

**Investigating English Learners Engagement and Challenges in a Process Oriented
Guided Inquiry Learning (POGIL) Based General Chemistry Classroom.**

by
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Abstract

Active learning approaches in introductory chemistry classrooms have improved students' outcomes in course performance and decreased achievement gaps between underrepresented groups and non-underrepresented groups. With the English Learners (ELs) population increasing steadily in the U.S., finding thoroughly inclusive learning strategies for those who struggle to keep up in STEM classrooms due to achievement gaps and language barriers is essential. This study focused on ELs' engagement in a small group conversation and possible challenges they faced.

Data were collected during the Spring 2021 and Fall 2021 semesters in a General Chemistry hybrid class with an enrollment of 24 students. ELs students were invited for an interview. All interviews were transcribed and analyzed using thematic analysis. Findings suggest that ELs faced common challenges when engaging in small groups including feeling overwhelmed, answering models with heavy reading portions due to time, learning new scientific terminology, and language proficiency skills. Therefore, specific accommodations must be made in facilitation when instructing ELs due to English language proficiency and challenges faced while working in small groups. The accommodations should be set to help students reach sufficient familiarity as non-EL students to succeed in mainstream instruction.

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Introduction

In general chemistry classrooms, professors aim to guide students to adequately understand ideas, practices, and thinking methods in a chemical science environment (National Research Council, 2012). Active learning has been shown to improve student outcomes in course performance (Freeman et al., 2014), critical thinking (Kim et al., 2013), and class attendance (e.g., Alley et al., 2007). Therefore, instructors should implement various active learning approaches. One pervasive approach explicitly used in introductory science, technology, engineering, and mathematics (STEM) classrooms are collaborative learning approaches (Freeman et al., 2014). Collaborative learning is a form of active learning where students work collaboratively on a task and in doing so, build new understanding through discursive interactions. Recent studies have revealed that students tend to have positive learning outcomes, such as the ability to apply and integrate knowledge, when engaging in small groups in collaborative learning settings (Towns and Kraft, 2015).

Recent research sufficiently demonstrates that the effectiveness of active learning strategies depends on how well they are implemented (Freeman et al., 2014). Additional factors can have a significant role, including class size, instructor skill, and student diversity. Since student diversity plays an essential role in an active learning classroom, we dedicated part of our research to study an underrepresented group of students in the research field: English Learners (ELs). English Learners are a diverse population of students with a native language that is not English. Previous studies regarding ELs demonstrate that this diverse student population encounters challenges such as language barriers (Torres and Zeidler, 2002), fear of being judged by their peers (Baecher et al.,

2012), lack of a sense of belonging to the class social community (Washburn, 2008), stereotype threat (Spencer et al., 2016), and achievement gaps between ELs and mainstream students (Lee, 2005). This study will expand upon these previous studies by generating hypotheses about the characteristics of the learning environment and how the ELs students engage with others during collaborative group work.

Process-Oriented Guided Inquiry Learning (POGIL) is a well-known active learning strategy in undergraduate chemistry courses (Walker & Warfa, 2017). Students working in a collaborative environment are effectively given opportunities to tackle a task, construct knowledge, and apply this new knowledge through the use of POGIL (Rodriguez et al., 2020). The POGIL active learning approach is centered on a social constructivist theory, which contends that for students to construct and apply new knowledge, they must actively engage in learning while communicating with their peers (Amineh & Asl, 2015). The framework contains multiple levels that the learner must go through in order to execute and effectively generate accurate new knowledge.

Previous studies reveal that discussion and verbal interaction with peers helps with knowledge construction (King, 1994), and talking through a concept helps a more rapid and elevated quality of internalizing newly acquired knowledge, and it impacts students' achievement and performance in the classroom (Sedova et al., 2019). Although POGIL is a well-known form of active learning and there are many studies on this subject (e.g. Vincent-Ruz et al., 2020; Walker & Warfa, 2017), few studies have considered the experiences of underrepresented minorities (including ELs) in these learning environments. This study seeks to understand the challenges and barriers ELs face

when POGIL active learning approach is implemented in the classroom and in what possible ways it could be modified to meet their needs.

Thesis Statement

This study aimed to determine, examine, and investigate the challenges ELs face while interacting and engaging in small group conversations in a POGIL active learning general chemistry class. The following research question guides this study:

What are the common issues regarding engagement and small-group interactions of English Learners (ELs) in POGIL based general chemistry classroom?

The hypotheses for this study are as follows:

1. ELs are not familiar with the norms and expectations of the class, leading to confusion on what their role is while working in their small groups.
2. ELs struggle with understanding activities that include a heavy reading portion, therefore, if they are unable to understand the model, they won't be able to contribute to the group conversation.
3. Stereotype threat is a barrier for ELs' engagement in a group conversation.
4. Students with limited fluency in English cannot express themselves on scientific tasks and sometimes ELs don't have the adequate vocabulary to express their ideas, thus preventing them from participating in their small group discussions.
5. Scientific language is already complex for most students and learning science language can even be more challenging for EL students. In higher education learning environments, EL students may face more challenges because the science content becomes more complex and the science language becomes more precise (Bergey et al., 2018).

6. Some ELs prefer to direct their questions to the instructor (in some cases, even outside of the class). This hypothesis was based on the study of Vasu and his colleagues in which he states that different cultural backgrounds between learners can cause dissatisfaction with the quality of peers' feedback leading students to prefer to receive feedback from the instructor (Vasu et al., 2016).
7. A personality trait can influence ELs participation in the class and in their small group conversations.
8. When a student has a sense of belonging, they are more likely to engage in a small group conversation. This hypothesis was divided into two sub-hypotheses:
 1. Sense of belonging depends on the student's relationship with other students.
 2. Sense of belonging depends on the student's relationship with the instructor.

A. Conclusion

The emphasis and goals of this study were explicitly stated in this chapter. Some of the challenges EL students have in mainstream settings have been addressed in previous literature. This study expanded on previous studies and emphasized on ELs' engagement in group settings. The chapter discussed the research question that guided our study and possible hypotheses we had prior to this study. The next chapter will discuss more thoroughly the literature that guided this study and aided us in better understanding different active learning approaches, collaborative vs. cooperative learning, POGIL as a collaborative active learning approach, and EL challenges in mainstream classrooms.

II. Literature Review

A. Introduction

The fastest-growing student population in American schools today is the population of English learners (ELs) with an estimated enrollment of 4.9 million students in public schools (Sandilos., et al. 2020; Mitchell, 2021). Providing quality education for EL students ultimately helps to have scientifically literate citizens and diversifies the STEM workforce (Jordt et al., 2017; Torres & Zeidler, 2002). Previous studies regarding ELs demonstrate that this diverse student population encounters challenges such as language barriers (Torres and Zeidler, 2002), fear of being judged by their peers (Baecher et al., 2012), lack of a sense of belonging to the class social community (Washburn, 2008), and stereotype threat (Spencer et al., 2016). These threats and challenges can negatively influence student learning (Xie et al., 2022).

Collaborative learning strategies, such as Process Oriented Guided Inquiry Learning, have been shown to have positive effects on student performance in STEM fields (Freeman et al., 2014) and helps narrow the achievement gaps between underrepresented minority groups and other minority groups (Theobald et al., 2020). The concept of collaboration as a learning strategy has existed throughout human history. Collaborative Learning strategies are used nationwide. For example, in Indonesia, the ebb and flow examination into Collaborative Learning and adult learning are increasingly centered around the parts of electronic and web-based learning (Sarbaini et al., 2019). More recently, studies have revealed that students tend to have positive learning outcomes, such as the ability to apply and integrate knowledge when engaging in small groups and collaborative learning settings (Lumpkin et al., 2015). However, the effects of efficient collaborative, student-centered

learning are mediated by several factors, including instructor facilitation (Anderson et al., 2007; Fredricks et al., 2004) and student diversity within groups (White, 2003). Due to the collaborative and social nature of collaborative learning environments, ELs might face additional challenges specifically while constructing knowledge in their small groups.

This chapter is divided into four sections. First, I provide an overview of active learning and examine the importance of active learning and its effectiveness in STEM classrooms. The chapter explores two types of active learning approaches: collaborative learning and cooperative learning. Next, I discuss literature and the challenges that come with implementing active learning approaches in the classroom, such as student diversity and group composition. Then, Process Oriented Guided Inquiry Learning (POGIL) is discussed as a collaborative active learning approach. The chapter further describes the conceptual framework based on the idea of social constructivism, explaining the different levels students go through to construct knowledge. Finally, the chapter explains barriers and challenges faced by ELs in a POGIL based classroom.

B. Active Learning in Undergraduate STEM Courses

This study was conducted in a college-level chemistry classroom that utilized an active learning approach to facilitate students in understanding chemistry through group discourse. This section of the chapter explores what active learning is and goes into further detail about the advantages of using active learning strategies in STEM undergraduate courses. Additionally, various active learning approaches are discussed and analyzed.

1. Active learning strategies enhance students' performance in classrooms.

The value of active learning approaches has been acknowledged in literature as a prominent learning strategy to transform science education (Lombardi & Shipley, 2021).

The definition of active learning is highly contested by academics. For this literature review, the definition of Brent & Felder (2009) was used to interpret active learning. Brent & Felder (2009) suggest that active learning consists of students engaging in brief, course-related individual, or small-group activities, interspersed with instructor-led intervals during which student responses are analyzed, and knowledge is constructed. In other words, active learning is where students collaborate on problem-solving activities to construct new knowledge. Active learning strategies explicitly challenge students to draw connections between new and pre-existing knowledge to deepen their understanding. In other instances, instructors may create assignments encouraging students to address their misconceptions and then rebuild their understanding using more accurate information (Cooperstein and Kocovar-Weidinger, 2004). Here we discuss the benefits of active learning in STEM classrooms including (a) enhancing student critical thinking, (b) enhancing student performance and attendance, and (c) increasing inclusivity of classrooms.

Active learning has been shown to enhance student critical thinking which improves student learning (Kim et al., 2013). In this study, Kim and her colleagues used active learning strategies to promote critical thinking. Critical thinking skill was defined as "the ability to identify issues, analyze data and evidence, make judgment, critically and reflectively evaluate relevant elements, and draw conclusions." (p. 226). Kim et al. incorporated critical-thinking activities that involved small groups solving specific, real-life natural disaster situations, after which they presented individual reports that examined, summarized, and assessed the topics mentioned during group work. The activities were developed to involve students in several collaborative group activities in order to promote

conceptual understanding and the integration of existing knowledge while dealing with the geoscience challenges of a natural disaster. Out of 105 students, over 50% ($n=47$) remained at the same level of critical thinking. In contrast, 31 students (30%) improved their critical thinking level from individual report I to individual report II. Furthermore, students' percentage mean scores improved (7.31 points) from individual report I ($M=68.34$) to individual report II ($M=75.66$). Based on these results, Kim and her colleagues concluded that when students are productively engaged in explaining, clarifying, debating, and critiquing their ideas, collaboration can lead to cognitive engagement resulting in enhanced student learning and critical thinking.

In a different study on active learning enhancing critical thinking, Hager, Sleet, Logan, and Hooper (2003) incorporated critical-thinking tasks by using open problems that required students to apply chemistry and physics concepts to real-world problems, and they found that using open problems and tasks in small cooperative groups was effective for improving students' reasoning skills. They concluded that it is critical for students to rotate roles in order to acquire specific skills associated with each role and to stress the importance of sharing responsibilities if a group is to function in a truly co-operative way.

Active learning can also enhance class attendance and test scores (Alley et al., 2007). Alley and her colleagues used two active learning measures in the classroom. The first was a set of fill-in-the-blank notes available to students before lectures. The second was a graded active learning exercise given in each class period. Findings revealed that using a combination of the sentence-headline slide design and active learning measures led to increases in test scores and attendance by more than 15%. In addition, using active learning

measures has improved student attitudes overall and they were more effective at helping students learn the course material.

Other research studies have demonstrated that active learning strategies significantly increase inclusivity in the classroom. Haak and his colleagues (2011) investigated the impact of active learning on students enrolled in an introductory biology course at the University of Washington (Haak et al., 2011). When multiple highly structured approaches to promote active learning were incorporated into the introductory biology course, all students in the course benefited by reducing the achievement gaps among them. Theobald et al., 2020 also investigated active learning in undergraduate science, technology, engineering, and math classes. In their study, Theobald and his colleagues compared the performance of underrepresented students to their overrepresented classmates in active learning and traditional lecturing treatments. They found that active learning reduced achievement gaps in examination scores and narrowed gaps in passing rate by 45% (Theobald et al., 2020). Nevertheless, the effectiveness of active learning strategies depends on how well they are implemented (Freeman et al., 2014). Additional factors can play a significant role in the implementation of these activities, including class size, instructor approaches to facilitation, and student diversity.

2. Collaborative Learning as an Active Learning Approach

One pervasive active learning approach explicitly incorporated in introductory science, technology, engineering, and mathematics (STEM) classrooms is the collaborative learning approach (Freeman et al., 2014). Collaborative learning is a form of active learning where students work together on a task and, in doing so, build new understandings

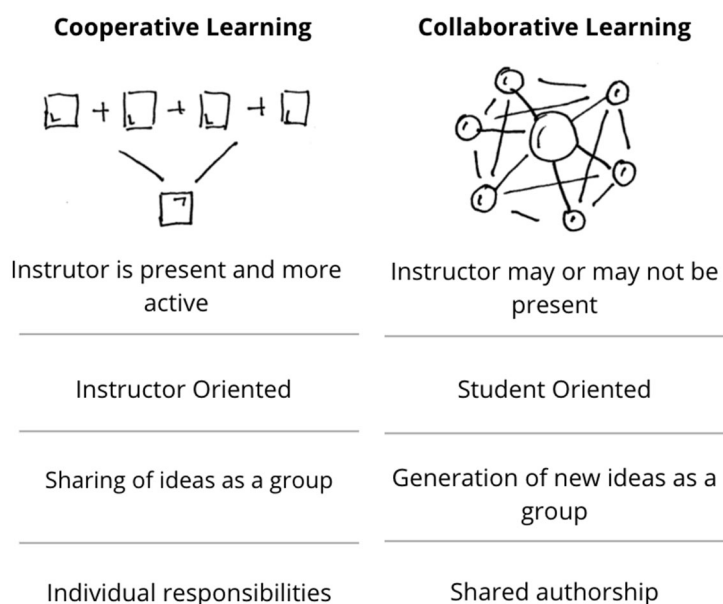
through discursive interactions (Blatchford, Kutnick, Baines, & Galton, 2003). Another active learning approach also used in STEM classrooms is cooperative learning. Cooperative learning is arguably an older form of group learning compared to collaborative learning (Davidson & Major, 2014). Cooperative Learning consists of structured small group activities that have five fundamental components: positive interdependence, face-to-face promotion interactions, individual accountability, interpersonal and small group skills, and group processing (Johnson et al., 1998). Cooperative learning is distinguished from collaborative learning by these systematic structural properties. In a study done on cooperative learning, Warfa investigated the effect of implementing cooperative learning in 25 chemical education studies involving 3985 participants ($N_{\text{treatment}} = 1845$; $N_{\text{control}} = 2140$). According to the study's findings, the median student performance in a cooperative learning group would be 25 percentile points higher than that of a median student performing at the 50th percentile in a traditional group (Warfa, 2015). Therefore, on average, students in a cooperative learning class significantly outperformed their counterparts in traditional classes.

The goal of cooperative and collaborative learning approaches is the discovering, understanding, and production of knowledge. However, in cooperative learning, the focus is on working together, or interdependence. On the other hand, collaborative learning focuses more on working with each other (but not necessarily interdependently (Davidson & Major, 2014)). For instance, in a cooperative learning environment, students can work in groups to split and assign individual roles to achieve the common goal. Collaborative learning, on the other hand, requires students to collaborate and holds all members of the group accountable to increase their knowledge by working on all parts of the material, not

just the piece that they present in their role (See figure 1). This study is based on the collaborative active learning approach. The role of student discourse in small groups is critical and therefore, that is where the foundation of the study.

Figure 1

The Difference Between Cooperative Learning and Collaborative Learning.



Recent studies reveal that students tend to obtain positive outcomes such as the ability to apply and integrate knowledge (Towns & Kraft, 2010), enhance respect for different perspectives through open exploratory discussion, and encourage team building (Davidson & Major, 2014) when engaging in small group, collaborative learning settings. According to Towns and Kraft (2010), collaborative learning enhanced student achievement outcomes ($SD = 0.68$, $M = 0.68$), ($N_{\text{treatment}} = 1845$; $N_{\text{control}} = 2140$). The study concluded that a student in a collaborative learning group would perform 25 percentile points better than a student in a traditional group performing at the 50th percentile in

achievement outcomes. In another study, Geraldine Nerona (2019) also investigated the effectiveness of collaborative learning strategies in enhancing students' achievement and learning outcomes. The study took place in three general engineering courses and Pre-test/post-test control group experimental design was used. The post-test achievement scores of the respondents showed significant differences. The experimental groups engaging in collaborative learning scored much higher than their control group peers. The groups that participated in collaborative learning also achieved significantly better learning outcomes than the traditional groups in the areas of collaborative learning, problem-solving, feedback, peer interaction, group skills, problem-solving skills, and communication skills (Nerona, 2019).

In another study on collaborative learning, students reported that sharing responsibility reduced the anxiety associated with problem-solving (Gokhale, 1995). Gokhale found that students who participated in collaborative learning had performed significantly better on the critical-thinking test than students who studied individually. She also concluded that group diversity in terms of knowledge and experience contributed positively to the learning process (Gokhale, 1995). Therefore, instructors should implement various active learning approaches that encourage knowledge construction in a diverse group setting.

In summary, collaborative learning is an effective active learning approach. It enhances respect for different perspectives through open exploratory discussion and encourages team building. Collaborative learning obtains positive outcomes in applying and integrating knowledge. This study investigates a pervasive collaborative learning

approach known as Process Oriented Guided Inquiry Learning (POGIL) and its role in helping students construct knowledge in a group setting.

3. POGIL as an Active Learning Approach

Process Oriented Guided Inquiry Learning (POGIL) is a commonly used active learning approach in undergraduate chemistry courses. POGIL is effectively utilized to provide scaffolded opportunities (i.e., guided in POGIL) to students working in a collaborative setting to complete a task, construct knowledge, and apply this new knowledge (Rodriguez et al., 2020). POGIL is built on the foundational work in the areas of cognitive development, collaborative learning, and instructional design (Moog & Spencer, 2008). POGIL is based on a social constructivist framework, which holds that students need to be actively engaged in learning while interacting with their peers to construct and apply new knowledge (Amineh & Asl, 2015). The social constructivist framework includes many levels, such as internalization, externalization, objectivation, legitimation, and reification, that the student has to go through in order to implement and efficiently construct accurate new knowledge. For instance, previous studies reveal that discussion and verbal interaction with peers help with knowledge construction (King, 1994), and talking through a concept helps a more rapid and elevated quality internalization of newly acquired knowledge, and it impacts students' achievement and performance in the classroom (Sedova et al., 2019).

In a POGIL-based classroom, students work in small groups, typically with assigned roles where they work on specific and carefully crafted activities (Moog & Spencer, 2008). The instructor is not primarily lecturing but rather serves as a facilitator of student learning.

Although POGIL is a well-known form of active learning, and there are many studies on this subject (e.g., Vincent-Ruz et al., 2020; Walker & Warfa, 2017), few studies have considered the experiences of underrepresented minorities (including ELs) in these learning environments. This study seeks to understand the challenges and barriers ELs face when POGIL active learning approach is implemented in the classroom and in what possible ways it could be modified to meet their needs.

C. Conceptual Framework

The conceptual framework is based on the learning theory of social constructivism. Social constructivism is the idea that a student learns through social interaction by interpreting and understanding new concepts in a group setting (Vygotsky, 1962). The major significance of Lev Vygotsky (1962) to constructivism stems from his theories on language, thought, and their mediation by society. Vygotsky believed that the process of constructing knowledge is influenced by other people and is interceded by culture and society. According to social constructivists, the process of sharing individual views, known as collaborative elaboration (Meter & Stevens, 2000), leads to students developing a group understanding of an idea and this process cannot be done alone within individuals (Amineh & Asl, 2015).

Berger and Luckmann developed a framework known as *The Social Constructivism of Reality*. In their book, they divided their framework on social constructivism into eight levels: personal knowledge, internalization, transformation, habituation, externalization, objectivation, legitimation, and reification (Berger & Luckman, 1966). Personal knowledge was defined as what an individual knows and it consists of “typification

schemes'', which are the frameworks used to interpret and make sense of the actions of other people and the physical world. Personal knowledge is constructed through a number of processes. The first process is internalization, which describes the absorption of knowledge by a recipient. The second process can be done through habituation which is the development of knowledge into useful routines through repetition of work or tasks. One can also go through the process of transformations by changing the subjective reality and creating new ideas. Then an individual goes through a process of externalization, which is the expression of knowledge in a symbolic form such as speech, artifacts or gestures into the physical world, such that others can perceive and internalize it. Consequently, the objectivation process occurs when the creation of shared, social constructs represents a group's, rather than an individual's, understanding of the world. Legitimation is a process whereby knowledge is authorized and accepted by people or groups who have power. Finally, the last process is known as reification, in which concepts harden in the minds of the group and attain an existence, apparently independent of human beings and can no longer be challenged.

In this conceptual framework, the process of knowledge construction is divided into seven levels: prior knowledge, internalization, transformation/habitation, externalization, objectivation, legitimation, and reification. The conceptual framework is a cycle that starts with the student having prior knowledge (See figure 2). At this level, students come to class with some prior knowledge, where they know some information about the concept and use it to explore and interpret the POGIL activity's models. The model can be a paragraph of information about the concept, a table/graph, or some sort of demonstration. Accordingly, students try to use their prior knowledge to make sense of what's happening in the model.

Consequently, students use their prior knowledge in two different ways. One is through the habituation level, creating new knowledge by combining existing knowledge. This process happens individually. The second way is through the transformation level. Where prior knowledge is not enough or inaccurate for interpreting the model, so the student needs to change and "transform" their prior understanding of the concept. Then students begin to construct new knowledge by reading, interpreting, and answering a few questions directly related to the module. This level is called internalization. After this level, the student has completed the exploration part of the cycle that leads to knowledge construction.

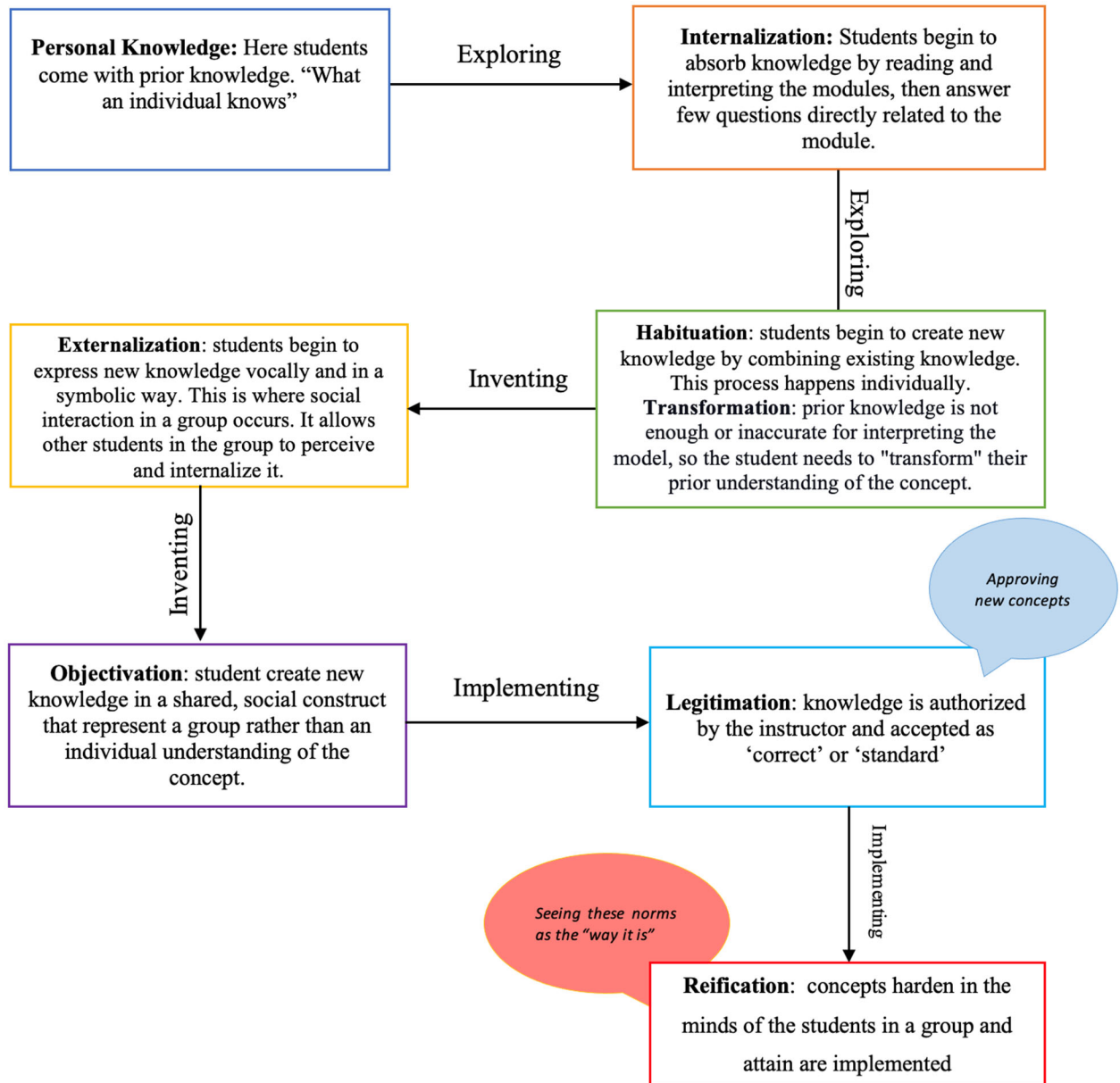
The next part of the cycle is invention (See figure 2). Here the student goes through two levels: externalization and objectivation. Students begin to express both new and personal knowledge vocally and symbolically at the externalization level. This is where social interaction and engagement in a group occur. It allows other students in the group to perceive and internalize the new knowledge creating a small group conversation. Students will start asking questions, critiquing ideas, and reasoning with each other. Through small group conversations, students reach a consensus that we call a shared understanding. In this process, students create new knowledge in a shared social construct representing a group rather than an individual understanding of the concept. This level is known as objectivation. It is a very crucial level because each student would not be able to reach that understanding alone.

Finally, the last part of the cycle is implementing the new knowledge, which also consists of two levels: legitimation and reification. At the legitimation level, students go through a process whereby knowledge is authorized by the instructor and accepted as 'correct' or 'standard.' At this level, facilitation occurs. After receiving the instructor's

approval, concepts harden in the students' minds and attain an existence that the concept can no longer be challenged. After the final level, the cycle can keep reoccurring depending on how many new concepts are provided in the POGIL activity. Therefore, this is an ongoing cycle of knowledge construction. This conceptual framework will be utilized to identify which framework level is affected after identifying the challenges English Learners (ELs) face while constructing knowledge in their small groups.

Figure 2

Conceptual framework on knowledge construction in a POGIL-based classroom based on social constructivism.



D. Barriers and Challenges faced by ELs.

The success and motivation of students in their academic endeavors determines the efficiency of teaching and learning in any educational setting and circumstance. Learning barriers and obstacles are common phenomena even in the most successful universities across the globe. Students may face personal, emotional, financial, psychological, situational, or even organizational obstacles to learning (Liton, 2016). This study focuses on an underrepresented group of students in the research field; English Learners (ELs). It is crucial to understand and identify the barriers and obstacles ELs face to provide quality education and ultimately help to have scientifically literate citizens and diversifies the STEM workforce (Jordt et al., 2017; Torres & Zeidler, 2002).

Previous studies regarding ELs demonstrate that this diverse student population encounters challenges when it comes to language (Torres & Zeidler, 2002). In this study, Torres and Zeidler investigated 380 students who were Hispanic English language learners and native English language speakers. They were enrolled in tenth grade earth science, biology, and chemistry classes (N=158). Students were required to take a language and scientific reasoning skills tests and they were categorized in groups based on: 1) English language proficiency, 2) scientific reasoning skills and 3) native language. The study showed that English language proficiency had a significant contribution to the students' performance on the standardized science test. Another barrier ELs students face in the classroom was identified by Washburn in his study about developing strategies for working with English language learners. Washburn states that English learners struggle with having a sense of belonging to the class social community (Washburn, 2008). He stated that confusion is a natural response to a new system when people do not know how they are

supposed to act or what they are expected to do. Washburn suggests that relating classwork to their home country when appropriate acknowledges the presence of the ELs and gives them a familiar connection. This is one way to ensure ELs feel like they belong in the classroom. Another way he suggests for instructors to create a sense of belonging atmosphere is by making sure their body language is visible and noticed by the ELs and that it is congruent with what they are talking about (Washburn, 2008).

In a study on stereotype threat, Spencer et al., 2016 defined stereotype threat as a situation in which there is a negative stereotype about a persons' group, and he or she is concerned about being judged or treated negatively on the basis of this stereotype. Spencer et al. emphasize that students face extra pressure to avoid confirming the stereotype alleging their group's intellectual inferiority. Studies have shown that this type of pressure can undermine the targeted groups' performance making it more difficult for them to succeed (Spencer et al., 2016). Stereotype threat can be triggered by any cue indicating that the stereotype might be applied in a given situation (Spencer et al., 2016).

This study is going to expand on these barriers and challenges that ELs face in the classroom. We have hypothesized about some challenges and barriers that ELs might face while working in a collaborative, small group setting in a POGIL-based general chemistry class.

E. Conclusion

Numerous studies on active learning have shown its effectiveness when implemented in STEM classrooms. Active learning enhances student critical thinking, performance, and attendance and increases the inclusivity of classrooms. However, some challenges and barriers come with implementing active learning approaches in the classroom, such as

student diversity and group composition. The chapter further discussed two active learning approaches: collaborative and cooperative learning. POGIL was discussed as a collaborative active learning approach. The chapter examined Berger and Luckmann's framework, *The Social Constructivism of Reality*, which helped us develop our conceptual framework based on the idea of social constructivism, explaining the different levels students go through to construct knowledge. Finally, the chapter presented some barriers and challenges ELs face in a POGIL-based classroom.

III. Methodology

A. Research Design

This study is a comparative exploratory case study that answers the research question using a qualitative approach. A case study is a research method that is used to gain a thorough, comprehensive grasp of a complex issue in its real-life context (Crowe et al., 2011). The data collection methods were adapted to meet the needs of this case study to capture descriptive information about ELs' student-student interactions in the general chemistry classrooms. All methods and forms used in this research project were submitted to IRB and approved (19-2253) (See Appendix A). For this study, the data was collected from the 2021 spring and fall semesters in a General Chemistry class at a large public university located in the southeastern United States. Data were previously collected by the research team (including the author). In these courses, students worked in small collaborative groups (3-4 students per group) to complete POGIL-based activities. In the spring semester, students met on Mondays, Wednesdays, and Fridays for 55 minutes. In the fall semester, students met on Tuesdays and Thursdays for one hour and 25 minutes. The course was taught by a professor with more than twenty years of experience with teaching chemistry and an experienced POGIL trainer. As part of the larger project, all students were invited to participate in this study during the second week of the class. Due to COVID-19, students were divided into two subgroups and alternated between meeting in-person and joining the Zoom breakout rooms. For small group conversations, the instructor sent the students to pre-assigned breakout rooms consisting of up to two students who were present in the class and up to two students who were online that day. Students did not have assigned roles in their groups. Usually, the group conversations took ten to

twenty minutes. While students were working on the activity in their small group, the instructor checked in with groups and answered their questions. Each group had an iPad to share the screen while working on the POGIL activity. The small group discussions in the breakout rooms were recorded to capture the interaction among students and the instructor's small group facilitation.

B. Data Collection

In the 2021 spring semester, twenty-two students (6 males and 16 females) out of 24 consented to participate in the research, and they provided their demographic information by taking a short survey on Qualtrics (Qualtrics, 2020) (See Appendix C). Five students (5 females) self-identified as EL, and they all signed the consent form. However, one of the females that self-identified as an EL dropped the course after three weeks. All four ELs students were invited for an interview via email, and they all agreed to help with this part of the study. One other ELs from the previous classes with a similar environment were also interviewed (See Table 1). The interviewees' time was compensated with electronic gift cards at a rate of \$10 per hour. All interviews were transcribed using Otter or Temi transcription websites (Otter.ai, 2021; Temi, 2021). Interviews were conducted in the third month of the Spring 2021 semester to make sure that students had enough experience with working in small groups.

Table 1*Demographic Information of ELs Students in the Spring 2021 Semester*

Spring 2021 Semester				
Participant Name	Gender	EL	International Student	Language
Rachel	Female	Yes	No	Arabic
Luna	Female	Yes	No	Spanish
Faith	Female	Yes	Yes	Unspecified
Fiona	Female	Yes	No	Farsi/Turkish
Joy	Female	Yes	No	Arabic

For the Fall 2021 semester, twenty-two students (8 males and 14 females) consented to participate in the research, and they provided their demographic information by taking a short survey on Qualtrics (Qualtrics, 2020). Seven students (2 male, 2 females) self-identified as ELs, and they all signed the consent form (See Table 2). All seven ELs students were invited for an interview via email, and four agreed to help with this part of the study. Additional interviews were conducted with non-ELs students to compare students' experiences working with POGIL and in a group setting. Before interviewing ELs students, each student was invited to take a personality test (See Appendix D) to see if specific personality traits could affect their group participation. For example, if a student being introverted/extroverted would possibly influence their participation. Students sent the results to all personality tests via email. During the interview, ELs students were asked about the influence of their personality traits on their small group engagement based on the test they took.

Table 2*Demographic Information of ELs Students in the Fall 2021 Semester*

Fall 2021 Semester				
Participant Name	Gender	EL	International Student	Language
Sarah	Female	Yes	No	Arabic
Kevin	Male	Yes	No	Arabic
Casey	Female	Yes	No	Arabic
Paul	Male	Yes	No	Arabic

C. ELs Interviews

The interview protocol with open-ended questions was designed based on the suggested problems from the literature regarding ELs' possible issues in a POGIL-based chemistry class. Pilot interviews were conducted with some other ELs students to ensure question clarity, and questions were modified accordingly. All interviews were conducted through Zoom and were recorded. The interviews included specific questions generated to better understand the participant's perception of the classroom and group interactions and what was needed to create the necessary change (See Appendix B). Therefore, students were asked about their educational background, group conversations, experience working on POGIL activities, language proficiency, and student-instructor interaction. Each interview took about 30-60 minutes based on how detailed the interviewee was answering the questions.

Each one of our hypotheses was tested by asking some questions in the interviews related to the hypothesis (See Table 3). For example, we hypothesized that ELs have problems with understanding activities with a heavy reading portion. In other words, if they

cannot understand the model they won't be able to contribute to the group conversation. To test this hypothesis we asked ELs about their experience working on POGIL activities, challenges they faced when working on POGIL tasks, and in what ways could the POGIL activities be modified to help ELs develop a better understanding of the topic.

Table 3

Hypotheses and Interview Questions for Spring 2021 and Fall 2021 Semester.

Hypotheses	Examples of Interview Questions Asked
Hypothesis 1 -ELs are not familiar with the norms and expectations	Tell me about your educational background. What are the expectations and norms in this class?
Hypothesis 2 - ELs students have difficulties engaging in a group conversation - they are quite in their group because they are uncomfortable	How does working in your small group make you feel? Why do you feel this way? Tell me about a time working in your group made you feel uncomfortable. Tell me about a time working in your small group made you feel comfortable. When working in small groups, what do you see as your role? How do you see the role of your peers? Have you initiated a conversation in your group?
Hypothesis 3 - A personality trait can influence ELs participation in the class and in their own groups	Based on the personality test you took in class. Do you feel that there's a specific trait that influences your participation in a good or bad way? How and why? (This question was not asked in the Spring Semester)
Hypothesis 4 - When student have a sense of belonging they're more likely to engage in a small group conversation - relationship with other students	Do you have a groupme or group chat for your group specifically? If so, tell us about that. (This question was not asked in the Spring Semester)
Hypothesis 5 - Students with limited fluency in English are not able to express themselves on scientific tasks and that sometimes ELs don't have the adequate vocabulary to express their ideas -this prevents them from participating in their group discussion	You mentioned in the consent form that English is not your first language. On a scale of 1 to 10, how do you evaluate your English proficiency? In which of the speaking, reading, listening, or writing do you think needs more improvement? How does the lack of proficiency in x skill influence your group participation? Is there any adjustment in your group composition or the activity that can support you? For example, do you prefer to be in a group with other ELs or with your non-EL peers?
Hypothesis 6 - ELs have problems with understanding activities with a heavy reading portion - if they cannot understand the model they won't be able to contribute to the group conversation	Tell me about your experience working on POGIL activities as an EL and non-EL. Tell me about the challenges you experience when working on POGIL tasks In what ways could the POGIL activities be modified to help you develop a better understanding of the topic?
Hypothesis 7 - Scientific language is already difficult for most students and learning science language can even be more challenging for EL students.	In what ways do you feel that the scientific language and terminology in the class becomes a barrier or is it beneficial for your participation in small group conversations?
Hypothesis 8 - Some ELs prefer to ask their questions from the instructor - in some cases even outside the class Hypothesis 9 - When student have a sense of belonging they're more likely to engage in a small group conversation - relationship with instructor	Do you prefer to ask your questions from the instructor? Or your peers in your group? And why?

D. Data Analysis

Each interview was analyzed separately then thematic analysis was used to analyze all interviews of both the Spring 2021 and Fall 2021 semesters. Thematic analysis (TA) is a qualitative analytic method that involves finding repeated meaning across a data set (Xu and Zammit, 2020). The first step of analyzing the interviews thematically was to familiarize ourselves with the data. To do so, 177 videos from the spring semester were transcribed to observe students' engagement in their small groups. Those transcripts served as a tool to hypothesize challenges ELs face in their small groups, and therefore, we were able to come up with interview questions. In addition, analytical memos were made to make sense of the data and record ideas and questions that came up during the transcription and first listening to the interview processes. In the subsequent step, transcripts were used for a constant comparison analysis where the data were reread several times, and initial codes were generated. During this process, interviews were used to capture students' views fully by involving their own language as codes (Vivo codes). We looked at their answers for every question and compared their answers to our hypotheses. After familiarizing with data and developing codes, the next step involved searching for general themes. In this step, broader patterns of shared meaning across the data set were identified. Data from the fall and spring semesters were compared and common patterns were identified. Key findings from interviews were used for triangulation purposes and to make sense of ELs students' engagement and challenges in their small groups.

IV. Results and Discussion.

This chapter discusses the analysis of each interview from the Fall 2021 and Spring 2021 semesters. The names used in this study are pseudonyms to keep the confidentiality of the participants. The chapter explores the following nine findings based on our data and the analysis from the interviews: 1) we redefined the ELs population because we found that there are different subgroups among the ELs population, 2) K-12 ELs students are more engaged in small group conversations, 3) ELs students are not familiar with the expectations and norms of the class, 4) Personality influences participation in small group engagements positively, 5) English fluency limit ELs to express themselves on scientific tasks, 6) scientific terminology is a barrier for EL students, 7) stereotype threat isn't a barrier for EL engagement in group conversations, 8) the chapter discusses ELs experiences with POGIL activities, 9) ELs have a sense of belonging due to their relationship with the instructor.

A. Case Studies from the Spring 2021 Semester

Rachel

Rachel has identified herself as an EL student in the consent form (See Appendix C). She was part of Delta group which was composed of 2-ELs and 2 non-ELs students. She was born in North Carolina. She learned English from her neighbors and from school. She was enrolled in an English as a Second Language (ESL) program early on in her education. She is a child of immigrants, and her first language is Arabic. Based on the group recordings, she was the one initiating the conversation in her group and was helping her peers when they had any questions. Rachel stated in her interview that she felt comfortable engaging in her small group.

Luna

Luna has identified herself as an EL student in the consent form (See Appendix C). She was part of the Charlie group with two other ELs and one non-EL. She came to the United States when she was five years old. She is a child of immigrants who grew up knowing only Spanish as her first language. Luna identified herself in the interview as bilingual. She attended kindergarten in the US and according to what she said in her interview, she taught herself English. About halfway through the semester, Luna had to travel back to El Salvador due to one of her family members having health issues. This has affected her learning, but she stated that being in a small group helped her to be caught up on the material for the class.

Faith

Faith is an EL student who identified herself as an international student in the consent form (See Appendix C). She was part of the Foxtrot group who had 2 ELs and 2 non-ELs. She is from Kenya, and she moved to the United States to get her undergraduate degree with a student visa. Faith stated in her interview that she doesn't have any relatives in the US but she has friends, also from Kenya, who live here. Based on our observations from the group recordings, Faith was an active listener in her group. She didn't engage in group conversation the majority of the time. She stated in her interview that her English language proficiency was a barrier for her to engage because she feared being misunderstood by her peers.

Fiona

Fiona has self-identified herself as an EL student in the consent form (See Appendix C). She went to pre-school in Iran and went to Kindergarten in Turkey then started first

grade in the United States. She stated some challenges she faced when learning English as her third language. Fiona mentioned that she experienced a culture-shock coming to the United States. She is a child of immigrants, and she is trilingual with Farsi being her first language, Turkish being her second, and English as her third. Fiona also shared her experience with COVID and how it has affected her mental health and learning. Our data showed that Fiona missed many classes throughout the semester, however, whenever she was present in her small group she would engage in the conversation.

Joy

Joy has identified herself as an EL. However, she was a student in the Honors section of the class. The Honors section was also a POGIL-based class and was taught by the same instructor. Joy is a child of immigrants who was born in the United States. Her first language is Arabic. She was interviewed to gather more data on ELs who were taking the class in the same semester, and she was asked the same interview questions. In her interview, Joy expressed that being in a group was helpful, but she wished her group composition was consistent and wasn't changing every week.

B. Case Studies from the Fall 2021 Semester

Sarah

Sarah has identified herself as an EL student. She is originally from Egypt and her first language is Arabic. She came to the United States when she was in eighth grade. Sarah was placed in the Limo group with three other ELs students. Her group didn't have non-ELs students. All ELs students in Sarah's group were also from Egypt and they all spoke Arabic. Sarah mentioned that she knew her peers in the group prior to taking the course and she stated that they went to high school together. Sarah's group engagement was great

because the discourse was completely in Arabic. Therefore, she felt comfortable because she was speaking in her native language. However, Sarah mentioned that when a non-EL student joined the group, the engagement was affected badly, and she did not engage in the conversation at all.

Paul

Paul has identified himself as an EL student in the consent form (See Appendix C). He is originally from Egypt and Lived in New Jersey for a couple of years before moving to Tennessee. Paul moved to the United States when he was in high school. He is part of the Golf group which had 2 non-ELs students and he was the only EL in his group. Paul enjoys being in a small group and finds it very helpful. Based on our observations using the group recordings, Paul is more of an active listener in his group. In the interview, he mentioned that he engaged vocally a couple of times but most of the time he's just listening to his peers.

Casey

Casey self-identified as an EL student. She came to the United States when she was in middle school. She is originally from Egypt and her first language is Arabic. Casey was part of the Limo group, and she was one of the three other ELs in her group. Casey was in the same group as Sarah. In her interview, Casey stated that she's been in the United States the longest out of her group, so she felt the pressure that she had to know what was going on in the class. She also mentioned that sometimes her group had to use google to translate some of the questions in the POGIL handouts which affected her learning because she felt like her group didn't have enough time to answer all the questions asked. Casey said that being in a small group has created a safe environment for her to ask questions. In addition,

she shared that having the same group in the lab also helped her connect with the instructor and her peers as well.

Kevin

Kevin identified himself as an EL student in the consent form (See Appendix C). Kevin is originally from Egypt, and he came to the United States in the eighth grade of middle School. His parents are immigrants, and his first language is Arabic. Kevin is part of the Limo group with 3 other EL students. While Kevin likes to work by himself, he enjoys being in a small group. He feels comfortable and confident and thinks being in a small group is helpful. Kevin shared that he didn't feel comfortable when he was moved into another group due to his group peers being absent. He felt rushed and overwhelmed that the group was moving fast. Kevin also shared his struggles with how his chemistry prior knowledge has affected his learning and his group engagement.

C. Redefining the ELs population

Upon starting this study, we divided the population of students in the classroom into English Learners (ELs) and non-English Learners (non-ELs) (see Figure 3). However, a closer look at the data showed that there are three subgroups among the ELs population. Based on the educational background question we asked the students in the interview; we discovered that students who were born in the United States or have studied here from pre-school to college are more likely to be bilingual students rather than English Learners (ELs). In this case, we decided to refer to them as K-12 EL students. In this study, Rachel, Luna, Fiona, and Joy are classified as K-12 EL students (See Table 4). Students who came to the United States with a student visa, have no educational background in the United States, and have identified themselves as International Students in the consent form are

referred to as EL-I students. Fiona was the only student that we classified as an International EL (See Table 4). Finally, students who immigrated to the United States at an older age and have a much lower experience in the American educational system are referred to as EL-SE students (English Learners-Secondary Education Students). As our data have shown, those students came during their secondary education years and are facing more barriers with their English language proficiency than K-12 students. All students from the Fall 2021 semester were classified as SE-EL students (See Table 5).

Figure 3

A) EL Population vs. Non-EL Population

B) EL Population vs. Non-EL Population After Redefining the EL Population and Dividing Them Into Subgroups.

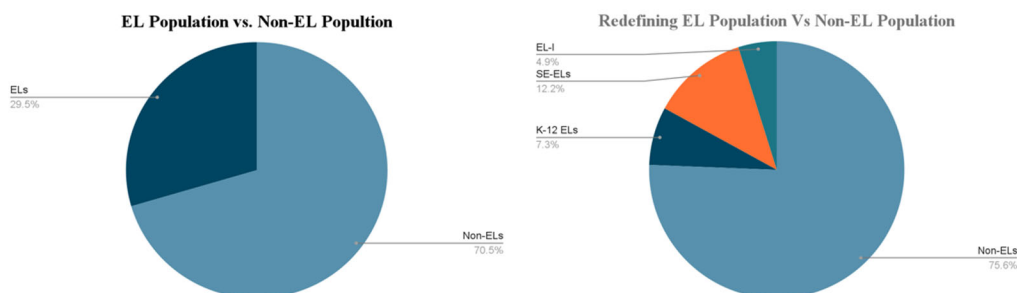


Table 4*Type of ELs student in the Spring 2021 Semester.*

Spring 2021 Semester	
Participant Name	Type of EL Student
Rachel	K-12
Luna	K-12
Faith	EL- I
Fiona	K-12
Joy	K-12

Table 5*Type of ELs student in the Fall 2021 Semester.*

Spring 2021 Semester	
Participant Name	Type of EL Student
Kevin	SE-EL
Sarah	SE-EL
Casey	SE-EL
Paul	SE-EL

D. K-12 ELs are more Engaged in Small Group Conversation

Based on the recordings of the small group conversations, we found that K-12 EL students are more engaged in small group conversations than other ELs students. When we asked students in the interview how working in small groups made them feel and if there was a time they felt uncomfortable, K-12 ELs students answered that they feel comfortable

working in small groups and find it helpful working with their peers. Rachel, who is a K-12 EL student from the spring 2021 semester, stated in her interview:

I like working in small groups because you know, if there's something that like, I don't understand, usually my partner will. Or if maybe my partner understands something, it gives me a chance to think through it because I feel like when you when you're teaching it to somebody else, you're thinking through it more, remembering it more for the exam. So it's really helpful to me. (Rachel, 2021)

Fiona, who is another K-12 EL student from the spring 2021 semester, said, “I just think small groups are really helpful in making people feel more comfortable asking questions.” Therefore, K-12 EL students feel comfortable in their small groups and don’t have any challenges to contribute to the discussion when it comes to feeling comfortable with their peers.

For EL-I students, our data showed that they like being in a small group because it gives them the opportunity to discuss and ask questions. However, some international students struggle with feeling comfortable to contribute to the discussion due to the fear of not being understood. Faith, an international student, stated in her interview “everyone can contribute ideas...you can ask your fellow group members to at least elaborate for you...At first, it was so hard for me, but, you know, as the time goes, you, you adapt you...you know, it's sometimes it's not effective actually, because sometimes you can type and somebody doesn't understand that.” Based on our observations from the small group recordings, this international student was an active listener in her group and wouldn’t engage in the conversation. Therefore, our data supports that international students have a fear of being misunderstood which affects their small group engagement.

EL-SE students also feel comfortable engaging in their small groups. All four of the EL-SE stated in their interviews that they feel comfortable engaging in their small groups and asking questions because it gives them the ability to share ideas and help each other. Sarah shared in her interview “I feel comfortable working with the groups, because working as a group gives you the ability to like share ideas” In another interview with an EL-SE student, Kevin stated “I'm confident and comfortable because I know these people, so it's fine. If I got something wrong, it's fine to discuss with them what's right, what's wrong. What's what we have to do? And this step? Yeah.” Therefore, EL-SE students feel comfortable to engage in a group discourse.

An interesting finding was that EL students are less likely to participate in the discourse if the group composition changes during the semester. This observation was made based on what some of the fall semester EL students stated in their interviews. In his interview, Kevin stated:

One time, they all were. They all were absent. So I went to work in another group. I didn't feel comfortable because they were talking together. Like, they not ignore me. But they weren't comfortable with me, because I didn't like talk to them before. Yeah. So I was working by myself. (Kevin, 2021)

In addition, Joy, one of the EL students who was interviewed from the Honors section, mentioned that the group composition in her class section was changing weekly and she would have preferred to have the same people in her group. Joy stated:

There were a lot of groups where I was like the one who would start talking, and then other people would join in, because sometimes you're putting groups where nobody talks...it's randomized. So I'm not with the same people every time. And

it's kind of rare when I'm put with the same person... it would have been nice to build up with the same people. (Joy, 2021)

Therefore, we perceive having consistent group compositions is crucial for ELs to feel comfortable to engage in the small group conversation. They get used to their peers and start to build a relationship with them.

E. ELs Aren't Familiar with the Expectations and Norms of the Class

Based on our findings, ELs are not familiar with the expectations and norms of the class. Based on the interview done with the instructor, she expects students to answer her questions, to show up to the class, and to participate in class and group discussions. Out of the thirteen ELs who participated in the study, two of them were somewhat familiar with the expectations and norms of the class. Those two students were K-12 ELs students. The first one, Rachel, stated “she expects us to be present to show up on the days that were assigned. I guess she just expects us to put in an effort and things like that.” The other student, Fiona, mentioned “to definitely prep yourself before class. So do the readings, do the practice problems, even though they're like you're not going to take them up from you and come to class prepared to ask questions, ask for help.... if you put in the time into your classes, if you go to classes, that's a big expectation for her.” Therefore, we assume their familiarity is based on having a good educational background of the education system in America. On the other hand, EL-I are not familiar at all with the expectations and norms of the class. Faith stated “you're given like three topics to understand and be able to, to answer the questions.....you can ask your fellow, you know, it's so easier, you can ask your fellow colleague than asking the professor directly, you know” Her response doesn't support the instructor's expectations of the class.

SE-ELs students struggled the most with understanding the expectations and norms of the class which has affected their engagement in the group conversation. According to Kevin, he stated “she expects us to know more about chemistry and to know more about the things that she gave us without excep..., like, without going over the answers...That was the hardest part in the class.” Casey also stated:

I think Dr. Phelps' expectations are high because she, although she goes a lot in details, but she also expects us to learn on our own and search and like, go over work. And she expects us to like to give effort even out of the class, because I realized this mostly on her homeworks there was a lot of things that I didn't know, I had to go and like search and watch video. (Casey, 2021)

This was a challenge that SE-ELs faced because their chemistry prior knowledge isn't enough for them to be able to answer POGIL questions and therefore, it would set them back in trying to learn a new concept. Therefore, if ELs students are not familiar with the expectations and norms of the class, they won't be able to participate in their small group conversation.

F. Personality Influences Participation in Small Group Engagements Positively

After analyzing the spring semester's interviews, we decided to expand the project and investigate ELs students in the Fall 2021 semester. We decided to add more questions to the interviews to test more hypotheses we made after our preliminary findings. One of our hypotheses was that a personality trait could possibly influence an ELs student participation in the class and in their own small groups. For example, a student who is extroverted is more likely to engage in small group conversation than a student who is introverted.

Prior to interviewing ELs students, each student was invited to take a personality test (See Appendix D) to see if specific personality traits could affect their group participation. Students sent the results to the personality tests via email. During the interview, ELs students were asked about the influence of their personality traits on their small group engagement based on the test they took. Sarah, an SE-EL student, stated in her interview “ I remember that it was true that I like working with groups but like, like, you know, the same language, like all my friends, I was working on them. They were like, super helpful because they can explain the things I don't understand.” Based on her answer, while Sarah’s personality test results were accurate, she doesn’t think it affects her engagement in the group conversation because she feels comfortable talking to her peers.

Casey, an SE-EL student, stated in her interview that her personality results were accurate, and she mentioned that being an extrovert helped her engage and talk in her group. She said:

One of the one of these results was that I was extrovert and this definitely helps me with like the group work in class because it's hard for me I was so scared that the beginning which he said, we're gonna do groups and like the videos like the cameras watching us and that we have to act a certain way or things like that, but then, like being an extrovert helped me a lot like when communicating with my friends and classmates to solve problems and not being shy. (Casey, 2021)

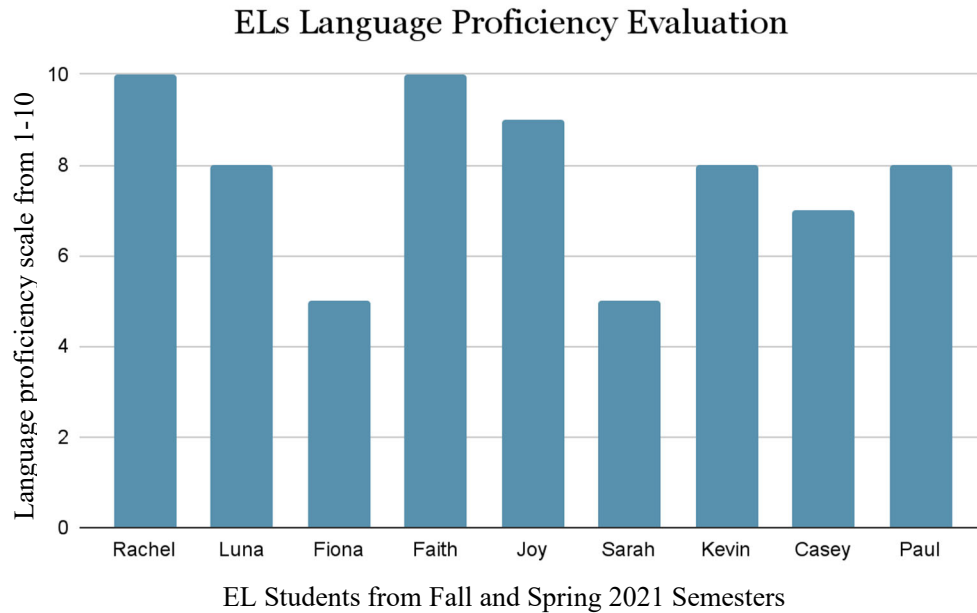
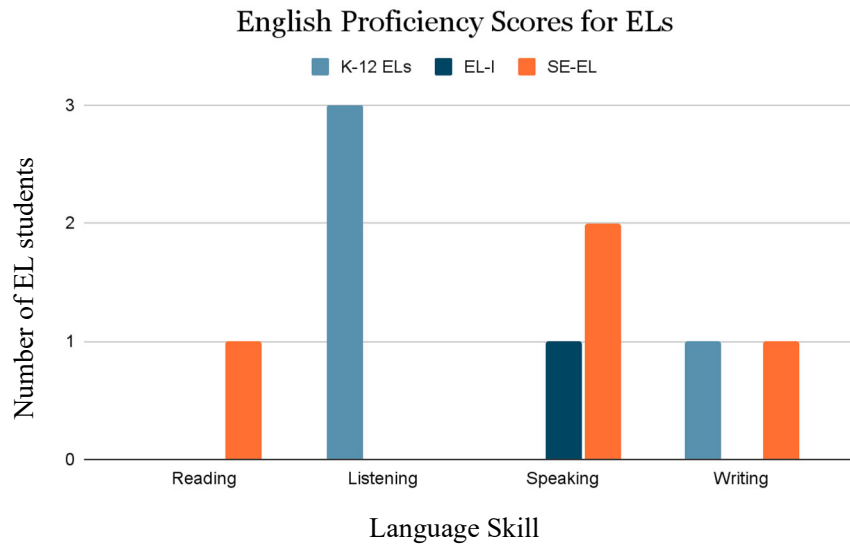
In this case, Casey considers that her personality benefited her in participating in the small group discussion and it had a positive influence on her engagement. In addition, based on our observations from the group recordings we collected, Casey was engaging in her group and she was the one who was responsible to keep her group on track and write

down the answers to the questions in the POGIL handouts. Kevin also stated that his personality influenced his group engagement in a good way as he mentioned “I think yes, it flows my group by because one of my results was like not giving up on something the im like if I didn't know what I'm gonna do, and that helped my group that we tried more than one time until we get the answers that we need.”

In conclusion, our data do not support our hypothesis that an EL's participation in small group discussions is influenced by a personality trait. According to ELs' responses in their interviews, personality traits impacted their group engagement positively. In other words, a personality trait is not a barrier to ELs engagement.

G. English Fluency limit ELs to express themselves on Scientific Tasks

English fluency was found to be a barrier to all subgroups of the ELs student population. In the interview, we asked students to evaluate their English proficiency on a scale of 1 to 10. This question was asked based on how ELs identified on the consent form that English is not their first language. We observed that our K-12 students ranked their English language proficiency higher than EL-I and SE-EL students (See Figure 4). In addition, we asked what language skill (speaking, reading, listening, or writing) did they need the most improvement on. K-12 students Rachel, Luna, and Fiona stated that they need more improvement on their listening skill. Our international student said Speaking. SEL-EL students had different answers to this question; Sarah said she struggled mostly with speaking and writing, Casey said she struggled with writing, Paul said he struggled with reading, and Kevin stated that he struggled with speaking the most. To compare their answers, we created a chart to help us visualize the differences (See figure 5).

Figure 4*ELs Language Proficiency Evaluation on a Scale from 1-10***Figure 5***English Proficiency Scores for ELs*

As a result, K-12 EL students struggle mostly with Listening. One of the K-12 EL students, Luna, stated in her interview:

Like, if I'm, if my thoughts are in Spanish, and then I have English coming at me, it like gets jumbled in my head sometimes. And so sometimes that switches involuntary, and I can't turn it off, and then I'll be in a lecture or in a lab, and then I'll just have straight Spanish thoughts. And then I'm like, how, and then I'll read like the lab report. I'm like, this does not make any sense to me...I don't think it plays that big of a part. However, if there was another one, then I would automatically feel like that switch turned on, or I would just have Spanish thought. (Luna, 2021)

Luna struggled mostly with listening because sometimes she unconsciously starts thinking in Spanish and therefore, listening becomes a barrier for her. Rachel also stated that she struggles with listening and it influences her learning because she would constantly ask for clarification. As she stated,

Sometimes I have to ask my team member for clarification on like, what exactly we're doing. If she went through the instructions too quickly, or if I was looking at something else, I sometimes I can't like, look at something and read something and then like, Listen to the same time. So I'll have to ask for clarification and things like that. (Rachel, 2021)

EL-I student mentioned in her interview that she struggles mostly with speaking. Earlier in her interview, Fiona described her fear of participating in the group discussion was due to her language proficiency. She stated in her interview “Sometimes I I feel like I'm not comfortable speaking because of my English...like, some people understand. And others don't. So you don't know. Like, if someone will judge you or...” Therefore, Fiona's

lack of speaking skill is a barrier for her to participate in a group discussion creating a fear of being judged and misunderstood.

SE-EL students needed improvement on different proficiency skills. However, they stated that it didn't influence their group participation because they spoke Arabic in their group. While the language proficiency skills didn't influence their engagement, it did influence their learning. For example, Casey struggled with writing and stated in her interview "Well, it does some words like I mean, sometimes I'm like, okay, hold on, wait, let me translate this and then come back to you." This resulted in her group taking more time to translate the question and then think about answering it, which meant that they were set behind. Another downgrade to the group speaking in their native language and not in English is that the instructor couldn't tell if they were constructing knowledge and learning new concepts accurately which was a critical part in the learning cycle of constructing knowledge.

H. Scientific Terminology is a barrier for EL students

In the interview, we asked EL students if the scientific language and terminology in the class becomes a barrier or if it's beneficial for their participation in their small group conversation. The reason we believed it might be beneficial for them is because both ELs and native speakers are learning new terminology and concepts. Therefore, they wouldn't be at a disadvantage since both populations are not familiar with the topics taught in class. We hypothesized the reason it would be a barrier is due to their language proficiency. For K-12 students, we found that some students find it a barrier and some don't. For example, Rachel stated that she doesn't find it a barrier to her group engagement. Luna on the other hand found it to be a barrier. She stated in her interview:

I tell my group all the time, that the big words scare me. Because I'll know like, what they mean, and like how to get there, but it's just, I guess, seeing like, the bigger terminology, that always just freaks me out for some reason. But I think, as a bilingual person and seeing like a bigger word, I naturally try and digested like, Oh, that's like, and then the Spanish translations, but at the same time, like, I didn't grow up, trying to find out what the word equilibrium was in Spanish. So sometimes it's hard. But I think that, honestly, if you just keep up with the lectures, it's not as terrifying, you know. (Luna, 2021)

Faith, another K-12 student, stated in her interview:

I think the only thing is like coming into college coming into academia, it's like everybody starts using big words like the professor's use big words. And everybody's I kind of expected to know them. And I don't struggle like all the time in general, because I feel like I use context clues to fill it in. And that's what I always did as a kid when I wouldn't read. But I think that's struggled for everybody...So I think it's terminology. So if you don't understand the vocabulary, it makes it harder. So like, as someone who used to read a lot as a kid, like, I can kind of figure out what things mean using context clues. But that makes it a lot harder as if you don't know what's going on. (Faith, 2021)

She also shared, “I'm a first-generation college student. So like, there's nobody in my family who's like, use this terminology. There's nobody in my family who like uses all these big words. There's nobody in my family who's talked to me or can talk to me about these concepts. So it's just kind of like, figuring it out for myself. Whereas like, oh, like”

Hence, we found that K-12 ELs find learning the scientific terminology as a barrier, and when it is not a barrier it doesn't necessarily mean it is beneficial to their learning or engagement in their small groups. For EL-I, Fiona stated that she doesn't find the scientific terminology a barrier. Finally, SE-EL students find the scientific language a barrier to their learning. For instance, when Sarah was asked in the interview about learning new scientific terminology, she stated "I think yes. Because most of the time, I know the stuff. I know like some things in Arabic now in English, so most of the time I get confused between both of them." Furthermore, Casey stated:

Usually it is, when it comes to science. Usually the words the thing I'm like, what is that? Because I don't even use it. And I didn't heard about it. Like, maybe if it's like, me, I would know science words, when I went in in Arabic even though I didn't study it...And so I'm don't have any background about like anything about science, or like, what is this word mean? Or what is this organ mean? Or like, what is what is that term? And so it's kind of, you have to learn it in class. And so I did, it was like, kind of like I was saying, I didn't have to translate a lot of the words in it was like a main word in a question. Like, where and when you if you don't know this word, just don't know anything. (Casey, 2021)

Kevin also stated "yes...And when the teacher comics, please do like, it's easy to forget the words to figure out the language and the questions." However, Paul disagreed with the other SE-EL student saying it wasn't a barrier to him because he utilized his group to ask them if he didn't understand anything or he would ask the instructor of the class as he states, "Oh, no, no, I usually asked my group members if something I didn't get maybe or or Dr. phelps, of course." In conclusion, the majority of SE-EL students find scientific

terminology to be a barrier to their learning when one word could affect their understanding of the whole concept. In summary, the scientific terminology is a barrier for most K-12 EL students and SE-EL students. According to our data, it was not a barrier to our EL-I student.

I. Stereotype threat Isn't a Barrier for EL Engagement in Group

Conversations

Similar to our personality hypothesis, we hypothesized that stereotype threats could be a possible barrier for ELs to engage in their small group conversations. This hypothesis was made after our preliminary findings from the Spring 2021 semester. To test this hypothesis, we gave ELs the definition of stereotype threats and provided an example on how Asians face a stereotype that they are expected to be intelligent due to their race. After providing the definition and example of stereotype threats, we asked ELs if they faced any stereotype threats while working in their small groups. Three out of four students stated that they haven't experienced any stereotype threats. Casey was the only one who experienced a stereotype threat in her group stating:

We all come from like, a specific background...but I would say one of the things that we that really comes up is the idea that oh, you spend in America the most so you must be like the the smartest, like it does, like they don't see that it's not about like being here the most, like knowing the language the most because like, some of us is an the group been there, like was born here. And so they know the language the best, you know? And so, mostly like, Oh, so you've been here the most so you must like understand everything. Like it's not it's not the language like because we

won't be born in them country, their country, their own country, and you know that language (Casey, 2021)

Casey experienced a stereotype threat when her group measured how smart she was based on her language proficiency and how long she's been in the United States. Casey has been in the United States the longest out of her group so she felt the pressure that she had to know what was going on in the class. Overall, ELs don't face stereotype threats from their group peers and therefore, it is not a barrier for them in their small groups.

J. ELs and their Experience with POGIL Activities

In this case study, students had to answer questions on their POGIL handouts in their small groups. Each POGIL handout had a module for students to read to guide them and help them learn the new concepts as they are answering the questions following the module. The information that were provided in the module were different depending on each POGIL handout. Some modules had definitions, tables, graphs, background information about the topic, or an equation. Students were expected to read the module before answering the questions to better understand the concept and answer the questions.

We hypothesized that ELs students would face challenges working POGIL activities due to heavy reading portions. Therefore, if they cannot understand the module they won't be able to contribute to the group composition. To test this hypothesis we asked ELs students to share their experience working on POGIL activities, what challenges they faced while working on POGIL tasks, and in what ways they would modify the questions to help them better understand the concepts.

K-12 student Rachel shared her experience working with POGIL activities stating, "I really haven't really had many challenges with POGIL activities. Usually when I don't

understand something, you know, my partner will or like I said before, Dr. Phelps will come in and explain it. So I think it's been pretty. It's been running pretty smoothly. I wouldn't say I had any challenges.” Later on in the interview, Rachel explained that she would have preferred if the instructor of the course would have lectured before working on those activities as a group. She felt that the modules weren't enough to introduce the topic or help them answer the questions. As for Luna, she said in her interview that she took the prerequisite course with the same instructor the semester prior to Spring 2021 semester so it was helpful that she was exposed to the POGIL learning approach. She stated:

As far as challenges or like experiences with the activities, it's mainly just, if you don't have a solid grasp of the material, it's obviously going to be a disadvantage when you're doing the activities. And they're set up to help you understand as you go along. But if you don't have like that base understanding, then really is. And that's been in some cases for me, if you don't have like that solid understanding then your group is basically teaching you kind of as you go through the sheet, but I do like how it starts off. Like from the base, and then it just goes on with all of the information that we're learning. Because then like, we can use what we applied in like, previous questions on the same worksheet as we go along, down the sheet.

(Luna, 2021)

Overall, Luna had a good experience working with POGIL handouts. She finds it challenging when her prior knowledge isn't enough for her to be able to answer the questions. Answering the POGIL questions is like going through a cycle to learn the concept and every question builds upon each other. Therefore, if the student faces a challenge in one part of the cycle, it will affect their learning.

International student Fiona enjoyed working on the POGIL handouts but she found time to be a challenge. When Fiona was asked about her experience working with POGIL, she said that she found the handouts to be helpful but she did face a challenge with time as she stated, “Okay, sometimes Oh, yeah. Sometimes we have like a minimal time. For example, Dr. Phelps often gives us five minutes. And then we do we do. Some of the, like, asking someone, and then before that time and before he or she answers. Yeah, that's the I can see that being an issue. Because sometimes we are given like, five minutes. We discuss something.” When Fiona was asked in what ways she would modify the POGIL activities she said she would want to have more time to work on them as she stated “Okay, I think... timing... that is the one because the question will remain if this is no way you can make up...so you feel sometimes the questions are, like long that you don't have enough time to answer all of them? is that”

Fiona was not the only student who mentioned that time is a challenge while working on POGIL handouts. Casey mentioned in her interview that she felt rushed working on the questions and that she didn't have enough time to answer all the questions assigned. She shared her experience working on POGIL activities stating:

Well, most of our issues with it is the language like there's like, like, a chemistry word, or like some big science word that we don't understand. This is more like we use translate translator all the time, like, a lot of the time, actually. And, yeah, they like, but the papers itself, it really helps with like, the testlings. Like we always make sure that we finished everything and everything is right, because like without these papers, I would have have passed any of my teslings. ...I would say with time, I don't I don't there's not a specific challenges. But it's time, like the time because

you know, we have to finish things in the class period, because we have test every week. And so you want to finish all of it, because you want to know everything in here, because it's gonna come into test and you're gonna miss something. And so we be rushing, rushing, we need to know everything before the class ends, because you don't have any other time, you know? So i feel like, they're a little big, but I understand why they are like, there are many questions because every thing, everything comes into this. (Casey, 2021)

Casey expresses how necessary it is for her to finish all the questions in a POGIL handout to perform well in the class. The two challenges she faced with POGIL were time and her language proficiency. Sarah also shared how she struggled understanding the concept due to her language proficiency. She stated:

But some words is, like hard to understand. for most students...Sometimes. Yeah. I would say it's helpful sometimes, but sometimes sounds like, I feel dumb....And sometimes I don't mean, I don't even know the topic we're covering class. Like chemistry related the content part....I would say, how I like, so I know the answer sometimes, but I forget or I don't know how like to put in complete sentences or on a way that makes sense. like I will know, like, a points to the answer. And I couldn't like type it or say it to make sense (Sarah, 2021).

Based on the data, SE-EL students and EL-I students had more challenges working on POGIL activities than K-12 students. For SE-EL students, their language was the main barrier. In their small groups, SE-EL students had to spend time translating some of the POGIL questions. For EL students who are not proficient in English, reading the prompt in English, processing the information and making sense of it, organizing the ideas in a

coherent way, and translating them into English take longer time than non-ELs students. The process of translation imposes a higher cognitive load for ELs that can increase the time that they need for externalizing their ideas. Thus, while they are preparing what they want to share with the group, a non-EL has already answered the If language wasn't an issue, SE-EL students wouldn't find POGIL handouts as challenging. As Sarah stated in her interview, "I will say like, I think it's helpful. If English is not the issue, it's helpful...'adding more pictures, or visualising can be helpful for someone whose first language is not english' Yeah, It'll be helpful for both of us"

An interesting finding was that ELs learn better when the instructor uses an analogy. Many ELs students have mentioned in their interviews an instance where the instructor used an analogy to teach students about equilibrium. The analogy described equilibrium through a manufacturing company that had 100 employees in the building at once and throughout the day twenty employees go on break each hour as twenty other employees return from break (See Figure 6). This analogy aided them to understand the definition of equilibrium and hardened the concept in their head.

Figure 6

Analogy for Dynamic Equilibrium

*Model 1:
Dynamic
Equilibrium*



Acme Manufacturing has been restricted to 100 employees in the building at one time. Throughout the day, twenty employees go on break each hour as twenty other employees return from break.

In summary, ELs face challenges and barriers when working on POGIL activities. However, K-12 students face less challenges working on POGIL than EL-I and SE-EL students. EL-I and SE-EL students struggle with time management to answer the questions assigned by the instructor in a POGIL handout. One reason time becomes an issue is due to language. Some SE-EL students have to translate some of the questions in order to understand what it is asking. The scientific terminology is also a barrier when working on POGIL activities. Furthermore, ELs expressed that they learn better when an instructor uses an analogy to teach a concept.

K. ELs have a sense of belonging due to their relationship with the instructor

Our data have shown that ELs students have a sense of belonging because they are comfortable with the instructor who created a safe environment for them to be able to ask questions. We asked ELs students if they preferred to ask questions from the instructor or their peers. K-12 students Rachel, Luna, and Faith stated that they prefer to ask their peers. EL-I student Fiona and SE-EL student Sarah prefer to ask questions directly to the instructor because the instructor is a valid source meaning they would get an accurate response. SE-EL students Paul, Casey, and Kevin all stated that they feel comfortable to ask the instructor questions but they tend to ask their peers first before going to the instructor. Therefore, ELs students feel comfortable asking their instructor questions. When ELs were asked to share how they perceive their relationship with the instructor and the instructor's relationship with their peers, they agreed that the instructor has a great relationship with them and with their peers. They also mentioned that the instructor doesn't show favoritism.

L. Conclusion

Overall, our results showed that ELs students face challenges and barriers while engaging in a small group setting in a POGIL-based general chemistry class. Data from the spring 2021 and fall 2021 semesters revealed that the population of English Learners is divided into different subgroups: K-12 students, SE-EL students, and EL-I students. Although each subgroup had similar challenges and barriers when it comes to engagement in small groups, differences among the subgroups are present. K-12 ELs are the least subgroup to face challenges when working in a small group setting. Our data showed the following about K-12 ELs students:

1. They feel comfortable engaging in discourse with their peers.
2. They have a sense of belonging because of their relationship with their peers and the instructor.
3. They are somewhat familiar with the expectations and norms of the class.
4. Scientific terminology can be a barrier to their learning.
5. Their language fluency doesn't influence their engagement significantly.
6. They find POGIL activities to be helpful for their learning but time can be an issue.

Next, SE-EL students face more challenges than K-12 students. Our data revealed the following on SE-EL students:

1. They feel comfortable engaging in discourse with their peers.
2. They have a sense of belonging because of their relationship with their peers and the instructor.
3. They are not familiar with the expectations and norms of the class.
4. The scientific terminology is a significant barrier to their learning.

5. Their language fluency doesn't influence their engagement in the group discourse.
However, their language becomes a barrier while working on POGIL activities.
6. Due to their language proficiency, SE-EL students often have to translate the POGIL questions in order to understand what it is asking them.
7. They learn better when the instructor uses an analogy.

Finally, EL-I students face the most challenges and barriers when it comes to engaging in small group conversations and learning through POGIL active learning approach. Our data revealed the following on EL-I students:

1. They don't feel comfortable engaging in discourse with their peers.
2. They struggle with having a sense of belonging. They have a fear of being misunderstood.
3. They are not familiar with the expectations and norms of the class.
4. The scientific terminology is a significant barrier to their learning.
5. Their language fluency influences their engagement in the group discourse.
6. They prefer to ask questions from the instructor.

To tie our findings back to the conceptual framework, we found that some of the challenges and barriers will affect different levels of the framework. Prior knowledge, internalization, habituation, externalization, and objectivation were all influenced by those challenges and barriers. Therefore, ELs' challenges and barriers in their small group conversations affect their engagement and influence knowledge construction.

Our data indicated that while ELs students' population is growing in our undergraduate STEM courses, there may be subtle differences in how they contribute to small group discussions. This finding can help researchers understand that classifying ELs

with other minorities and asserting that all minorities have similar needs—or just relying on the fact that their native language isn't English—won't be sufficient for the learning of this population of students. Since this study is a qualitative case study, we analyzed every interview separately and found common themes by doing a thematic analysis (See Tables 6 & 7). The findings of this study can help instructors who have EL students in their classrooms understand that EL-I students may require extra assistance in order to engage with their peers in group discussions more than ELs who have had time to cope with challenges related to language and culture.

Table 6

Summary of Spring 2021 Semester hypotheses and Findings for each ELs Student.

Spring 2021 Semester				
Conceptual Framework Levels	Rachel	Luna	Fiona	Faith
Prior Knowledge	Not affected	Affected	Affected	Affected
ELs are not familiar with the norms and expectations	Does not Support	Support	Support	Does not Support
Externalization/Objectivation	Affected	Affected	Affected	Affected
ELs students have difficulties engaging in a group conversation - they are quite in their group because they are uncomfortable	Does not Support	Does not Support	Support	Does not Support
A personality trait can influence ELs participation in the class and in their own groups	N/A	N/A	N/A	N/A
When student have a sense of belonging they're more likely to engage in a small group conversation - relationship with other students	Supports	Supports	Does not Support	Support
Students with limited fluency in English are not able to express themselves on scientific tasks and that sometimes ELs don't have the adequate vocabulary to express their ideas -this prevents them from participating in their group discussion	Supports	Supports	Supports	Does not Support
Stereotype threat is a barrier for ELLs' engagement in a group conversation.	N/A	N/A	N/A	N/A
Internalization/habituatation	Affected	Affected	Affected	Affected
ELs have problems with understanding activities with a heavy reading portion - if they cannot understand the model they won't be able to contribute to the group conversation	Does not Support	Does not Support	Does not Support	Does not Support
Scientific language is already difficult for most studenys and learning science language can even be more challenging for EL students.	Does not Support	Supports	Does not Support	Supports
Legitimation	Not Affected	Not Affected	Not Affected	Not Affected
Some ELs prefer to ask their questions from the instructor - in some cases even outside the class	Does not Support	Does not Support	Supports	Does not Support
When student have a sense of belonging they're more likely to engage in a small group conversation - relationship with instructor	Supports	Supports	Supports	Supports

Table 7

Summary of Fall 2021 Semester hypotheses and Findings for each ELs Student.

Fall 2021 Semester				
Conceptual Framework Levels	Sarah	Paul	Casey	Kevin
Prior Knowledge	Affected	N/A	Affected	Affected
ELs are not familiar with the norms and expectations	Supports	Supports	Supports	Supports
Externalization/Objectivation	Affected	Affected	Affected	Affected
ELs students have difficulties engaging in a group conversation - they are quite in their group because they are uncomfortable	Does not Support	Does not Support	Does not Support	Does not Support
A personality trait can influence ELs participation in the class and in their own groups	Does not Support	N/A	Supports	Supports
When student have a sense of belonging they're more likely to engage in a small group conversation - relationship with other students	Supports	Supports	Supports	Supports
Students with limited fluency in English are not able to express themselves on scientific tasks and that sometimes ELs don't have the adequate vocabulary to express their ideas -this prevents them from participating in their group discussion	Does not Support	Does not Support	Supports	Does not Support
Stereotype threat is a barrier for ELLs' engagement in a group conversation.	Does not Support	Does not Support	Supports	Does not Support
Internalization/habituatation	Affected	Affected	Affected	Affected
ELs have problems with understanding activities with a heavy reading portion - if they cannot understand the model they won't be able to contribute to the group conversation	Does not Support	Does not Support	Does not Support	Does not Support
Scientific language is already difficult for most studenys and learning science language can even be more challenging for EL students.	Supports	Does not Support	Supports	Supports
Legitimation	Not affected	Not affected	Not affected	Not affected
Some ELs prefer to ask their questions from the instructor - in some cases even outside the class	Supports	Supports	Does not Support	Does not Support
When student have a sense of belonging they're more likely to engage in a small group conversation - relationship with instructor	Supports	Supports	Supports	Supports

V. Discussion and Conclusion

Previous studies provide evidence suggesting that active learning approaches in introductory chemistry classrooms has improved students' outcomes in course performance and critical thinking as well as decreased achievement gaps between underrepresented groups and non-underrepresented groups. With the English Learners (ELs) population increasing steadily in the U.S., finding learning and thoroughly inclusive strategies for those who struggle to keep up in STEM classrooms due to achievement gaps and language barriers is essential. This study focused on ELLs' engagement in a small group conversation and possible challenges they faced. The following research question guided this study: What are the common challenges regarding engagements and small-group interactions of ELLs in a POGIL based general chemistry classrooms?

This research project concluded that ELs face common obstacles and challenges when engaging in their small groups. Some challenges include feeling overwhelmed while working in a group, answering models with heavy reading portions due to time, learning new scientific terminology and concepts, and language proficiency. Therefore, specific accommodations must be made in facilitation when instructing ELs due to English language proficiency and the challenges faced while working in small groups.

Professors need to be aware that while learning may still be achieved through active listening, it is more likely to occur and will be of higher quality when students interact verbally. Therefore, all students must be encouraged by their instructors to engage in class discussions. However, instructors should be aware that ELs can be more comfortable interacting and discussing with their classmates by creating a friendly and low-stress learning atmosphere. This study has established that ELs are not familiar with the

norms and expectations in the class. In order to learn and perform successfully, students must be aware of the norms and expectations in the class. As a result, instructors should explain such norms and expectations vocally and repeat them over the first few weeks of the semester to ensure that students are completely informed. Additionally, instructors must take into account that EL students require longer time to express their thoughts. It is crucial to allow them sufficient time to organize their ideas and present them to their peers. The environment should be created so that each student has the opportunity to participate in group discussions actively. Giving each student a role that is critical to the group's success can help instructors achieve this goal. Formal role assignments can divide up the group's responsibilities, giving each member of the group something to do that is relevant to the group's achievement on the learning task (Hoffman & Richardson, 2019).

Reading the prompt in English, digesting the material, making sense of it, arranging the concepts in a meaningful fashion, and translating the POGIL questions to English take longer for EL students who are not proficient in English. The translation process places a greater cognitive strain on ELs, which might lengthen the time required to externalize their thoughts. As a result, while they are planning what they will share with the group, a non-EL has already responded to the question. To solve this issue, instructors can aid ELs by passing the POGIL handouts to students a day or two before they need to work on them, therefore, allowing EL students to translate at home rather than spending time translating during class.

Our data indicate that while the number of EL students in our undergraduate STEM courses is increasing, there may be complexities to their contribution in a small group discussion. This observation can help researchers understand that classifying ELs with

other minorities and asserting that all minorities have similar needs—or just relying on the fact that their native language isn't English—won't be sufficient for researching this population. To understand ELs' experiences, further background knowledge is required. Researchers should be aware that the demographic of EL students may need to be redefined and that there are several subgroups with various needs within this population. In addition, instructors are also encouraged to use analogies to teach a concept. As our ELs students have shared, analogies are more likely to stick with an EL student than a regular definition of the concept. Since ELs students' language proficiency is limited, using visuals for them to learn a new concept is superior for their learning.

Limitations

The author of this study is an EL student who took the same class with the same instructor. As a result, the researcher's interpretation and analysis of the data might have been biased. The author attempted to lessen the influence of ELs researchers' personal experiences on the data by discussing the discovery and sharing the data with other researchers in the group. Another drawback of this study is that this is a case study, meaning the data originates from only one university and one classroom. As a result, the study's findings cannot be applied to other contexts without replication of similar analyses in a variety of settings and institutions.

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VII. Appendices

A. Appendix A

MTSU IRB 19-2253

IRB
INSTITUTIONAL REVIEW BOARD
 Office of Research Compliance,
 010A Sam Ingram Building,
 2269 Middle Tennessee Blvd
 Murfreesboro, TN 37129



IRBN001 - EXPEDITED PROTOCOL APPROVAL NOTICE

Thursday, October 21, 2021

Protocol Title *Collaborative Research: Investigating classroom discourse in active learning environments for large enrollment chemistry courses*
 Protocol ID **19-2253**
 Principal Investigator **Gregory Rushton** (Faculty)
 Co-Investigators Shaghayegh Fateh, Jonah Schiavone, Amy Phelps, Demer Kirbulut, Anika Chowdhury, Marzea Akter, Steven Berryhill, Oluwatobiloba Ayangbola (ota2g), Joshua Reid, and Fatima Kaya
 Investigator Email(s) *gregory.rushton@mtsu.edu and sf3u@mtmail.mtsu.edu*
 Department Tennessee STEM Education Center, MTSU

Dear Investigator(s),

The above identified research proposal has been reviewed by the MTSU Institutional Review Board (IRB) through the **EXPEDITED** mechanism under 45 CFR 46.110 and 21 CFR 56.110 within the category (7) *Research on individual or group characteristics or behavior*. A summary of the IRB action and other particulars in regard to this protocol application is tabulated below:

IRB Action	APPROVED for ONE YEAR		
Date of Expiration	6/30/2022	Date of Approval	6/11/19
Sample Size	100 (ONE HUNDRED)	Recent Amendment	10/21/21
Participant Pool	Primary Classification: Healthy Adults - 18 years or older Specific Classification: College students		
Type of Interaction	☒ Virtual/Remote/Online Interaction ☐ In person or physical Interaction – Mandatory COVID-19 Management		
Exceptions	1. Contact information allowed. 2. Audio or/and video recording are permitted for data collection. 3. Approved to use informed consent for verbal recruitment		
Restrictions	1. Mandatory ACTIVE informed consent using MTSU template; the participants must have access Part A of the informed consent. 2. All identifiable data/artifacts that include audio/video data, photographs, handwriting samples, and etc., must be used only for research purpose and they must be destroyed after data processing. 3. This study is NOT approved for online data collection.		
Approved Templates	MTSU Informed Consent		
Funding	National Science Foundation (NSF 1914813)		
Comments	This notice is updated to the 2021 Format (08/20/2020)		

Post-approval Requirements

The PI must read and abide by the post-approval conditions (Refer "Quick Links" in the bottom):

- **Reporting Adverse Events:** The PI must report research-related adversities suffered by the participants, deviations from the protocol, misconduct, and etc., within 48 hours from when they were discovered.
- **Final Report:** The PI must close-out this protocol by submitting a final report before **6/30/2022** (Refer to the Continuing Review section below); **REMINDERS WILL NOT BE SENT.** Failure to close-out or request for a continuing review may result in penalties including cancellation of the data collected using this protocol and/or withholding student diploma.
- **Protocol Amendments:** An IRB approval must be obtained for all types of amendments, such as: addition/removal of subject population or investigating team; sample size increases; changes to the research sites (appropriate permission letter(s) may be needed); alterations to funding; and etc. The proposed amendments must be clearly described in an addendum request form. The proposed changes must be consistent with the approval category and they must comply with expedited review requirements.
- **COVID-19:** Regardless whether this study poses a threat to the participants or not, refer to the COVID-19 Management section for important information for the PI

Continuing Review (Follow the Schedule Below)

This protocol can be continued for up to THREE years (**6/30/2022**) by obtaining a continuation approval prior to **6/30/2022**. Refer to the following schedule to plan your annual project reports and be aware that separate **REMINDERS WILL NOT BE SENT.** Failure in obtaining an approval for continuation will result in cancellation of this protocol. Moreover, the completion of this study **MUST** be notified by filing a final report in order to close-out.

Reporting Period	Regulation Deadline	IRB Comments
First year report	Progress report received (06/25/2020). A CR conducted on the protocol determined the study is in good condition and the PI may continue the protocol for an additional year. Minor amendment is also done as described later (IRB ID IRBCR2020-059). Current investigators: Rushton (PI), A Phelps, S Fateh, D Kirbulut, A. Chodhury, J Shrivane, M Akter, S Berryhill and J. Reid.	
Second year report	Progress report received (05/26/2021). A CR conducted on the protocol determined the study is in good condition and the PI may continue the protocol for an additional year (IRB ID IRBCR2021-097). Current investigators: Rushton (PI), A Phelps, S Fateh, D Kirbulut, A. Chodhury, J Shrivane, M Akter, S Berryhill, J. Reid, S. Zakher, O. Ayangbola and K. Aboulyamin.	
Final report	5/31/2022	NOT COMPLETED

Post-approval Protocol Amendments:

Only two procedural amendment requests will be entertained per year. In addition, the researchers can request amendments during continuing review. This amendment restriction does not apply to minor changes such as language usage and addition/removal of research personnel.

Date	Amendment(s)	IRB Comments
08/30/2019	Shaghayegh Fateh (sf3u - CITI28917043) is an approved co-investigator	IRBA2020-040
09/27/2019	Grace Millican (gem3h - CITI 33398256) is an approved co-investigator	IRBA2020-055
10/09/2019	Jonah Shrivane (jas2ta - CITI33000069) and Johann Mejia (adb2ev - CITI 33642204) have been approved to join the research team	IRBA2020-060
10/16/2019	Amy Phelps (amy.phelps CITI31797802) and Demet Kirbulut	IRBA2020-066

Institutional Review Board		Office of Compliance	Middle Tennessee State University
Date	Amendment(s)	IRB Comments	
	(CITI33739947) are added to the investigating team.		
12/06/2019	Anika Chowdury (ato4g - CITI8883231) is an approved co-investigator	IRBA2020-078	
04/10/2020	Marzea Akter (ma2ey: CITI8951155) is added to the protocol	IRBA2020-130	
05/11/2020	An interview protocol to interview the course instructor has been approved An updated informed consent template to add the interview protocol (IRBA2020-139) has been added.	IRBA2020-139 IRBA2020-143	
05/27/2020	Steven Berryhill (steven.berryhill@mtsu.edu; CITI7776875) is an approved co-investigator.	IRBA2020-145	
06/25/2020	Joshua Reid (jwr4k: CITI5610010) is added to the protocol.	IRBCR2020-059	
07/30/2020	Permitted to continue data collection with modified class structure that includes "hybrid" class sections with virtual interactions involving the platform Zoom.	IRBA2020-161	
08/20/2020	The informed consent will be administered via a Qualtrics link (on file). The investigating team is updated.	IRBA2021-173	
02/03/2021	Changes to data collection to allow hybrid methods are approved. This was done to address challenges due to COVID-19.	IRBA2021-212	
02/16/2021	Student worker Sylvia Zakher (swz2a - CITI9879058) is added to the protocol.	IRBA2021-216	
02/24/2021	Student worker Oluwatobiloba Ayangbola (ota2g - CITI8211312) is added to this protocol.	IRBA2021-220	
03/09/2021	Karolin Abouelyamin (ka0f - CITI9959130) is added to this protocol.	IRBA2021-225	
04/06/2021	A new student interview protocol is added.	IRBA2021-231	
07/23/2021	A new interview protocol is added.	IRBA2022-266	
10/04/2021	Fatima Kaya (CITI575996) is added to the protocol.	IRBA2022-296	
10/21/2021	A new instrument is approved.	IRBA2022-306	

Other Post-approval Actions:

Date	IRB Action(s)	IRB Comments
NONE	NONE.	NONE

COVID-19 Management:

The PI must follow social distancing guidelines and other practices to avoid viral exposure to the participants and other workers when physical contact with the subjects is made during the study.

- The study must be stopped if a participant or an investigator should test positive for COVID-19 within 14 days of the research interaction. This must be reported to the IRB as an "adverse event."
- The MTSU's "Return-to-work" questionnaire found in Pipeline must be filled by the investigators on the day of the research interaction prior to physical contact.

Institutional Review Board

Office of Compliance

Middle Tennessee State University

- PPE must be worn if the participant would be within 6 feet from the each other or with an investigator.
- Physical surfaces that will come in contact with the participants must be sanitized between use
- **PI's Responsibility:** The PI is given the administrative authority to make emergency changes to protect the wellbeing of the participants and student researchers during the COVID-19 pandemic. However, the PI must notify the IRB after such changes have been made. The IRB will audit the changes at a later date and the PI will be instructed to carryout remedial measures if needed.

Data Management & Storage:

All research-related records (signed consent forms, investigator training and etc.) must be retained by the PI or the faculty advisor (if the PI is a student) at the secure location mentioned in the protocol application. The data must be stored for at least three (3) years after the study is closed. Additional Tennessee State data retention requirement may apply (refer "Quick Links" for MTSU policy 129 below). The data may be destroyed in a manner that maintains confidentiality and anonymity of the research subjects.

The MTSU IRB reserves the right to modify/update the approval criteria or change/cancel the terms listed in this letter without prior notice. Be advised that IRB also reserves the right to inspect or audit your records if needed.

Sincerely,

Institutional Review Board
Middle Tennessee State University

Quick Links:

- Post-approval Responsibilities: <http://www.mtsu.edu/irb/FAQ/PostApprovalResponsibilities.php>
- Expedited Procedures: <https://mtsu.edu/irb/ExpeditedProcedures.php>
- MTSU Policy 129: Records retention & Disposal: <https://www.mtsu.edu/policies/general/129.php>

B. Appendix B**Interview Questions****Spring 2021**

1. Tell me about your educational background.
2. What are the expectations and norms in this class?
3. How does working in your small group make you feel?
 1. Why do you feel like that? Tell me about a time working in your group made you feel uncomfortable. Tell me about a time working in your group made you feel comfortable.
4. What do you like/enjoy during discussions in your group?
 1. Tell me about a time when you enjoyed and felt safe during your small group discussions.
5. When working in small groups, what do you see as your role? How do you see the role of your peers? (Have you ever initiated a conversation in your group?)
 1. Do you feel that your contributions are valued by your peers?
 2. In what ways do you feel you contribute to your group discussions and how often?
 3. What are some challenges to contributing to group discussions in your small group?
6. Tell me about your experience working on POGIL activities as an ELLs/non-ELLs?
 1. Tell me about the challenges you experience when working on POGIL tasks.

2. In what ways could POGIL activities be modified to help you to participate more in group conversation
 3. In what ways could the POGIL activities be modified to help you develop a better understanding of the topic?
7. How do you think your group peers see you as a contributing member of the group? Can you provide an example of a time when your peers made you feel like a valued member of the group? What about a time when you felt your peers did not value you?
8. You mentioned in the consent form that English is not your first language. On a scale of 1 to 10, how do you evaluate your English proficiency? (If they said something less than 10 then I can ask the below questions)
1. In which of the Speaking, Reading, Listening, or writing you think need more improvement?
 2. How does the lack of proficiency in x skill influence your group participation? Is there any adjustment to your group composition or the activity that can support you? For example, do you prefer to be in a group with other ELLs or with your non-ELLs peers?
9. Our classes are recorded on Panepeto. Do you go back to watch the class videos? Why?
10. In what ways do you feel that the scientific language and terminology in the class becomes a barrier or is beneficial for your participation in small group conversations?
11. While working on the activity, do you prefer to ask your questions from the instructor or your peers in your group? Why?
12. Do you prefer to be called on by the instructor to share your ideas, or are you more comfortable with answering on your own accord? Has an instructor ever forced you to

participate in class discussions? Which approach do you believe would help you be more successful?

Fall 2021 Semester

1. Tell me about your educational background.
2. What are the expectations and norms in this class?
3. What is the best way for you to learn (read from the book/watch videos/go to office hours/penapto/PowerPoints)?
4. Based on the personality test you took in class; do you feel that there's a specific trait that influences your participation (in a good or bad way)? How and why?
5. Do you have GroupMe or group chat for your group specifically? If so, tell us about that.
6. Do you have any study groups outside of the class? If so, Is it the same group that you work with in the class? Do you discuss course material with them before/after class?
7. Do you feel comfortable asking a question in the class/in your group and why?
8. Do you feel comfortable asking the instructor for help in the class and why?
9. Do you attend office hours?
10. How do you evaluate the instructor relationship with you? How about with other students?
11. While working on the activity, do you prefer to ask your questions from the instructor or your peers in your group? Why?
12. How does working in your small group make you feel? Why do you feel like that? Tell me about a time working in your group made you feel uncomfortable. Tell me about a time working in your group made you feel comfortable.
13. When working in small groups, what do you see as your role? How do you see the role of your peers? (Have you ever initiated a conversation in your group?) Do you feel that your

contributions are valued by your peers? In what ways do you feel you contribute to your group discussions and how often? What are some challenges to contributing to group discussions in your small group?

14. What do you like/enjoy during discussions in your group? Tell me about a time when you enjoyed and felt safe during your small group discussions.
15. How do you think your group peers see you as a contributing member of the group? Can you provide an example of a time when your peers made you feel like a valued member of the group? What about a time when you felt your peers did not value you?
16. Tell me about your experience working on POGIL activities as an ELLs/non-ELLs?
17. Tell me about the challenges you experience when working on POGIL tasks.
18. In what ways could the POGIL activities be modified to help you develop a better understanding of the topic?
19. You mentioned in the consent form that English is not your first language. On a scale of 1 to 10, how do you evaluate your English proficiency?
20. In which of the Speaking, Reading, Listening, or writing you think need more improvement?
21. How does the lack of proficiency in x skill influence your group participation? Is there any adjustment to your group composition or the activity that can support you? For example, do you prefer to be in a group with other ELLs or with your non-ELLs peers?
22. Our classes are recorded on Panopto. Do you go back to watch the class videos? Why?
23. In what ways do you feel that the scientific language and terminology in the class becomes a barrier or is beneficial for your participation in small group conversations?

C. Appendix C
Quartics Consent Form
Chemistry Discourse Project

**Collaborative Research: Investigating Classroom Discourse in Active Learning
Environments for Large Enrollment Chemistry Courses**

Primary Investigator: Gregory Rushton PI Department & College: Tennessee STEM
Education Center, MTSU

Protocol ID: 19-2253

Approval Date: 06/11/2019

Expiration Date: 06/30/2022

Information and Disclosure Section

Purpose: The purpose of this study is to better understand how students learn about certain chemistry topics while engaged in active learning exercises. You are being asked to participate in this study because you are currently enrolled in a section of General Chemistry I (CHEM 1120). Your participation in this research study is voluntary. You are also free to withdraw from this study at any time. In the event new information becomes available that may affect the risks or benefits associated with this research study or your willingness to participate in it, you will be notified so that you can make an informed decision whether or not to continue your participation in this study.

Q16 I have read the information pertaining to the research (see below).

- No (1)
- Yes (2)

Q17 The research procedures to be conducted are clear to me.

- No (1)
- Yes (3)

Q18 I confirm that I am 18 years or older.

- No (1)
- Yes (3)

Q16 By clicking below, I affirm that I freely and voluntarily choose to participate in this study. I understand I can withdraw from this study at any time.

- No, I do not consent (2)
- Yes, I consent (5)

Description: If you decide to participate in this study, we would ask you to do the following: - Complete a questionnaire with your demographics- Allow us to audio and video record your group activities in class and via Zoom meetings. All students will participate in all classroom learning activities - i.e. in-lecture clicker responses, quizzes, homework, activities – as these are required components of the coursework. Students who do not consent to participate in this study will not be video and audio recorded, interviewed for content understanding, asked for demographic information, and will have their data removed from the analysis for dissemination of outcomes. We will take steps to ensure that all data collected is kept confidential. Your name will be replaced with a pseudonym for analyses. All the study data that we get from you will be kept secure. If any papers and talks are given about this research, your name will not be used. All video and audio recordings will be kept on a secure server accessible only by the researcher investigators for transcribing. All written data will be locked in a secure cabinet inside of a password-

protected digitally locked office, and all electronic data will be stored on a secure, password-protected share drive. All identifiable data will be destroyed upon completion of data analysis.

Duration: This survey should take approximately 20 minutes to complete. Here are your rights as a participant: Your participation in this research is voluntary. You may skip any item that you don't want to answer, and you may stop the experiment at any time (but see the note below) If you leave an item blank by either not clicking or entering a response, you may be warned that you missed one, just in case it was an accident. But you can continue the study without entering a response if you didn't want to answer any questions. Some items may require a response to accurately present the survey.

Risks & Discomforts: There are no foreseeable risks or discomforts associated with your participation in this study.

Benefits: There is no direct benefit expected as a result of you being in this study.

Identifiable Information: Your name may will be collected as part of this survey but will be anonymized before analysis begins.

Compensation: There is no compensation for participation in this study.

Confidentiality. All efforts, within reason, will be made to keep personal information private but total privacy cannot be promised. Your information may be shared with MTSU or the government, such as the Middle Tennessee State University Institutional Review Board, Federal Government Office for Human Research Protections, *if* you or someone else is in danger or if we are required to do so by law.

Contact Information. If you should have any questions about this research study or possibly injury, please feel free to contact Gregory Rushton by telephone 615-904-8573 or

by email gregory.rushton@mtsu.edu. Please contact MTSU IRB for compliance issues (615 494 8918 or compliance@mtsu.edu).

End of Block: Informed Consent

Start of Block: Demographics

Q62 What is your name?

Q17 Last Four Digits of MTSU ID#:

Q19 How old are you?

Q20 What are you studying at MTSU?

Q22 1. Gender Identification:

- Female (1)
- Male (2)
- Other (4)
- Prefer not to say (5)

Q23 If you selected "Other" above and would like to explain, please do so below.

Q18 2. Race:

- American Indian or Alaska Native (1)
- Asian/Asian American (2)
- African/African American (3)
- Hawaiian/Pacific Islander (4)
- White/Caucasian (5)
- Other (6)

Q19 If you selected "Other" above and would like to explain, please do so below.

Q20 3. Ethnicity:

- Hispanic or Latino or Spanish Origin (1)
- Not Hispanic or Latino or Spanish Origin (2)

Q21 4. Are you an international student?

- Yes (1)
- No (2)

Q22 5. Is English Your First Language?

- Yes (1)
- No (2)

Q23 If you chose Yes, please answer the next question. If you chose No, please move on to question 7 and leave question 6 blank.

Q24 6. What language did you learn first?

- Spanish (1)
- Chinese (Cantonese or Mandarin) (2)
- Italian (3)

- Russian (4)
- Other (5)

Q25 If you selected "Other" above and would like to explain, please do so below.

Q26 7. Are You a First-Generation College Student? (Neither parent has more than a high-school education)

- Yes (1)
- No (2)

Q55 8. Did you take any chemistry courses before (high school level or college level)?

- Yes (1)
- No (2)

Q57 If you selected "Yes" please list all chemistry courses you took before.

End of Block: Demographics

D. Appendix D**Personality Test**

You regularly make new friends.

Agree  Disagree

You spend a lot of your free time exploring various random topics that pique your interest.

Agree  Disagree

Seeing other people cry can easily make you feel like you want to cry too.

Agree  Disagree

You often make a backup plan for a backup plan.

Agree  Disagree

You usually stay calm, even under a lot of pressure.

Agree  Disagree

At social events, you rarely try to introduce yourself to new people and mostly talk to the ones you already know.

Agree  Disagree

You prefer to completely finish one project before starting another.

Agree  Disagree

You are very sentimental.

Agree  Disagree

You like to use organizing tools like schedules and lists.

Agree  Disagree

Even a small mistake can cause you to doubt your overall abilities and knowledge.

Agree  Disagree

**You feel comfortable just walking up to someone you find interesting and striking
up a**

conversation.

Agree  Disagree

**You are not too interested in discussing various interpretations and analyses of
creative works.**

Agree  Disagree

**You are interested in so many things that you find it difficult to choose what to try
next.**

Agree  Disagree

You are prone to worrying that things will take a turn for the worse.

Agree  Disagree

You avoid leadership roles in group settings.

Agree  Disagree

You are definitely not an artistic type of person.

Agree  Disagree

You think the world would be a better place if people relied more on rationality and less on their feelings.

Agree  Disagree

You prefer to do your chores before allowing yourself to relax.

Agree  Disagree

You enjoy watching people argue.

Agree  Disagree

You tend to avoid drawing attention to yourself.

Agree  Disagree

Your mood can change very quickly.

Agree  Disagree

You lose patience with people who are not as efficient as you.

Agree  Disagree

You often end up doing things at the last possible moment.

Agree  Disagree

You have always been fascinated by the question of what, if anything, happens after death.

Agree  Disagree

You usually prefer to be around others rather than on your own.

Agree  Disagree

You become bored or lose interest when the discussion gets highly theoretical.

Agree  Disagree

You find it easy to empathize with a person whose experiences are very different from yours.

Agree  Disagree

You usually postpone finalizing decisions for as long as possible.

Agree  Disagree

You rarely second-guess the choices that you have made.

Agree  Disagree

After a long and exhausting week, a lively social event is just what you need.

Agree  Disagree

You enjoy going to art museums.

Agree  Disagree

You often have a hard time understanding other people's feelings.

Agree  Disagree

You like to have a to-do list for each day.

Agree  Disagree

You rarely feel insecure.

Agree  Disagree

You avoid making phone calls.



You often spend a lot of time trying to understand views that are very different from your own.



In your social circle, you are often the one who contacts your friends and initiates activities.



If your plans are interrupted, your top priority is to get back on track as soon as possible.



You are still bothered by mistakes that you made a long time ago.



You rarely contemplate the reasons for human existence or the meaning of life.



Your emotions control you more than you control them.

Agree  Disagree

You take great care not to make people look bad, even when it is completely their fault.

Agree  Disagree

Your personal work style is closer to spontaneous bursts of energy than organized and consistent efforts.

Agree  Disagree

When someone thinks highly of you, you wonder how long it will take them to feel disappointed in you.

Agree  Disagree

You would love a job that requires you to work alone most of the time.

Agree  Disagree

You believe that pondering abstract philosophical questions is a waste of time.

Agree  Disagree

You feel more drawn to places with busy, bustling atmospheres than quiet, intimate places.

Agree  Disagree

You know at first glance how someone is feeling.

Agree  Disagree

You often feel overwhelmed.

Agree  Disagree

You complete things methodically without skipping over any steps.

Agree  Disagree

You are very intrigued by things labeled as controversial.

Agree  Disagree

You would pass along a good opportunity if you thought someone else needed it more.

Agree  Disagree

You struggle with deadlines.

Agree  Disagree

You feel confident that things will work out for you.

