Science Education International
Vol. 26, Issue 1, 2015, 56-79

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

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 utilising a guided model of inquiry learning (POGIL) to alleviate advanced level high school students' difficulties learning organic chemistry.

Minimizing the amount of paper used in the classroom is not only 'green,' but also saves the school district money. From a conservative estimate, Ben Johnson (2011) concludes that a school with one hundred teachers uses 250,000 sheets of paper annually, which costs the district $25,000 in paper alone (The Numbers section, para. 5). With school districts becoming increasingly strapped for cash, this cost can be

* 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

significant. Such savings can thereby be utilized by the district to invest in their students, faculty or facilities. Therefore, cutting paper from certain aspects of the classroom can benefit the economy within the school, as well as the environment without.

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 (HA): 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 (Centres 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?

This study included a total of twelve assignments for each group. For both classes, the results for the average homework grade and completion were within two percentage points of one another. As is outlined in the chart below (Figure 1), the OC had an average completion rate of 72.5%, compared to the 74.1% rate for the PC. Over the course of these same assignments, the average grade was 58.8% for the OC and 60.8% for the PC.

Whereas the groups were statistically very similar for the homework rates of completion and the average homework grades, the overall final grade mean for the OC was 71.8%, compared to 62.3% for the PC. These scores effectively represented the students' final grades for the entire first quarter, meaning that it factored in tests, laboratory assignments and homework scores. The statistical difference between these two groups seemed significant at first glance and is discussed further in the next section.

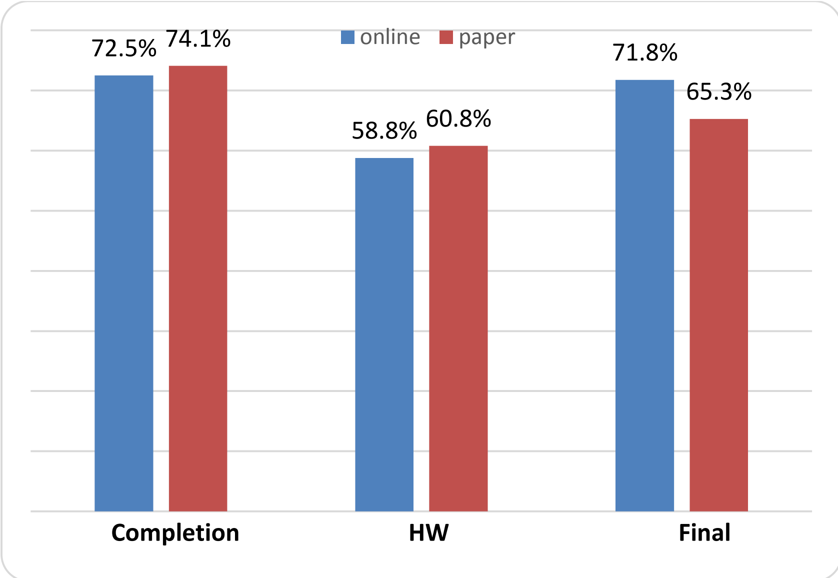


Figure 1. Completion, HW and final grades for online class and paper class.

Perhaps the largest difference between the groups could be found in the category of participation. Class participation (Figure 2) differed between the two classes, with the OC having an average of 2.4 marks less than the PC. Whether this is the result of homework or classroom dynamics is discussed further in the next section. The full results for homework completion and grades are given in Appendix 3.

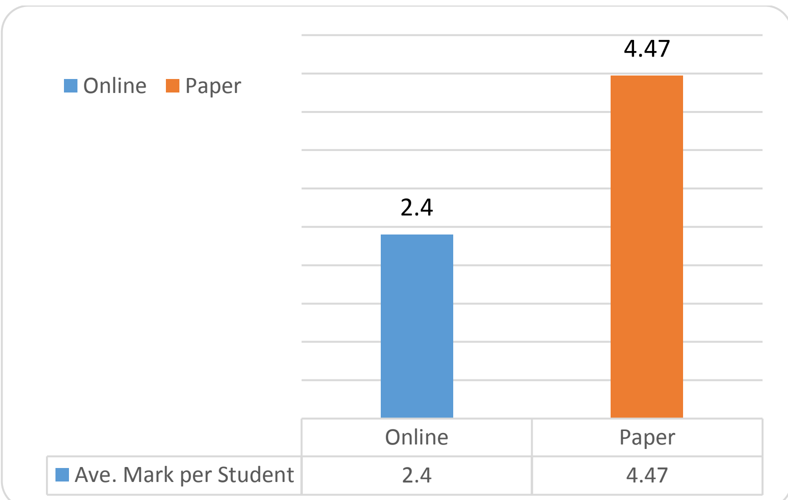


Figure 2. Average student participation between paper and online classes.

DISCUSSION

Prior to the study, I predicted that there would be little difference between a group given online homework and one that was assigned traditional homework. I expected students in the online group to have some difficulty at first, but after practice, it would have the same results/completion rates as regular homework. In light of the aforementioned successes with online learning, I predicted that the online learning group would be at least as successful, if not more successful, than the traditional learning group.

After analysing the data, two things jump out: both classes have nearly equal rates of completion and grades in their homework, but there is a clear difference in participation and final grades. Let's focus on the rates of completion and grades first. With only a 1.6% and a 2% difference in homework completion and homework grade, respectively, the averages are clearly very similar. However, when taking standard deviation into account, one can see that the PC has a much wider range of scores than the OC. For example, in homework completion, one standard deviation for the OC is 12.6%, whereas one standard deviation in the OC is 18%. This seems to indicate that the work the OC completed is much more uniform, and that perhaps, if 'zeros' aren't taken into account, we may find that the OC on average has a much higher grade rate. Because of the fact that there was only a 2% difference in completion, this can usefully lead to a follow-up study taking these added factors into account.

Of note is that the OC scored 9.5% higher for their quarterly final grades, which are influenced by these homework grades both in terms of points as well as content. If there is a direct correlation between homework grades and final grades, the expectation is that the class with the higher homework grade has a higher final grade. As aforementioned, this is not the case. The reasons behind this remain unknown. Perhaps the OC is simply a better test-taking group. On the other hand, perhaps the online homework, although similar in actual grades, is somehow more conducive to learning when going over it in class. In either case, it is difficult to tell, but further study are suggested towards finding an answer.

Another major difference between classes was classroom participation. Prior to the study, I predicted that the class with the most background knowledge about a topic (and therefore the class that performed better on their preparatory homework) would participate more often in class because of this knowledge. However, there was a large difference between the classes in average participation, despite the fact that both classes remained similar in homework completion and grades. The results seemed to indicate one of two things: Either the online homework provided a much weaker platform for students to spring from when discussing concepts in class, or homework and classroom participation weren't closely related. Because the OC had nearly the same homework grades and a significantly higher overall grade, it would suggest that the first option should be discarded and acceptance of the second conclusion, which was that background knowledge and participation weren't necessarily related with one another. Something that I certainly noticed during the study, but was difficult to measure because of its subjectivity, was that one class (OC) had students that were much more introverted than the other. This was the case in many situations, and although participation should increase student learning, through experience it was shown that it wasn't fully necessary in every case. Therefore, although the students in the PC participated more regularly than those in the OC, including participation into judgment of homework effectiveness was not meaningful.

Lastly, it was worth noting that both classes had students with IEP's (Individual Education Plans). Five of the nineteen students in PC had an IEP. Compared to three students with IEP's in the OC. Because the numbers of these students with accommodations were relatively similar to each other, this was not seen as accounting for a significant difference between test groups, and therefore the data could be interpreted in its present form.

Action Component

The approach and outcomes of this study were shared with my professional colleagues. To do so, I created a pamphlet with information and tools so that other teachers within my district could use the information that I had researched. Because so many teachers were unaware of the online tools and the possibilities that each tool presented to a class, I created a list of resources available, all of which were free for use. With these resources, I added descriptions so that educators could understand the pros and cons of each program, thus enabling educators to personalize their own online homework in a way that suited them and their classes. In order to stay true to the goals of this study, the information was made available on the school district's network folder (online), so that all staff could use it at any time and no paper was used in the process. The pamphlet was as shown in Appendix 4. On top of providing this information on the network, I spoke at one of the district's in-service meetings to enable everyone to know my results and make sure that the staff was aware of the resources compiled.

In light of the results from this study, I have endeavoured to make all of my classes as paperless as possible, with all homework being available online. This online homework, in conjunction with previous studies in which I focused on removing the textbook from the classroom, is intended to make student learning much more up-to-date and interactive in the long term.

Conclusion and Recommendations

I had predicted that the OC would perform at least as well as the PC, and overall, this was the case. Although there was a slight drop in completion and homework grades in the OC, the difference between 1.6% and 2% were seen as insignificant. Despite my initial fears that there would be a significant learning curve for the students in the OC, I felt enough time was spent in class preparing them for the online homework. Although there were moments of troubleshooting, the OC began the quarter with strong completion rates which never dipped below the 52.9% mark. Similarly, the PC began the grading period with strong completion rates, but as the quarter progressed, a steady, near constant decline in these rates occurred. This decline was not present in the OC, and this was exemplified by the fact that there were two assignments that were below the 48% mark in the PC.

There was also a discrepancy in the final grades for both classes. Because a portion of these final, quarterly grades were directly influenced by how well a student did on his/her homework, the results should be seen as significant and not thrown out. However, there was no apparent trend between the homework grades and the final grades.

Despite the relatively minor variation of homework completion rate and grades, there seemed to be a clear discrepancy between the participation of the two classes. This could indicate one of two things: Either the online homework provided a much weaker platform for students to spring from when discussing concepts in class or homework and classroom participation aren't closely related.

Limitation

A larger sample size would have helped solidify these findings, and further studies are suggested before drawing any firm conclusions in regards to the link between homework type and in class student participation.

Recommendation

As online homework significantly impacts on student performance, it is recommended this web-based method of collecting assignments can be utilized within the classroom, both for the environmental and time-saving advantages. As we are provided with more and more technological tools within the classroom, this information enables teachers throughout the country to use less paper, and therefore produce less waste in and out of the classroom, all without hindering student learning.

REFERENCES

Alhami, I. & Alsmadi I. (2011 October). Automatic Code Homework Grading Based on Concept Extraction. *International Journal of Software Engineering and Its Application, 5*(4), 77-84.

Anderson, K. (2012, January 19). The Hidden Expense of Energy—Print is Costly, Online Isn't Free. *The Scholarly Kitchen*. Retrieved on April 27, 2013 at: http://scholarlykitchen.sspnet.org/2012/01/19/the-hidden-expense-of-energy-costs-print-is-costly-online-isnt-free/

Arasasingham, R.D., Martorell, I., & McIntire, T.M. (2011). Online Homework and Student Achievement in a Large Enrolment Introductory Science Course. *Journal of College Science Teaching, 40*(6), 70-79.

Barack, L. (2005). Digital Divide. *School Library Journal. June, 24*.

Doorn, D., Janssen, S., & O'brien, M. (January 2010). Student Attitudes and Approaches to Online Homework. *International Journal for the Scholarship of Teaching and Learning, 4*(1).

European Paper and Packaging Industries. (2011). *Myths and Realities*. Paper Online. Retrieved from: http://www.paperonline.org/myths-and-realities

Hakverdi-Can, M., & Sonmez, D. (2012, December). Learning How to Design a Technology Supported Inquiry-based Learning Environment. *Science Education International, 23*(4), 338-352.

Hoffman, R., & McGuire, S.Y. (2010). Learning and Teaching Strategies. *American Scientist, 98*, 378-382.

Hong, E., Wan, M., & Peng, Y. (2011). Discrepancies between Students and Teachers Perceptions of Homework. *Journal of Advanced Academics, 22*(2), 280-308.

Hoskins, S.G., & Stevens, L.M. (2009). Learning our L.I.M.I.T.S.: less is more in teaching science. *Adv. Physio Education, 33*, 17-20.

Johnson, B. (2011, February 23). *Paper and pencil curriculum: How much do you rely on it?* Edutopia. Retrieved from: http://www.edutopia.org/blog/paperless-schools-techology-ben-johnson

Kupetz, A. H. (2008, February). Is the Paperless Classroom Possible? *BizEd*, 36-40.

Poon, C., Toh, F., & Tan, A. (2010). Bees in the news: connecting classroom science to real-life issues. *Science Scope, summer*.

Richards-Babb, M., Drelick, J., Henry, Z., & Robertson-Honecker, J. (2011). Online Homework, Help or Hindrance? What Students Think and How They Perform. *Journal of College Science Teaching, 40*(4), 81-93.

Schmidt, P.R. (1999, April). KWLQ: Inquiry and literacy learning in science. *The Reading Teacher, 52*(7).

Stopher, J. (2010, September 10). Parents embrace online learning. Pearson: Always Learning.

Yager, R.E., Choi, A., Yager, S.O., & Akcay, H. (2009). Comparing Science Learning Among 4th-, 5th-, and 6th-Grade Students: STS Versus Textbook-Based Instruction. *Journal of Elementary Science Education, 21*(2), 15-24.

APPENDICES

Appendix 1. An example of homework for both test groups

Paper:

Ecology HW 7.3 "Head Above Water"

*Name*____________________
*Date*____________________
*Period*____________________

Read the article and answer the following questions.

____ 1.) What is the main focus of the article?

a.) Global warming is creating more Hurricanes throughout the world.
b.) Water levels are rising due to global warming, causing problems for islands in the Indian Ocean.
c.) Maldivian government is fighting global warming by creating green jobs.
d.) Dudes working on their statistics course underwater.

____ 2.) What is going to happen to the Maldivian people in the year 2100?

a.) They will be a separate nation from their parent government in Samoa.
b.) The people are going to throw a party for the 100^{th} anniversary of their country.
c.) The Maldivian people will have to relocate because their islands will be under water.
d.) Their population will continue to grow as they make money on ecotourism.

____ 3.) How high are waters today, compared to 100 years ago?

a.) 0.13 inches
b.) 13 feet
c.) 8 inches
d.) 16 feet

____ 4.) Why do higher temperatures cause sea levels to rise?

a.) Warm water takes up more space than cold water.
b.) Warmer water has a higher pH which corrodes beaches.
c.) Warm water evaporates less frequently than cold water.
d.) Higher temperatures do not cause a rise in sea levels.

____ 5.) What is the Maldivian government doing about this problem?

a.) Effort to slash emissions within its country.
b.) Making a plea to other countries to cut their emissions.
c.) Building a wind farm that will power their capital city.
d.) All of the above.

OCEANS

Head Above Water

A sinking island nation sets an example by cutting emissions.

By Mirva Lempiainen

This wasn't your typical cabinet meeting. Sure, the Maldivian president and 11 ministers were all there, gathered around tables. But instead of suits they had donned diving gear, and they were sitting on the seafloor, signing an SOS note.

The plea for help was part of a stunt last fall to draw attention to the plight of this Indian Ocean country of nearly 1,200 coral islands. The United Nations estimates that rising sea levels may make the Maldives—whose average height is about five feet above the watermark—uninhabitable by 2100, leaving its 360,000 citizens among the world's first environmental refugees.

To protect their home, Maldivians are taking measures to go carbon-neutral by 2020. "There is no higher ground we can move to," says Abdul Ghafoor Mohamed, the country's ambassador to the United Nations. "There is no safe island within the archipelago."

Rising water levels threaten

other island nations, too, including Fiji and Samoa. Residents of Papua New Guinea's Carteret Islands, which are expected to be completely uninhabitable by 2015, have already started to move to the main island of Bougainville, and the entire populace will be relocated within five years. By 2050 there will be at least 25 million climate refugees, the International Organization for Migration reports. "Small island nations are going to be destroyed by global warming," says Joseph Romm, founder of the blog Climateprogress.org and a climate expert at the Center for American Progress, a think tank. Low-lying coastal areas of Bangladesh, Vietnam, the Netherlands, San Francisco Bay, and Florida are also at risk.

Globally, sea level climbed .13 inches per year from 1993 to 2008. Waters today are nearly eight inches higher than they were a century ago, and more than two inches higher than 16 years ago. Higher temperatures cause sea level to rise because warmer water takes up more space than cold, and because of runoff from melting glaciers and ice sheets.

The Maldives government is moving forward with its effort to slash emissions. This past November the country signed an agreement for a 75-megawatt wind farm that will power the capital, Male, and a number of tourist resorts, and cut a quarter of the country's CO_2 emissions. "We can make our country carbon-neutral, island by island, and use this as a symbolic model for other countries," says Mohamed.

Maldivians are hoping other nations will follow suit to ensure global temperatures don't rise more than 1.5 degrees. The world didn't settle on a binding agreement at the climate meetings in Copenhagen last December. But the Maldivians are already looking to the next talks in Mexico in the fall, where they may carry out new attention-grabbing stunts.

Weebly:

7.3 Head Above Water

10/14/2011

15 Comments

Click on the link below and read the article. Answer the following questions.

eco_hw_7.3_head_above_water.pdf
Download File

_____ 1.) What is the main focus of the article?

a.) Global warming is creating more Hurricanes throughout the world.

b.) Water levels are rising due to global warming, causing problems for islands in the Indian Ocean.

c.) Maldivian government is fighting global warming by creating green jobs.

d.) Dudes working on their statistics course underwater.

_____ 2.) What is going to happen to the Maldivian people in the year 2100?

a.) They will be a separate nation from their parent government in Samoa.

b.) The people are going to throw a party for the 100th anniversary of their country.

c.) The Maldivian people will have to relocate because their islands will be under water.

d.) Their population will continue to grow as they make money on ecotourism.

_____ 3.) How high are waters today, compared to 100 years ago?

a.) 0.13 inches

b.) 13 feet

c.) 8 inches

d.) 16 feet

_____ 4.) Why do higher temperatures cause sea levels to rise?

a.) Warm water takes up more space than cold water.

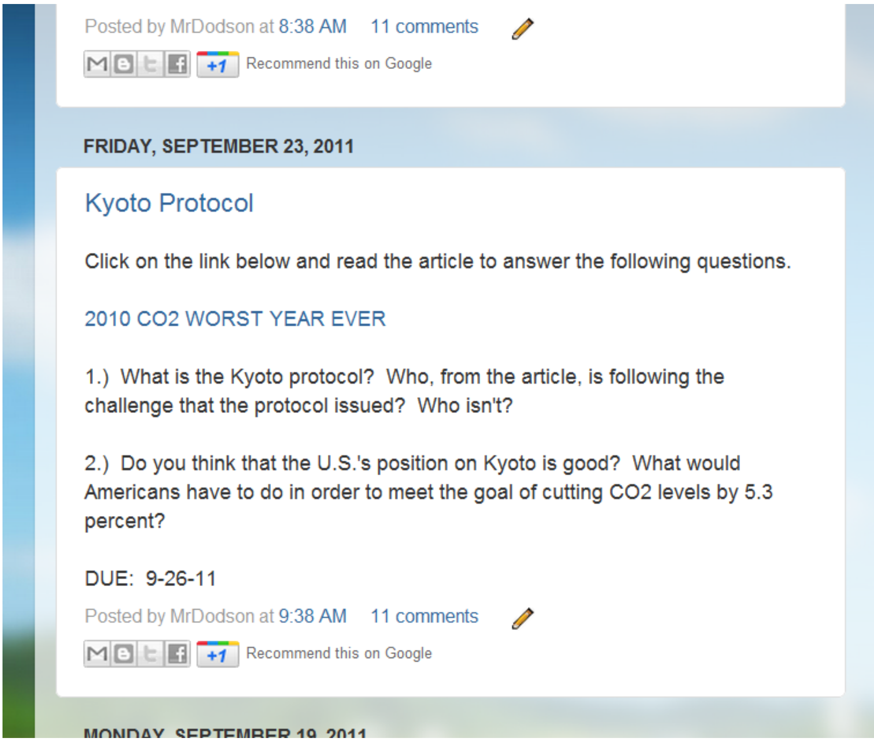
b.) Warmer water has a higher pH which corrodes beaches.

c.) Warm water evaporates less frequently than cold water.

d.) Higher temperatures do not cause a rise in sea levels.

_____ 5.) What is the Maldivian government doing about this problem?

Blogger:



Appendix 2. Subject material covered over the course of the study

- Introduction to Environmental Science
    - Environmental Problems
    - Parts of an ecosystem
    - Review of basic ecological principles
- Climate
    - The atmosphere
    - Factors that affect climate
    - Atmospheric pollutants/Greenhouse gases
    - Ozone layer

Appendix 3. Grading and Participation of Test Groups

IAP Data - Online vs. Paper Homework

	COMPLETION	Online Class	Paper Class		**COMPLETION**	Online Class	Paper Class
Blogger	1.1	10	18	Blogger	1.1	58.8%	94.7%
	1.1.1	14	18		1.1.1	82.4%	94.7%
	1.2	16	17		1.2	94.1%	89.5%
	1.3	15	15		1.3	88.2%	78.9%
	2.1	13	13		2.1	76.5%	68.4%
	6	14	17		6	82.4%	89.5%
	6.1	12	15		6.1	70.6%	78.9%
Weebly	6.2	11	7	Weebly	6.2	64.7%	36.8%
	7.3	9	9		7.3	52.9%	47.4%
	7.3.1	11	13		7.3.1	64.7%	68.4%
	7.3.2	12	13		7.3.2	70.6%	68.4%
	7.3.3	11	14		7.3.3	64.7%	73.7%
		out of 17	out of 19		**AV**	72.5%	74.1%

	AVERAGE GRADE	Online Class	Paper Class		**AVERAGE GRADE**	Online Class	Paper Class
Blogger	1.1	1.2	1.8	Blogger	1.1	60.0%	90.0%
	1.1.1	0.8	1.8		1.1.1	40.0%	90.0%
	1.2	1.8	1		1.2	90.0%	50.0%
	1.3	1.3	1.3		1.3	65.0%	65.0%
	2.1	1.3	1.3		2.1	65.0%	65.0%
	6	1.3	1.3		6	65.0%	65.0%
	6.1	1.2	1.3		6.1	60.0%	65.0%
Weebly	6.2	0.8	1	Weebly	6.2	40.0%	50.0%
	7.3	1	0.5		7.3	50.0%	25.0%
	7.3.1	1	1.2		7.3.1	50.0%	60.0%
	7.3.2	1.2	0.8		7.3.2	60.0%	40.0%
	7.3.3	1.2	1.3		7.3.3	60.0%	65.0%
		out of 2	out of 2		**AVE**	58.8%	60.8%

IAP Data - Online vs. Paper Homework		
CLASS PARTICIPATION		
	Online Class	Paper Class
Ave. Mark per student	2.4	4.47
FINAL GRADES		
	Online Class	Paper Class
	71.8	62.3

Appendix 4. Active Aspect – Teacher resource that was posted on the school district's website.

Rittman Faculty

I have recently completed a preliminary study about the use of online homework within the classroom. My results indicated that there was not a significant difference in completion rates between online and traditional (paper) homework assignments. I have made it an effort in my classroom to minimize the amount of paper that we use, and in the future I am trying to implement online homework in all of my classes. I am sharing this information with you all so that you can make an informed decision about using paper within the classroom. Below, I have added numerous (free!) websites that can be used for scholastic assignments, research, presentations, and much more. If anyone has any questions about my experiences in utilizing online environments for classroom assignments, feel free to ask.

List of useful, free online resources for the classroom:

Resource	***Location***
Google scholar – A web search engine that provides links to a wide array of scholarly literature. Good starting point for any student research project.	http://scholar.google.com/
OpenOffice – Word processing/publishing/PowerPoint for students that don't have access to these resources at home. Fully convertible into .doc files and can read Microsoft Office.	http://www.openoffice.org/
Weebly – Free website creation, easy design and use. Great for setting up a classroom website.	http://www.weebly.com/
Blogger – Free website creation, I found it less friendly than Weebly, but it is available nonetheless.	http://www.blogger.com/

Jing – Online website that allows users to create images and videos of what you see on your computer screen and share them with students. Good for posting lectures/discussions on class websites for students who have been absent or can be used as a reinforcement tool for students who were present.	http://www.techsmith.com/jing.html
Voicethread – Create videos and post them online. Can be used as an interactive classroom website for students to post videos, music, online lessons, etc.	http://voicethread.com/
YouTube – Place to post class videos or to assign educational student projects.	http://www.youtube.com/
Vimeo – Similar to YouTube, this is another online location to post class videos.	http://vimeo.com/
USGS Education – Great science resource for lesson ideas, videos, online lectures, and a lot more.	http://education.usgs.gov/
Purdue OWL – Provides useful examples and format for both MLA and APA citations. Great resource for students learning citation rules and for examples when assigning class research papers/projects.	http://owl.english.purdue.edu/owl/resource/560/01/