Post-test POGIL vs non-POGIL	
	t	*df*	*t*	*df*
Student cohesiveness	1.93	120	2.30*	117
Teacher support	0.23	120	0.75	117
Involvement	1.07	120	2.42*	117
Cooperation	0.05	120	3.75**	117
Equity	0.80	120	1.45	117
Personal relevance	1.10	120	2.15*	117
Enjoyment of chemistry lessons	0.63	120	2.87**	117
Academic efficacy	0.58	120	0.87	117

$^{*}p < 0.05$; $^{**}p < 0.01$

Table 4 Students' achievement in end-of-semester assessment

Curriculum Std.	POGIL		Non-POGIL		Effect size Cohen's *d*	*t*	*df*
	M	Std. Dev	M	Std. Dev			
18.11	74.72	24.53	65.31	33.72	0.31	2.09*	117
22.2	82.98	24.64	74.24	35.5	0.28	2.00*	117
22.9	64.45	29.66	54.21	42.75	0.27	1.95*	117

* $p < 0.05$

in experimental group by an average of 8 to 10% as compared to the comparison group. The academic efficacy as perceived by students in POGIL classes, though was not statistically significant after a *t* test (see Table 3), but their achievement scores give an indication that POGIL is helpful in improving their understanding of chemistry content.

Discussion

The study highlights an approach utilised to make POGIL a culturally relevant pedagogy in Qatar. Although the initial appropriation of POGIL in the Qatari context has largely been the result of a Foundation Chemistry course in pre-medical education on Education City campus, the transfer of the pedagogical model to the local secondary schools involved several stages of intensive work systematically carried out by the POGIL practitioners, science teachers and the supportive Ministry of Education in Qatar. Based on the design and development of POGIL intervention in Arabic, mentoring and observation of teachers implementing POGIL, and quantitative findings from the WIHIC survey, the study provides the following outcomes.

Cultural and Constructive Alignment of POGIL Intervention in Qatar's Secondary Science Education

To achieve successful implementation of culturally relevant POGIL, particularly at secondary levels in Qatar, an active partnership (see Fig. 1) with local education authorities, school management and teachers is essential. A prior study undertaken by Balawi et al. (2016) also accentuated that support from the faculty and the institution is important in making problem-based learning (PBL) a culturally relevant pedagogical practice in STEM disciplines in the MENA (Middle East and North Africa) region. The present study also identifies the key ingredients for the constructive alignment of POGIL intervention (with the Grade 10 curriculum recommended by the MOE) in Qatar: teachers' participation in introductory POGIL workshops; streamlining of POGIL materials with embedded examples from Qatari context by experienced POGIL practitioners; and teachers' self-reflection of their POGIL implementations. The approach utilised in this study is consonant with previous studies on the development and use of CRPs which indicate the need of the following: explicit conjugation between culture and learning (Howard 2003); research informed learning process (Tate 1995); professional development and support network to help teachers (Johnson 2011); and teachers' critical self-reflection (Irvine 2010).

Students' Learning in a Culturally Relevant POGIL

The qualitative findings suggest that students' learning of chemistry content is influenced by the appropriateness of POGIL worksheets, teacher's prior preparation for the POGIL class and teachers' engagement and facilitation of small group discussions. Prior research indicates that pedagogical efforts intended to prepare Arab students as independent learners and critical thinkers right from high school levels are sought to enhance their participation in STEM disciplines (Haidar 2000). The *role-based* POGIL format designed to facilitate student-student and student-teacher communications is proven to provide a positive and dynamic classroom learning environment for students' learning of chemistry. The findings support the view of Alhammad (2015), who recommended the use of pedagogical approaches that encourage active classroom communication, especially in the Gulf region.

Positive Impact of POGIL on Students' Perception of their Chemistry Learning and Cognitive Gains

An important finding from this study is that POGIL is effective in improving students' perceptions of their chemistry learning and academic performance as a result of their active engagement in the classroom. Based on the analyses of WIHIC data obtained from experimental and comparison groups, the study identified improvement of several affective characteristics in POGIL classes. For example, students' post-test mean scores for the subscales of student cohesiveness, involvement and cooperation were high in POGIL classes where students worked in role-based small group active discussions. Emilov and Tafrova-Gergorova (2016) reported a similar trend in WIHIC scores among high school chemistry students from Kosova where student-centred instructional strategies were implemented. This study in Qatar high schools identified statistically significant improvement in students' enjoyment of chemistry lessons and academic efficacy at the end of post-test WIHIC in POGIL classes. Prior studies on the effectiveness of POGIL in college-level chemistry (Baepler et al. 2014; Bailey et al. 2012; Straumanis and Simons 2008) also reported similar gains in students' perceptions and academic achievement. Interestingly, in the case of Qatar, according to the latest PISA results (OECD 2015), the students' improvement in mean performance in science and attitude toward science reinforces the sector-wide growth as a result of educational reforms (Qureshi et al. 2016). Although the assessment encompassed just three standards from the MOE's curriculum standards, the students' levels of attainment of standard scores may be better assessed/viewed when POGIL activities are implemented throughout the year.

Conclusions

The research is significant for the teaching and learning of science in Qatari schools in five important ways:

Firstly, the teaching and learning of chemistry using POGIL fits the local cultural context. In this small sample study, POGIL was seen to be beneficial to Qatari students. Secondly, the student-centred strategy used in POGIL teaches students the curriculum content whilst also building on life-long skills such as cooperation, time management and critical thinking which are regarded as key-skills for success at the tertiary level and beyond in the workforce. Thirdly, the study further empowers science teachers in Qatar to try and adopt new teaching strategies into the local cultural context. Fourthly, from this research, there are POGIL teaching resources available in Arabic that are well-structured to suit Qatar's local culture and education context. Lastly, the study may help in enhancing affective outcomes of high school students and increasing their aspirations of accessing the most challenging courses offered at the international institutions located in Qatar.

The study, being the first to implement POGIL in Qatari secondary schools, is has limitations such as the following: (1) small sample size, (2) selective implementation of POGIL in terms of number of schools and curriculum content, (3) the MOE's identification of schools and classes and (4) the lack of externally referenced data confirming students' attainment of curriculum standards. However, the outcomes from this study could serve as a model to motivate aspiring teachers from other curricular areas and schools in the gulf region for the contextual alignment and widespread implementation of contemporary innovative pedagogical interventions in Qatar's educational landscape.

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