Science Education International
Vol. 26, Issue 1, 2015, 56-61

The Effect of POGIL on Academic Performance and Academic Confidence

S. DE GALE[*], L. N. BOISSELLE[†]

ABSTRACT: POGIL (Process Oriented Guided Inquiry Learning) is a collaborative learning technique that employs guided inquiry within a cyclic system of exploration, concept invention, and application. This action research explores students' academic performance on a unit of organic chemistry work taught using POGIL, in addition to the effect of POGIL on their academic confidence. The academic performance was measured using a summative assessment at the end of the study whilst academic confidence was measured using a pre- and post- test questionnaire. A qualitative comparison to the previous term's academic scores suggested a varied academic performance, whilst tests of significance indicated an improved level of academic confidence among the students involved. It is hoped that this study will serve as a platform for the use of more student-centred pedagogies in chemistry at the institution at which it was enacted, and education at large.

KEY WORDS: Academic performance, academic confidence, inquiry based science education, POGIL, organic chemistry, Trinidad and Tobago/ Caribbean/ West Indies.

INTRODUCTION

Learners have demonstrated longstanding difficulties interconverting chemical knowledge through microscopic, macroscopic and symbolic forms; many studies have documented students' difficulties and tried to suggest solutions (for example see O'Dwyer, 2012; Sirhan, 2007; Wu, Krajcik, & Soloway, 2000). The issue has also been considered across a variety of contexts for example Oman (as illustration see Al-Balushi, Ambusaidi, Al-Shuaili, & Taylor, 2012), and Ireland (e.g. O'Dwyer, 2012 ; O'Dwyer & Childs, 2014). Students in Ireland for instance, have been found to have difficulty with organic chemistry in general, and tend to either perform poorly on, or to all out avoid organic chemistry questions on state examinations (O'Dwyer & Childs, 2014). Indeed, the numerous difficulties

[*] The University of the West Indies, St. Augustine Campus, School of Education, E-mail: stefandegale@gmail.com
[†] (Corresponding author) The University of the West Indies, St. Augustine Campus, School of Education, E-mail: boissellelaila@gmail.com

that learners encounter with organic chemistry has promoted a plethora of suggested methods to improve pedagogical efficiency (see Eastwood, 2013; Hein, 2012; Pargas, Cooper, Williams, & Bryfczynski, 2007)

There is a dearth of similar studies within the context of the twin-island Caribbean nation of Trinidad and Tobago and the wider West Indies. This action research reports on classroom practice in a Trinidadian classroom utilizing a guided model of inquiry learning (POGIL) to alleviate advanced level high school students' difficulties learning organic chemistry.

Research Questions

Two research questions with respective, corresponding hypotheses are addressed in this study:

1. How do students perform at the end of a unit of organic chemistry taught using POGIL?
2. What is the effect of POGIL on the academic confidence of students during a unit of organic chemistry?

Null Hypothesis (H_0): POGIL has no effect on the academic confidence of students.
Alternative Hypothesis (H_A): POGIL impacts the academic confidence of students.

BACKGROUND

Whilst being a secondary school student an unexpected hurdle came in the form of organic chemistry at the advanced level. The principal author found it challenging to link concepts from one reaction to another and particularly to follow the stepwise procedures, (i.e. reaction mechanisms (Sykes, 1986)), through which reactions progressed. This was caused by my inability at the time to visualise the formation of the molecular intermediates and final products of organic chemical reactions which also made it challenging to mentally create or manipulate the organic molecules that I studied from textbooks or encountered on assessment questions. As a result, it was difficult to grasp the underpinning concepts involved in organic chemistry and their related reactions possibly because, according to Piaget's stages of cognitive development, my lack of formal operations was perhaps being challenged by aspects of organic chemistry. I might have been more successful in my organic chemistry studies if generalisations of the behaviour and reactions of organic molecules had been made using concrete experiences involving objects that were actually present (Biehler, Mc Cown, & Snowman, 2009). Indeed, there is argument that science education should be considerate of educational and child psychology as well as science-education theory (Johnstone, 2000 as cited in Tsarpalis, 2008).

In my present practice as a Chemistry teacher to 16 to 18 year old boys, I have found that my students also have similar concerns regarding organic chemistry as I did when I was a student. This has led to some challenges in keeping my students confident in their ability when studying organic chemistry, and has certainly caused them to relay their lack of confidence in the soundness of their oral and written responses to organic chemistry problems. These experiences have further retarded their motivation to pursue organic chemistry related work. My students' performance though, mirrors a wider issue. The Caribbean Examination Council responsible for the administration of advanced level examinations in the region, has reported that students' performance generally ranged from moderate to poor in organic chemistry questions ranked from knowledge to analysis on Bloom's taxonomy (Caribbean Examinations Council, 2011a).

The students under discussion make up a class of 22 second year advanced level, sixth form students in a boys' college. The entire population is male and ranges in age from 16–18 years old. Based on the previous end of term results and a tacit knowledge of the students, this group may be considered to be a class of mixed ability. The members of the group had previously been observed to relate well to each other, perhaps as a result of being in the same class for the last six years. As a group too, this class was very curious and routinely tried to find relationships, (often inventing new scientific hypotheses in response), between their personal experiences, topics covered during chemistry class, and new science areas that they had read about independently. To respond to these complaints and concerns surrounding student performance in organic chemistry in previous years, molecular model building sets were used in an attempt to concretise abstract images so that students could better describe and manipulate them. Students were able to develop and use their own explanations of the molecular structures, their behaviour, and their reactions. Once students developed their explanations after exploring the topics themselves, their complaints were observed to decrease significantly. Additionally, they also appeared to be more determined and confident to seek solutions to organic chemistry assessment questions. Process Oriented Guided Inquiry Learning (POGIL throughout this paper), as a collaborative learning strategy, was thought able to extend the advantages of molecular modelling as it can provide the concrete experiences that could help these students to learn organic chemistry better. POGIL may aid in this respect by allowing the learner to build their own methods of approach to organic chemistry in order to develop their own understandings (Littlewood, 2009). This study was meant to promote a more student-centred approach to delivering the curriculum by encouraging student participation in the learning process. POGIL is a student-centred pedagogy (Eberlein et al., 2008) that was initially used in, and adapted to, chemistry classrooms by Rick Moog, Jim Spencer, and John Farrell in the mid-1990's (Straumanis, 2010).

The Problem

The challenge being faced in this study can be summarized as follows:

1. The students' ability to conceptualize processes happening at the molecular level in organic chemistry reactions.
2. The students' ability to manipulate and use organic chemistry concepts that they learn within new situations.
3. The students' academic confidence levels in organic chemistry.

The Purpose of the Study

A unit of organic chemistry was taught to students in the second year of the advanced level, (i.e. upper sixth students who are approximately 16-18 years old), using POGIL. The study measured the post-unit academic performance of the students, and the impact of POGIL on their academic confidence.

REVIEW OF THE RELEVANT LITERATURE

POGIL and its Suitability to the Study

It is difficult to neatly divide organic chemistry concepts into discrete topics in the same way as might be possible in other areas where topics show little conceptual overlap (Phillips & Grose-Fifer, 2011). Within organic chemistry the academic performance of students may not be at its best if there are gaps for the students in previously covered topics. Additionally, for students to learn and manipulate concepts in reaction mechanisms, various forms of reaction modelling may be an irreplaceable tool. This is important given that it has been found that "Chemists cannot talk to each other without the use of drawings" (Habraken, 2004, p. 90), itself a form of modelling as is too the representation of the concepts in organic reactions via equations and mechanisms. If students are to learn and manipulate concepts in reaction mechanisms, various forms of reaction modelling may be an irreplaceable tool. Therefore, in the teaching and learning of organic chemistry opportunities for concept invention and development may prove useful.

POGIL, similar to Problem Based Learning (PBL) and Peer-Led Team Learning (PLTL), is built on a platform of social constructivism (Eberlein et al., 2008). Vygotsky suggests that "learning awakens a variety of internal developmental processes that are able to operate only when the [student] is interacting with people in his environment and with his peers" (Vygotsky, 1978 as cited in Nihalani, Wilson, Thomas, & Robinson, 2010, p. 500). This implies that with social-constructivist strategies such as POGIL, knowledge is something between the individual and a community or a group, and is aided by cooperative social interactions (Eberlein et al., 2008). Furthermore, "observations of students working together have found that peer-to-peer interactions may be even more facilitative for active meaning-making than teacher-student interactions, given the shared perspectives and life experiences" (Nihalani et al., 2010, p. 502). Within the knowledge-constructions of inquiry-learning "knowledge is not transmitted directly from the teacher to the student, but is actively developed by the student" (Zion & Mendelovici, 2012, p. 383). Moreover, studies have also indicated that attempting to solve real world problems whilst engaged with peers has increased students' self-efficacy and motivation (Yalcinkaya, Boz, & Erdur-Baker, 2012). Furthermore, Dewey argued that inquiry was needed to better develop scientific knowledge and that it was also necessary for the understanding and application of scientific concepts and methods (Bell, Urhahne, Schanze, & Ploetzner, 2010). By extrapolation, POGIL's ability to allow students to apply content knowledge while trying to solve real world problems through peer-collaboration suggests that it may be used/employed/able to develop cognitive skills across the hierarchy of Bloom's Taxonomy (Kuhn, Black, Keselman, & Kaplan, 2000) and so affect academic performance as reflected by students' grades.

POGIL hinges on a cycle of exploration, concept invention and application (Eberlein et al., 2008). The exploration phase may be critical in constructing personal knowledge through an active process guided and facilitated by the teacher. Within this project, group work used in POGIL also provided a more realistic setting for the limited material that was available for the execution of the study. The POGIL Project that was co-funded by the US National Science Foundation, the Toyota USA Foundation, the US Department of Education, and the Hach Scientific Foundation, reported that the implementation of a POGIL approach in general chemistry led to examination results that indicated significant shifts in student performance from lower scores to higher scores, and did so uniformly across low- through high- achieving students. Moreover, when one of three general chemistry lectures each week was replaced with a peer-led team learning session using POGIL materials, it was found that the students who attended the group learning sessions achieved a higher average score on the common examinations (The POGIL Project, 2012-2014).

POGIL employs structured chemistry exercises given to, and carried out by, students. The students operate in groups to work through the steps outlined in the exercises in order to formulate their own understanding of the topic. As their understanding of the topic develops, students should be better able to solve new problems which may fall anywhere in the hierarchy of cognitive skills (E. Mitchell & Hiatt, 2010) and therefore impact their academic performance. Academic performance outcomes may be categorised by students' grades (Centers for Disease Control and Prevention (CDC), 2010). Students' grades obtained across various cognitive levels after implementing POGIL were used to reflect the academic performance of the students in this study.

These self-managed groups of students follow a learning cycle in each exercise involving POGIL. The learning cycle used is as follows:

- *Exploration.* In this phase the students interrogate the information in the given exercises through discussion within their groups. This may lower the degree of uncertainty in students since the teacher provides the inquiry questions and procedures (Zion & Mendelovici, 2012). This stage may therefore impact upon the academic confidence of students. POGIL provides a process for exploration which is needed to address difficulties students have in mentally forming chemistry concepts (Walsh, 2006). The exercises therefore may involve the making of observations, the analysis of results or data, or even the design of an experiment. Students are to generate hypotheses and test them in order to explain and understand the information. In this phase of exploration, each exercise should work harmoniously with others to meet specific learning objectives (Hanson, 2005).
- *Concept Invention.* In this phase the students describe or explain the observations made whilst exploring. The concepts are concretised when each group reports their findings from the exercises to the entire class allowing further discussion which is moderated by the teacher. Reports can be submitted by having a representative present the findings of individual groups, or groups may simultaneously place their findings on the class' chalk or white board so that their results can be interrogated by the entire class (Hanson, 2006). After the students have constructed and expressed their own understandings, conventional related terminology is introduced by the teacher.
- *Application.* This phase of the learning cycle requires deductive reasoning skills since it relates the general concepts derived in the previous phase to new situations (Hanson, 2005). Application to new situations builds learner confidence and provides the opportunity to solve real world problems (Lombardi, 2007). Noteworthy is that "application" in this context, encompasses possible analyses, syntheses and evaluations which may arise and is not confined to the third place of "application" in the hierarchy of Bloom's taxonomy.

The POGIL learning cycle stated above is similar to Bloom's Taxonomy since there is a combination of content learning with process skills (E. Mitchell & Hiatt, 2010). Therefore, there are implications of using POGIL on the cognitive, affective and psychomotor skills of students. This may be reflected in better performance in examinations assessing these aspects of student learning (E. Mitchell & Hiatt, 2010). Additionally, students are able to reflect on their learning process through the activities and discussions that are a formal part of each POGIL session. Moreover, the interactivity and communication skills of students are challenged as they are required to communicate scientific ideas whilst working in groups. POGIL also helps students to develop competencies in decision making as they formulate hypotheses (Bauer, Cole, & Walter, 2005).

POGIL can also impact students' confidence to study organic chemistry. Academic confidence is subsumed in the concept of self-efficacy (Sander & Sanders, 2005). Albert Bandura defined self-efficacy "as people's judgements of their capabilities to organise and execute courses of action required to obtain designated types of performance" (Bandura, 1986, p. 391). POGIL can promote such self-efficacy since students are engaged primarily in concept invention which helps them to facilitate/promote their own understandings. Hence, if students can discuss their performance on tasks associated with their self-efficacy whilst pursuing academic goals, then we can have a measure of their academic confidence. Academic confidence was found by Sander and Sanders (2005) to cluster around the following factors:

- Studying
- Understanding
- Verbalising
- Clarifying
- Attendance

The above factors or capabilities classify courses of action which are pursued to meet a desired end and are represented on the Academic Confidence Scale (ACS) developed and validated by Paul Sander and Lalage Sanders (Sander & Sanders, 2005). The version which is used in this study has been truncated to better reflect classroom activities of the target group (see Appendix 1). Many statements in the ACS load across more than one factor so that analysis within this study is not undertaken to reflect performance within any one factor.

The degree of student agreement with the positively-skewed statements related to the above mentioned factors suggests the levels of academic confidence of the students involved in this study. Academic confidence scores as evidenced by responses to the questionnaire do not necessarily predict academic performance; however academic performance may affect academic confidence (Sander & Sanders, 2005). POGIL too has shown the ability to improve student confidence (Straumanis, 2010).

Setting-up and Using POGIL Groups

The size of the groups should ideally be restricted to three or four members. Larger groups may result in less focused exploration whilst smaller groups tend to have richer exchanges. However, a larger number of groups may require additional teachers present to facilitate the POGIL process for some of the clusters (Shatila, 2007) with the teacher intervening only where and when needed (Eberlein et al., 2008). Hence, with a greater number of groups the demand for teacher intervention may increase. The composition of any group can include a high and low performing student, and students of various ethnicities. In classrooms with male and female students, gender differences can also be considered when putting the groups together (Hanson, 2006).

Specific roles are also assigned to the members of a group and these can be rotated from lesson to lesson. These roles are as follows (Hanson, 2006):

- *The Manager.* This student has the responsibility of keeping the group on the task and seeks to assure that each member of the group participates and understands the content.
- *The Recorder.* This student prepares a report of the group's findings. The report must be compiled through consultation with the other group members.
- *The Strategy Analyst.* This student has the task of reflecting on the group's performance and identifies its strong and weak points. Similarly to the recorder, this role is done in consultation with the other group members. There is a greater demand on the metacognitive skills of this student since he or she must reflect on the learning process, which is just as important as reflecting on the content.
- *The Spokesperson.* This student is responsible for communicating the findings of the group to the class.

Using the POGIL method, the students are guided through a course that is focused on concepts (Eberlein et al., 2008). POGIL uses new situations to which students must apply learned concepts and against which information may be analysed and products synthesised. If students find the concepts difficult to apply, exploration can be used to map a way to a solution and hence also serve as reinforcement of studied material. The use of POGIL is suited to help develop the target students' academic achievement and confidence in organic chemistry. It also seems especially useful given that it supports, in this class, natural curiosity, inquisitiveness, tendency to invent solutions, and to work collaboratively with their peers.

The use of POGIL within this study necessitated moving away from the usual "one behind the other" arrangement of desks found in many classrooms, to multiple circular arrangements that could better promote and facilitate group work. This arrangement improved the teacher's physical access to students, and assisted the teacher in focusing on, and assessing students' understanding through direct observation of the group discussions of individual groups. This was advantageous to other forms of assessment that would not have allowed the teacher to be aware of all the steps within a given reaction mechanism that students would have personally formulated whilst developing their own understandings.

The POGIL approach was new to the Chemistry Department of my school. The conclusions drawn from this study were expected to inform the practice of teachers in the school's science department primarily in the teaching of organic chemistry. It is often thought that the nature of organic chemistry necessitates the use of the direct method of instruction in which teachers are the sole source of information in the classroom. Hopefully this study can encourage not only science-teachers at my school, but also those teaching chemistry to similar populations, to consider that students can take greater responsibility for their knowledge construction within units of work on organic chemistry.

METHODOLOGY

Theoretical Framework

This study is action-research. Action-research's primary aim is to use systematic methods to make improvements within educational settings by solving noted problems (Tomal, 2010). Although different types of action-research have been defined (e.g. technical, practical, and emancipatory (Zuber-Skerritt, 1996)), this study holds primarily to Tomal's (2010) description which reflects technical action research. Zuber-Skerritt (1996) agrees that technical action research "aims to improve effectiveness of educational…practice. The practitioners are co-opted and depend greatly on the researcher as a facilitator" (p. 3). Though action-research is able to incorporate elements from quantitative and/or qualitative research, this study collects numerical data for both research questions one and two and performs analyses primarily through statistical means. Simply described, qualitative research is naturalistic, inductive, emergent, and seeks to capture participants' constructed worldviews usually through text-based methods. Alternatively, quantitative research is deductive, and primarily considers/deciphers the relationships between variables through statistical analysis of numerical data (Creswell & Plano-Clark, 2007).

Design of the Study

The study can be described as having a quasi-experimental design since the participating upper-six class was not randomly chosen (M. Mitchell & Jolley, 2010). Randomisation is not always an appropriate option, especially in cases like this where only a small group is available for implementation of the intervention (Harris et al., 2004). Additionally, there is only one upper-six chemistry class at the college where the study was carried out. Hence, there could be no control group and there is an inability to say that results were not influenced by factors unattributed to the intervention (Slavin, 2007). The lack of a control group however, eliminated the possibility of any unethical, biased treatment of classes through the application of an intervention which could be potentially beneficial or harmful to the treatment group, whilst being denied to the control group (Cook & Campbell, 1979; Thyer, 2012). The study also does not require the identities of students to be divulged and so protects any sensitive information that may arise.

To answer question one a post-test only design was used. The intervention was made at the beginning of the organic chemistry module and scores relating to the students' previous performance in organic chemistry were unavailable, hence the choice of a post-test only design. As a result, there is no means of comparing the effectiveness of the strategy used to previous organic chemistry work pursued by these students; that is, any changes in academic performance are not necessarily attributable to the POGIL intervention. However, the students' performance in the post-test was qualitatively discussed against their academic scores from the previous end of term examinations to get some indication of how well they were proceeding through the curriculum (Olson, 2005).

A pre- and post-test design was utilised to obtain a response to question two. Both the one group post-test only design utilised for question one, and the one group pre-test/post-test design utilised for question two, do not allow reasonable causal inferences to be made about the effect of the intervention (Cook & Campbell, 1979). Also, this study was carried out as a research project within an in-service teacher-education programme for a short period over a unit of work, and only through a fraction of a single module of the syllabus. The time period then may, or may not have been, enough for the intervention to impact upon the observed behaviours of students.

Even so, as action-research the study is pedagogically valuable to the research group as it promotes reflection and collaboration and can help to improve educational practice (Parsons & Brown, 2002). The findings of this study may bear utility to teachers in similar contexts and should be considerately applied with realisation that the small size of this sample does not allow for results to be broadly generalised. Moreover, there is very little data on the study of science and its teaching and learning within Caribbean classrooms and this study can lend some insight.

Methods

For question one, student scores on a summative end of unit post-test were collected and descriptive statistics extracted. The results of this assessment were compared qualitatively, and solely for the sake of a comparative discussion, to the end of term results of the previous school term which was considered as a base score. The previous end of term scores, as a summary of three months' work over a variety of chemistry curriculum units, was taken as a reliable indicator of student performance against which the post-test scores could be qualitatively discussed – however, not statistically compared. Additionally, the analysis of the post-test summative assessment investigates student performance at various levels of Bloom's Taxonomy. Since the previous term's performance scores had not been analysed with such granularity, only overall performances in the post-test and the previous term's scores could be compared.

For question two numerical scores were collected. A questionnaire with positively-skewed questions prompted responses on a Likert scale to gather data reflective of students' academic confidence (Sander & Sanders, 2005) both before, and at the conclusion of the study. Descriptive and inferential statistics were also calculated on students' overall scores on the pre- and post- test questionnaires to measure students' agreement with the positively-skewed questionnaire statements.

Additionally, a non-directional t-test was used to compare the means of the pre- and post- questionnaires to suggest whether there was any significant difference between them. Qualitative conclusions about students' academic confidence were then made.

Research Plan

The study was conducted over a two week period. The students were briefed on the details of the study and informed of their assigned group roles during the week before the commencement of the intervention.

The unit of work consisted of eight lessons:

1. *Carbon compounds and homologous series.* Students identify the various families of organic compounds called homologous series, and the general formulae which define them.
2. *Nomenclature of organic compounds.* Students develop their own system of naming organic molecules before they are introduced formally to standard rules for naming the compounds within various homologous series of organic compounds.
3. *Isomerism.* Students identify and illustrate different types of monomers using two- and three-dimensional models.
4. *Movement of electrons in organic molecules and types of reagents.* Students describe the behaviour of electrons in different molecules in order to classify the molecules as electrophiles and nucleophiles.
5. *Hybridisation and physical properties of alkanes and alkenes*. Students attempt to illustrate hybridisation and the effect it has on the shapes, and hence the properties, of molecules.

6. *Reactions of alkanes and alkenes.* Students use drama and molecular models to describe substitution vs. addition reactions among other types of reactions undergone by alkanes and alkenes.
7. *Naming of alcohols.* Students name and classify alcohols as primary, secondary, and tertiary.
8. *Reactions of alcohols.* Students discuss the oxidation of the different classes of alcohols.

Each lesson consisted of activity sheets comprising a combination of multiple choice questions, structured questions, and free response questions. Many of the related activities involved the drawing of two dimensional representations of molecules, and the building of three dimensional representations of the same. The unit and final assessment comprised questions which fell into the knowledge, comprehension, application, and analysis categories of Bloom's Taxonomy representing 15%, 33%, 26%, and 26% of the final score respectively. Students were also required to develop a concept map as the unit of work progressed to reflect their maturing understandings of how each topic within the unit related to the others.

The questionnaire to measure academic confidence was distributed at the start of the first day of the intervention and at the end of the intervention after the final assessment. The summative academic test was administered as an instrument after the completion of the unit.

RESULTS AND DISCUSSION

Research Question 1: How Do Students Perform at the End of a Unit of Organic Chemistry Taught Using POGIL?

Fourteen (63.6%) of the total 22 boys who participated in the study wrote the final examination. Eight (36.4%) candidates were hence excluded.

From Figure 1 below, eleven (11) of the fourteen (14) students who attempted the academic post-test scored above forty percent (40%) which is the pass mark of the Caribbean Examination Council's (C.X.C.) Advanced Proficiency Examinations (C.A.P.E.). This represents 79% of the examined class population. Within CAPE a grade I and II imply that students show a comprehensive and good grasp respectively of the key concepts, knowledge, skills and competencies required by the syllabus. A grade III and IV imply that students show a fairly good and moderate grasp respectively of the key concepts, knowledge, skills and abilities required by the syllabus (Caribbean Examinations Council, 2011b). Grades I and II cover the 60-100 percentile range and grades III and IV fall in the 45-59 percentile range. From Figure 1 as well, one (1) student scored between 80%-100%, three (3) students scored between 60-79%, seven (7) students scored between 50%-59%, one (1) student scored between 45%-49% and two (2) students scored below 40%. The number of students scoring within those ranges represents 7.1%, 21.4%, 50%, 7.1% and 14.3% of the examined population respectively.

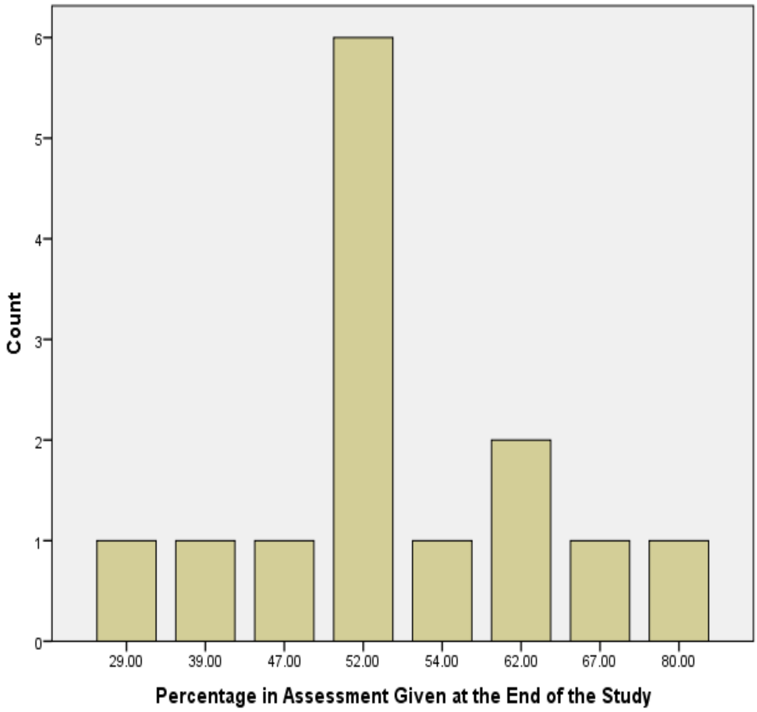

Figure 1. Percentages Obtained in Summative Assessment at the End of the Study.

There was a reduction in the mean scores from the base scores taken from the previous end of term examinations to the scores from the summative assessment given at the end of the study (58.79% to 53.71%). This was also accompanied by a reduction in the number of students scoring above the Caribbean Advanced Proficiency Examinations (CAPE) pass mark of 40% (13 to 11). Both the base score and those taken at the end of the study showed a comparable standard deviation (13.27 and 12.07 respectively). These data suggest that that there was a lower student performance at the end of the study as compared to their performance at the end of the previous term. The reduction in student performance after POGIL does not support the research that there would be improved student performance in examinations (E. Mitchell & Hiatt, 2010). This is possibly as a result of students' inexperience with POGIL and them not fully adapting to the POGIL method. Indeed the literature suggests that students have shown greater adaptability to the POGIL model at higher educational levels if they have been exposed to it at earlier chemistry education (Shatila, 2007). Additionally, students have been shown within some contexts to prefer a combination of POGIL and lectures rather than a pure POGIL approach (Shatila, 2007; Straumanis, 2010).

Table 1. Student Performance Summary at Different Taxonomic Levels

Taxonomic Level	Mean	N	Std. Deviation
Knowledge	76.07	14	37.42
Comprehension	76.71	14	18.29
Application	22.88	14	24.63
Analysis	37.89	14	43.00

Table 1 shows that students performed well using POGIL when faced with knowledge and comprehension level questions. Dewey's claim that inquiry was needed to better develop scientific knowledge and that it was part of understanding (Bell et al., 2010) is supported by this study. The students' performance at these levels of questioning differed from performance on the knowledge and comprehension levels within the Caribbean Advanced Proficiency Examinations (CAPE), 2011 external examinations in which students were said to have performed modestly or experienced great challenges (Caribbean Examinations Council, 2011a). The application and analysis questions in the summative assessment post-test average scores indicate that students show a very limited grasp of the key concepts, knowledge, skills and competencies required by the syllabus (Caribbean Examinations Council, 2011b). With mean scores of 22.88% and 37.89% at application and analysis levels respectively, this study did not show that students were able to competently use scientific knowledge to solve new problems as suggested by E. Mitchell and Hiatt (2010).

Research Question 2: What is the Effect of POGIL on the Academic Confidence of Students during a Unit of Organic Chemistry?

Table 2 gives a summary of responses to individual statements from the pre-questionnaire. On the Likert questionnaire "strongly agree" was scored as five; "agree" as four; "neutral" as three; "disagree" as two; and "strongly disagree" as one. Investigation of the modal scores in Table 2 shows that the majority of responses in ten (10) of the twelve (12) statements indicated general student agreement whilst the mode response for the other two (2) statements (7 and 8) indicated that the students were generally neutral.

Table 2. Summary of Responses to Individual Questions in the Pre-Questionnaire

Question No.	1	2	3	4	5	6	7	8	9	10	11	12
N Valid	22	22	22	22	22	22	22	22	22	22	22	22
Missing	0											
Mean	3.82	3.55	3.68	3.45	3.68	3.77	3.91	3.45	4.18	4.05	3.77	3.45
Mode	4.00	4.00	4.00	4.00	4.00	4.00	3.00[a]	3.00[a]	4.00	4.00	4.00	4.00
Std. Deviation	0.91	0.96	0.84	1.06	0.78	1.02	0.81	1.01	0.50	0.49	0.69	1.07
Skewness	-1.295	-0.670	-0.372	-0.535	-0.011	-1.866	0.175	-0.473	0.413	0.147	0.323	-1.067

a - Multiple modes exist; the smallest value is shown

Table 2 additionally shows a negative skew for most of students' responses in the questionnaire. Except for questions seven, nine, ten, and eleven most students' responses were above the indicated mean. Altogether the data hence suggests general agreement with the positively skewed statements.

Table 3. Summary of Responses in the Pre-Questionnaire

		Total Number of Student Responses that Stated Strongly Disagree	Total Number of Student Responses that Stated Disagree	Total Number of Student Responses that Stated Neutral	Total Number of Student Responses that Stated Agree	Total Number of Student Responses that Stated Strongly Agree
N	Valid	22	22	22	22	22
	Missing	0	0	0	0	0
Sum		8.00	10.00	67.00	137.00	42.00

All 22 students responded to the pre- and post- questionnaire on academic confidence. In the pre-questionnaire the majority of responses, as shown in Table 3, indicated that students agreed with the positively-skewed questions related to academic confidence. A total of 264 responses were possible for 22 students across 12 questions each. Altogether, 179 responses showed high levels of agreement on the Likert scale (137–"agreed" and 42-"strongly agreed"), whilst the remaining 85 responses were divided among "strongly disagree" (8), "disagree" (10), and "neutral" (67).

Table 4 gives a summary of responses to individual statements from the post-questionnaire. On the Likert questionnaire "strongly agree" was scored as five; "agree" as four; "neutral" as three; "disagree" as two; and "strongly disagree" as one. Table 4 shows an even divide in responses where that the mode of responses in six (6) of the twelve (12) statements indicated that the students agreed and the mode response for the other six (6) statements indicated that the students strongly agreed. The right skew for every question showed an above average and strong support for the positively phrased questions.

Table 4. Summary of Responses to Individual Questions in the Post-Questionnaire

Question No.	1	2	3	4	5	6	7	8	9	10	11	12
N Valid	22	22	22	22	22	22	22	22	22	22	22	22
Missing	0	0	0	0	0	0	0	0	0	0	0	0
Mean	4.23	4.27	4.05	4.09	4.09	4.36	4.50	4.56	4.50	4.50	4.32	4.00
Mode	4.00[a]	4.00	4.00	4.00	4.00	5.00	5.00	5.00	5.00	5.00	5.00	4.00
Std. Deviation	0.75	0.70	0.84	0.87	0.87	1.00	0.60	0.67	0.67	0.74	0.72	1.02
Skewness	-0.413	-0.442	-1.137	-0.667	-0.667	-2.085	-0.736	-1.221	-1.033	-1.163	-0.569	-1.466

a - Multiple modes exist; the smallest value is shown

Table 5. Table Showing Summary of Responses in Post-Questionnaire

	Total Number of possible Student Responses that Stated Strongly Disagree	Total Number of possible Student Responses that Stated Disagree	Total Number of possible Student Responses that Stated Neutral	Total Number of possible Student Responses that Stated Agree	Total Number of possible Student Responses that Stated Strongly Agree
N Valid	22	22	22	22	22
Missing	0	0	0	0	0
Sum	2.00	5.00	31.00	104.00	122.00

Given the possibility of a total of 264 possible responses for 22 students across 12 questions, the majority of student responses (as shown in Table 5) indicated that students strongly agreed with the positively-skewed questions related to academic confidence. Altogether, 226 responses showed high levels of agreement on the Likert scale (104–"agreed" and 122-"strongly agreed") whilst the remaining 38 responses were divided among "strongly disagree" (2), "disagree" (5), and "neutral" (31).

Table 6. Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Percentage Scored in Post Questionnaire	86.63	22	9.12	1.94
	Percentage Scored in Pre Questionnaire	75.00	22	11.20	2.39

From Table 7 below since the class population is twenty-two (22) the degree of freedom (df) is 21. At a 95% confidence interval the p-value (t) calculated from the raw data was found to be 5.488. At the same confidence level the p value from the tables was found to be 2.080. Since the calculated p-value exceeds 2.080 the null hypothesis (H_0): "POGIL has no effect on academic confidence of students" may be rejected at a 0.05 (95% confidence) level of significance.

Table 7. Table Showing Results of Paired Sample T-test Using Pre and Post Questionnaires

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Percentage Scored in Post Questionnaire-Percentage Scored in Pre Questionnaire	11.6364	9.94530	2.1204	7.2269	16.0459	5.5	21	.000

The alternative hypothesis (H_A): “POGIL impacts the academic confidence of students” was accepted at the same level of significance. Together with the larger mean and smaller standard deviation in the overall scores (see Tables 6 and 7) for the post-questionnaire it was deduced that the impact was a positive one, meaning that academic confidence was increased by the intervention.

Furthermore, investigation of Tables 2 (pre-test) and 4 (post-test) indicate a general increase in the means and modes, and a general decrease in the standard deviations across questions indicating a general increase across all areas of academic confidence from the pre to the post test. The data gathered from the pre-questionnaire suggests that before the study students already had a high level of academic confidence. They felt that they were generally competent in the tasks related to studying, understanding, verbalizing, clarifying and attendance (Sander & Sanders, 2005). The data also suggests that with POGIL there was an increase in the students’ academic confidence since they showed improved efficacy in the tasks related to the factors stated above.

After the intervention there was a general improvement in students’ academic confidence. Additionally, the results of this study suggest that a reduction in academic performance did not negatively affect academic confidence as might have been expected (Sander & Sanders, 2005). The results of the pre-questionnaire suggested that before the study students already exhibited a high level of academic confidence. The students involved in this study may be considered to be high academic performers having all attained distinctions in their ordinary level chemistry examinations. Their performance and pre-questionnaire results then supports the view that academic performance affects academic confidence (Sander & Sanders, 2005).

CONCLUSIONS AND RECOMMENDATIONS

Students showed a varied academic performance at the end of an organic chemistry unit of work taught using POGIL with a general overall class decrease in the mean score. Even so, POGIL has shown itself able to improve students’ academic confidence.

The weighting of the various levels of questioning in the summative assessment may have given a better description of academic performance if equal, though not guaranteeing an improved performance in application and analysis. Additionally, the inclusion of synthesis and evaluation levels of questioning could be included to observe student performance across the entire range of Bloom’s Taxonomy.

One group was unavoidably large- six students- and required longer periods of time to complete activities whilst simultaneously ensuring that every member was able to express how they understood particular concepts.

This at times became frustrating to the remaining groups (of four members each) who had to wait before plenary reporting sessions could commence. This challenge supports the view that the size of the groups should be restricted to three or four members to maintain focus and clarity within groups (Hanson, 2006). However, when the class number does not allow for another complete group it may have been advantageous to have another teacher or teaching assistant present to facilitate any further questioning or clarification of new strategies/mechanisms developed by students. Alternatively, another teacher may have allowed for existing groups to be broken up in order to form smaller groups and provide excellent opportunities for further collaboration among teachers of the chemistry department.

The use of journal entries may have also served as a good tool to obtain additional data about students' academic confidence since the questionnaire used (Sander & Sanders, 2005) classified academic confidence within a narrow group of categories. The use of journals might have allowed for coding of emergent features of academic confidence, and for further discussion of academic performance and academic confidence.

Analysis of the concept maps that students developed to depict their growing understandings of the topic as the unit progressed might also yield data on how POGIL works to grow student understanding of the topic. There may be scope here for further research though time restricted such activity in this roll-out.

Many of the activities engaged the students in drama and artistic representations in the building of models. This suggests that POGIL may provide a solid platform for curriculum integration. This may involve further collaboration among teachers within, and external to, the science department. A formal POGIL approach may then require administrators and Heads of Departments to adjust time-tables and even the length of periods (among other things) to facilitate this change.

References

Al-Balushi, S. M., Ambusaidi, A. K., Al-Shuaili, A. H., & Taylor, N. (2012). Omani twelfth grade students' most common misconcpetions in chemistry. *Science Education International, 23*(3), 221-240.

Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs, NJ: Prentice Hall.

Bauer, C. F., Cole, R. S., & Walter, M. H. (2005). POGIL asessment guide https://pogil.org/uploads/media_items/assessment-handbook-part-1.original.pdf

Bell, T., Urhahne, D., Schanze, S., & Ploetzner, R. (2010). Collaborative inquiry learning: Models, tools, and challenges. *International Journal of Science Education, 32*(3), 349-377. doi: 10.1080/09500690802582241

Biehler, R., Mc Cown, R., & Snowman, J. (2009). *Psychology applied to teaching*. Belmont, CA: Wadsworth, Cengage Learning.

Caribbean Examinations Council. (2011a). *Report on candidates' work on the advanced proficiency examinations.* St. Michael, Barbados: CXC.

Caribbean Examinations Council. (2011b). *Understanding our exams*. Retrieved from http://www.cxc.org/examinations/understanding-our-exams.

Centers for Disease Control and Prevention (CDC). (2010). *The association between school based physical activity, including physical education, and academic performance.* Atlanta, GA: US Department of Health and Human Services.

Cook, T. D., & Campbell, D. T. (1979). *Quasi-experimentation: Design & analysis issues for field settings.* Boston: MA: Houghton Mifflin Company.

Creswell, J. W., & Plano-Clark, V. L. (2007). *Designing and conducting mixed methods research*. Thousand Oaks:CA: Sage Publications, Inc.

Eastwood, M. L. (2013). Fastest fingers: A molecule-building game for teaching organic chemistry. *Journal of Chemical Education, 2013*(90), 8. doi: 10.1021/ed3004462

Eberlein, T., Kampmeier, J., Mihderhout, V., Moog, R. S., Platt, T., Varma-Nelson, P., & White, H. B. (2008). Pedagogies of engagement in science: A comparison of PBL, POGIL, and PLTL. *Biochemistry and Molecular Biology Education, 36*(4), 262-273. doi: 10.1002/bmb.20204

Habraken, C. L. (2004). Integrating into chemistry teaching today's student's visuospatial talents and skills, and the teaching of today's chemistry's graphical language. *Journal of Science Education and Technology, 13*(1), 89-94. doi: 10.1023/B:JOST.0000019641.93420.6f

Hanson, D. M. (2005). Designing process-oriented guided-inquiry activities. . In S. W. Beyerlein & D. K. Apple (Eds.), *Faculty Guidebook-A comprehensive Tool for Improving Faculty Performance.* (pp. 381-384). Lisle, IL: Pacific Crest.

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

Harris, A. D., Bradham, D. D., Baumgarten, M., Zuckerman, I. H., Fink, J., & Perencevich, E. (2004). The use and interpretation of quasi-experimental studies in infectious diseases. *Clinical Infectious Diseases, 38*(11), 1586-1591. doi: 10.1086/420936

Hein, S. M. (2012). Positive impacts using POGIL in organic chemistry. *Journal of Chemical Education, 89*(7), 860-864. doi: 10.1021/ed100217v

Kuhn, D., Black, J., Keselman, A., & Kaplan, D. (2000). The development of cognitive skills to support inquiry learning. *Cognition and Instruction, 18*(4), 495-523.

Lombardi, M. M. (2007). Authentic learning for the 21st century: An overview. *Educause Learning Initiative, 1*(2007), 1-12.

Littlewood, W. (2009). Process-oriented pedagogy: Facilitation, empowerment, or control?. ELT Journal, 63(3), 246-254. doi: 10.1093/elt/ccn054

Mitchell, E., & Hiatt, D. (2010). Using POGIL techniques in an information literacy curriculum. *The Journal of Academic Librarianship, 36*(6), 539-542. doi: 10.1016/j.acalib.2010.08.010

Mitchell, M., & Jolley, J. (2010). *Research design explained*. Belmont, CA: Wadsworth, Cengage Learning.

Nihalani, P. K., Wilson, H. E., Thomas, G., & Robinson, D. H. (2010). What determines high- and low- performing groups?. The superstar effect. *Journal of Advanced Academics, 21*(3), 500-529. doi: 10.1177/1932202X1002100306

O'Dwyer, A. (2012). *Identification of the difficulties in teaching and learning of introductory organic chemistry in Ireland and the development of a second-level intervention programme to address these.* (Unpublished doctoral thesis), University of Limerick, Ireland. Retrieved from http://hdl.handle.net/10344/2846

O'Dwyer, A., & Childs, A. (2014). Organic chemistry in action! Developing an intervention program for introductory organic chemistry to improve learners' understanding, interest, and attitudes. *Journal of Chemical Education, 91*(7), 987-993. doi: 10.1021/ed400538p

Olson, L. (2005). Benchmark assessments offer regular achievement. *Education Week, 25*, 13-14.

Pargas, R., Cooper, M., Williams, C., & Bryfczynski, S. (2007). *Organicpad : A tablet pc based interactivity tool for organic chemistry*. Paper presented at the Pen-Based learning Technologies, 2007.PLT 2007. First International Workshop on, Catania.

Parsons, R. D., & Brown, K. S. (2002). *Teacher as Reflective Practitioner and Action Researcher*. Belmont, CA: Wadsworth/Thomson Learning.

Phillips, K. E., & Grose-Fifer, J. (2011). A performance enhanced interactive learning workshop model as a supplement for organic chemistry instruction. *Journal of College Science Teaching, 40*(3), 90-98.

Sander, P., & Sanders, L. (2005). Measuring confidence in academic study: A summary report. *Electronic Journal of Research in Educational Psychology and Psychopedagogy, 1*(1), 1-17.

Shatila, A. (2007). *Assessing the impact of integrating POGIL in elementary organic chemistry*. Ann Arbor, MI: Proquest Information and Learning Company.

Sirhan, G. (2007). Learning difficulties in chemistry: An overview. *Journal of Turkish Science Education, 4*(2), 2-20.

Slavin, R. (2007). *Educational research in the age of accountability*. Boston, MA: Allyn & Bacon.

Straumanis, A. (2010). Classroom implementation of process oriented guided inquiry learning: A practical guide for instructors. http://guidedinquiry.org/wp-content/uploads/IG_2e.pdf

Sykes, P. (1986). *A guidebook to mechanism in organic chemistry*. Essex, England: Longman Scientific & Technical.

The POGIL Project. (2012-2014). Effectiveness of POGIL. Retrieved from https://pogil.org/about/effectiveness

Thyer, B. (2012). *Quasi-experimental research designs*. New York, NY: Oxford University Press.

Tomal, D. R. (2010). *Action Research for Educators* (2nd ed.). Plymouth, UK: Rowman & Littlefield Education.

Tsarpalis, G. (2008). Using PARSEL modules to contextualizing the states-of-matter approach (SOMA) to introductory chemistry. *Science Education International, 19*(3), 323-330.

Walsh, K. (2006). Fighting the good fight: Implementing POGIL in an AP chemistry course.

http://www.learningace.com/doc/692308/f3525a3c31a44d3c1075d7cc5d102334/walshaprfinal

Wu, H. K., Krajcik, J. S., & Soloway, E. (2000). *Promoting conceptual understanding of chemical representations: Students' use of a visualization tool in the classroom*. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, New Orleans, LA. eric.ed.gov/?id=ED443678

Yalcinkaya, E., Boz, Y., & Erdur-Baker, O. (2012). Is case-based instruction effective in enhancing high school students' motivation toward chemistry? *Science Education International*, *23*(2), 102-116.

Zion, M., & Mendelovici, R. (2012). Moving from structured to open inquiry: Challenges and limits. *Science Education International*, *23*(4), 383-399.

Zuber-Skerritt, O. (1996). Introduction: New directions in action research. In O. Zuber-Skerritt (Ed.), *New Directions in Action Research*. London, UK: Farmer Press.

APPENDICES

Appendix 1. Questionnaire Used to Determine Academic Confidence

QUESTION	STRONGLY DISAGREE	DISAGREE	NEUTRAL	AGREE	STRONGLY AGREE
I am able to study effectively on my own independently.					
I am able to prepare thoroughly for class.					
I am able to read the recommended background material.					
I remain adequately motivated throughout the unit of work.					
I am encouraged to produce the best work I can					

in coursework assignments.					
I am encouraged to be on time for class.					
I am confident in my understanding to respond to questions asked by my teacher in front of the entire class.					
I am able to engage in profitable academic debate with my peers.					
I am able to ask my teacher questions about the material being taught during class.					
I am able to ask my teacher questions about the material being taught in a one-to-one setting.					
I am confident in my ability to apply the concepts taught to new situations.					
I am encouraged to read ahead to prepare for upcoming topics.					