Process Oriented Guided Inquiry Learning: A Strategy to Promote Active Learning

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Concordia University

An Action Research Proposal Presented to

The Graduate Program in Partial Fulfillment of the Requirements

For the Degree of Masters in Education

Concordia University - Portland

2017
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Knowledge of chemistry is useful to everyone (Zumdahl et al., 2007). However, many students think learning chemistry is difficult. For instance, students in chemistry find it difficult to remember the names and symbols of the elements, various types of chemical reactions, the unique system of writing chemical equations, and understand all of the basic principles of chemistry - the models of chemistry (Zumdahl et al., 2007). The National Research Council (2011) argued that effective instruction in science, mathematics, and engineering requires students’ active engagement throughout their schooling. Also, Warren (2015) suggested that students would learn best through visualization or modeling of ideas. Visualization and modeling is a great way to help students create a mental picture of what is happening during a chemical process both in a microscopic and macroscopic way (Warren, 2015). For example, instead of telling students about the atomic structure, a model or a diagram of an atom can be provided to show the number and location of protons, electrons, and neutrons (Trout, Rickey, Moog, & Lee, n.d.). Educators in the areas of science, technology, engineering, and mathematics (STEM) have developed a wide variety of approaches to improve student learning, enthusiasm, and retention (Kussmaul, 2012). Process Oriented Guided Inquiry Learning (POGIL) is one of these approaches that is widely adopted since its beginning in the 1990s (Farrell, Moog, & Spencer, 1999; as cited in van Opstal et al., n.d.). POGIL was originally developed at the Franklin and Marshall College to teach general chemistry (Yang, 2013). In this investigation process, the question that I am seeking to answer is: “What effect does implementing the Process Oriented Guided Inquiry Learning (POGIL) strategy as an introduction to the unit’s content have on student's understanding of chemistry concepts in a high school general level class?”
Review of the Literature

Several studies have found that Process Oriented Guided Inquiry Learning (POGIL) is an effective strategy to promote successful learning in the classroom using active learning through model exploration, concept invention, and application of the material (Loertscher, Minderhout, & Bailey, 2011; Picione, Murphy, & Holme, n.d.; Verlinden, Trumbo, Soltis, Kruger, & Carroll, 2015; van Opstal, Gessel, Frazier, Daubernmire, Draus, & Bunce, n.d.; Villagonzalo, 2014; Jin, and Bierma, n.d.; Roller, 2015).

This literature review focuses on theoretical foundations of POGIL as an instructional strategy in the classroom, effective methods and procedures of POGIL implementation, limitations of POGIL implementations, background and demographics of the participants, research methods, data collection and analysis techniques, the strength and weaknesses of the studies, and ethical procedures and techniques used to ensure the safety, and privacy of the participants involved during the study.

Theoretical Foundations of POGIL

Several studies support the argument that POGIL is an instructional strategy grounded in the idea of constructivism (Minderhout et al., 2011; van Opstal, et al., n.d.; Brown, 2010; Vanags et al., 2013; Douglas and Chiu, 2013; Varma-Nelson et al., 2008; Kussmaul, n.d.). Koonce (2015) defined constructivism as a learning approach in which students construct new understandings through active engagement. Unlike the traditional lecture approach to instruction, the role of the teacher in a POGIL classroom is to facilitate the learning. The first step of POGIL activity is important in building student knowledge through an active process which is guided by the teacher. In the second phase, students begin to synthesize ideas or concepts, constructing and expressing their own understanding (De Gale & Boisselle, 2015; Douglas, 2013; Roller, 2015; &
Yang, 2013). Similar to the first phase, student are provided with guiding questions that will help students develop a concept from the information obtained during the exploration process (Trout et al, n.d.). In this phase, new terms are introduced. These terms match the information that students have mentally constructed during the initial process. In the final phase of POGIL activity, students are required to demonstrate their understanding of the concept by applying it to new situations (Trout, et al, n.d). This process requires deductive reasoning skills since it “relates the general concepts derived in the previous phase to new situations” (Hanson, 2005; as cited in De Gale & Boisselle, 2015, p. 61). Vanags et al., (2013); van Opstal et al., (n.d.); Brown, (2010); Douglas and Chiu, (2013); Varma-Nelson, (2008); & Minderhout et al, 2011) argued that in a POGIL classroom, the role of the teacher is to support students in their construction of knowledge rather than telling students the answers. Moreover, students in a POGIL classroom are asked with an open-ended question that will require them to expand their new knowledge through reflection, exploration, and generalization (Douglas and Chiu, 201). Through active learning, students are more motivated to do the task required in the classroom and are able to sustain prolonged attention during the process of learning (Wilson and Korn, 2007; as cited in Picione, Murphy, and Holme (n.d.).

POGIL is a strategy that is based on the philosophy of inquiry-based learning (Williamson, et al., Kussmaul n.d., 2013; Brown, 2010; Picione et al., n.d., Jin and Bierma, n.d.). Typically, POGIL activities follow the three phases of the Learning Cycle- exploration, concept invention, and application (Trout et al, n.d.; Williamson, Willison, Pyke, & Metha, 2013; Kussmaul, 2012; & Douglas, 2013). POGIL activities begin with an exploration phase where a series of models, diagrams, or experimental data are provided to guide students in their construction and understanding of a concept. In addition, students are provided with carefully
planned questions. These questions are designed to help students make sense of the information implied in these models, diagrams, or experimental data, and to identify inherent pattern or trends (Trout et al., n.d.). There are three types of questions that students are tasked to answer within POGIL—direct questions, convergent questions, and divergent questions (Douglas, 2013; Kussmaul, 2012; Trevathan, & Myers, 2013). Direct questions are questions that can be answered directly from the data or information provided in the POGIL exercises. On the other hand, convergent questions are questions that require groups to attain consensus of the solution. Finally, divergent questions are questions that could have a range of possible correct answers.

During POGIL activities, students are guided in the discovery of a specific concept through reading and processing information (Picione et al., n.d.; Brown, 2010). The strategy takes into account student’s prior knowledge which includes misconceptions, allowing them to explore models such as data, graph, or an illustration, and asking students questions that will lead them to concept invention (Brown, 2010).

**Effective Methods and Procedure of Implementation**

Studies revealed several methods and techniques that were found effective in successful POGIL implementation in the classroom. First, when implementing POGIL in the classroom, it is important that the teacher facilitates the activity by walking around the class, listening to the groups, observing their progress, and guiding them when they ask question (Minderhout et al., n.d.; Roller, 2015; Yang, 2013). Listening to students’ discussion will give the teacher an idea of whether learning is taking place or an intervention is needed. Minderhout et al., (n.d.) argued that teachers should discuss with students that making mistakes is part of the learning process to ensure a learning environment that is safe, and promotes a sense of community. These procedures are effective ways to give students a sense of ownership of learning, helps students
construct their own understanding, and afford students an insight into the process of scientific inquiry (Trout et al, n.d.). POGIL provides an opportunity for teachers to uncover students’ unfamiliarity of concepts or misconceptions (Minderhout et al., n.d.).

Second, a study on POGIL found that the students who attended the group learning sessions achieved a higher average score on the common examinations (The POGIL Project, 2012; as cited in De Gale & Boisselle, 2015). For instance, in the study conducted by Verlinden et al (2015), the participants during the study were assigned in groups of four students for a period of three years. During the first year of study, students were taught using lecture format. Then, students were taught using POGIL strategy in the last two years of the study. The results of the study showed that students’ examination scores increased between 3.3 to 4.5 percent higher than their previous examination. In addition to the increase in test scores, Verlinden et al., (2015) indicated that students’ performance on questions requiring higher order thinking skills had significantly improved. Their data showed an average increase of 7.0 percentage points (Verlinden et al., 2015).

Further, a study indicated successful implementation of POGIL in a large lecture classroom setting using active learning approach (Minderhout et al., 2011). In a large lecture classroom, students were arranged in groups consisting of either three or four members. During POGIL exercises, three members of the group were assigned roles. Roles would be manager, recorder, and presenter. The manager of the group was tasked to ensure that the group was on task, to keep track of the time, and to evaluate responses shared by other groups. The recorder was tasked to read the questions out loud while the presenter was the person that asked the teacher questions, write responses from the group on the board. Minderhout et al., (2011) concluded that active learning and using POGIL in the classroom increased students’ learning
motivation, helped students in their understanding of the core concepts in biochemistry, and provided an opportunity for students to develop the transferrable skills (Minderhout at al., 2011). During POGIL exercises, students were guided to learn new material using process skills such as teamwork, communication, and problem solving. In addition, the teacher’s timely feedback, and interaction to misconception were very critical to student’s cognitive development (Minderhout et al., 2011). Quantitative assessment analysis indicated a significant increase in students’ understanding of the core concepts in biochemistry such as bond energy, pH/pKa, and free energy (Minderhout et al., 2011). Minderhout et al., (2011) reported mean score gain of 3.4 points. In addition, students’ affective survey showed that 85% of students agreed to use POGIL in the classroom. One participant during the study said that POGIL activities and the process of reporting their answers made the learning environment less intimidating to ask question. Another student commented that the work kept him or her focus.

Moreover, studies suggested that POGIL implementation in a large group setting could also be successful when active learning is supported by other learning techniques such as interactive exploration, and Toulmin model of argumentation (Jin & Bierma, n.d; van Opstal et al., n.d.). Jin and Bierma (n.d) structured POGIL as an interactive exploration using hands-on and computer simulation techniques. During hands-on simulation, students in groups of ten would use pieces of paper to simulate a process while in the computer simulation, students would use clickers to input data into the computer right away so that students were able to observe, and draw conclusions. Students’ mastery of content was assessed through quizzes. Students’ quiz results showed a small but statistically significant increase from previous semesters. In addition, students’ self assessment survey indicated that 84% of students favored the use of POGIL and strongly agreed that POGIL modules helped them to understand the material better.
In the study of van Opstal et al., (n.d.) the Toulmin model of argumentation was used to facilitate students’ group discussion in a large classroom. The Toulmin model of argumentation consists of three features: data, a warrant, and the claim (van Opstal et al., n.d.). Using the Toulmin model of argumentation, students were required to provide evidence that supports their answers. van Opstal et al.,(n.d.) argued that using the Toulmin model of argumentation would help students move beyond recognizing patterns. Data from the study indicated that students who were taught with both POGIL strategy and Toulmin model of argumentation scored higher in the American Chemical Society (ACS) exam both in the categories of algorithmic and conceptual test questions. Their data showed that the POGIL group scored 2 points higher than non POGIL group (van Opstal et al., n.d.).

Finally, POGIL studies showed that POGIL implementation in the classroom is more effective when combined with mini lectures, probing questions, and using a clicker during checking of understanding (Brown, 2010; Douglas, & Chiu, 2013; & Yang, 2013). Students’ survey indicated that the mixture of POGIL and lecture were more preferable than a full POGIL implementation (Williamson et al., 2013; Douglas, & Chiu, 2013).

Limitations of POGIL

POGIL exercises are designed to promote active, and inquiry learning in the classroom (Geiger, n.d.; Douglas, & Chiu, 2013; Pichione et al., n.d.; Minderhout et al., 2011; van Opstal, et al., n.d.). However, teachers must create well-designed POGIL exercises, and must set clear expectations to ensure content are covered, and students are fully engaged during the learning process. (Verlinden et al., 2015; Jin, & Bierma, n.d.; van Opstal et al., n.d.; Brown, 2013).

Moreover, student readiness is one of the key factors that determine successful POGIL implementation in the classroom (Gieger, n.d.). According to Grow (1996), students are less
likely to engage in POGIL activities when the level of self-directed learning and cognitive challenge is increased before students are ready (as cited in Geiger, n.d.). In the study conducted by Geiger (n.d.), the results indicated that the general chemistry students in the community college introductory chemistry class performed less than general chemistry students in bachelor’s degree. According to Lewis & Lewis (2007), students who are not operating at Piaget’s formal operational stage and are unable to think abstractly are at significant risk for failing general chemistry (as cited in Geiger, n.d.).

During POGIL exercises, students are provided a chance to engage in meaningful discourse between their peers and their teacher (van Opstal et al., n.d.; Geiger, n.d.). However, giving students the correct answer all the time would be a disadvantage. In the study of van Opstal et al. (n.d.), students’ test scores differ between the groups that were always given the answers to POGIL questions and students with a teacher that responded more questions as a way of guiding the students to the answer. Students who were engaged in discourse without given the answers all the time scored higher in American Chemical Society (ACS) exams both in the algorithmic and conceptual categories of questions. POGIL students had a mean score of 10.86, whereas the other group had a mean score of 8.80.

**Research Methods, Data Collection and Data Analysis**

In the review of the studies included in this literature review, three experimental designs were used—pretest–post test designs, quasi-experimental designs, and single–subject and time series designs. For instance, Villagonzalo (2014); van Opstal et al. (n.d.); Vanags et al. (2013); Roller (2015); and Geiger (2010) designed and conducted a Quasi- experimental research to compare the effect of POGIL between the POGIL and the non-POGIL group of students. However, Brown (2010); Minderhout et al. (2014); Williamson et al.(2013); Jin & Bierma
(n.d.); Trevetahn & Myers (2013); De Gale & Boiselle (2015); Yang (2013); Kussmaul (2012); Verlinden et al. (2015); Pichione et al. (n.d.); Douglas & Chiu (2013); and Geiger (2010) designed a Single-subject time series experiment to study the effect of POGIL on students’ understanding of the material taught in the classroom. On the other hand, Pichione et al. (n.d.); Verlinden et al. (2015); Kussmaul (2012); Yang (2013); De Gale & Boiselle (2015); Jin and Bierma (n.d.); and Brown (2010); and Villagonzalo (2014) used quantitative approach to study the POGIL’s impact on students’ learning in the classroom.

Douglas and Chiu (2013) conducted a qualitative research to study the effect of POGIL on students’ learning in an engineering class. In the study of Douglas and Chiu (2013), qualitative data was collected using formal and informal interviews. The collected information from the interviews was analyzed by grouping statements into four broad themes. The first theme was recognizing the benefits of working into groups. The second theme was worksheets increased students’ level of understanding of the content and their engagement. The third theme was the use of guided inquiry had minimal benefit for some students. The final theme was students’ description of specific strategy that they developed to help them in class. In the study of Trevathan and Myers (2013), qualitative data was collected through teacher’s anecdotal observation. Information from this anecdotal observation was analyzed by arranging the information into two categories- positive and negative effect of POGIL as a strategy to promote learning in information technology course.

Using the mixed method of research, van Opstal et al. (n.d.), and Trevethan & Myers (2013) collected both qualitative and quantitative data during their study. For instance, van Opstal et al. (n.d.) collected and analyzed students’ grade, SAT math scores, scores on the group Assessment of Logical Thinking (GALT), and student’s algorithmic and conceptual scores on
American Chemical society (ACS). In addition, qualitative data of Van Opstal et al. (n.d.) was collected using videotape footage of the class section—one with professor A whose teaching style was opposite to professor B. Professor A always gives answers to students while professor afforded students more practice using reasoning skills by asking more questions.

To assess students’ perception of POGIL as an instructional strategy in the classroom several studies conducted an affective survey using the Likert five points scale of strongly agree, agree, neutral, disagree, and strongly disagree (Jin and Bierma, n.d.; Minderhout et al., 201); De Gale & Boiselle, 2015; Williamson et al., 2013; Jin and Bierma, n.d.; and Trevethan & Myers, 2013. Students’ response in the survey was analyzed using simple percentage calculation technique.

In the study of Verlinden et al., (2015); and Brown (2010) students’ perceptions of POGIL as an instructional strategy were assessed using the Individual Development and Educational Assessment (IDEA) form. Students were asked to rate their progress on the main objectives of the course and to identify elements of the teacher’s style and methods of teaching. However, though Brown (2010) and Verlinden et al., (2015) used the same survey method, their analysis of the data differ. Verlinden, et al., (2015) analyzed the data using percentage calculations while Brown (2010) used two-tailed Student’s t-test analysis technique.

In addition to the affective survey using Likert scale, Jin and Bierma (n.d.) conducted a pre–and post-survey method to assess students’ inquiry and appreciation skills (Jin and Bierma, n.d.). Information from this survey was tabulated and values were analyzed using percentage calculation.

Participants and Demographics
In this literature review, sixteen studies about POGIL were included. However, only two were conducted in the high school level (Villagonzalo, 2014; De Gale & Boissele, 2015). Most of the studies exploring the effectiveness of POGIL were conducted at a college level science classes such as Allied Health Chemistry course (Geiger, 2010), Material Science course (Yang, 2013), Environmental Health course (Jin and Bierma, n.d.), Introductory Chemistry course (Williamson et al. (2013; van Opstal, n.d.), Fundamental Nursing course (Roller, n.d.), Introduction to Pharmaceutical Sciences course (Verlinden et al, 2015), Engineering course (Douglas and Chiu, 2013), Information Technology course (Trevethan and Myers (2013), Computer Science course (Kussmaul, (2012), and Introductory Anatomy and Physiology course (Brown, 2010). Also, none of the sixteen studies reviewed provided complete demographics of the participants during the study such as gender, socioeconomic background, and race.

**Reliability and Validity**

Validity and reliability are important elements of all educational research. For instance, Vanags et al., (2013) claimed that POGIL can help improve long-term learning even when the teaching is done by inexperienced teachers. This claim was based only on the outcome of a two-week study on the impact of implementing POGIL within three different conditions – POGIL exercises with no guidance from a facilitator, POGIL exercises with no report out, and POGIL with facilitator, and team-based learning. During the study, each group was assigned a tutor with no experience in POGIL. Also, students were only given five minutes to complete the post quiz. Given this very little for students to complete an assessment, some students may not be able to respond or answer all the questions specially questions that require explanation. Also, if the questions that students were asked to answer in this post test assessment only require a yes or no answer, then it could not be used as a measure of how much actually students learn from the
lesson activity. Thus, the outcome from this data collection technique could not be considered as reliable and valid.

McMillan (2016) argued that when comparing two groups during a study, it is important to establish the equivalency of the groups. Thus, using quasi-experimental designs could reduce the reliability and validity of the studies of Villagonzalo (2014); van Opstal et al. (n.d.); Vanags et al. (2013); Roller (2015); and Geiger (2010). In a classroom setting, it is difficult to control all of the conditions that are surrounding the participant such as their level of interest and experience, prior knowledge, and level of cognitive skills.

Also, in the study of Douglas and Chiu (2013); Williamson et al., (2013); Trevathan & Myers (2013) was the absence of evidence to indicate improvement in student’s content knowledge and skills. The goal of the study was to determine the effect of POGIL at improving learning outcome. The outcome of the studies could be more significant if both qualitative and quantitative data were collected and analyzed.

**Ethical Procedures and Techniques**

According to McMillan (2015), research must be conducted in ways that harmless, fair, and beneficial to the participants. In the study conducted by Vanags et al., (2013), there were three groups of students. One group was the POGIL group of which students were required to work in a small group, to have roles within the group such as manager. Unlike the non POGIL group, students in the POGIL group were required to report their answers. In addition, the group was provided with POGIL exercises that contain diagrams or model. Also, the POGIL questions were directed, and later questions encouraged deeper understanding of the material. The questions in POGIL exercises given to the POGIL group were similar to the non POGIL group except the non POGIL group’s worksheet did not include models or diagrams. The experimental
conditions Vanags et al., (2015) created to study the effect of POGIL in students’ learning was not fair especially the students who did not have the opportunity to engage in active learning. Also, assigning an inexperienced facilitator in the classroom was not fair to students. In this study, the non POGIL group was deprived of the opportunities to engage in a real and more meaningful learning experience. McMillan (2016) argued: “Researchers are sensitive to the welfare of all individuals, take into account all perspectives in making decisions, and do not allow biases to result in unjust actions (p. 30).

Analysis

After reviewing several articles on studies that examined Process Oriented Guided Inquiry Learning (POGIL), it was found that effective implementation of POGIL could help increase students’ understanding of materials taught in the classroom (van Opstal et al., n.d.; Verlinden et al., 2015; Jin and Bierma, n.d; Minderhout et al., 2011; Villagonzalo, 2014; Picione, et al, n.d.). However, several factors could impact POGIL’s success such as teacher’s approach to instruction, knowledge and background of students, size of the population in the classroom, and technique used during POGIL implementation (van Opstal et al., n.d.; Minderhout et al., 2011; Jin and Beirma, n.d.).

Studies suggested that student-centered approach to instruction was an effective way to implement POGIL in the classroom (Verlinden et al.; Picione et al.; Minderhout et al.; van Opstal et al.; & Jin and Bierma, n.d.; Villagonzalo, 2014). Small group cooperative learning, and team –based learning were the most common strategies researchers have used in their implementation of the POGIL in the classroom (van Opstal, et al., n.d.; Verlinden et al., 2015; & Minderhaut et al., 2011. Cooperative and team-based learning were both characterized as student-centered strategies. The outcome of the study conducted by van Opstal et al., (n.d);
Verlinden et al., (2015); & Minderhout et al., (2011) indicated successful implementation of POGIL in the classroom. Interestingly enough, it was also found that the size of the participants’ population did not affect the outcome. For instance, there were 111 pharmaceutical students who participated in the study conducted by Verlinden, et al., (2015). However, no students in the class had grades of D (60%) or below. On the other hand, De Gale & Boisselle’s (2015) analysis of data showed varied academic performance among students with overall decrease in the class mean score. De Gale and Boisselle (2015) argued that the outcome might have been affected by the large grouping arrangement of the participants. For instance, one group during the study consisted of six members. The group took longer time to complete activities. The waiting time that the other group had to spend caused some frustrations and unable to maintain focus during activities. The results of the study showed only one out of 14 students who participated in the study scored between 80% -100% and 10 students scored below 59% in their final assessment. Evidence from this study indicated that POGIL is only effective if the classroom is structured to promote student-centered and cooperative approach (Minderhout et al., 2011; Brown, 2010; Verlinden et al., and Picione et al, n.d.).

Another factor that could affect POGIL’s success in the classroom was the teacher’s style of instruction (van Opstal et al., n.d.; Jin and Beirma, n.d.; Minderhout et al., 2011; & Verlinden et al., 2015). Van Opstal et al., (n.d.) study revealed that despite POGIL being a student – centered approach to instruction, teachers still play significant roles in helping students develop their reasoning skills. In this study, there were groups of students who always receive the answers from the teacher and a group that did not. Students who were asked more questions and encouraged to answer probing questions performed better in the test than students who were always given answers. In addition, the study of Minderhout et al. (2011) suggested POGIL could
be effective in larger classrooms by including a frequent communication technique, structuring groups by assigning roles to students, and encourage students’ engagement. For instance, the Toulmin model of argumentation is could be useful strategy to promote active learning using the POGIL strategy. This provides more opportunities for students to engage in a more meaningful discussion, and encourage them to utilize their critical thinking, and communication skills.

**Conclusions**

As a result of this literature review, new perspectives about POGIL have been generated. Successful implementation of POGIL in the classroom requires students to be actively involved. When using POGIL as a strategy for instruction, it should be implemented along with team-based learning, and small group discussion. Furthermore, POGIL’s success in the classroom also depends on teacher’s teaching style (van Opstal et al., n.d.; Vanags et al., 2013). If the teacher is always giving the answers, students learn to wait passively for information instead of constructing the concepts on their own (Vanags et al., 2013). Thus, I am reminded to avoid giving answers to my students all the time. Instead, I should encourage them to discuss and process the information among themselves.

Learning chemistry is not only about learning the content, but also helping students develop their process skills (Verlinden et al., 2015; Villagonzalo, 2014; Minderhout et al., 2011; Jin and Bierma, n.d.; van Opstal et al., n.d.; Picione et al., n.d.). Several studies provided evidence to support the claim that POGIL is an effective strategy to promote content learning in chemistry (Verlinden at al., 2015; Villagonzalo, 2014; Roller, 2015; and van Opstal et al., (n.d.). The group discussion during POGIL implementation helped deepened and enhanced students’ understanding of concepts and learning (Douglas and Chiu, 2013). Unlike the lecture approach to instruction, learning through POGIL emphasized the learning of transferrable skills also called
process skills such as problem solving, collaboration, information processing, and metacognition (Brown, 2010; Kussmaul, 2012). Therefore, I aim to explore the effectiveness of Process Oriented Guided Inquiry Learning in the high school chemistry classroom.

**Demographic Data for the Proposed Project**

My research will be conducted in a Title I high school in one of the cities in Northern [state]. The school is currently serving 796 students high school students. Thirty-nine percent of students receive free lunch and nine percent receive reduced-price lunch. Ninety-five percent of the student population is white, 0.4 % is Asian, 1% is black, 0.3 % is Hawaiian, 1 % is Hispanic, and 1 % is American Indian. In addition, forty-nine percent of the student body is female.

The study will take place in four sections of chemistry classes of which one section is an honor chemistry class. Two of the students in this class are 9th graders, one 12th grade, and 15 11th graders. There are three males and 15 females in this class. The class meets in the afternoon right after lunch period. The next class is a general chemistry class. The class consists of three 10th graders and 8 11th grades. There are 3 males and 8 females in this class. One of the students in this class has a 504 plan and one has an IEP. The class meets 80 minutes every morning and every other day of the week. Another general chemistry class consists of 17 11th grade students. Seven of them are males and the rest are females. In this section, two students are in IEP and two are in 504. The fourth chemistry class is a general chemistry consists of 13 11th grade students. There are four males and 9 females in this class, and two of them receive IEP’s.

The group of students that I am trying to impact are the general chemistry students most specially students with IEP’s and 504 plans. These students will benefit from this strategy because they will be engaged in a team-based learning through Process Oriented Guided Inquiry Learning (POGIL). Students who are receiving special education services are mostly within the
area of basic reading and reading comprehension. Working as a group will give them the opportunity to hear other students’ explanation and ways in processing information provided in POGIL exercises.

The focus of this study was selected due to the concern that the population of students who are interested in the study of science, technology, engineering, and mathematics (STEM) is declining in the United States. U.S News reported that the number of U.S. citizens and permanent citizens earning graduate degrees in science and engineering fell 5% in 2014 from its peak in 2008 (Neuhauser, 2016). In addition, most of the in demand jobs and fastest growing occupations in United States require the knowledge of STEM such as nurse practitioners, biomedical engineers, physician assistant, and physiologist (U.S. Bureau of Labor Statistics, n.d.; as cited in Campus Explorer, 2017). Most of these highly in demand jobs require understanding of chemistry.

In the school of which this study will be conducted, only 50% of students who graduated last year have indicated their interest of going to college. In addition, there were low percentage of students who are looking to enter in a college program related to science, technology, engineering, and mathematics (STEM). If this trend continues, the school will continue to contribute to the declining population of students in the United States who are not interested in fields that require knowledge of chemistry. The school’s report card of SY 2015-2016 showed that only seven percent of school’s total population was enrolled in AP chemistry. This year, less than 10 students are taking AP chemistry. In addition, the 2016 state science assessment showed that there were only 14% of students who have achieved science proficiency. Moreover, only about 10% of the total student population is currently taking chemistry. Therefore, to encourage more students to be motivated in the study of chemistry, teachers need to use an instructional
strategy that will effectively guide them in the learning process. Vanags, et al. (2013) argued that chemistry teachers need to change the way they present information to their students. Vanags et al., (2013) further argued that teacher must use a strategy that will allow students to become active learners.

**Proposed Action**

After reviewing several researches on POGIL, three strategies were found to be the key for successful POGIL implementation in the classroom. These key strategies include team-based learning, guided inquiry learning, and combination learning.

Reports from several studies have indicated that active learning is one of the key elements for successful POGIL implementation in the classroom (Douglas & Chiu, 2013; Pichione et al., n.d.; Minderhout et al., 2011; van Opstal et al., n.d.). Team-based learning is an active learning strategy used for successful implementation of the POGIL activities in the classroom. As a chemistry teacher for several years, I find that students who are actively involved during the learning process, were more likely retain information and increase their understanding of the material. The idea of allowing students work together in groups to answer questions is already a common practice in my classroom. POGIL exercises will provide time for students to discuss new material, and resolve any thinking processes that maybe incorrect (Yang, 2013). Unlike the traditional lecture method of teaching, students in the POGIL activities are allowed to interact with their peers while working on understanding the concept that is presented in POGIL exercises. Students during POGIL exercises will be required to work as a team in a small group of three or four. Members of the group will have roles to play during group discussion and class presentation. These roles are manager, presenter, and reflector. Sousa & Pileckie (2013) asserted that students who are engage actively in the learning process are more
likely to understand STEM concepts deeply. Further, students’ active participation in the learning process will help them recognize that chemistry is part of their everyday lives, and learning chemistry is interesting, and important (Zumdahl et al., 2007).

The scripted guided inquiry learning strategy in POGIL activities are designed to help students construct their own knowledge (Kussmaul, 2012). Jin & Bierma (n.d.) argued that POGIL emphasizes guided inquiry so that students can draw their own conclusion or explanation from the evidence or models they are provided in the POGIL activities. POGIL implementation is a learning cycle of three states—exploration, concept invention, and application (Kussmaul, 2012; Williamson et al., 2013; Douglas & Chiu, 2013). In my experience as a high school chemistry teacher, I find that students learn and remember best when they discover concepts on their own. The models that are presented in POGIL activities serve as scaffolding tools to help students visualize ideas or concepts, and shape their thinking. The structured guided inquiry learning in POGIL activities promotes higher knowledge and concept development (Geiger, n.d.).

Researches indicated that POGIL implementation is more effective when use in the classroom together with other instructional techniques (Williamson et al., 2013; Pichione at al., n.d.; Geiger, n.d.). “Combination learning is a new teaching and learning strategy for the 21st century” (Heick, 2018, para. 1). As I implement POGIL in my classroom, students will be given mini lectures using PowerPoint presentation before and after POGIL implementation. The purpose of the mini lectures is to provide a basic introduction of the new material, a review of concepts that students already learned, and clarify some of their misconceptions. In my experience as a chemistry teacher, students are less likely to engage when the material that is being presented to them is either too hard or too difficult, and feel that ideas are too confusing
and doesn’t make sense. Students during the POGIL activities will be asked with additional probing questions to encourage their critical thinking and problem solving skills. Concept mapping is another strategy researcher suggested to be useful and effective in helping students to organize their knowledge, and understand the concept presented through the POGIL activities (Pichione at al., n.d.).

Looking at the evidence that support the importance of these three strategies in the implementation of POGIL activities in the classroom, it is very reasonable to use all three in implementation of POGIL in my classroom. Vasquez Sneider, & Comer (2013) proposed five best practices or guidelines for STEM or STEAM education. Two of these best practices were emphasizing twenty-first century skills, and challenging the students. Using Team-based learning, guided inquiry learning, and combination learning in the implementation of POGIL activities will effectively promote student’s ability the twenty-first century skill such as collaboration, and communication. In addition, students will be challenged to use their critical thinking, and problem solving skills. As a chemistry teacher, it is my goal to provide my students the opportunity to be engaged in a learning process that will encourage them to take on a rigorous, meaningful, and challenging discussion.

Data Collection and Analysis Methods

Matrix for Data Triangulation

<table>
<thead>
<tr>
<th>Quantitative</th>
<th>Qualitative</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source 1</td>
<td>Source 2</td>
</tr>
<tr>
<td>Unit Pre-test and Post Test</td>
<td>Midterm/ Final exam</td>
</tr>
</tbody>
</table>
In planning and designing an educational research, the step of choosing the appropriate data collection and analysis method is critical to ensure the validity and reliability of the research outcome. In this study, I am planning to collect both qualitative and quantitative data to document the impact of the strategy on students’ understanding of the unit’s concepts in chemistry. This way, I will be able to validate each of the outcomes and see whether there are patterns or trends, whether the quantitative analysis of data is supported by the qualitative evidence, and vice versa.

Quantitative data will be collected for the following reasons: to quantify their understanding of the unit’s concepts, and assess students’ perception of POGIL as an instructional strategy for learning chemistry. Quantitative data will be collected using the following data collection techniques- midterm exam (appendix E), unit tests (appendix E), and pre- and post activity questions (see appendix C). A pretest will be administered prior to using POGIL in the classroom (see appendix D and E). In the unit test and midterm exam, there are three categories of questions students will be asked- multiple choices, problem solving, and apply and reasoning question. The purpose of exit question is to see what students are thinking and what they have learned from the particular POGIL activity they are engage during the class. Exit questions comprise only of one to two content targeted response questions. Midterm exam is a modeling exam created by the American Modeling Teachers Association.

Students’ perception and attitude about the new strategy will be determined by conducting an affective survey using the Likert scale of strongly agree, agree, neutral, disagree, and strongly disagree( see appendix A). Analysis of this data will enable me to see how the general population of my students feels about their learning experiences using the POGIL strategy.
Students’ scores in the midterm exam, unit tests, and daily exit questions will be analyzed using standard deviation statistical analysis. Student’s average midterm exam will be compared to their average scores in unit tests and exit questions. The unit’s pretest scores will be compared to the unit’s post tests to see whether students are able to improve their scores which indicate understanding, and retention of learning. Student’s score in the midterm exam will be analyzed to see whether students are able to retain their learning throughout the semester.

Analysis of the cognitive assessments show several possible themes that I expect to emerge such as increase in knowledge and understanding of concepts after the POGIL learning experience in the classroom. Also, I expect an increase in inquiry, critical thinking, and problem solving skills.

Qualitative data will be collected in the form of teacher’s daily anecdotal observation, students’ weekly journals, and formal interview. The teacher’s anecdotal observation will include lists of events, particular activities such as group work, group presentation, group discussion, attendance, and homework completion (see appendix F). Students ‘daily journal will be used to obtain information about students’ thoughts and experiences in the classroom as they engage in POGIL activities (see appendix G). This information will be analyzed to see whether there is a correlation between students’ assessment outcome and their actual learning experiences, and attitude in the classroom. According to Efron and Ravid (2013) student’s own daily written journal will reveal patterns in classroom interactions, and illuminate constraints and possibilities that I am unable to see or notice during class. In addition, students’ journal entries will validate some of my own recorded observation of a student classroom attitude, behavior, performance, and interaction in the classroom. Students will be interviewed to obtain some
information about their overall perception of their learning experience in the classroom (see appendix B).

In the analysis of these qualitative data, I expect themes such as student’s recognition of the benefits of working in groups or teams. I expect to see comments such as developing cooperative skills, retaining content knowledge, and promoting critical thinking skills. Another theme that I expect to see in all these qualitative data is that using POGIL worksheets help students in their understanding of concept. The models and the guiding questions students will answer during the POGIL activities will help them be actively involved in the problem solving process (Douglas & Chiu, 2013). I also expect a theme of slight resistance or resistance of being engage in POGIL activities especially during the initial introduction of POGIL activities specially students with low content background or students who have no experience in learning through POGIL activities.

**Ideas for Sharing Findings**

According to Efron and Ravid (2013) I will probably feel more comfortable sharing my inquiry with colleagues, who like myself, are interested in finding ways to improve their classroom practices through action research. Though some of my fellow teachers are already using the Process Oriented Guided Inquiry Learning (POGIL) as a strategy to teach the material in their classroom, I am hoping to encourage more teacher use the POGIL strategy as one of the their strategies to promote active learning in their classroom.

Also, I find that presenting my topic during professional development will be a useful way for me promote the focus of my study, and encourage not only the science teacher , but teachers of other discipline to explore this strategy and the possibilities for them to develop learning materials similar to the POGIL activities.
Though it is important to communicate my research study to other professionals such as my colleagues, Efron and Ravid (2013) suggested that the purpose of my action research is primarily to take action in order for me to see the impact of the new strategy to my own classroom. Thus, I am also planning to implement the strategy in my classroom to see the effect of the Process Oriented Guided and Inquiry Learning strategy on my students’ understanding of the unit’s concept in chemistry.

Finally, reflecting on the topic that I selected to investigate in this action research, I realized that my journey is not complete. As a result of my experience in developing my action research proposal, new ideas or topics have emerged. Thus, I am planning to explore another strategy to improve my practices in the classroom. I agree with the argument proposed by Efron and Ravid, 2013) that “action research tends to continue from one study to the next because the answer to one research questions leads to new questions” (p. 238).
References


## Appendix A: Likert Five Points Scale Student Affective Survey

<table>
<thead>
<tr>
<th>Questions</th>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The activity motivated my interest in chemistry.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. The activity helped me develop my critical and problem solving skills.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. I understand the concepts presented in the activity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Completion of POGIL activities helped me become more confidence in taking the tests and quizzes.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. It was given a clear instruction on what to do in the activity.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. I would recommend the use of POGIL activities to other students.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. I would recommend taking chemistry to other students.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Working with a group helped me become a better learner.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Appendix B: Formal Student Interview Questionnaire

<table>
<thead>
<tr>
<th>Questions</th>
<th>Answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Overall, what part of the classroom activities you like the most? Why?</td>
<td></td>
</tr>
<tr>
<td>2. Which POGIL unit activity did you find was the best? Why?</td>
<td></td>
</tr>
<tr>
<td>3. Share one positive and one negative experience you had during group learning activities.</td>
<td></td>
</tr>
<tr>
<td>4. Additional comment you would like to share to help improve your learning experience in the classroom</td>
<td></td>
</tr>
</tbody>
</table>
Appendix C: Pre POGIL and Post POGIL Exit Question

**Topic: The Periodic Table**

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. What do you know about the Periodic Table?</td>
<td></td>
</tr>
<tr>
<td>3. What is the periodic law?</td>
<td></td>
</tr>
</tbody>
</table>
Appendix D- Unit Test on matter

Unit 1 Test: Matter

Name: __________________________ Date: ________________

Part I- Multiple Choices: Write ONLY the letter that correspond to the best answer.

1.) The type of matter that contains only one kind of atom.
   a. Compound
   b. Element
   c. Mixture
   d. Both a and c

2.) A type of matter that contains two or more kinds of atoms chemically combined.
   a. Compound
   b. Element
   c. Mixture
   d. Both b and c

3.) A type of matter that has no definite composition.
   a. Compound
   b. Element
   c. Mixture
   d. All of the above

4.) A type of matter that can be separated only by chemical means.
   a. Compound
   b. Element
   c. Mixture
   d. Both b and c

5.) This type of matter has properties that are different than the properties of the elements it contains.
   a. Compound
   b. Element
   c. Mixture
   d. Both b and c

Part II- Identification:
A- Tell whether the following is a homogeneous mixture (solution), heterogeneous mixture, element or compound. Write your answer on the space provided before each number. 1 pt each

1.) pizza
2.) table salt (NaCl)
3.) sugar (C_{12}H_{22}O_{11})
4.) gold 
5.) Steel 

B. Tell whether the following is a physical (PC) or chemical change (CC). Write your answer on the space provided before each number.

1.) dissolving salt with water 
2.) digesting food 
3.) burning gasoline 
4.) stretching copper wire 
5.) melting ice 

C. Tell whether the following is a physical (PP) or chemical property (CP). Write your answer on the space provided before each number.

1.) Burns easily (flammable) 
2.) Boils at 450°C 
3.) good conductor of heat 
4.) reacts violently with chlorine 
5.) High density 

Part D: Read the passage below. Then, answer the questions that follow.
Solutions of the substance potassium dichromate are bright orange in color. If a potassium dichromate solution is added to an acidic solution of iron(II) sulfate, the orange color of the potassium dichromate disappears, and the mixture takes on a bright green color as chromium(III) ion forms.

a. From the information above, indicate one physical property and one chemical property of

Part E - Particle Diagram
1. Consider the four containers below and answer questions 1 - 4. Write your answer on the blank before each number. Some may require more than one answer.

1. Which container(s) contain mixture?
2. Which container(s) contain pure substance?

3. Which container(s) contain only element?

4. Which container(s) contain only a compound?

Part F. Consider the four containers below and answer the questions that follow: Write your answer on the blank provided before each number. Some may require more than one answer.

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
</tr>
</tbody>
</table>

1. Which container(s) contain mixture?

2. Which container(s) contain pure substance?

3. Which container(s) contain only compounds?

4. Which container contains only elements?

5. Which container(s) contain a gas matter?

6. Which container contain(s) a solid matter?

Part G: Reading Scales and Measurements

1.) Give the best estimate of the length of the cylinder using the following ruler? 1 pts each

   a. left ruler ____________

   b. right ruler ____________
2. Give the best estimate of the volume of the liquid in:

a. the left cylinder? ________

b. the middle cylinder? ____________

c. the right cylinder? ________

4. Which cylinder would you use if you want a measurement with 3 Significant figures? ________

Part H: Identify the separation techniques pictured below. Write your answer inside the box next to the figure.

a. Which technique would be useful to separate a mixture of sand and salt? Explain why? Make sure to use the correct property terms and technique(s). 3 points

b. Which technique would be useful to separate salt and water mixture? Explain why? Make sure to use the correct property terms and technique(s). 3 points
c. Explain why the technique at left would not be effective in separating a mixture of salt and sugar. 3 points

Part I: Classifying Matter
1. Draw particle representations for the following: 2 points each

| A mixture of carbon and oxygen | A compound of carbon and oxygen |

2. Explain why a magnet can separate iron atoms from the mixture but not from the compound. 2 points

3.) You are given two bottles. Bottle #1 contains hydrogen and oxygen gas. Bottle #2 contains water vapor. How are they different? Explain your answer using your knowledge about pure substance, and mixture. 3 points

Part J: Problem Solving
1. What is the formula for calculating percent error? 

2. In an experiment, a student found that the percent of carbon in a sample of C$_6$H$_{12}$O$_6$ was 40.5%. If the accepted value is 40.0%, what is the percent error? Show your work.  3 points

3. What is the formula for calculating percent yield?

4. In a chemistry class, students were tasked to separate a mixture of sand, salt, and iron filings. The data table below contains all the data students collected during the experiment. Complete the table and use the information provided in the data table to answer questions A – C.

<table>
<thead>
<tr>
<th>Material</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filter paper</td>
<td>0.245 g</td>
</tr>
<tr>
<td>Filter paper plus sand</td>
<td>2.345 g</td>
</tr>
<tr>
<td>Sand</td>
<td></td>
</tr>
<tr>
<td>Empty 2.50 mL beaker</td>
<td>45.601 g</td>
</tr>
<tr>
<td>Beaker plus salt</td>
<td>46.895 g</td>
</tr>
<tr>
<td>Mass of salt</td>
<td></td>
</tr>
</tbody>
</table>

A. What was mass of sand was recovered after separation?  2 pts.

B. What was the mass of salt recovered after separation?  2 pts

C. If the actual mass of sand before mixing was 2.8 grams, calculate the percent yield for the sand recovered in this experiment.  3 pts.

D. Is object E or object F denser? [Assume the particles are uniformly distributed throughout each object, and particles with a larger size have a larger mass.] Explain your reasoning.  2 pts.
4. In Figure 4 below, a graph shows the relationship between mass and volume for two substances, A and B.

Use the graph to answer questions 1 through 4 about substance A and B.

![Graph showing mass vs. volume for substances A and B](image)

You have built a simple two-pan balance shown above to compare the masses of substances A and B.

1.) What would happen to the balance if you put equal masses of A and B in the two pans? Equal volumes of A and B in the two pans? Explain your reasoning. 2 pts

2.) If you put 10.0 mL of A in one balance pan, what mass of B would you need in the other pan to make it balance? Justify your answer. 2 pts.

3.) If you put 35.0 mL of B in one balance pan, what volume of A would you need in the other pan to make it balance? Justify your answer. 2 pts.
4) Water has a density of 1.00 g/mL. Sketch the line representing water on the graph in Figure 4.

Part K. Essay question:

Your mom asked you to boil an egg. However, you forgot the egg until you realized the water in the pot has all been evaporated. Is boiling water a chemical or physical change? Is boiling egg a chemical or physical change? Explain your answer. 3 points

Appendix E: Midterm Exam

Chemistry – 1st Semester Exam

Name: ___________________ date: ______

1. What length should be recorded for the object at right?
   a. 1.6 cm
   b. 1.65 cm
   c. 1.650 cm
   d. 1.7 cm

2. What volume should be recorded for the liquid at right?
   a. 8.2 mL
   8.20 mL
   c. 8.04 mL
   d. 8.40 mL

3. The prefix milli means
   a. 1/1000
   b. 1/100
   c. 1/10
   d. 1000

4. A kilogram is the same as
   a. 1/1000 g
   b. 1/100 g
   c. 1/10 g
   d. 1000 g
5. The best answer for the value of $\frac{7.1}{42.8}$ is
   a. 0.2
   b. 0.16
   c. 0.17
   d. 0.166

6. The correct expression for 0.0034 in scientific notation is
   a. $34 \times 10^{-4}$
   b. $3.4 \times 10^{-3}$
   c. $0.34 \times 10^{-2}$
   d. $3.4 \times 10^{3}$

7. The decimal notation of $1.22 \times 10^{3}$ is
   a. 122
   b. 122.0
   c. 1220.00
   d. 1220

8. The drawing at right represents an apparatus for the separation of water into hydrogen gas and oxygen gas. Tube B contains
   a. H atoms
   b. H$_2$ molecules
   c. O atoms
   d. O$_2$ molecules
9. The apparatus pictured at right would be appropriate for separation of
   a. carbon dioxide and water
   b. alcohol and water
   c. copper sulfate (aq) and water
   d. silver chloride (ppt) and water

10. Which of the following is the correct set-up for the problem:
    How many centimeters are there in 25 kilometers?
    a. \(25 \text{ km} \times \frac{1 \text{ km}}{1000 \text{ m}} \times \frac{100 \text{ cm}}{1 \text{ m}}\)
    b. \(25 \text{ km} \times \frac{1000 \text{ km}}{1 \text{ m}} \times \frac{1 \text{ m}}{100 \text{ cm}}\)
    c. \(25 \text{ km} \times \frac{1000 \text{ m}}{1 \text{ km}} \times \frac{1 \text{ cm}}{100 \text{ m}}\)
    d. \(25 \text{ km} \times \frac{1000 \text{ m}}{1 \text{ km}} \times \frac{100 \text{ cm}}{1 \text{ m}}\)

11. The number of oxygen atoms in Ca(NO\(_3\))\(_2\) is:
    a. 6
    b. 5
    c. 3
    d. 2

12. The number of hydrogen atoms in one mole of H\(_2\)O molecules is
    a. 1
    b. 2
    c. \(6.0 \times 10^{23}\)
    d. \(1.2 \times 10^{24}\)
Use the diagram below to answer Questions 13 & 14.

13. The density of lead is 11.4 g/cm$^3$. The density of gold is 19.3 g/cm$^3$. Which line in the graph above represents lead?
   a. Line A
   b. Line B
   c. Line A if the piece of lead is larger than the piece of gold.
   d. Line A if the piece of gold is larger than the piece of lead.
   e. not enough information to tell

14. Which of the following has the greatest volume?
   a. 80 g of substance B
   b. 80 g of substance A
   c. both have the same volume
   d. not enough information to tell

15. Which of the above diagrams could be molecules of an element?

16. Which of the above diagrams could be molecules of a compound?
17. The equation that correctly describes the reaction above is
   a. $\text{Al}_2 + 3 \text{Cl}_2 \rightarrow \text{Al}_2\text{Cl}_6$
   b. $2 \text{Al} + 3 \text{Cl} \rightarrow 2 \text{AlCl}_3$
   c. $2 \text{Al} + \text{Cl}_2 \rightarrow 2 \text{AlCl}$
   d. $2 \text{Al} + 3 \text{Cl}_2 \rightarrow 2\text{AlCl}_3$

18. Which of the following substances is likely to dissolve in water to form a conducting solution?
   a. $\text{CaCl}_2$
   b. $\text{C}_6\text{H}_12\text{O}_6$
   c. $\text{CO}_2$
   d. All of these would form conducting solutions.

19. The molar mass of $\text{Ca(OH)}_2$ is
   a. 57.1 g/mole
   b. 58.1 g/mole
   c. 74.1 g/mole
   d. 114.2 g/mole

20. Which of the following descriptions best matches the energy flow diagram above?
   a. warm water cools down and freezes
   b. a cold glass of water warms up to room temperature
   c. hot tea cools down to room temperature
   d. liquid water evaporates
21. Which of the following statements best describes the substance as you move from X to Y on the graph?
   a. the kinetic energy of the water is increasing
   b. the molecules of the water are moving more rapidly
   c. the interaction energy of the water remains constant
   d. the interaction energy of the water is increasing

22. Which of the following statements best describes the substance as you move from Y to Z on the graph?
   a. the kinetic energy of the water is increasing
   b. the water is beginning to boil
   c. the water is melting
   d. the interaction energy of the water is increasing

23. How much energy must be added to 50.0g of water to move from point X to point Y on the graph? $Q = mH$, where $H_f = 334 \text{ J/g}$, $H_v = 2260 \text{ J/g}$ or $Q = mc\Delta t$ and $c = 4.18 \text{ J/g}^\circ\text{C}$
   a. 0 b. 209 J c. 16.7 kJ d. 113 kJ

24. Liquid water is being warmed in a pan on a stove. The burner on the stove is set on “LOW.” Eventually the water boils. While the water is boiling the burner is turned to the “HIGH” setting. What happens to the temperature of the liquid water?
a. It decreases slightly due to the extra boiling.
b. It decreases very much due to the extra boiling.
c. It increases, and it does so at a faster rate than when the burner was on “LOW.”
d. It remains the same

25. Which of the following energy graphs best matches the energy flow for an exothermic reaction before the system comes to equilibrium with its surroundings?
26. Which of the following is **not** true about one mole?
   a. one mole contains $6.02 \times 10^{23}$ particles
   b. 12 g of carbon equals one mole of carbon atoms
   c. the number of atoms in 1 mole of carbon = the number of atoms in 1 mole of calcium
   d. the mass of 1 mole of carbon atoms = the mass of 1 mole of calcium atoms

27. What is the *empirical* formula of a compound that contains 4.0 g of hydrogen and 28 g of nitrogen?
   a. N$_2$H
   b. NH$_2$
   c. N$_2$H$_4$
   d. none of these

28. Butyric acid, the compound responsible for the odor of rancid butter, has the empirical formula C$_2$H$_4$O. The molar mass of this compound is 88 g/mole. Its *molecular* formula is
   a. C$_2$H$_4$O
   b. C$_4$H$_8$O$_2$
   c. C$_3$H$_4$O$_3$
   d. not enough information to tell

29. ___CaCl$_2$ + ___Na$_2$CO$_3$ \rightarrow CaCO$_3$ + NaCl

   When the equation above is correctly balanced with integer coefficients, the sum of the coefficients is:
   a. 4
   b. 5
   c. 6
   d. 10

30. ___Al(OH)$_3$ + ___HNO$_3$ \rightarrow ___H$_2$O + ___Al(NO$_3$_)$^3$-

   When the equation above is correctly balanced the coefficient of H$_2$O is
   a. 1
   b. 2
   c. 3
   d. 8
31. Copper metal reacts with silver nitrate to produce silver metal and copper(II) nitrate.
The correct equation for this reaction is:
   a. Cu + SiN —> Si + Cu2N
   b. 2Cu + AgNO3 —> Ag + Cu2NO3
   c. Cu + 2 AgNO3 —> 2 Ag + Cu(NO3)2
   d. Cu + AgNO3 —> Ag + CuNO3

32. The reaction between potassium metal and water produces potassium hydroxide and hydrogen gas.
The correct equation for this reaction is:
   a. K + H2O —> KOH + H2
   b. K + H2O —> KOH + H
   c. 4K + 3 H2O —> 4KOH + 2H
   d. 2K + 2 H2O —> 2KOH + H2

33. A balanced equation verifies the law of conservation of matter because
   a. the molar masses of all substances are the same
   b. the coefficients on both sides of equation are the same
   c. the moles of reactants equals the moles of products
   d. the mass of reactants equals the mass of products

34. What is the correct name for K2CO3?
   a. potassium tricarbonate
   b. dipotassium carbon trioxide
   c. dipotassium carbonate
   d. potassium carbonate

35. What is the correct formula for iron(III) chloride?
   a. FeCl
   b. Fe3Cl
   c. FeCl3
   d. Fe(III)Cl
36. The element Y forms the Y\(^{+2}\) ion while X forms the X\(^{-3}\) ion. What is the formula of the compound formed by Y and X?
   a. XY\(_3\)
   b. Y\(_2\)X
   c. X\(_2\)Y\(_3\)
   d. Y\(_3\)X\(_2\)

37. In the reaction modeled above the ratio of moles of Cl\(_2\) produced to moles of CCl\(_4\) consumed is
   a. \(\frac{1\text{ mole Cl}_2}{4\text{ moles CCl}_4}\)
   b. \(\frac{2\text{ moles Cl}_2}{1\text{ mole CCl}_4}\)
   c. \(\frac{1\text{ mole Cl}_2}{2\text{ moles CCl}_4}\)
   d. \(\frac{1\text{ mole Cl}_2}{1\text{ mole CCl}_4}\)

Questions #38-39 refer to the following equation:

\[
2 \text{ KClO}_3 \rightarrow 2 \text{ KCl} + 3 \text{ O}_2
\]

38. How many moles of oxygen would be produced by the decomposition of 1.2 moles of KClO\(_3\)? [Hint: make a BCA table on your scratch paper.]
   a. 1.8
   b. 0.80
   c. 40.3
   d. 57.6

39. What mass of KCl is produced when 0.250 moles of KClO\(_3\) are decomposed?
   a. 18.7 g
   b. 30.6 g
   c. 37.2 g
   d. 61.2 g

For questions 40 and 41, consider the diagram below. In the box below left is a mixture of sulfur dioxide gas and oxygen gas. The box below right shows the contents after the reaction is complete.

\[
\begin{array}{c}
\text{●} = \text{S} \\
\text{○} = \text{O}
\end{array}
\]
40. Which of the equations below best represents the reaction between sulfur
dioxide and oxygen gases?
   a. \( \text{SO}_2 + \text{O}_2 \rightarrow \text{SO}_3 \)
   b. \( 2 \text{SO}_2 + \text{O}_2 \rightarrow 2 \text{SO}_3 \)
   c. \( 4 \text{SO}_2 + 4 \text{O}_2 \rightarrow 4 \text{SO}_3 + 2 \text{O}_2 \)
   d. \( \text{SO}_2 + 2 \text{O}_2 \rightarrow \text{SO}_3 \)

41. Which is the limiting reactant?
   a. \( \text{SO}_2 \)  
   b. \( \text{O}_2 \)  
   c. \( \text{SO}_3 \)  
   d. none of these is limiting

42. Which of the following is not conserved in chemical reaction?
   a. the mass of the system
   b. the number of molecules
   c. the number of atoms
   d. actually, all of these are conserved

Questions 43-44 refer to the following reaction.
   \[ \text{Mg} + \text{ZnCl}_2 \rightarrow \text{MgCl}_2 + \text{Zn} \]
   19.0 g of magnesium are reacted with 76.0 g of zinc chloride. [Hint: make a BCA
table on your scratch paper.]

43. Which reactant is in excess?
   a. Zn
   b. MgCl\(_2\)
   c. ZnCl\(_2\)
   d. Mg

44. Calculate the mass of magnesium chloride that \textit{should} be produced.
   a. 19.0 g
   b. 53.1 g
   c. 74.5 g
   d. 76.0 g

45. Which of the following changes will \textbf{not} increase pressure
   a. the molecules collide with the side of the container more often
   b. the molecules move faster
   c. more molecules are added to the container
   d. the volume is increased
46. The pressure of the gas in the flask at right is
   a. 733 mm
   b. 787 mm
   c. 679 mm
   d. standard pressure, 1 atm

47. A sample of N\textsubscript{2} gas has a volume of 30.0 ml at
   25\textdegree C and 730 mmHg.
   What would be the volume of the gas at 50\textdegree C and
   1 atm pressure?
   a. 31.2 ml
   b. 26.6 ml
   c. 33.9 ml
   d. 57.6 ml

48. Which of the following would be the most comfortable bath water temperature?
   a. 100\textdegree F
   b. 100\textdegree C
   c. 100 K
   d. standard temperature

49. Which graph above describes the relationship between pressure and volume?

50. Which graph shows the relationship between pressure and absolute
    temperature?
## Appendix F: Teacher Structured Anecdotal Daily Observation

<table>
<thead>
<tr>
<th>Teacher’s Structured Daily Anecdotal Observation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group Discussion</td>
</tr>
<tr>
<td>Homework or assignment completion</td>
</tr>
<tr>
<td>Peer-Peer Interaction</td>
</tr>
<tr>
<td>Student-Teacher Interaction</td>
</tr>
<tr>
<td>Attendance</td>
</tr>
</tbody>
</table>
Appendix G: Student’s Weekly Journal

Guided Student Daily Journal Entry

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>What work well today?</td>
<td></td>
</tr>
<tr>
<td>What did I learn today?</td>
<td></td>
</tr>
<tr>
<td>What did not work well today?</td>
<td></td>
</tr>
<tr>
<td>What are the things that were challenging in class today?</td>
<td></td>
</tr>
<tr>
<td>What do I want to learn tomorrow?</td>
<td></td>
</tr>
</tbody>
</table>