INVESTIGATING DISCOURSE PRACTICES FOR STUDENTS IN A HYBRID POGIL INTRODUCTORY CHEMISTRY CLASS

by

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ABSTRACT

Having discussions and working together in groups with other learners is the indicator of the collaboration aspect of engagement. Collaborative engagement can be fostered through active learning approaches, since they provide more opportunities for interaction among learners. In Process Oriented Guided Inquiry Learning (POGIL) classrooms, small groups of peers discuss and verbalize ideas with each other to reach a shared understanding. As students discuss ideas and share ideas with others, they can hear different viewpoints and develop understandings that may not have been possible individually. This dissertation considers this approach toward learning, focused on two big ideas: 1) the English Learner (EL) student population and their engagement in small group conversations 2) the impact of converting a POGIL class to a hybrid format on students' engagement in small group conversations.

1) the English Learner (EL) student population and their engagement in small group conversations

Increasing numbers of immigrants in the United States have led to an increase in the number of ELs in American classrooms. A typical challenge for ELs in American science classes is that they are unfamiliar with the norms and expectations of class and may not feel valued and accepted. Instructors may also have lower expectations for them, affecting their learning and achievement. Due to these difficulties, English learners might have a different experience and engage in small group discussions differently than non-English learners in a POGIL-based. Our analysis indicated that ELs are less likely to engage in discursive moves that lead to shared understanding than non-ELs, which could indicate missed opportunities for knowledge construction. In addition, we provided

evidence that EL populations may need to be redefined and subgroups within them considered. According to our findings, the EL population can be categorized into subgroups based on students' educational backgrounds. The defined subgroups of ELs engaged differently in small group conversations and those who spent more time in the US educational system participated more actively in conversations.

2) the impact of converting a POGIL class to a hybrid format on students' engagement in small group conversations.

Nowadays, distance education plays an important role in the educational system. Transactional distance theory argues that distance education creates a psychological separation between students and their instructors, preventing students from interacting and being engaged. Studies suggest that distance education could benefit from active learning approaches to reduce transactional distance. In this study, a hybrid POGIL class with half of the students attending in person and the other half participating remotely was investigated to see how this particular active learning approach influenced students' interactions. Despite the active learning approach in this design, analysis of students' conversations showed that they were sometimes less engaged in group discussions when interacting remotely, suggesting that the transactional distance for remote students was present. Student participants and the course instructor attributed this pattern to more distractions in remote classes, difficulties in engagement caused by the nature of online courses, and less accountability. Upon analysis at the individual student level, we found that the patterns we observed for the entire class were not the same for each student. From student participants' and the instructor's point of view, sometimes students'

personality (e.g., some people are comfortable sharing their ideas with others but some people do not) and their attitude toward the course could have a greater impact on how they engaged in small group discussions than whether they were in person or remote. To understand the dynamic behind these observed patterns and optimize the learning experience in distance education, more research is needed on student characteristics, group dynamics, facilitation, and task types.

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CHAPTER ONE: PURPOSE OF STUDY

The present dissertation is based on two different studies, one focusing on the English Learner population and their experiences in a Process Oriented Guided Inquiry Learning (POGIL) chemistry class and the second study comparing students' experiences in remote versus in person sessions of a hybrid POGIL-based chemistry class. In this chapter, the problem statement and the importance of each study will be discussed separately.

STUDY 1

Study 1: Introduction

Students whose first language is not English, English Learners (EL), are a growing population in classrooms in the United States. It is expected that EL students will constitute 40% of the K - 12 population in the USA by 2030 (Hur & Suh, 2012). Educational systems should ensure that this group of students receives a quality education equivalent to their native English speaking peers at all levels (e.g., higher education) and in all subjects (e.g., science), and adequately prepares them for future careers in Science, Technology, Engineering, and Mathematics (STEM). A review of the literature (see Chapter two) shows that EL students in classes may encounter challenges such as unfamiliarity with the class norms and expectations, feelings of not being valued and socially accepted, and instructors' lower expectations of them (Lee, 2005; Terry & Irving, 2010). Being treated differently and having these feelings rooted in racial and ethnic differences, can impact students' ability to develop the required skills for high

academic achievement (Richards et al., 2007). Having different racial and ethnic backgrounds from mainstream students can lead to disparities in academic performance. Consequently, there may be an achievement gap between EL students and native English speaker students (Lee, 2005). To address these challenges, engaging EL students in active learning (e.g., classrooms that incorporate inquiry-based learning) and offering more direct, explicit guidance from facilitators are suggested by previous studies (National Research Council, 2012; Freeman et al., 2014; Wiggins et al., 2017; Theobald et al., 2020).

In active learning settings students construct their own understanding of a concept through meaningful engagement in course activities and interaction with their peers (Freeman et al., 2014). Although there is a consensus that active learning (in comparison to direct instruction) can address some of the aforementioned problems including decreasing the achievement gap, it is important to know that active learning is a broad concept that can be interpreted and conceptualized in different ways and instructors make decisions about active learning implementation based on the context of their classrooms (Zayapragassarazan & Kumar, 2012). Therefore, it is necessary to investigate how different forms of active learning strategies impact the EL population since they may have different experiences from native speakers and may benefit from different instructional approaches. By comparing the experiences of ELs and non-ELs in an active learning environment, we can begin to understand how active learning can benefit all students irrespective of their linguistic backgrounds.

Study 1: The Problem Statement and the purpose of study

As mentioned in the introduction, active learning is suggested as a solution for addressing some of the challenges that ELs encounter in STEM classes. Active learning is an ill-defined and broad concept (Lombardi et al., 2021). There are various types of pedagogical practices that are classified as active learning instruction such as problem-based learning or collaborative learning (Prince, 2004; Zayapragassarazan & Kumar, 2012). Instructors make decisions about implementing an active learning method based on the size of the class, the available physical space, and the time that they can allocate to an activity (Zayapragassarazan & Kumar, 2012) as well as their familiarity with the reform and their teaching experience. More studies are needed to better understand how different active learning strategies impact the EL population and examine if each of them addresses some of the investigated challenges or if it creates new challenges.

Process Oriented Guided Inquiry Learning (POGIL) is one of the socially mediated active learning strategies to promote engagement of students and fosters opportunities for student collaboration in small groups (Moog & Spencer, 2008; Rodriguez et al., 2020). POGIL was introduced into the field of chemistry in 1990s and has been implemented in different disciplines of chemistry and in other fields such as biology, mathematics, and computer science (Bénéteau, 2017; Yadav et al., 2021). “In a POGIL learning environment, students are actively engaged in mastering the concepts and content of a discipline; at the same time, they are developing important learning skills by working in self-managed teams on guided inquiry activities designed specifically for this purpose and environment” (Moog & Spencer, 2008, p. 1)”. In a POGIL class, students are required to work in small groups (3 to 5 students), and “the

team interactions in a POGIL classroom serve both as the means for learning and as an objective of the learning (Hoffman & Richardson, 2019, p. 116)". Previous studies have discussed implementing the POGIL strategy in both chemistry and non-chemistry contexts and the positive impact (e.g., positive impact on students' achievement) of this approach on students' learning (Vincent-Ruz et al., 2020; Walker & Warfa, 2017). In those studies, however, the students were considered homogeneous with respect to their backgrounds (e.g., racial, ethnic, linguistic), so the affordances and constraints of a POGIL-based class were not discussed for students from diverse backgrounds. One understudied and growing population in the American educational system is students whose native language is not English (EL). Most articles on POGIL-based classes did not consider the background of students at all, or when they did all minority students were treated as a single homogeneous group. Therefore, EL students and other minority students have been treated homogeneously, with little distinction between their independent needs. As a growing population in US classrooms, it is important to learn about ELs' experiences in an active learning environment such as a POGIL-based classroom to see if they have specific challenges that need to be addressed, and to ensure that the environment is equitably effective for this population (Cooper & Brownell, 2016; Eddy et al., 2015).

Additionally, previous research on POGIL has used a primarily quantitative approach (Rodriguez et al., 2020), which does not illuminate the experiences of a specific population. The use of quantitative methods allows for large-scale studies, which may make generalizability easier, but it is also important to keep in mind that some important

information, such as the characteristics of participants, explanations for findings, and participants' perspective toward the topic might be overlooked (Savela, 2018). Through a qualitative approach, it will be possible to make sense of what ELs experience and interpret their behaviors in the context of the classroom to better understand the impact of an active learning environment on this student population (Patton, 2014). Qualitative data can also be used to generate hypotheses for larger-scale studies in the future.

Additionally, most previous studies on EL students in classroom settings were at the K-12 level with little data available about the experiences of EL students in college STEM courses (e.g., Adams et al., 2015; Sheng et al., 2011; Lee, 2005). Therefore, studies that focus on EL students' issues in a POGIL-based chemistry class in post secondary settings using a qualitative approach can help educators think about influential factors in EL students' educational success and provide a more equitable educational experience for this group of students. The aim of study #1 was to investigate ELs' engagement in group conversations in a POGIL-based chemistry class while interacting in small groups and see if it was different from non-ELs'. Furthermore, it was investigated whether the EL population was homogeneous or if there were any subgroups. Apart from observing behaviors and patterns, the reasons behind these behaviors were also investigated.

STUDY 2

Study 2: Introduction

The number of students who attend college via distance education is increasing day by day (Poll et al., 2014). The COVID-19 pandemic, which shut down face-to-face learning across the country necessitated a quick pivot to online remote learning—a trend that was already on the rise for reasons of convenience (Van Wart et al., 2019). Beyond the COVID-19 pandemic, online teaching is a promising endeavor in a growing digital world (DeCoito & Estaiteyeh, 2022) and this option will remain for the post-pandemic life. Despite distance education being an important component of today's educational system and all advantages it might have (e.g., lower expenses, and higher convenience for students and faculty), there is some level of skepticism among educators in terms of students and instructors' social presence that might impact students' learning (Van Wart et al., 2019). In spite of widely varying definitions, common features of social presence include the immediacy and personal nature of interactions, the trust and confidence built up in the learning environment, and the quality of communication and interaction (Van Wart et al., 2019; Ozto & Brett, 2011). According to Bettinger et al., (2017) and Xu and Jaggars (2011), taking online courses lowers students' grades in the course, their success and progress in college, and they are more likely to fail or withdraw. Often, students in online classes complain about technical difficulties, being isolated from peers and instructors, and a general lack of support, which all can contribute to students' lower outcomes in online classes (Xu & Jaggars, 2011). Educators who believe that learning is a social process that happens through interactions with other learners might be concerned

with the lower level of interactions in distance education and ultimately the way that this lower level of interactions influences students learning (Jaggars & Xu, 2016; Paulsen & McCormick, 2020; Trespalacios et al., 2021; Van Wart et al., 2019).

Study2: The Problem Statement and the purpose of study

Distance education is formalized instructional learning in which geography and time constraints prevent students from in person interactions with their peers and instructors (King et al., 2001). In today's educational system, online courses are a well-established form of distance education (Paulsen and McCormick, 2020). As of 2016, more than 25% of higher education students reported taking at least one online course (Allen & Seaman, 2016; Seaman et al., 2018). In spring 2020, the transition to emergency remote teaching (Al-Taweel et al., 2020; Hodges et al., 2020) was an immediate action in response to the COVID-19 pandemic that made most students at K-20 levels experience distance education (Gutierrez et al., 2022). As online education grows, it is vital to ensure that students receive a quality education in online courses and they are provided with learning environments that are as effective as traditional face-to-face classes. However, there is a degree of uncertainty regarding the quality of this type of education, especially in terms of the social interactions among students and instructors (Trespalacios et al., 2021; Knapp, 2018). Paulsen and McCormick (2020) found that online education falls behind other modes of education in terms of student collaboration and engagement. Keengwe et al. (2013) also indicated that students and instructors in online classes often face the absence of social presence and interaction. Not having adequate interactions and collaborations among students is an issue because social interactions among learners and

the instructor is the key component of learning as explained in some learning theories such as social constructivism or situated learning.

Assuming that an online learning environment cannot provide a proper context for social interaction will lead to questioning the quality of learning in these environments, especially learning concepts at higher levels that require synthesis (Maddix, 2012). However, it is important to remember that similar to in person classes, different instructors will choose different pedagogies and course designs for online courses as some instructors might offer more teacher-centered online classes while others offer student-centered online classes. In this regard, Palloff and Pratt (2001) state "the key to success in our online classes rests not with the content that is being presented but with the method by which the course is being delivered" (p. 152). Most previous studies agreed that designing online courses based on the idea of active learning can encourage students' interaction and engagement in dialogue (Brent et al., 2021; Khan et al., 2017) which can lead to increasing students' achievement in these learning environments (Jaggars & Xu, 2016). The role of student discussion in online courses has been highlighted in previous studies (e.g., Khan et al., 2017; Poll et al., 2014), and Maddix (2012) argues that the degree of discussion can determine the effectiveness of an online course.

According to Brent et al. (2021) and Khan et al. (2017), it is possible to incorporate active learning strategies into online courses; however, many active learning strategies have not been examined in online contexts to determine if they enhance the interaction and engagement of students. It is important to investigate the students' experiences and evaluate the quality of their interactions in different types of online

courses. This will help with gathering more empirical evidence about the possibility of designing online courses that are effective in terms of student engagement. In this study, POGIL, one of the active learning strategies used in chemistry, was extended to a remote learning environment through the design of a hybrid course. The aim of this study was: 1) investigating students' interaction and conversations in a hybrid active learning (POGIL) class and compare the quality of students' conversations in the remote and in person portions of the course 2) understanding motivations behind the observed behaviors in remote and in person portions of the hybrid POGIL class from the perspective of students and the course instructor.

REFERENCES

Allen, I. E., & Seaman, J. (2016). *Online report card: Tracking online education in the United States*. Babson Survey Research Group. Babson College, 231 Forest Street, Babson Park, MA 02457.

Al-Taweel, D., Al-Haqan, A., Bajis, D., Al-Bader, J., Al-Taweel, A. M., Al-Awadhi, A., & Al-Awadhi, F. (2020). Multidisciplinary academic perspectives during the COVID-19 pandemic. *The International Journal of Health Planning and Management, 35*(6), 1295-1301.

Bénéteau, C., Guadarrama, Z., Guerra, J. E., Lenz, L., Lewis, J. E., & Straumanis, A. (2017). POGIL in the Calculus Classroom. *PRIMUS, 27*(6), 579–597.

Bettinger, E., Fox, L., Loeb, S., & Taylor, E. (2015). Changing distributions: How online college classes alter student and professor performance. *Stanford Center for Education Policy Analysis*, 15-10.

Cooper, K. M., & Brownell, S. E. (2016). Coming out in class: Challenges and benefits of active learning in a biology classroom for LGBTQIA students. *CBE—Life Sciences Education*, *15*(3), ar37.

DeCoito, I., Estaiteyeh, M. (2022). Transitioning to Online Teaching During the COVID-19 Pandemic: An Exploration of STEM Teachers' Views, Successes, and Challenges. *J. Sci. Educ. Technol.*, *31* (3), 340–356.

Eddy, S. L., Brownell, S. E., Thummaphan, P., Lan, M. C., & Wenderoth, M. P. (2015). Caution, student experience may vary: Social identities impact a student's experience in peer discussions. *CBE—Life Sciences Education*, *14*(4), ar45.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, *111*(23), 8410-8415.

Gutierrez, K. S., Kidd, J. J., Lee, M. J., Pazos, P., Kaipa, K., Ringleb, S. I., & Ayala, O. (2022). Undergraduate Engineering and Education Students Reflect on Their Interdisciplinary Teamwork Experiences Following Transition to Virtual Instruction Caused by COVID-19. *Education Sciences*, *12*(9), 623.

Hodges, C. B., Moore, S., Lockee, B. B., Trust, T., & Bond, M. A. (2020). The difference between emergency remote teaching and online learning.

Hoffman, M. M., & Richardson, S. (2019). Team construction and accountability. In S. R. Simonson (Ed.), *POGIL: An Introduction to Process Oriented Guided Inquiry Learning for Those Who Wish to Empower Learners*, (pp, 113-140). Stylus Publishing.

Hur, J. W., & Suh, S. (2012). Making learning active with interactive whiteboards, podcasts, and digital storytelling in ELL classrooms. *Computers in the Schools, 29*(4), 320-338.

Jaggars, S. S., & Xu, D. (2016). How do online course design features influence student performance? *Computers & Education*, *95*, 270-284.

Keengwe, J., Adjei-Boateng, E., & Diteeyont, W. (2013). Facilitating active social presence and meaningful interactions in online learning. *Education and Information Technologies*, 18, 597–607.

King, F. B., Young, M. F., Drivere-Richmond, K., & Schrader, P. G. (2001). Defining distance learning and distance education. *AACE Review (Formerly AACE Journal)*, *9*(1), 1-14.

Lee, O. (2005). Science education with English language learners: Synthesis and research agenda. *Review of Educational Research*, *75*(4), 491–530.

Lombardi, D., & Shipley, T. F. (2021). The Curious Construct of Active Learning. *Psychological Science in the Public Interest: A Journal of the American Psychological Society*, *22*(1), 8–43.

Moog, R. S., & Spencer, J. N. (2008). POGIL: An Overview. In *ACS Symposium Series* (pp. 1–13). https://doi.org/10.1021/bk-2008-0994.ch001

National Research Council. (2012). *Discipline-based education research: Understanding and improving learning in undergraduate science and engineering*. The National Academies Press.

Oztok, M., & Brett, C. (2011). Social presence and online learning: A review of the research.

Palloff, R. M. and Pratt, K. (2001). *Lessons from the cyberspace classroom: The realities of online teaching*. San Francisco: Jossey-Bass.

Paulsen, J., & McCormick, A. C. (2020). Reassessing disparities in online learner student engagement in higher education. *Educational Researcher*, *49*(1), 20-29.

Patton, M. Q. (2014). *Qualitative research & evaluation methods: Integrating theory and practice*. Sage Publications.

Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education*, *93*(3), 223–231.

Richards, H. V., Brown, A. F., & Forde, T. B. (2007). Addressing diversity in schools: Culturally responsive pedagogy. *Teaching Exceptional Children*, *39*(3), 64-68.

Rodriguez, J.-M. G., Hunter, K. H., Scharlott, L. J., & Becker, N. M. (2020). A Review of Research on Process Oriented Guided Inquiry Learning: Implications for Research and Practice. *Journal of Chemical Education*, *97*(10), 3506–3520.

Savela, T. (2018). The advantages and disadvantages of quantitative methods in schoolscape research. *Linguistics and Education*, *44*, 31-44.

Seaman, J. E., Allen, I. E., & Seaman, J. (2018). Grade increase: Tracking distance education in the United States. *Babson Survey Research Group*.

Terry, N. P., & Irving, M. A. (2010). Cultural and linguistic diversity: Issues in education. *Special Education for All Teachers*, *5*, 109–132.

Trespalacios, J., Snelson, C., Lowenthal, P. R., Uribe-Flórez, L., & Perkins, R. (2021). Community and connectedness in online higher education: A scoping review of the literature. *Distance Education*, *42*(1), 5-21.

Theobald, E. J., Hill, M. J., Tran, E., Agrawal, S., Arroyo, E. N., Behling, S., Chambwe, N., Cintrón, D. L., Cooper, J. D., Dunster, G., Grummer, J. A., Hennessey, K., Hsiao, J., Iranon, N., Jones, L., 2nd, Jordt, H., Keller, M., Lacey, M. E., Littlefield, C. E., … Freeman, S. (2020). Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology,

engineering, and math. *Proceedings of the National Academy of Sciences of the United States of America*, *117*(12), 6476–6483.

Van Wart, M., Ni, A., Rose, L., McWeeney, T., & Worrell, R. (2019). A literature review and model of online teaching effectiveness integrating concerns for learning achievement, student satisfaction, faculty satisfaction, and institutional results. *Pan-Pacific Journal of Business Research*, *10*(1), 1-22.

Vincent-Ruz, P., Meyer, T., Roe, S. G., & Schunn, C. D. (2020). Short-Term and Long-Term Effects of POGIL in a Large-Enrollment General Chemistry Course. *Journal of Chemical Education*, *97*(5), 1228–1238.

Walker, L., & Warfa, A.-R. M. (2017). Process oriented guided inquiry learning (POGIL) marginally effects student achievement measures but substantially increases the odds of passing a course. *PloS One*, *12*(10), e0186203.

Wiggins, B. L., Eddy, S. L., Wener-Fligner, L., Freisem, K., Grunspan, D. Z., Theobald, E. J., ... & Crowe, A. J. (2017). ASPECT: A survey to assess student perspective of engagement in an active-learning classroom. *CBE—Life Sciences Education*, *16*(2), ar32.

Xu, D., & Jaggars, S. (2011). Online and hybrid course enrollment and performance in Washington State community and technical colleges.

Yadav, A., Mayfield, C., Moudgalya, S. K., Kussmaul, C., & Hu, H. H. (2021). Collaborative Learning, Self-Efficacy, and Student Performance in CS1 POGIL.

Proceedings of the 52nd ACM Technical Symposium on Computer Science Education, 775–781.

Zayapragassarazan, Z., & Kumar, S. (2012). Active learning methods. *Online Submission*, *19*(1), 3-5.

CHAPTER TWO: LITERATURE SYNTHESIS

Overview of Chapter

In this chapter, previous literature related to studies #1 and #2 of this dissertation will be discussed in separate sections.

For study #1, Process Oriented Guided Inquiry Learning (POGIL)-based instruction will be discussed as a socially mediated strategy that is used widely in chemistry classes. Then, English Learners (ELs) will be introduced as one of the growing populations in the US education system, and therefore how investigating their experiences in active learning chemistry classes such as POGIL-based contexts is important. Additionally, the findings from studies that have specifically explored the issues that ELs face in classrooms will be synthesized and what the studies have suggested for addressing these problems will be discussed. These previously discussed issues in the literature will be used as a source for collecting proper data (e.g., asking interview questions that can help us to answer our research questions) and making sense of what is seen at the context (e.g., how students interact in small group and the possible reasons behind those behaviors) in this dissertation study. The findings from this review will be used to highlight topics related to the EL population in POGIL-based instruction that need further investigation.

For study #2, previously designed online courses that have discussed student engagement and interactions will be reviewed to see the types of course designs that are more helpful for encouraging a higher level of interactions and engagement among students in online classes. The literature review sections will set the stage for introducing

the unique hybrid class environment utilized in this study, which provided students the chance to be in person for half of the classes and join the class remotely for the other half.

STUDY 1

Study 1: Introduction

A significant focus of chemistry education has been on helping students develop a better understanding of the concepts, practices, and ways of thinking in the chemical sciences (National Research Council, 2012). Several recent reports have highlighted the advantages of active learning strategies in supporting students within these domains (Freeman et al., 2014; National Research Council, 2012). Active learning-based environments aim to keep students engaged in their learning process rather than participating as passive consumers of content (Freeman et al., 2014; Driver et al., 2000). Theories of learning, such as constructivism, emphasize the importance of the role of learners in constructing knowledge and suggest that lecturing in an instructor-focused environment is not the most effective mode of instruction for most students to learn meaningfully (Bodner, 1986; Deslauriers et al., 2019). Additionally, Vygotsky argued that learning primarily happens on the social level through person to person interactions and secondarily at the individual level (Vygotsky, 1978). Therefore, it matters how students interact in an active learning setting.

A recent review of studies in chemistry education found that "socially mediated forms of learning…that employ small group learning produce positive outcomes." (Towns & Kraft, 2011, p.7). Working in small groups allows students in STEM disciplines to practice interpersonal and professional skills while gaining and applying

discipline-specific content knowledge (Balgopal et al., 2017). POGIL is one of the socially mediated strategies of active learning that has been used effectively in chemistry classrooms and features students working in small groups with the instructor acting as a facilitator (Moog & Spencer, 2008; Rodriguez et al., 2020; Vincent-Ruz et al., 2020). Through working in small groups of three to four and completing activities designed based on the learning cycle, students construct knowledge in a specific content area while improving their process skills (Frey & Shadle, 2018). In a POGIL-based class, besides the oral communication in their groups, students are engaged in listening, reading, writing, and reflecting through the use of assigned roles (Liyanage et al., 2020). POGIL as an active learning strategy pays explicit attention to critical thinking and building ideas across different students through teamwork (Vincent-Ruz et al., 2020). POGIL strategy "marries conceptual learning and the development of process skills" (p. 43) such as critical thinking, oral and written communication, teamwork, self and peer assessment, problem-solving, and information processing (Cole et al., 2019).

The literature shows that POGIL has short-term and long-term positive effects on students' learning and performance (Walker & Warfa, 2017; Liyanage et al., 2020; Vincent-Ruz et al., 2020). Specifically, studies discussed how using POGIL in different chemistry courses, including general chemistry, organic chemistry, biochemistry, and analytical chemistry, influenced students' learning positively and increased the number of students who passed the course (Vincent-Ruz et al., 2020). For instance, Vincent-Ruz et al. (2020), Walker and Warfa (2017), and Minderhout and Loertscher (2007) talked about the positive influence of POGIL on students' achievement. Becker et al. (2015),

Daubenmire et al. (2015), Kussmaul (2017), Liyanage et al. (2020), and Stanford et al. (2016) talked about facilitation in different POGIL-based courses and how facilitators play an important role in influencing students' interactions and discourse. Lo and Mendez (2018) in their book chapter reviewed previous studies on POGIL classes in different disciplines and ultimately suggested areas that need further investigation. Two areas highlighted by Lo and Mendez (2018) were focusing on 1) students' behaviors, affect, and identities and 2) the intersectionality of student identities.

However, it is important to remember that these positive effects might not be ubiquitous of all students because of students' differing backgrounds. Meeting some expectations such as critical thinking or engaging in productive discussions can be challenging for some students who come from different backgrounds, in particular those who come from different cultures that do not encourage these practices (Lee, 2005). It should be known that a set of given instructional opportunities can be beneficial for mainstream students but may be detrimental for students with different cultural and linguistic backgrounds. In this regard, Au (1998) noted that even a constructivist approach to teaching will be inadequate when we "assume that similarities among students override differences related to ethnicity, primary language, and social class" (p. 306). Therefore, it is a valid question whether POGIL works equitably for all students from different backgrounds or if there are specific challenges that students from diverse backgrounds are faced with in an undergraduate level POGIL-based chemistry course.

Diversity is a fundamental characteristic of the present world, so it is common to see students with different languages and cultural backgrounds present in classrooms

(Terry & Irving, 2010). It is important to make sure that the needs of all students despite their backgrounds are met in a class. The United States is becoming increasingly diverse and the population of English Learners (ELs) has been increasing rapidly in this country (Washburn, 2008). According to Bergey et al. (2018), the number of international students in higher education doubled in the USA between 1990 and 2014 and reached 1.1 million students in the 2016-2017 academic year. Despite this increase, there has been little thought given to EL students' linguistic and cultural backgrounds within the expected norms and practices to improve their learning in science classes. Therefore, EL students may encounter difficulties in assimilating to the established institutional cultures (Lee, 2005).

There is a common misconception that "good teaching for native speakers is good for ELs" (Harper & De Jong, 2004, p. 158). Those instructors who are aware of cultural differences can be more responsive and are more likely to adjust their pedagogy in a way that meets EL students' needs (Sheng et al., 2011). Instructors need to facilitate their students' learning, unlock their potential, and help them to be prepared for their future careers. Harper and De Jong (2004) argued that when instructors work with EL students, they should consider different factors, including ensuring that ELs have the required language skills to perform a task or engage in an activity; interpreting ELs' behavior by considering the cultural and educational background and their approach toward learning; identifying the language demands of a specific content area; and providing appropriate and sufficient feedback to their work.

Although POGIL is a well-known active learning strategy, few studies (e.g., Hu and Shepherd, 2014; Kussmaul, 2017) considered the experiences of underrepresented minorities, including ELs, in these learning environments. Consequently, doing research on EL students' needs in POGIL-based chemistry classes and finding ways to meet their needs can equip the instructors with tools to differentiate their lessons to include ELs. Providing quality education for EL students ultimately helps develop scientifically literate citizens and diversifies the STEM workforce (Jordt et al., 2017; Torres & Zeidler, 2002). Reviewing EL issues in other contexts can give a general picture of issues that also may exist in a POGIL-based class. Also, reviewing the literature can provide some information about suggested solutions to address some of EL students' issues to help encourage equitable facilitation within POGIL-based instruction.

Study 1: Research questions in this literature review

In this literature review, the following research questions will be addressed:

1) What are common issues regarding teaching and learning for EL students in K-16 science classes?

2) What are the common strategies found in the research literature to facilitate EL students' learning in K-16 science classes?

Study 1: Literature Search Procedure

I conducted a systematic literature review to answer the above two specific review questions. My dissertation is part of a larger NSF-funded project (NSF award #1914813)

that aims to investigate productive discourse in active learning environments and across diverse instructional settings and student populations. To find related data sources, I started with the project proposal references and selected papers related to EL students. In the next step, I used the snowballing method and chose more papers from the references of the primary selected articles (Jalali & Wohlin, 2012; Ong et al., 2020). Additionally, the literature search was conducted using the Google Scholar and Education Resources Information Center (ERIC) database by searching for terms "English Language Learners' issues", "English Language Learners in active learning", "Supporting English Language Learners", "English Language Learners in small group interactions", "English Language Learners in mainstream classes", and "English Language Learners in POGIL-based classes". I used the Google Scholar database because it covers many data sources such as abstracts, books, and articles. Also, one helpful feature offered by Google Scholar is the "Cite by" that can be useful in giving researchers a sense of the salience of those articles. Additionally, the list of papers that cited the primary article is a valuable source to find more articles covering similar topics (Pan, 2016). I used the ERIC database as well to make sure that I included more related articles that do not exist in the Google Scholar database. ERIC gives users the option of more targeted search, such as including only peer reviewed articles, or choosing specific descriptors, authors, or publication type. It helps users to more easily narrow down the relevant sources (Pan, 2016).

Study 1: Inclusion criteria

1. To gain an understanding of previous findings about ELs' teaching and learning issues, the literature that discussed EL students or minority students

with a focus on ELs are included in this review. Several studies (e.g., Cummins (1986), Cummins (2001), White (2005), White (2011), Toven-Lindsey et al. (2015), Jordt et al. (2017)) treated racial, ethnic, and linguistic minority students homogeneously and hypothesized that their needs are the same. Therefore, those studies that considered EL students part of their participants are also included.

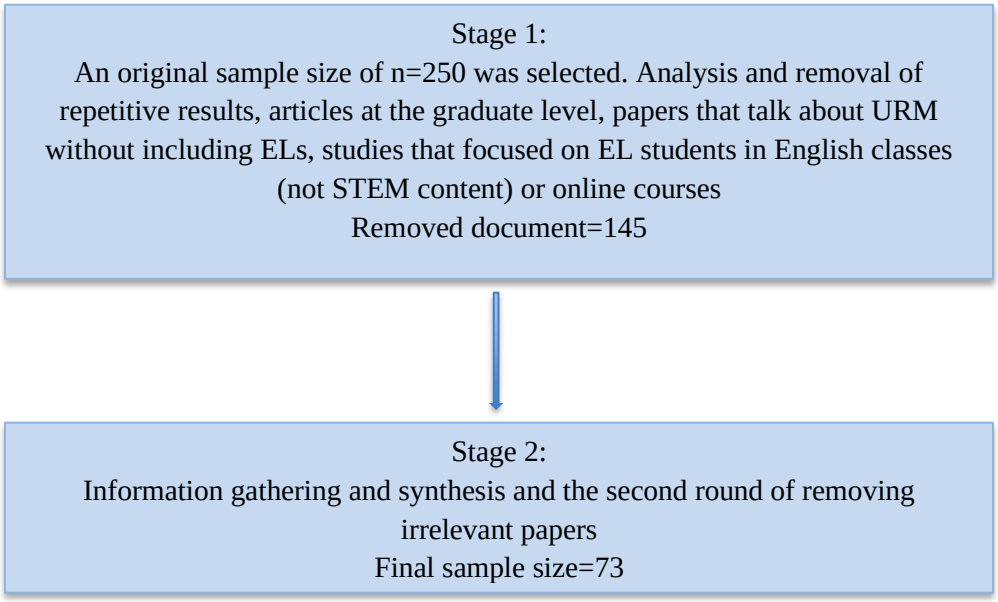
2. Both K-12 and higher education studies have been included in this review. Most research on EL students has been at the K-12 level, so including these studies helps to gain a more complete picture of what has been done so far in this area.
3. The included studies must be empirical and peer-reviewed.
4. The studies must be found in Google Scholar or ERIC databases with the searching method.

Study 1: Selection and Analysis Process

An original sample size of n = 250 articles was collected. First by reading the abstract and the context information, all repetitive articles, the articles that were irrelevant to the topic, studies that focused at graduate level context, papers that talked about URM without explicitly including ELs, or all the articles focused on EL students in English classes (no STEM content) or in online courses were removed. Second, the full text of papers were reviewed in order to remove irrelevant studies to this review. This resulted in a sample size of n = 73 (Figure 2.1).

Figure 2.1

Workflow for selecting articles (Study #1)



For the 73 articles, I wrote a summary of their important findings. These summaries helped me to organize the findings and develop a list of emergent themes of EL issues. From this list, I suggested solutions for addressing the issues and identified the gap in the literature.

Study 1: Results and Discussion

Emerging Themes for Issues Faced by ELs in Science Classrooms

The first emergent theme was related to unfamiliarity with science class norms and expectations. Some studies, such as Lee (2005), Lee et al. (1995), and Harrison and Shi (2016), revealed that at both K-12 and higher education the interactions, communication, and discourse patterns among students from diverse cultures and

linguistic backgrounds were different than school science expectations. For example, students in science classrooms are expected to ask and answer questions but EL students coming from a cultural background that values respect for authority and knowledge of elders may not be willing to participate in class discussions. In another example, Alfred (2003) noted that immigrant participants in higher education mentioned critiquing ideas and challenging the power of authority is a form of confrontation in their culture, rather than a necessary step for learning. This is aligned with Luttrell's (1989) conclusion that race and class relations of power are factors that influence shaping students' attitude toward learning and knowing in adult education.

Students from different cultures in science classes often need multiple forms of support (e.g., explicit guidance on class norms and expectations) and cannot be expected to learn the desired rules and classroom behaviors on their own because they have no prior knowledge of these classroom practices. Kuhn et al. (2010) discussed how values in different cultures influence the way that high school and university students engage in discursive practices. For example, some cultures perceive value in argumentative discussions, while others avoid argumentative discourses. Therefore, ELs may not be aware of certain social norms and the usual ways of participating in class discussions (Alfred, 2003). In other words, ELs understand the scientific concepts but are not able to properly communicate them in the social context.

In this regard, Warren et al. (1991) emphasized that learning science and scientific literacy is not about gaining specific knowledge and skills, but rather a social and cultural way of thinking and sense-making based on specific norms, values, and beliefs. Because

of this, teachers need to explicitly talk about the rules and expected class norms to help students from different cultures meet their expectations (Lee, 2005). Effective science instruction must consider students' language and cultural background in making pedagogical decisions (Lee, 2005). Knowing about these features helps the instructor to understand how different students may approach science learning in different ways and be able to accommodate their specific needs. For instance, Westby et al. (1999) mentioned that the Haitian American fourth graders in their study were much less familiar with working collaboratively in small groups, and needed to receive more direct and explicit guidance from the teachers. Therefore, in an active learning setting, students with various backgrounds need more support such as acknowledging their involvement (e.g., the instructor can repeat students' statements even if the answer is wrong to show their contribution were heard and valued), scaffolding (e.g., direct and explicit scaffolding for cuing and clarification), or using questioning strategies (e.g., rewording the question to help them understand the question) to be able to engage in quality discussions (Westby et al., 1999).

The second emergent theme was related to inadequate English proficiency of some EL students. Torres and Zeidler (2002) concluded that English proficiency, scientific reasoning skills, and the interaction between these two variables have a statistically significant effect on tenth graders' science learning. Science language is already difficult for most students and learning science language can even be more challenging for EL students. In higher education learning environments, EL students face more challenges because the science content becomes more difficult and the science

language becomes more precise (Bergey et al., 2018). Curtis and Millar (1988) argued that students with limited fluency in English were not able to express themselves on scientific tasks and that occasionally ELs did not have the adequate vocabulary to express their ideas. This finding supports the idea of Lee et al. (1995) that elementary level students who have limited language skills often give a false impression that they have no science knowledge, even if they deeply understand the scientific concepts.

Different factors, such as how long an EL student has been in an English-speaking country, their age when they relocated to that country, and their parents' English proficiency, play a major role in K-12 EL students' English proficiency (Sheng et al., 2011). For example, the achievement gap between English native speakers and ELs who were in Britain for more than eight years decreased with improved English proficiency (Curtis & Millar, 1988).

Not being proficient in English can cause confusion for EL students even when the instructor provides clear instructions for the goal of lesson or activity. Research on EL pre-service teachers showed that if they don't fully comprehend their professor's instruction, they will not be able to perform as expected and become confused and experience feelings of nervousness (Washburn, 2008). This level of frustration is unproductive and hinders EL students' learning. Kiang (1992) found that many EL college students feel embarrassed by their English proficiency and prefer to stay silent in class. Not engaging in class discussion and being silent is the strategy that many EL students use for coping with anxiety (Pappamihiel, 2002; Ashcraft & Krause, 2007). Entering the class with limited English proficiency adds an additional stress on EL

students, which can increase their anxiety level. Anxiety happens when someone interprets a situation as potentially negative and harmful (Pappamihiel, 2002). As Horwitz et al. (1986) mentioned, feelings of anxiety in ELs can be related to fear of negative evaluation, test anxiety, and communication apprehension. The anxiety resulting from this stressful situation influences EL students learning adversely because of divided attention, occupying a fraction of working memory and not being able to concentrate on the task (Horwitz et al., 1986).

Instructors can take an active role in reducing language anxiety by helping EL students to increase their self-efficacy and to see the situation in class as not threatening (Pappamihiel, 2002). Giving wait time to EL students for processing the situation can be the first step to decrease EL students' language anxiety (Pappamihiel, 2002). By providing sufficient wait time, teachers can support code-switching (e.g., thinking in one language and switching to another) (Mohr & Mohr, 2007). Allowing students to use their native language in class, and not demanding students to talk in front of the class (Pappamihiel, 2002) are other techniques for decreasing the language anxiety among EL students. Washburn (2008) suggested pausing between phrases to give EL students enough time for processing, repeating what is mentioned (not paraphrasing), and presenting the same thing in different ways (e.g., speech, written, and graphs) to help EL students comprehend the concept and reduce their fear of communication.

Rosebery et al. (1990) argued that engaging ELs in hands-on activities can help them to learn the scientific definitions and correct pronunciation of scientific terms. Additionally, with hands-on activities, ELs can gain a personal understanding of science

concepts that could be more meaningful. Buck et al. (2005) noted that hands-on activities in cooperative group projects between ELs and non-ELs helped with engaging EL middle schoolers in the assigned task.

Bautista (1997) mentioned that using some special methods such as pictures, physical models, and flashcards can help teachers to teach ELs more effectively at the secondary level. Buck et al. (2005) also showed that using more visuals in classrooms could help ELs engage in class discussions at the middle school level. Using important scientific terms only in speech may not be enough for EL students, and using visuals or physical models can facilitate learning these terms. Visuals provide EL students with more concrete systems to process, reflect on, and integrate information (Hur & Suh, 2012). Although visuals provide positive learning outcomes for ELs, in some cases, the visuals are not directly related to the concept and cause some misconceptions. Buck et al. (2005) showed that ELs struggled with more abstract concepts such as cells, allergies, and diabetes that were extremely difficult to place in a relevant context with pictures, and were more comfortable with learning about science concepts that had an obvious connection to their lives.

The third emergent theme is about ELs' social acceptance, fear of being judged, and their sense of belonging. EL students may feel isolated and alienated from their classmates. A lack of sense of belonging to the class social community can prevent EL students from benefiting and learning in the classroom (Washburn, 2008). Students from racial, cultural, and linguistic minority groups may feel that their ideas are not valued by the instructors and their peers, which limits their willingness to engage in activities. In

White's (2007) case study, participants (students from different backgrounds including an EL) mentioned that they were not willing to speak up in the class, using their voices/discursive styles, for fear of being judged by their peers. Blumenfeld et al. (1996) reported that in an active learning environment where students work in small groups, minority students may be presumed less competent and even be excluded or rejected by mainstream students. Therefore, another challenge for ELs can be related to social acceptance.

Instructors should focus on preventing EL students' confusion, frustration, and alienation and help them to gain a greater sense of belonging (Washburn, 2008). Learning EL students' names and being able to pronounce them correctly can be an important step that instructors can take to increase this population's sense of belonging. Also, trying to find a connection between classwork and EL students' backgrounds, when appropriate, can acknowledge their presence and help with the sense of belonging (Washburn, 2008).

The fourth emergent theme is related to instructors' lower expectation of EL students resulting from some stereotypes about this population. Stereotype threat is another challenge that EL students may encounter. "Stereotype threat is a phenomenon that has been demonstrated to occur when people who identify with a particular group (e.g., gender, ethnicity) are negatively stereotyped" (Seidel et al., 2015, p. 2). Negative stereotypes cause interpretation of behavior or performance of a specific group. The members of the stigmatized group may experience anxiety of being judged because of those stereotypes (Spencer et al., 2016). Bautista (1997) showed that mainstream secondary level students and teachers may hold prejudices about EL students.

Sometimes, EL students think they are considered as a symbol or representative of their ethnic group. In this case, their ideas and beliefs will be highlighted, which can be stressful for them and prevent their class participation and learning. Many students from minority groups think they do not have enough knowledge to represent the whole social group that they come from (White, 2011).

As Terry and Irving (2010) and Atwater (2000) noted, teachers usually have lower expectations of students from different backgrounds, which can develop from teachers' personal biases or prejudices against this group of students. Having lower expectations of these students influences the interaction that teachers have with these students. For instance, these students may be called on less than other students in class, or receive less positive feedback or direct instruction. Additionally, Trujillo (1986) showed that there was a statistically significant difference in the way that instructors interact with minority students and mainstream students at the college level, even if the group participation rate was the same. Cooper and Allen (1998) also reported that instructors interacted less frequently with minority students than Euro-American students in the classroom at K-12. Lower levels of interaction between instructors and students with a different background, compared to the mainstream students, can impact students' development and achievement negatively (Chang, 2005).

Trujillo (1986) also demonstrated that instructors give less formative feedback to minority students' questions, finish their conversations with minority students at quicker rates, and usually give minority students the answer rather than working to help them reach the answer on their own. Additionally, having lower expectations of minority

students can be observed as positive feedback bias. Positive feedback bias happens when an instructor provides more praise and less criticism to minority students than mainstream students. Due to positive feedback bias, minority students' academic learning can be undermined by not properly challenging their ideas and helping them improve them (Harber et al., 2012).

It should be noted that in addition to the negative stereotypes, positive stereotypes also exist and those can create some challenges for people with different backgrounds as well. Positive stereotypes happen when perceptions of outgroups include evaluatively favorable components (Czopp, 2007). For instance, women are perceived as kind, sensitive, and nurturing, or Asians are labeled as a “model minority” because of their educational performance. At first glance, these stereotypes can be considered as compliment and highlighting an advantage of that specific group. However, stereotypes are confining because they are based on group membership not individual information (Czopp, 2007). Not being seen as an individual separate from the group can cause negative emotions for some people (Siy & Cheryan, 2013). Fiske et al. (2002) argues that most of the time these positive stereotypes have complimentary negative stereotypes. For instance, women may be perceived as kind but weak.

Additionally, positive stereotypes can cause the invisibility of some needs that are related to that perceived positive feature. For example, in light of the model minority positive stereotype, it is perceived that Asians have less mental health problems. Therefore, this stereotype contributes to the invisibility and even neglecting Asian’s mental health needs (Cheng et al., 2017). Another hazard of positive stereotypes, such as

"model minority," is posing pressure of high expectations. For instance, there is a positive stereotype that Asian students are good at math. This positive stereotype can make Asian students' anxious, prevent them from focusing on math related tasks, and ultimately influence their performance negatively. In other words, this positive stereotype creates a fear of failing to confirm that Asians are good at math (Cheryan & Bodenhousen, 2000).

The fifth emergent theme was related to the presence of an achievement gap between ELs and the mainstream students. Learning is mediated by linguistic, cultural, and social factors. Therefore, students' learning is enhanced when they can relate to the context in terms of language, culture, and social aspects. Students with different linguistic, cultural, and social backgrounds from those of mainstream students may struggle in science classes and face challenges (Lee, 2005; White, 2007). Lee (2005) recognized that there is an achievement gap between Els and mainstream students in K-12 science classes and showed that cultural patterns affect science learning within each group of non-mainstream students. Language is one of the cultural tools that each society develops over time "to carry the concepts that reflect the experience of that cultural group" (Au, 1998, p. 301). Therefore, people with different languages come from different cultural backgrounds who may have different preferences in interactions and thoughts. As Au (1998) noted, these preferences are the results of socialization practices in each community and reflect the values of that society.

Other studies, such as Hunter and Bartee (2003), Johnston and Viadero (2000), and Theobald et al. (2020), also concluded that disparities in academic performance is

primarily related to learners' different racial and ethnic backgrounds. These differences can hinder students' ability in gaining required skills for high academic achievement and ultimately create an achievement gap between minority students (e.g., ELs) and the majority students. It is well documented that poor academic achievement can set the stage for dropping out of school (Sheng et al., 2011). Addressing the achievement gap between EL and non-EL students can eliminate one of the risk factors leading to EL students' school dropout.

Theobald et al. (2020) argued that engaging underrepresented students in active learning will reduce or eliminate the achievement gap in STEM courses and improve equity in higher education. The study emphasized that courses that implemented high-intensity active learning were successful in narrowing the achievement gap between underrepresented and mainstream students. A common suggested way of teaching science to EL students is inquiry-based teaching (Cuevas et al., 2005). Warren et al. (1991) argued that at the high school level, collaborative inquiry built upon Vygotsky's theory helps with socially constructing knowledge through activity, talk, and interaction around meaningful problems. For example, Kelly and Breton (2001) examined how two particular ways of framing problems, making observations, and engaging in spoken and written discourse practices helped a group of elementary EL students engage in scientific inquiry. In this study, teachers engaged their students in discussion by asking questions, reframing their ideas, and varying the use of language. Collaboration in small groups in inquiry-based classes helps EL students to have access to different formats of communications such as oral, written, gestural, and graphical representation from

different people (Lee, 2005). Warren et al. (1991) emphasized that collaborative inquiry can provide social and cognitive support for group members. In other words, group members share responsibilities so the whole burden does not rest on any particular student. Warren and colleagues argued that sharing responsibilities in small groups can be even more beneficial for EL students as the language could overwhelm and impact their learning.

Study 1: Summary

Previous studies on ELs in different contexts provide some information about ELs' issues and possible solutions to address some of them. Table 2.1 summarizes EL's issues in science classes and the suggested solutions to addressing these issues.

Table 2.1

EL's issues in science classes and the associated suggested solutions to address these issues.

EL's issues in science classes	Suggestions
Unfamiliarity with science class norms and expectations	More explicit guidance on classroom norms and expectations from the instructor
The impact of English proficiency on EL students' learning, feeling anxiety	Engaging students in hands-on activities and using visuals Giving wait time to EL students for processing the situation

	Allowing ELs to use their native language in class, and not demanding students to talk in front of the class
	Helping EL students to see the situation in class not as threatening and increasing their self-efficacy
Not being Socially accepted, fear of being judged, and not feeling sense of belonging	Learning EL students' names and being able to say them correctly
	Trying to find a connection between classwork and EL students' personal backgrounds
Stereotype threat and instructors' lower expectations of EL students	-
Achievement gap resulted from the above issues	Engaging EL students in active learning environments

Many studies suggested employing active learning strategies over teacher-centered approaches (Theobald et al., 2020; Warren et al.,1991). Compared to direct instruction, there is a consensus that active learning can decrease the achievement gap between students from different backgrounds and the mainstream population (Hunter & Bartee, 2003; Johnston & Viadero, 2000). However, it is important to know that active learning is not inherently effective, and depends on how it is implemented in the classroom and facilitated by the instructor (National Research Council, 2015). For example, the advantages of learning through working in small groups are well-established; however, it is crucial to be aware that there are different factors that influence the effectiveness of working in small groups. Blumenfeld et al. (1996) mention that some factors influence the productivity of the group, such as the group composition,

the type of task that students are working on, who participates, and how the group is held accountable. Research shows that simply putting students in small groups does not make them more engaged, thoughtful, tolerant, and responsible, instead, the success of group work depends on the circumstances of the students and the context (Webb, 1982).

Designing an active learning environment and changing the classroom into more of a collaborative environment enhances the interaction between students with their peers and with the instructor. Instructors should be aware of the possible problems for specific groups of students resulting from increasing the interactions. For example, Webb (1982) noted that there are inconsistent results reported in different studies about the outcome of cooperative learning techniques. These inconsistencies resulted from different factors related to the context, such as students' ethnicity. These factors create different types of interactions between students where some are beneficial and some can be detrimental for learning (Webb, 1982).

Reviewing the previous literature showed that POGIL-based classes are common as an active learning approach in STEM classes, specifically in chemistry. There are several studies that focused on designing POGIL activities, facilitation in POGIL classes, or how POGIL classes are effective. However, there is a gap in the literature on how this instruction method influences different students' populations from various backgrounds such as ELs. It is not clear what Els, as a growing population in the US, experience in a POGIL-based class. Therefore, it is valuable to study ELs' experiences in a POGIL-based environment.

Study 1: Implications from the review

Possible challenges that ELs may have in a class

Reviewing the previous studies was helpful in creating a list of possible issues that ELs may have in a class, such as a POGIL-based chemistry class. To gain a better understanding of a POGIL-based chemistry context these issues should be considered in designing the study and data analysis. Specifically, the list provided on table 2.1 is helpful for designing the ELs' interview protocol and analyzing the interview data. This list ultimately can help in making sense of students' interactions during the class and the reasons behind their behaviors.

REFERENCES

Alfred, M. V. (2003). Sociocultural contexts and learning: Anglophone Caribbean immigrant women in US postsecondary education. *Adult Education Quarterly*, *53*(4), 242-260. (n.d.).

Ashcraft, M. H., & Krause, J. A. (2007). Working memory, math performance, and math anxiety. *Psychonomic Bulletin & Review*, *4*, 243-248. http://dx.doi.org/10.3758/BF03194059

Atwater, M. M. (2000). Equity for Black Americans in precollege science. *Science Education*, *84*(2), 154-179.

Au, K. H. (1998). Social constructivism and the school literacy learning of students of diverse backgrounds. *Journal of Literacy Research*, *30*(2), 297–319.

Balgopal, M. M., Casper, A. M. A., Atadero, R. A., & Rambo-Hernandez, K. E. (2017). Responses to different types of inquiry prompts: college students' discourse, performance, and perceptions of group work in an engineering class. *International Journal of Science Education*, *39*(12), 1625–1647.

Bautista, B. J. (1997). Effective teaching methodologies for ESL students learning secondary science: Recommendations from the field. *Studies in Teaching*,16.

Becker, N., Stanford, C., Towns, M., & Cole, R. (2015). Translating across macroscopic, submicroscopic, and symbolic levels: the role of instructor facilitation in an inquiry-oriented physical chemistry class. *Chemistry Education Research and Practice*, *16*(4), 769-785.

Bergey, R., Movit, M., Baird, A. S., & Faria, A. M. (2018). Serving English Language Learners in Higher Education: Unlocking the Potential. American Institutes for Research.

Blumenfeld, P. C., Marx, R. W., Soloway, E., & Krajcik, J. (1996). Learning with peers: From small group cooperation to collaborative communities. *Educational researcher*, *25*(8), 37-39.

Bodner, G. M. (1986). Constructivism: A theory of knowledge. *Journal of Chemical Education*, *63*(10), 873-878.

Buck, G., Mast, C., Ehlers, N., & Franklin, E. (2005). Preparing teachers to create a mainstream science classroom conducive to the needs of English-language learners: A feminist action research project. *Journal of Research in Science Teaching*, *42*(9), 1013–1031.

Chang, J. C. (2005). Faculty student interaction at the community college: A focus on students of color. *Research in Higher Education*, *46*(7), 769–802.

Cheng, A. W., Chang, J., O'Brien, J., Budgazad, M. S., & Tsai, J. (2017). Model minority stereotype: Influence on perceived mental health needs of Asian Americans. *Journal of immigrant and minority health*, *19*(3), 572-581.

Cole, R. S., Lantz, J. M., & Ruder, S. M. (2019). The Process. In S. R. Simonson (Ed.), *POGIL: An Introduction to Process Oriented Guided Inquiry Learning for Those Who Wish to Empower Learners* (pp, 42-68). Stylus Publishing.

Cooper, E., & Allen, M. (1998). A meta-analytic examination of the impact of student race on classroom interaction. *Communication Research Reports: CRR*, *15*(2), 151–161.

Cummins, J. (1986). Empowering minority students: A framework for intervention. *Harvard educational review*, *56*(1), 18-37.

Cummins, J. (2001). HER classic reprint: Empowering minority students: A framework for intervention. *Harvard educational review*, *71*(4), 649-676.

Curtis, S., & Millar, R. (1988). Language and conceptual understanding in science: A comparison of English and Asian language speaking children. *Research in Science & Technological Education*, *6*(1), 61-77.

Cuevas, P., Lee, O., Hart, J., & Deaktor, R. (2005). Improving science inquiry with elementary students of diverse backgrounds. *Journal of Research in Science Teaching*, *42*(3), 337–357.

Czopp, A. M. (2008). When is a compliment not a compliment? Evaluating expressions of positive stereotypes. *Journal of Experimental Social Psychology*, *44*(2), 413–420.

Daubenmire, P. L., Bunce, D. M., Draus, C., Frazier, M., Gessell, A., & van Opstal, M. T. (2015). During POGIL implementation the professor still makes a difference. *Journal of College Science Teaching, 44*(5), 72-81. https://doi.org/10.2505/4/jcst15_044_05_72

Deslauriers, L., McCarty, L. S., Miller, K., Callaghan, K., & Kestin, G. (2019). Measuring actual learning versus feeling of learning in response to being actively engaged in the classroom. *Proceedings of the National Academy of Sciences of the United States of America*, *116*(39), 19251–19257.

Driver, R., Newton, P., & Osborne, J. (2000). Establishing the norms of scientific argumentation in classrooms. *Science education*, 84(3), 287-312.

Fiske, S. T., Cuddy, A. J. C., Glick, P., & Xu, J. (2002). A model of (often mixed) stereotype content: competence and warmth respectively follow from perceived status and competition. *Journal of Personality and Social Psychology*, *82*(6), 878–902.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences, 111*(23), 8410-8415.

Frey, R. G. F., & Shadle, S. E. (2019). GI: The Guided Inquiry. In S. R. Simonson (Ed.), *POGIL: An Introduction to Process Oriented Guided Inquiry Learning for Those Who Wish to Empower Learners*, (pp, 69-84). Stylus Publishing.

Harber, K. D., Gorman, J. L., Gengaro, F. P., Butisingh, S., Tsang, W., & Ouellette, R. (2012). Students' race and teachers' social support affect the positive feedback bias in public schools. *Journal of Educational Psychology*, *104*(4), 1149.

Harper, C., & De Jong, E. (2004). Misconceptions about teaching English-language learners. *Journal of adolescent & adult literacy*, *48*(2), 152-162.

Harrison, J., & Shi, H. (2016). English language learners in higher education: An exploratory conversation. *Journal of International Students*, *6*(2), 415-430.

Horwitz, M. B., Horwitz, E. K., & Cope, J. A. (1986). Foreign language classroom anxiety. *The Modern Language Journal, 70* (2), 125-132

Hu, H. H., & Shepherd, T. D. (2014). Teaching CS 1 with POGIL activities and roles. *Proceedings of the 45th ACM Technical Symposium on Computer Science Education*, 127–132.

Hunter R, R. C., & Bartee, S. (2003). The achievement gap issues of competition, class, and race. *Education and Urban Society*, *35*(2).

Hur, J. W., & Suh, S. (2012). Making learning active with interactive whiteboards, podcasts, and digital storytelling in ELL classrooms. *Computers in the Schools*, *29*(4), 320-338.

Jalali, S., & Wohlin, C. (2012, September). Systematic literature studies: database searches vs. backward snowballing. In *Proceedings of the 2012 ACM-IEEE*

international symposium on empirical software engineering and measurement (pp. 29-38). IEEE.

Johnston, R. C., & Viadero, D. (2000). Unmet promise: Raising minority achievement. The Achievement Gap. *Education Week*, *19*(27), n27.

Jordt, H., Eddy, S. L., Brazil, R., Lau, I., Mann, C., Brownell, S. E., King, K., & Freeman, S. (2017). Values affirmation intervention reduces achievement gap between underrepresented minority and white students in introductory biology classes. *CBE Life Sciences Education*, *16*(3). https://doi.org/10.1187/cbe.16-12-0351

Kelly, G., & Breton, T. (2001). Framing science as disciplinary inquiry in bilingual classrooms. *Electronic Journal of Literacy through Science*, *1*(1), n1.

Kiang, P. N. C. (1992). Issues of curriculum and community for first-generation Asian Americans in college. *New Directions for Community Colleges*, *80*, 97-112.

Kuhn, D., Wang, Y., & Li, H. (2010). Why argue? Developing understanding of the purposes and values of argumentive discourse. *Discourse processes*, *48*(1), 26-49.

Kussmaul, C. (2017). Patterns in classroom facilitation for process oriented guided inquiry learning (POGIL). *Proceedings of the VikingPLoP 2017 Conference on Pattern Languages of Program*, 1–17.

Lee, O. (2005). Science education with English language learners: Synthesis and research agenda. *Review of Educational Research*, *75*(4), 491–530.

Lee, O., Fradd, S. H., & Sutman, F. X. (1995). Science knowledge and cognitive strategy use among culturally and linguistically diverse students. In *Journal of Research in*

Science Teaching (Vol. 32, Issue 8, pp. 797–816). https://doi.org/10.1002/tea.3660320804

Liyanage, D., Lo, S. M., & Hunnicutt, S. S. (2020). Student discourse networks and instructor facilitation in process oriented guided inquiry physical chemistry classes. *Chemical Education Research and Practice*. https://doi.org/10.1039/D0RP00031K

Lo, S. M., & Mendez, J. I. (2019). Learning-The evidence. In S. R. Simonson (Ed.), *POGIL: An introduction to process oriented guided inquiry learning for those who wish to empower learners*, (pp, 85-112). Stylus Publishing

Luttrell, W. (1989). Working-class women's ways of knowing: Effects of gender, race, and class. *Sociology of Education*, 33-46.

Minderhout, V., & Loertscher, J. (2007). Lecture-free biochemistry: A process oriented guided inquiry approach. *Biochemistry and Molecular Biology Education*, *35*(3), 172-180.

Mohr, K. A. J., & Mohr, E. S. (2007). Extending English-language learners' classroom interactions using the response protocol. *The Reading Teacher*, *60*(5), 440–450.

Moog, R. S., & Spencer, J. N. (2008). POGIL: An Overview. In *ACS Symposium Series* (pp. 1–13). https://doi.org/10.1021/bk-2008-0994.ch001

National Research Council. (2012). *Discipline-based education research: Understanding and improving learning in undergraduate science and engineering*. The National Academies Press.

Ong, M., Jaumot-Pascual, N., & Ko, L. T. (2020). Research literature on women of color in undergraduate engineering education: A systematic thematic synthesis. *Journal of Engineering Education*, *109*(3), 581–615.

Pan, M. L. (2016). *Preparing literature reviews: Qualitative and quantitative approaches*. Taylor & Francis.

Pappamihiel, N. E. (2002). English as a second language students and English language anxiety: Issues in the mainstream classroom. *Research in the Teaching of English*, *36*(3), 327–355.

Rodriguez, J.-M. G., Hunter, K. H., Scharlott, L. J., & Becker, N. M. (2020). A Review of Research on Process Oriented Guided Inquiry Learning: Implications for Research and Practice. *Journal of Chemical Education*, *97*(10), 3506–3520.

Rosebery, A. Warren, B., & Conant, F. (1990). *Making Sense of science in language minority classrooms (Tech. Rep. No. -306).* Cambridge, MA: Bolt, Beranek, & Newman. (n.d.).

Seidel, S. B., Reggi, A. L., Schinske, J. N., Burrus, L. W., & Tanner, K. D. (2015). Beyond biology: A systematic investigation of noncontent instructor talk in an introductory biology course. *CBE Life Sciences Education*, *14*(4), ar43.

Sheng, Z., Sheng, Y., & Anderson, C. J. (2011). Dropping out of school among ELL students: Implications to schools and teacher education. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, *84*(3), 98–103.

Siy, J. O., & Cheryan, S. (2013). When compliments fail to flatter: American individualism and responses to positive stereotypes. *Journal of Personality and Social Psychology*, *104*(1), 87–102.

Spencer, S. J., Logel, C., & Davies, P. G. (2016). Stereotype threat. *Annual review of psychology*, *67*, 415-437.

Stanford, C., Moon, A., Towns, M., & Cole, R. (2016). Analysis of instructor facilitation strategies and their influences on student argumentation: A case study of a process oriented guided inquiry learning Physical Chemistry classroom. *Journal of Chemical Education*, *93*(9), 1501–1513.

Terry, N. P., & Irving, M. A. (2010). Cultural and linguistic diversity: Issues in education. *Special Education for All Teachers*, *5*, 109–132.

Theobald, E. J., Hill, M. J., Tran, E., Agrawal, S., Arroyo, E. N., Behling, S., Chambwe, N., Cintrón, D. L., Cooper, J. D., Dunster, G., Grummer, J. A., Hennessey, K., Hsiao, J., Iranon, N., Jones, L., 2nd, Jordt, H., Keller, M., Lacey, M. E., Littlefield, C. E., … Freeman, S. (2020). Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math. *Proceedings of the National Academy of Sciences of the United States of America*, *117*(12), 6476–6483.

Torres, H. N., & Zeidler, D. L. (2002). The effects of English language proficiency and scientific reasoning skills on the acquisition of science content knowledge by Hispanic English language learners and native English language speaking students. *The Electronic Journal for Research in Science & Mathematics Education*.

Toven-Lindsey, B., Levis-Fitzgerald, M., Barber, P. H., & Hasson, T. (2015). Increasing persistence in undergraduate science majors: a model for institutional support of

underrepresented students. *CBE Life Sciences Education*, *14*(2). https://doi.org/10.1187/cbe.14-05-0082

Towns, M., & Kraft, A. (2011). Review and synthesis of research in chemical education from 2000–2010. In *Second Committee Meeting on the Status, Contributions, and Future Directions of Discipline-Based Education Research.*

Trujillo, C. M. (1986). A comparative examination of classroom interactions between professors and minority and non-minority college students. *American Educational Research Journal*, *23*(4), 629–642.

Vincent-Ruz, P., Meyer, T., Roe, S. G., & Schunn, C. D. (2020). Short-Term and Long-Term Effects of POGIL in a Large-Enrollment General Chemistry Course. *Journal of Chemical Education*, *97*(5), 1228–1238.

Vygotsky, L. (1978). Interaction between learning and development. *Readings on the development of children*, *23*(3), 34-41.

Walker, L., & Warfa, A.-R. M. (2017). Process oriented guided inquiry learning (POGIL) marginally effects student achievement measures but substantially increases the odds of passing a course. *PloS One*, *12*(10), e0186203.

Warren, B., Rosebery, A., & Conant, F. (1991). Discourse and social practice: Learning science in language minority classrooms. Spener, D. (Ed.), *Adult biliteracy in the United States* (pp. 190-210). Office of Educational Research and Improvement, Washington, DC.

Washburn, G. N. (2008). Alone, confused, and frustrated: Developing empathy and strategies for working with English language learners. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, *81*(6), 247–250.

Webb, N. M. (1982). Student interaction and learning in small groups. *Review of Educational Research*, *52*(3), 421–445.

Westby, C., Dezale, J., Fradd, S. H., & Lee, O. (1999). Learning to do science: Influences of culture and language. *Communication Disorders Quarterly*, *21*(1), 50-64.

White, J. W. (2007). Sociolinguistic challenges to minority collegiate success: Entering the discourse community of the college. In A. Seidman (Ed.), *Minority student retention: The best of the Journal of College Student Retention— Research, Theory & Practice* (pp. 271–295).

White, J. W. (2011). Resistance to classroom participation: Minority students, academic discourse, cultural conflicts, and issues of representation in whole class discussions. *Journal of Language, Identity & Education*, *10*(4), 250–265.

STUDY 2

Study 2: Introduction

Significant advances in technology make online education accessible for more students and the number of students who take online classes is growing every day (Poll et al., 2014). Despite the growth of online courses, one of the instructors' concerns is how to design an online learning environment that leads to creating a learning community that encourages students' engagement, and fosters dialogue among learners (Glazer & Wanstreet, 2011). Moore (1993) introduced the transactional distance theory and claimed a psychological separation between learners and instructors called transactional distance exists in distance education. According to this theory, transactional distance prevents students from interacting and engaging in dialogue. On the other hand, students' engagement and interactions influence their learning and success in the course. (Khan et al., 2014). The social constructivism learning theory and the situated learning approach explained that collaborating and social interactions between learners and instructors are critical to learning (Vygotsky, 1987; Lave & Wenger, 1991). Sedova et al. (2019) also explicitly mentioned that talking through ideas and verbalizing them can help with a higher quality of learning. Therefore, it is important that in every learning environment, whether in person or remote, students are given the chance to interact with their peers and instructor and actively engage in their learning process. Assuming that, in distance education students might not have interactions with their peers will raise concerns about the quality of learning in such an environment.

In this review, first I will discuss the concept of engagement and the suggestions provided by previous studies to enhance students' engagement and interactions in online classes. I will also discuss how different types of online classes (e.g., synchronous, asynchronous, hybrid) might influence students' engagement. Reviewing different types of online class designs and how well they encourage student interaction and dialogue is the main objective of this review.

Study 2: Research questions of the literature review

In this literature review, the following research question will be addressed:

How can we encourage more students' interactions and engagement in higher education remote classes?

Study 2: Literature search procedure

The literature search was conducted using the Google Scholar and Education Resources Information Center (ERIC) database. The terms searched in each database are "students interactions in online classes", "students engagement in online classes", "small group interaction in online classes", "online POGIL classes", and "active learning in online classes". There is a special issue on lessons learned about teaching and learning in online education settings during the COVID-19 pandemic in the *Journal of Chemical Education*. I paid special attention to those papers and included studies related to students' engagement and interactions. Next, snowballing methodology was used to choose more papers from the references of the primary selected articles (Jalali & Wohlin, 2012; Ong et al., 2020). The Google Scholar database was used because it covers many

data sources such as abstracts, books, and articles. Also, one helpful feature offered by Google Scholar is the “Cited by” which can be useful in giving researchers a sense of the salience of those articles. Additionally, the list of papers that cited the primary article is a valuable source to find more articles covering similar topics (Pan, 2016). The ERIC database was used as well to make sure that more related articles that did not exist in the Google Scholar database were included. ERIC gave users the option of a more targeted search such as including only peer-reviewed articles or choosing specific descriptors, authors, or publication types. It helps users to more easily narrow down the relevant sources (Pan, 2016).

Study 2: Inclusion criteria

The review followed the inclusion criterion listed below:

1. To gain an understanding of previous findings on students’ interactions and engagement in online classes, the literature that discussed this topic regardless of the content of the class was included.

2. Since the context of this study is at the college level, only higher education studies have been included in this review

3. The included studies must be empirical and peer-reviewed.

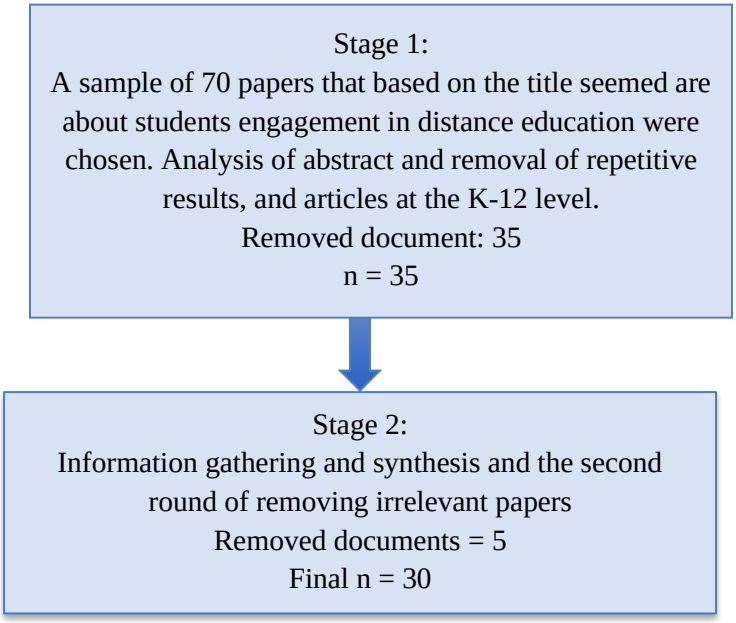
4. The studies must be found in Google Scholar or ERIC databases with the searching method.

Study 2: Selection and analysis process

A search was conducted using Google Scholar and ERIC databases for manuscripts related to students' engagement and interaction in online education settings. After the COVID-19 pandemic, several papers were published on distance education and online classes however including all those studies in a review is not possible. Therefore, only based on the title of studies, an original sample size of n=70 papers that focused on students' engagement and interaction in distance education were collected. By reading the abstract and the context information, all repetitive articles, articles that were irrelevant to the topic, and articles in K-12 setting were removed. Next, papers were synthesized, other irrelevant studies to this review were also removed based on insignificance to the inclusion criteria. After the full text screening, thirty articles remained for in-depth analysis within this review. The workflow for selecting articles is shown in Figure 2.2.

Fig 2.2

Workflow for selecting articles (Study 2)



In this section, some of the previous studies that focused on bringing different approaches (e.g., active learning, synchronous mode) into online classes to encourage higher levels of student interaction and engagement will be discussed. We aim to review the type of online class designs that have been discussed in those studies and the effectiveness of the designs in terms of encouraging students to have more interactions and dialogue.

Interactions and Engagement in Online Courses

Online education is becoming more readily available all over the world; however, there is some concern about the quality of this mode of education, particularly about student engagement and social interactions among students and instructors (Trespalacios

et al., 2021). According to Paulsen and McCormick (2020), online education is not as effective as other types of education in terms of student collaboration and engagement, which can negatively affect students' achievement (Jaggars & Xu, 2016). According to the transactional distance theory introduced by Moor (1993), the transactional distance present in online education prevents students from having interactions and engaging in conversations with their peers. In this theory, dialogue is the core component that can be an indicator of the proportion of the transactional distance, which means in a learning environment with having more dialogue among students the transactional distance will be less.

On the other hand, the significance of student engagement in discussion and collaboration with other learners in online courses has been highlighted in previous studies. (e.g., Khan et al., 2017; Poll et al., 2014). For instance, Maddix (2012) argued that the level of discussion that happens in an online course could determine the course's success and effectiveness. Consequently, the absence of adequate student interactions and engagement put the effectiveness of an online course in danger.

The previous studies' perspective on engagement and how the term has been defined can help us understand how to encourage students' engagement in online education. Redmond et al. (2018) introduced an online engagement framework for higher education (See table 2.2) based on the social constructivist theory in which learning happens through social interactions (Vygotsky, 1987). Rather than just interactions among students and instructors, the authors claimed that engagement has multi-elements including social engagement, cognitive engagement, behavioral engagement,

collaborative engagement, and emotional engagement. The authors provided a list of indicators of each aspect of engagement. For instance, learning with peers and relating to faculty members were introduced as two indicators of collaborative engagement. Considering these elements in designing online courses can help with facilitating students' engagement and enhance the effectiveness of online education. In particular, online classes should encourage collaborative engagement in light of this framework and the idea that students learn better when they share their ideas with other students.

Table 2.2

Online Engagement Framework for Higher Education.

Online Engagement Element	Indicators (illustrative only)
Social engagement	Building community Creating a sense of belonging Developing relationships Establishing trust
Cognitive engagement	Thinking critically Activating metacognition Integrating ideas Justifying decisions Developing deep discipline understandings Distributing expertise
Behavioral engagement	Developing academic skills Identifying opportunities and challenges Developing multidisciplinary skills Developing agency Upholding online learning norms Supporting and encouraging peers
Collaborative engagement	Learning with peers Relating to faculty members Connecting to institutional opportunities Developing professional networks

Emotional engagement	Managing expectations Articulating assumptions Recognizing motivations Committing to learning

Note. Adapted from "An Online Engagement Framework for Higher Education" by **P. Redmond**, **L. Abawi, A. Brown, R. Henderson, and A. Heffernan**, 2018, *Online Learning*, 22(1), p. 190. Copyright 2022 by the Online Learning journal. Reprinted by permission.

In another study, Poll et al. (2014) discussed six practices for students' online engagement and their retention including building a community, clarifying course expectations, employing online tools for interaction, encouraging the exchange of ideas, providing timely and relevant feedback, and creating a student-centered environment.

Social and collaborative aspects in the way that students work together are common themes in previous studies (e.g., Redmond et al., 2018; Poll et al., 2014) for increasing the students' engagement in online courses. Talking through the concepts and discussing them with peers allows students to understand them better (Sedova et al., 2019). Therefore, the assumption that online learning environments cannot provide the proper settings for social interactions will inevitably reduce the quality of learning in such environments. It is essential to create a context that encourages students' collaborations and interactions to increase students' achievement and the effectiveness of online classes.

There were two approaches in the literature to provide suggestions for increasing students engagement in online education:

1) By focusing on pedagogy and class practices

This is important to remember, same as in person courses, there is flexibility to adopt different pedagogies and course designs for online classes. Previous studies suggested some practices/approaches that can help in the design of online courses to keep students engaged in their learning process and encourage peer interactions. The literature suggests that bringing social aspects into designing online courses can provide an environment that encourages students' interactions, (Brent et al., 2021; Khan et al., 2017). For example, Brent et al. (2021) claimed that all strategies that are used in face-to-face classes for increasing students' interaction such as collaborative activities, discussion boards, and team project assignments can be used in online courses as well. In this regard, Khan et al. (2017) discussed the importance of student engagement in successful teaching and learning and indicated that providing the context for having a discussion, group work, and creating a collaborative environment are helpful strategies to foster student engagement in online courses. "Activities such as debates, role-playing, drama, and peer learning/teaching are valuable tools for increasing student engagement in the discussions" (Khan et al., 2014, p. 111). Researchers also claimed that it is possible to use an adapted version of active learning strategies that are used in face-to-face classes by using new technologies to design active learning online courses to help with student engagement (Khan et al., 2017).

2) By focusing on modes of online courses

To talk about engagement in online classes, some studies focused on the mode of online courses (e.g., synchronous and asynchronous) and investigated those modes that

can foster student engagement and interactions. Distance education can be categorized by considering different online features. For instance, asynchronous and synchronous are the two main modes for delivering content in distance education (Skylar, 2009). Synchronous mode happens when both instructor and students are present virtually at the same time and there is direct, virtual communication between them. Video/audio conferencing and live chat are examples of synchronous communication. Alternatively, in asynchronous mode (e.g., discussion board conversations and pre-recorded videos), the instructor and students are not required to be present in a virtual context at the same time and learners have access to the course material whenever they need it (Skylar, 2009). Distance education can also be categorized based on the amount of time spent online in the course. There are online courses that only use the digital network for interaction, learning and dialogue (that can be synchronous or asynchronous) and hybrid courses that take advantage of combining online education (that could be synchronous or asynchronous) and traditional in person designs (Fitriyana et al., 2021).

Tan et al. (2020) concluded that the synchronous online classes on Zoom can keep students engaged at the same level of engagement in an in person class. They indicated that synchronous online classes accommodate the social presence by providing the context for student connection, communication, and sharing their opinions in real-time. Similarly, Hurst (2020) indicated that synchronous online classes help with mimicking face-to-face classes by allowing students to work on group activities and improve their personal skills. Phillips (2005) indicated encouraging students to be actively engaged in the learning process and interaction among learners as principles of good practices in

education. These principles need to be considered in the design of online courses to give students the opportunity to interact with their peers, participate in online conversations, and receive feedback from the instructor. While designing active learning online classes, it is required to consider technologies that can support the necessary principles. For instance, providing students with the chance of real-time interaction is only possible through synchronous online classes offered by video conferencing software programs (e.g., Zoom). Hearing and seeing their peers and the instructor “live” allows students to receive an immediate response to their questions and insights about the course material. Video conferencing also personalizes interactions among members of the learning environment (Cobb, 2009). Wenzel (2020) also discussed transforming an active learning in person chemistry course into an active learning online course. In the study, students mainly worked on activities in their small groups in synchronous online classes (Wenzel, 2020). The findings revealed that online synchronous class design was more beneficial for students learning than asynchronous online classes and less beneficial than in person classes.

Although the majority of studies preferred synchronous online classes for enhancing students' engagement, Cafferty (2020) argued that both synchronous and asynchronous approaches to online education are complementary and should be considered in designing online courses. Cafferty (2020) designed a class that had both synchronous and asynchronous aspects and utilized the flipped classroom idea in which students were provided with some materials to work on prior to class and then expected to work in groups during class sessions. The results showed that students had productive

interactions and shared insightful ideas during the small group work and 94% participants agreed that working on activities in their small group has helped them to learn better.

Combining online and face-to-face aspects to create a hybrid learning environment is another approach that is suggested by researchers to increase student engagement and interaction. For example, Poirier (2010) discussed how a hybrid learning environment is helpful for students to interact and engage in a given lesson. Poirier (2010) mentioned that different approaches such as online chat, writing journals, and completing online assignments can be considered for the online portion of a hybrid class. This study claimed that the online portion of the class gave some participants the chance for more and easier interaction with other learners and the instructor because "people are less shy to speak up when typing" (Poirier, 2010, p. 30). Shea et al. (2015) also concluded that a well-designed hybrid class has promising results in terms of students' engagement and learning. For designing a successful hybrid course, establishing social, cognitive, and teaching presence is recommended by Shea et al. (2015). Social presence can be established through open communication in the class and by creating a sense of community through interaction among students and the instructor. Cognitive presence happens when the instructor and students construct and confirm meaning through discourse, and this presence can be established by guiding students' interactions and giving feedback on the quality of students' contributions (Pelz, 2010). Teaching presence contains three components: course design and organization, facilitation, and instruction that can be established by training the instructor and planning ahead.

POGIL in online settings

Based on previous studies, it is possible to design online classes by bringing special pedagogies such as active learning approaches or using specific online modes such as synchronous online sessions that have positive outcomes in terms of student engagement. POGIL is an active learning strategy often used in chemistry classes by instructors who wish to refrain from giving didactic lectures and engage students in the learning process. POGIL is a socially mediated active learning strategy that involves students interacting in small groups while completing POGIL activities (Moog & Spencer, 2008; Rodriguez et al., 2020; Vincent-Ruz et al., 2020; Simonson, 2019). Previous studies on POGIL in in person settings where students can talk to each other and the instructor face to face, talked about the positive impact of this approach on students' learning, pass rate, and achievement (Walker & Warfa, 2017; Liyanage et al., 2020; Vincent-Ruz et al., 2020; Minderhout & Loertscher, 2007).

POGIL is an active learning strategy that has been extensively studied in in-person settings, but there are few studies that have reviewed it in online settings. For example, Purkayastha et al., (2019) implemented POGIL in an online course setting and evaluated the effectiveness of this instructional method in improving the overall student performance (the course grade). Purkayastha et al., (2019) transferred an in person Health Information Management course taught didactically into a completely online POGIL based and examined how this intervention influenced students' performance in the course. The pre- and post-test indicated that online POGIL settings improved students' performance statistically significantly.

In another study, Joshi and Lau (2021) compared students' experiences of being in two in person and two synchronous 100% online sessions of a POGIL based Environmental Systems course in an architecture program. Though interviewing participants this study indicated that students in online sessions were more focused on completing the task than having conversations with their peers. It was therefore concluded that the online interface affected the quality of discussion and may limit students' ability to benefit from POGIL.

Reynders and Ruder's (2020) study is another example of transforming an in person active learning POGIL-based chemistry course into a completely online course including asynchronous and synchronous aspects. In the online version, students were expected to individually complete the POGIL activities in the asynchronous portion of the class while they were watching pre-recorded videos on the topic. The synchronous portion of the course happened through Zoom, and the class time was mainly allocated for group conversations (15 students in each group) and the whole class conversations. However, while this study claimed to have converted the POGIL class into a hybrid course; some of the main features of the POGIL strategy were neglected. For instance, in POGIL, students should work in groups of 3 or 4 to complete the activities, but in this study, students completed the activities individually outside of the class. During the class time, they joined the groups of 15 to ask their questions related to the activities. As a result, POGIL's cooperative learning strategy and small group size were neglected in that study.

Present Study: A Hybrid POGIL Class

As described in the previous paragraphs, there are few studies discussing implementing POGIL in online courses. Among the three studies discussed above, only one of them used POGIL in a chemistry class context. Additionally, none of them examined a hybrid approach toward POGIL.

We will study a general chemistry class that was designed by combining both in person and online approaches to compare students' engagement in small group conversations in these two formats. The course was designed based on utilizing POGIL as an active learning strategy and the synchronous remote portion happening simultaneously with an in-person portion. In contrast to Reynders and Ruder (2020), the instructor designed the course to include the standard features of a POGIL class, such as working in groups of four students and completing the assigned POGIL activities together. Having both remote and in person formats in one class can give us more empirical evidence about whether this way of structuring an online active learning environment might help facilitate productive small group conversation. Using this specific design helps with controlling a variety of variables such as the course content, the instructor, and individual differences (by switching online and in person sessions among students).

Contributing to the Field

This proposed study will contribute to the field in three ways.

1) First, by introducing a new active learning hybrid design to see how remote and in person students work together synchronously and how that influences students' interactions and their contribution into discourse patterns. This will provide information about the effectiveness of this design in terms of students' interaction for future studies and those instructors who want to consider a similar course design. In hybrid classes, there is usually less class time, and the remote online is asynchronous (Shea et al. 2015; Arispe & Black, 2012; Brunner, 2006), and in some cases, students work independently without interacting with their peers and instructors (Poirier, 2010; Becker et al., 2015). Currently only one study (Beatty, 2007) used web conferencing to provide online students with synchronous live online classes concurrently taking place with in-person classes. However, there was not any students' interaction or small group activities in that class. In our study, we did not reduce the class time. The remote portion was happening synchronously and simultaneously with the in person class. We assigned a mixture of remote and in person students to small groups because we hypothesized this can make remote students more connected to their peers and the instructor who are present in the class. The instructor could deliver the materials exactly the way they would do in an in person class while broadcasting it for remote students. If remote students were lost they had access to their peers and instructor to ask for help. With this novel design, we were able to control for some variables (e.g., the content, the instructor, and personal differences) while comparing students' contributions in small group conversations based on the type of learning environment (remote or in person).

2) Second, having a clear research question and studying a specific context to investigate students' interactions in distance education. This study can contribute to the field by providing empirical data and evidence for students' interactions in distance education in practice. Researchers and instructors will be provided with detailed information about students' conversations in a hybrid context to validate/invalidate their or other studies' claims and hypotheses. Some studies have discussed the importance of students' engagement and interactions in online classes and have suggestions for improving them in online classes, but they have not reported any findings to support their claims (e.g., Khan et al., 2017; Redmond et al., 2018; Poll, 2014). Also, among recent studies, there are studies that report on the transition from in-person to online during the COVID-19 pandemic, but they do not provide a clear data source, analysis methods, or research questions (Tan et al., 2020; Hurst, 2020; Wenzel, 2020). Our analysis will be more than just describing what happened in the class. We will use a research question and a framework to examine the context through a specific lens. A data set has been collected during the Spring semester, and we will be doing discourse analysis to answer our research question.
3) Third, focusing on the learning process and doing discourse analysis as the external measure of the learning process through small group interactions. Considering that students learn more effectively when engaging in verbal interactions and talking through their ideas, it makes it necessary to see how distance education will impact their interactions when active learning is the pedagogical approach. Study in this area can help with making decisions about

designing effective active learning distance courses considering the necessity of a context for students' interactions. Some studies focused on instructors' and students' perceptions of interaction and engagement in online classes. For example, Shea et al. (2015) used data from student surveys, instructor journals, and course activities. Findings suggest that the key to successful hybrid course design is to establish high levels of presence and to plan thoroughly in advance (Shea et al., 2015). In Ku et al. (2013) students' satisfaction and attitude toward an online collaborative course were examined by giving them a survey. Baber (2020) also focused on students' perceived learning outcomes and their satisfaction in online courses and he concluded that interaction is one of the important factors influencing students' perception and satisfaction. Knapp (2018) by using the end-of-semester surveys, investigated students' perception of different interactive structures in online classes (e.g., small group conversation, whole-class conversation) and which one can increase students' interactions. There are a few studies that used discourse analysis in different types of online classes to gain a deeper understanding of students' interactions. For example, Offenholley (2012) analyzed a discussion board of an online mathematics class and through discourse analysis found how facilitation influences students' contribution to online conversations on a discussion board. In another study, Wang et al. (2001) analyzed students' discussions in an online chatroom in a Statistical Methods in Psychology course and how it was correlated with their final grades. They showed students who were more active in online conversations finished the course with higher grades. Although there are studies that focused on

the social interactions in online courses, none investigated how those interactions are related to learning. According to Wallace (2003) and Dennen (2008) studying the learning process that happens through online conversations is an understudied topic that needs to be considered. We will be focusing on the externalization component of the learning process (students' conversations) that happens in POGIL classes and we will be comparing how students engage in this step of learning in remote and in person portions of our research context. Previous studies such as Offenholley (2012) and Wang et al. (2001) did the discourse analysis in discussion boards and a chatroom that conversations might have happened asynchronously outside of the class time and not in small groups. In our study we will study synchronous small group conversations that happened as part of the class time while students were learning new concepts through working on assigned activities. Discourse analysis will help us to make sense of students' interactions and how they contribute to the learning process (knowledge construction).

Table 2.3 provides a summary of comparison between previous studies, and our proposed study and how our study will contribute to the field.

Table 2.3

Comparison between previous studies and the proposed study

Previous studies	**My study**
The design of hybrid classes ● Less class time, and the online portion is usually asynchronous (Shea et al. 2015; Arispe & Black, 2012; Brunner, 2006) ● In some cases, students work independently without interacting with their peers and instructors (Poirier, 2010; Barker, 2015).	Introducing a novel hybrid design ● Not reducing the class time, the remote portion is happening synchronously and simultaneously with the in person class. ● A mixture of remote and in person students are working together in small groups
Discussing the importance of student engagement and interaction in distance education without conducting any experiments ● Discussing the importance of students' engagement and interactions in online classes and have suggestions for improving them in online classes, without reporting any data and analysis to back up the claims (e.g., Khan et al., 2017; Redmond et al., 2018; Poll, 2014)	Investigating students' interactions in distance education empirically ● Having a clear research question, collecting data during the semester, and doing discourse analysis to answer the question.
Describing an experience of running online classes during COVID-19 ● Report on the transition from in-person to online services during the COVID-19 pandemic, without providing a clear data source, analysis methods, or research questions (Tan et al., 2020; Hurst, 2020; Wenzel, 2020).	Having a clear research question and studying a specific context. ● Using a research question and a framework to examine the context through a specific lens.
Analytical frameworks that have been used to study students' engagement and interactions ● Focusing on instructors' and students' perceptions of interaction and engagement in online classes (e.g., Shea et al., 2015; Ku et al., 2013; Baber, 2020; Knapp, 2018). ● Focusing on the social interactions in online courses by conducting discourse analysis (e.g., Offenholley, 2012; Wang et al., 2001)., without investigating how those interactions are related to the learning process.	Doing discourse analysis to make sense of students' interactions and how they contribute to the learning process (knowledge construction). ● Focusing on the externalization component of the learning process (Students conversations) that happens in POGIL classes and comparing how students engage in this step of learning in remote and in person portions of our research context.

Study 2: Implication and conclusion

Reviewing previous literature helped gain an understanding of what has been done to address the transitional distance and encourage more interactions in online education. Generally speaking, most previous studies agreed that designing online courses based on the idea of active learning can encourage students' interaction and engagement in dialogue that ultimately decreases the transactional distance, which is a psychological separation between students and the instructor and other learners. Additionally, previous studies mainly revealed that synchronous online classes provide a context for students' engagement and interactions.

Although reviewing the previous studies indicate that bringing active learning ideas into online courses is feasible, many active learning approaches have not been examined in online contexts to see if they help with decreasing the transactional distance issue. Another important point that needs to be considered is the focus on students' engagement. As Redmond et al. (2018) introduced an online engagement framework, students' engagement has different aspects, and engaging in verbal interactions with other learners is only one of those aspects. Previous literature discussed engagement in a general way without focusing on students' conversations. Therefore, conducting more research to examine different online course designs and focusing on students' conversations can contribute to this field.

REFERENCES

Arispe, K., & Blake, R. J. (2012). Individual factors and successful learning in a hybrid course. *System*, *40*(4), 449-465.

Baber, H. (2020). Determinants of students' perceived learning outcome and satisfaction in online learning during the pandemic of COVID-19. *Journal of Education and e-learning Research*, *7*(3), 285-292.

Beatty, B. J. (2007). Hybrid classes with flexible participation options–If you build it, how will they come? *2007 Annual Proceedings-Anaheim: Volume*, *15*.

Becker, N., Stanford, C., Towns, M., & Cole, R. (2015). Translating across macroscopic, submicroscopic, and symbolic levels: the role of instructor facilitation in an inquiry-oriented physical chemistry class. *Chemistry Education Research and Practice*, *16*(4), 769-785.

Brent, R., Prince, M., & Felder, R. (2021). Promoting and managing student-student interactions in online STEM classes. *International Journal of Engineering Education*, *37*(3), 797-813.

Brunner, D. L. (2006). The Potential of the Hybrid Course Vis-à-Vis Online and Traditional Courses. *Teaching Theology & Religion*, *9*(4), 229-235.

Cafferty, P. (2020). Teaching a Flipped, Fully Online Class Using Small Group Work. *HAPS Educator*.

Cobb, S. C. (2009). Social presence and online learning: A current view from a research perspective. *Journal of Interactive Online Learning*, *8*(3).

Dennen, V. P. (2008). Looking for evidence of learning: Assessment and analysis methods for online discourse. *Computers in Human Behavior*, *24*(2), 205-219.

Fitriyana, N., Wiyarsi, A., Sugiyarto, K. H., & Ikhsan, J. (2021). The influences of hybrid learning with video conference and" chemondro-game" on students' self-efficacy, self-regulated learning, and achievement toward chemistry. *Journal of Turkish Science Education*, *18*(2), 233-248.

Glazer, H. R., & Wanstreet, C. E. (2011). Connection to the academic community: Perceptions of students in online education. *Quarterly Review of Distance Education*, *12*(1), 55.

Hurst, G. A. (2020). Online group work with a large cohort: challenges and new benefits. *Journal of Chemical Education*, *97*(9), 2706-2710.

Jaggars, S. S., & Xu, D. (2016). How do online course design features influence student performance? *Computers & Education*, *95*, 270-284.

Jalali, S., & Wohlin, C. (2012, September). Systematic literature studies: database searches vs. backward snowballing. In *Proceedings of the 2012 ACM-IEEE international symposium on empirical software engineering and measurement* (pp. 29-38). IEEE.

Joshi, N., & Lau, S. K. (2021). Effects of process-oriented guided inquiry learning on approaches to learning, long-term performance, and online learning outcomes. *Interactive Learning Environments*, 1-16.

Khan, A., Egbue, O., Palkie, B., & Madden, J. (2017). Active learning: Engaging students to maximize learning in an online course. *Electronic Journal of E-Learning*, *15*(2), pp107-115.

Knapp, N. F. (2018). Increasing interaction in a flipped online classroom through video conferencing. *TechTrends*, *62*(6), 618-624.

Ku, H. Y., Tseng, H. W., & Akarasriworn, C. (2013). Collaboration factors, teamwork satisfaction, and student attitudes toward online collaborative learning. *Computers in Human Behavior*, *29*(3), 922-929.

Maddix, M. A. (2012). Generating and facilitating effective online learning through discussion. *Christian Education Journal*, *9*(2), 372-385.

Offenholley, K. H. (2012). A discourse analysis of the online mathematics classroom. *American Journal of Distance Education*, *26*(4), 236-248.

Ong, M., Jaumot-Pascual, N., & Ko, L. T. (2020). Research literature on women of color in undergraduate engineering education: A systematic thematic synthesis. *Journal of Engineering Education*, *109*(3), 581–615.

Pan, M. L. (2016). *Preparing literature reviews: Qualitative and quantitative approaches*. Taylor & Francis.

Paulsen, J., & McCormick, A. C. (2020). Reassessing disparities in online learner student engagement in higher education. *Educational Researcher*, *49*(1), 20-29.

Pelz, B. (2010). (My) three principles of effective online pedagogy. *Journal of Asynchronous Learning Networks*, *14*(1), 103-116.

Phillips, J. M. (2005). Strategies for active learning in online continuing education. *The Journal of Continuing Education in Nursing*, *36*(2), 77-83.

Poirier, S. (2010). A Hybrid Course Design: The Best of Both Educational Worlds. *Techniques: Connecting Education and Careers (J1)*, *85*(6), 28-30.

Poll, K., Widen, J., & Weller, S. (2014). Six instructional best practices for online engagement and retention. *Journal of Online Doctoral Education*, *1*(1).

Purkayastha, S., Guntu, M., Ravindran, R., & Surapaneni, A. K. (2019, November). Learning Gains of Process Oriented Guided Inquiry Learning in an Online Course Setting. In European Conference on e-Learning (pp. 495-XII). Academic Conferences International Limited.

Redmond, P., Abawi, L. A., Brown, A., Henderson, R., & Heffernan, A. (2018). An online engagement framework for higher education. *Online learning*, *22*(1), 183-204.

Reynders, G., & Ruder, S. M. (2020). Moving a large-lecture organic POGIL classroom to an online setting. *Journal of Chemical Education*, *97*(9), 3182-3187.

Shea, J., Joaquin, M. E., & Gorzycki, M. (2015). Hybrid course design: Promoting student engagement and success. *Journal of Public Affairs Education*, *21*(4), 539-556.

Skylar, A. A. (2009). A comparison of asynchronous online text-based lectures and synchronous interactive web conferencing lectures. *Issues in Teacher education*, *18*(2), 69-84.

Tan, H. R., Chng, W. H., Chonardo, C., Ng, M. T. T., & Fung, F. M. (2020). How chemists achieve active learning online during the COVID-19 pandemic: using the Community of Inquiry (CoI) framework to support remote teaching. *Journal of Chemical Education*, *97*(9), 2512-2518.

Trespalacios, J., Snelson, C., Lowenthal, P. R., Uribe-Flórez, L., & Perkins, R. (2021). Community and connectedness in online higher education: A scoping review of the literature. *Distance Education, 42*(1), 5-21.

Wallace, R. M. (2003). Online learning in higher education: A review of research on interactions among teachers and students. *Education, Communication & Information, 3*(2), 241-280.

Wang, A. Y., Newlin, M. H., & Tucker, T. L. (2001). A discourse analysis of online classroom chats: Predictors of cyber-student performance. *Teaching of Psychology, 28*(3), 222-226.

Wenzel, T. (2020). Collaborative group learning in remotely taught analytical chemistry courses. *Journal of Chemical Education, 97*(9), 2715-2718.

CHAPTER THREE: STUDY ONE

Small Group Conversations in a POGIL-based Class: How English Learners Engage in Joint Knowledge Construction Process to reach a Shared Understanding

(Manuscript has been submitted to the Journal of Chemical Education)

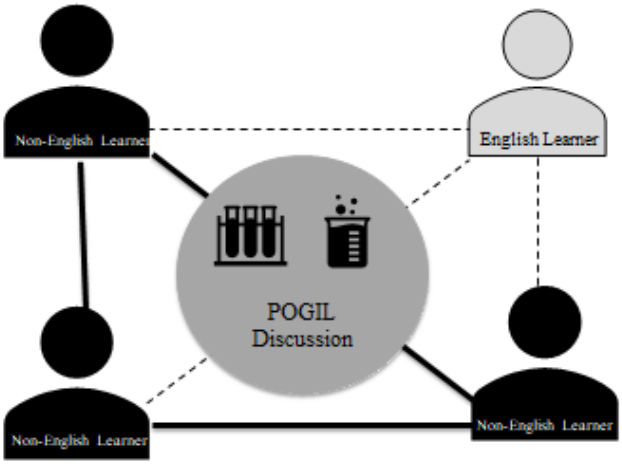
Abstract

Collaboration is an aspect of engagement that focuses on learning through group work and having discussions with other learners. Active learning approaches are a way to foster collaborative engagement because they provide more opportunities for interaction among learners. Process Oriented Guided Inquiry Learning (POGIL), a socially mediated active learning strategy uses verbalizing and discussing ideas with peers in small groups to reach a shared understanding. Due to the growing number of immigrants in the United States, the number of English Learners (ELs) in American classrooms has been increasing rapidly. ELs encounter challenges such as unfamiliarity with American science class norms and expectations, feelings of not being valued and socially accepted, and instructors' lower expectations of them that can impact this group of students' learning and achievement. Previous studies discussed the critical role of language in learning chemistry in particular and how learning chemistry can be more challenging for ELs. We argue that ELs utilize discourse moves differently compared to non-ELs in a POGIL-based class in terms of engaging in conversations that can lead to a shared understanding at the group level through a joint knowledge construction process. Our findings indicated that ELs were less likely to engage in discursive moves that can lead to

a shared understanding than non-ELs, which may indicate missed opportunities for joint knowledge construction. Additionally, we provide evidence that there may be a need to redefine EL populations and talk about the subgroups within this population. Our findings showed the subgroups of ELs engage differently in small group conversations. The graphical abstract for this study appears in Figure 3.1.

Figure 3.1

Graphical Abstract



Keywords: English Learners, General Chemistry, Small Group Conversation, Engagement, POGIL, Shared Understanding, Knowledge Construction.

Introduction

Undergraduate science courses are evolving in ways that emphasize student engagement with their learning process (Reid et al., 2021). Kahu (2013) has conceptualized student engagement as a multifaceted and complex construct that helps explain student outcomes (e.g., persistence, success, achievement), and as such is

typically regarded as a proxy for student participation (Kahu, 2013; Kuh, 2009). One aspect of engagement is collaboration that focuses on peer learning through discussion and group work (Redmond et al., 2018). Collaborative engagement is fostered through active learning approaches that provide students with opportunities to interact and socially engage with each other (Redmond et al., 2018). In active learning environments, students construct their own understanding of a concept through meaningful engagement in course activities (National Research Council, 2012; Freeman et al., 2014). One common active learning approach used in undergraduate chemistry courses is Process Oriented Guided Inquiry Learning (POGIL).

POGIL is based on a social constructivist framework which posits that students need to be actively engaged in the learning process while interacting with their peers in small groups to construct, evaluate, and apply new knowledge (Amineh & Asl, 2015). Previous studies have discussed implementing the POGIL strategy in both chemistry and non-chemistry contexts and the positive impact of this approach on students' learning (Vincent-Ruz et al., 2020; Walker & Warfa, 2017). However, the impact of the POGIL strategy on diverse populations of students (e.g., gender, race, language, ethnicity, etc.) is an understudied area in POGIL research (Lo & Mendez, 2019).

The United States is becoming increasingly diverse and the population of English Learners (ELs) has been increasing rapidly in American classrooms due to the influx of immigrant students since the beginning of the 20th century (Mahiri, 2017; Washburn, 2008). There are a few studies (e.g., Wilson, 2020; Markic & Childs, 2016; Adams et al., 2015) that consider the importance of language in learning chemistry and how engaging

with English in addition to chemistry technical language and content can be more challenging for ELs compared to English native speakers. Those studies argued that successful teaching and learning of chemistry requires instructors to recognize linguistic issues, students' linguistic skills, and growing linguistic heterogeneity in their classrooms.

Generally speaking, there is a need to investigate ELs' experiences in chemistry classes. In particular, the research literature is scant on how ELs navigate the aspects of the POGIL experience. This study was designed to investigate ELs' experiences in a POGIL-based classroom, focusing on their small group conversations. Verbalizing ideas is an important step in the learning process, which is why small group work is a critical part of the POGIL strategy (Hoffman & Richardson, 2019). For ELs to benefit from POGIL-based instruction, it is important to understand their experiences in these small group discussions. The goal of this study was to look at the discourse of ELs and compare how ELs and non-ELs engage in moves that lead to a shared understanding at the group level through joint knowledge construction. Joint knowledge construction occures when individuals exchange ideas to create a new form of knowledge that is influenced by collaboration and participation, resulting in a transition from individual perspectives to joint perspectives (Lombardi & Shipley, 2021). This study addresses the following research questions.

1) What differences exist, if any, between EL and non-EL students' contribution to small group conversations and the group-level joint knowledge construction in a POGIL-based general chemistry class?

2) What differences exist, if any, within the EL population in terms of contributing to small group conversations and the group-level joint knowledge construction in a POGIL-based general chemistry class?

-What might be accounting for any differences that are observed within the EL population, if any?

Conceptual Framework and Background

Social Constructivism

Vygotsky's social constructivism theory explains the learning and the development process based on three critical assumptions (Stetsenko & Arievitch, 1997). The first assumption is that the learner is not a passive receiver of external influences and information. According to the second assumption, knowledge is constructed at the social level and a higher level of mental processes happen through social interactions (Amineh & Asl, 2015; Driscoll, 2005; Vygotsky, 1987) through which learners can construct ideas and solutions that they would not be able to reach individually (Driscoll, 2005). The third assumption focuses on the vital role of language as a mediator in the learning process. Vygotsky (1987) argued that talk and thoughts are closely related and that talking through a concept helps promote a faster and higher quality internalization of newly learned knowledge (Sedova et al., 2019).

Although being present in a talk intensive learning environment and listening to actively participating peers is beneficial for learners and allows for internalization of the knowledge to some extent, there is a stronger link between the frequency and the quality

of their own talk and their individual achievement (Sedova et al., 2019; Webb et al., 2014; Ing et al., 2015). Based on these arguments, all students should benefit from active engagement in group conversations to maximize learning.

Small Group Interactions

Small groups are superior to large groups when it comes to constructing knowledge (Draskovic et al., 2004). Small groups allow more students to be engaged in conversation than large groups, and these small groups have been shown to have a positive impact on STEM majors' persistence, achievement, and attitudes (Smith et al., 2014). Encouraging ELs to interact with their peers in small group conversations is one of the practices suggested by Goldenberg (2008) to provide ELs with more support, the opportunity to share their ideas, and more practice in having academic conversations in a safe environment. Despite the positive effects of small group conversations for students' learning, little is known about how ELs actually engage in small group conversations in college classes.

POGIL

POGIL activities are aligned with the tenets of social constructivism and are designed based on the learning cycle, which includes exploration, invention, and application phases (Bauer et al., 2019). POGIL learning takes place with small groups of students. Engaging in this step-by-step process helps students construct new knowledge through interactions with other students in a small group. Our conceptual framework (Figure 3.2) posits knowledge construction in POGIL occurs via a process that includes

knowledge Internalization, Externalization, Objectivation, Legitimation, and Reification (Jackson, 2010).

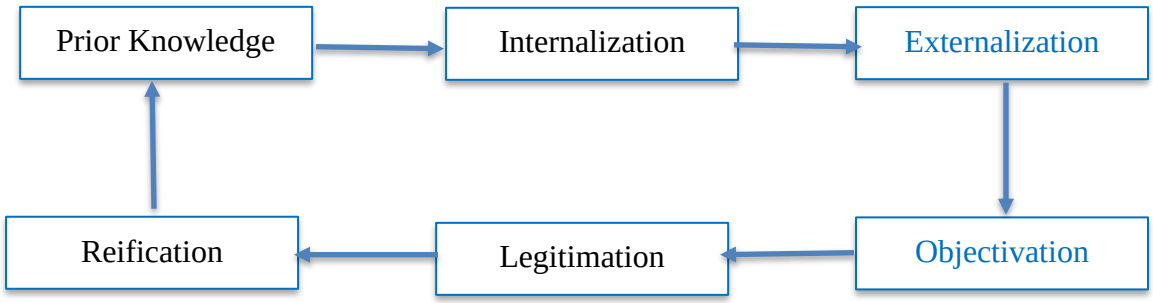
Students come to each POGIL activity with prior knowledge that is built upon by reading or interpreting the POGIL model. A model can be a table, graph, scheme, or any other form of information related to the topic under discussion (Ruder et al., 2020). Students combine what they have interpreted from the model and their prior knowledge individually through habituation or transformation (Internalization). When students encounter new information, their prior knowledge is leveraged to make sense of it. During the sense-making process, learners might elaborate on the new material by adding details, generating relationships between the new material and information already in memory (Habituation); or adopting a new perspective on the topic (Transformation) (King, 1994). In small groups, students can express their new knowledge verbally or in a symbolic way such as using body language (Externalization). Through interactions with other group members, students are expected to construct knowledge in community rather than individually (Objectivation). For many learners, the social construction of meaning plays a more important role than the individual cognitive construction of knowledge (Lombardi & Shipley, 2021).

POGIL is a cooperative learning strategy and the cooperative approach requires that learners reach a shared understanding (Cole et al., 2019). Working in small groups provides the context for hearing others' ideas and perspectives and having these conversations allows learners to reach a shared understanding about the concept. Engaging in conversations with other learners results in deep learning and knowledge

construction. This does not mean that students cannot construct knowledge on their own, but through social interaction and engaging in conversations with others the learning will likely be deeper (Lombardi & Shipley, 2021; Chi & Menekse, 2015). Then the emerging knowledge is considered and vetted by the instructor through small group facilitation or the whole class conversation (Legitimation) to solidify the concepts in students' minds (Reification). This cyclic process can happen several times during a single POGIL class.

Figure 3.2

The learning process in a POGIL-based classroom designed based on social constructivism



To study the internal process of knowledge construction, the external aspect of it must be interpreted and analyzed (King, 1994). Verbal expressions through discourse is one of the accepted forms that can provide insight to the researcher on the inner thinking of the students (Moon et al., 2017). Students externalize their ideas in the group and through discussion with their peers, they reach a shared understanding about a concept, construct new knowledge, and ultimately internalize it. Verbalizing ideas facilitates individuals' deeper knowledge construction because "conversation requires specificity, one must construct missing pieces or recognize the need for more information" (Lombardi & Shipley, 2021, p. 24). Verbalizing thoughts also helps with joint knowledge construction (that leads to shared understanding) because engaging in conversations allows each person to bring different elements that, all together, can offer a deeper and more complete understanding that none of the learners could have reached on his or her own (Lombardi & Shipley, 2021; Chi & Menekse, 2015).

In this study, we focused on ELs' engagement in small group conversations (the Externalization and Objectivation steps in Figure 3.2). We investigated the EL's contributions to the group discussions based on their use of discursive moves that can lead to a common understanding in the group (e.g., reasoning, presenting a claim, or explanation seeking) to see whether or not the Externalization and Objectivation components of the learning process occurring in a POGIL class are different for the EL and the non-EL populations, and if any differences among the EL population emerge as a result of this analysis (King, 1994; van Aalst, 2009; Warfa et al., 2014; Warfa et al., 2018). Findings from previous studies on ELs, primarily done in K-12 STEM classes, showed that EL students face some challenges such as having low English proficiency, fear of being judged, or feelings of not being valued and socially accepted (Lee, 2005; Terry & Irving, 2010). These challenges can affect ELs' group interactions and the way that they externalize their thoughts in their groups. Thus, by focusing on the Externalization and Objectivation components of the learning process in a POGIL class, the level of engagement in group conversation for ELs was compared to non-ELs' engagement. Also, Els' interviews were used to determine to what extent those in the EL population in this study experienced similar issues discussed in prior literature and how these issues affected their participation in group conversations.

Methods

This study is a comparative exploratory case study that will answer the research questions using a mixed-method approach (Yin, 2015). There are two cases units of analysis: ELs and non-ELs. Students self-identified as either ELs or non-ELs and this

information was used to define the two cases in this study. A cross-case analysis was done to gain an in-depth understanding of each case in terms of engaging in small group conversations in a POGIL-based general chemistry course (Patton, 2014). In order to answer research question two and study the possible subgroups within the EL population, new cases were defined based on the criteria that helped categorize this population.

Context

The data were collected during the COVID-19 pandemic over the Spring 2021 semester in a hybrid General Chemistry class with an enrollment of 24 students at a large Southeastern university. The course was taught by a faculty member with more than twenty years of experience teaching chemistry and an experienced POGIL trainer. Each class session was 55 minutes and there were three class meetings each week on Mondays, Wednesdays, and Fridays. This course utilized POGIL activities (See Appendix D) in addition to some whole-class conversations and interactive lectures.

Students worked in groups of four (Some groups had both ELs and non-ELs and some groups had only non-ELs) to complete the POGIL activities. The course instructor assigned students to small groups and the group compositions were maintained consistent throughout the semester. Students were randomly assigned to small groups based on whether or not they were English learners. In this hybrid class, half of the students were in Monday group (i.e., they were in person on Mondays and the rest of the class joined via Zoom) and the other half were in Wednesday group (i.e., they were in person on Wednesdays and the rest of the class joined via Zoom). Monday and Wednesday groups would switch places every other Friday to be in person or join via Zoom. Students who

attended class in person were expected to bring an electronic device to join the Zoom meeting. Each group also had an iPad for sharing the screen while working on the activity.

For small group conversations, the instructor sent the students to pre-assigned Zoom breakout rooms consisting of two in person students and two online students. Usually, the group conversations took about five to fifteen minutes. While students were working on the activity in their small groups, the instructor checked in with groups and answered their questions. After most of the groups had completed the assigned section of the POGIL activity, the instructor invited all students back to the main Zoom space and reviewed the important and or challenging points by selecting examples of students' work to create a whole-class discussion.

Participants and Recruitment Process

All students in this class were invited to participate in the study during the second week of the class and they provided researchers with their demographic information through a short survey on Qualtrics (Qualtrics, 2022). The demographic information was used to determine which groups contained at least one EL student to be included in this study. Out of total six groups (N=24) present in class, there were three groups that had at least one EL student and we focused on these three groups (N=12). However, the data related to three students who were members of these three groups were not included in this study because they did not provide consent or dropped the course. Since we were focused on individual utterances and not the pattern of the conversations we did not see this as a major concern. Table 3.1 summarizes the participants' demographic information

(N=9) (pseudonyms were assigned for all participants). All data collection was approved by the university Institutional Review Board (IRB protocol number: 19-2253) (see Appendix G).

Table 3.1

Demographic Information

Participant Name	Gender	EL	First Language	International Student
Nina	Female	No	English	No
Nancy	Female	No	English	No
Nadia	Female	No	English	No
Noah	Male	No	English	No
Kamila	Female	Yes	“Spanish”	No
Kiana	Female	Yes	“Farsi then Turkish”	No
Karla	Female	Yes	“Arabic”	No
Isabel	Female	Yes	Unspecified	Yes
Isaac	Male	Yes	Unspecified	Yes

All five EL students were invited for an interview via email and all of them agreed to help with this part of the study. The interviewees' time was compensated with electronic gift cards at a rate of $10 per hour.

Data Collection

Multiple data sources (interviews and small group Zoom meeting recordings of POGIL sessions) were used for studying each case and answering the research questions (Patton, 2014). Discourse analysis, using a three-level analytical framework that captures student interactions broadly and in-depth (Nennig et al., 2022), was used for making sense of students' group conversations, and a constant comparison approach was used for analyzing the ELs' interviews (Phelps, 1994). Details about collecting and analyzing each data source will be described below.

Zoom Meeting Recording

To work on the POGIL activities, students were assigned to their small groups in breakout rooms. A laptop was used for each breakout room to record the students' conversations and what they posted in the chat feature of Zoom. The recorded videos were saved on password-protected laptops and later were stored on a secure server accessible only by the researchers for transcription and analysis. All breakout rooms were recorded starting the fourth week of the class until the end of the semester (20 classes in total). All recordings were transcribed using online services such as Otter or Temi (Otter, 2022; Temi, 2022). Online transcription services convert audio or video files into text automatically. Although the automated transcription services use advanced speech recognition, for most of the transcripts there were some inaccuracies in the content and voice recognition. Therefore, before analysis, transcripts were reviewed and edited when needed.

ELs Interviews

To gain an understanding of what EL students experienced during small group conversations in a POGIL-based general chemistry class, semi-structured interviews were conducted with all five ELs who participated. Each interview took about 30-60 minutes based on how detailed the interviewee was in answering the questions. Interviews were conducted in the third month after the beginning of the Spring 2021 semester to ensure that students had enough experience working in their small groups. All interviews were conducted through Zoom and were audio and video recorded. They were transcribed using Temi or Otter (Temi, 2022; Otter, 2022).

The interview protocol (Appendix A), which included open-ended questions, was designed by the research team based on previous literature that discussed ELs' experiences in class conversations and possible factors that influence their interactions. For instance, as discussed in chapter 2 of this dissertation, EL students with limited fluency in English might struggle to express themselves on scientific tasks and sometimes EL students do not have the adequate vocabulary to express their ideas. Considering this statement, a few interview questions were designed to ask about EL students' perceived English proficiency and how it influenced their engagement in small group conversations. To ensure the clarity of the question, pilot interviews were conducted with two other EL students not participating in the study who were enrolled in another introductory chemistry course, and questions were modified accordingly. As an example, after the pilot interviews, researchers recognized that for all questions related to the breakout room conversations the term "breakout room interaction" should be explicitly used and

emphasized in the question to prevent the interviewees from talking about their general experiences outside of the class or during the whole class discussions.

Data analysis

Small Group Conversations Analysis

The breakout room recordings were used to analyze students' small group conversations qualitatively and quantitatively. A total of 60 small group conversations from three groups over 20 class periods were transcribed and analyzed. The results of the analysis were used to quantify the frequency of each student's talk turns and also to evaluate how often each student was engaged in specific discursive moves that can lead to a shared understanding through the joint knowledge construction process. These values were used to identify the differences between ELs and non-ELs and between subgroups within the EL population.

The Student Interaction Discursive Moves (SIDM) framework (Appendix C) was used to analyze students' small group conversations (Nennig et al., 2022). This framework was chosen because it allows a detailed analysis of students' conversations and their discourse moves. In the SIDM framework, there are two units of analysis; 'conversational turns' and 'utterances'. The first unit, 'conversational turn', is defined as every time a different person begins speaking. The second unit of analysis, 'utterances' is used when a 'conversational turn' includes multiple moves and cannot be characterized by assigning only one code. Therefore, the second unit of analysis is used to break down the turn and assign one code to each piece (Nennig et al., 2022).

Previous literature was used to identify key discursive moves that can lead to group-level shared understanding through joint knowledge construction during the small group conversation. For example, verbal interactions that can lead to a shared understanding include explanations, justifications, inferences, hypotheses, interpreting and evaluating new ideas, sharing, critiquing, and testing ideas at different levels (King, 1994; van Aalst, 2009). Warfa (2014, 2108) indicated that some discursive moves such as asking for confirmation and clarifying ideas, agreeing or rejecting with reasoning, and seeking group consensus helped students to reach a collective understanding.

In the next step, each key discursive move was matched with one of the nature of utterance codes of the SIDM framework based on the definitions provided by the codebook. Only codes matching the key discursive moves including assessing, presenting a claim, explanation seeking, reasoning, rejecting, rebutting, and summarizing were used as evidence of students' contribution to the joint knowledge construction process. Only these key discursive moves were used to compare EL and non-EL students and between subgroups within the EL population to answer our research questions. Table 3.2 shows examples of these discursive moves (assessing, explanation seeking, presenting a claim, reasoning, rebutting, rejecting, and summarizing) mentioned by our participants.

Table 3.2

Examples of discursive moves that can lead to a shared understanding through joint knowledge construction process.

Discursive moves that can lead to a shared understanding	Code definitions	Example
Assessing	Determining if the strategy addresses all aspects of the problem/task and is functional or if an answer makes sense	EX 1 - Nancy: *"I believe your answer is right for 1"* EX 2 - Noah: *"Yeah I was going to say it should probably be a little lower than 1500."*
Explanation Seeking	Requesting to share ideas, seeking an initial answer to a question or how to think about a problem, or requesting backing to a claim	EX 1 - Nadia: *"How do you know when you have to flip the reaction?"* EX 2 - Kamila: *"So Nina, how did you decide that?"*
Presenting a Claim	Suggesting an idea (may be tentative in nature)	EX 1 - Kiana: *"is a guess but it dissolved so"* EX 2 - Noah: *"Okay so I think we can say that we can speed up reactions by heating them up"*
Reasoning	Thinking through the problem/scenario or justifying or supporting an idea with scientific reasoning	EX 1 - Karla: *"For the first one, it's because it is a gas"* EX 2 - Nina: *"...because sodium chloride is held together by an ionic bond, which isn't a real bond. So, I guess as soon as it can get apart, it will. And that's kind of the idea of entropy is that if it can spread out, then it's going to"*
Rebutting	Rejecting an assertion supported with reasoning	EX 1 - Nina: *"I don't think... I don't know that we can say that yet. Because it remains constant within the concentration of NO changes. And the rate changes so that in the next one NO stays the same and H_2 changes and the rate changes."* EX 2 - Maria: *"I'm not sure because salt dissolves in it no matter what"*
Rejecting	Explicitly voicing disagreement with an utterance	EX 1 - Noah: *"I don't think so, I'm pretty sure equilibrium is met when the reaction proceeds in both directions at the same rate"*

		EX 2 - Karla: *"I don't think so then. Remember she said that would decrease probability of it being the right orientation"*
Summarizing	Summarizing ideas or steps to solve a problem that arose from the conversation	EX 1 - Nina: *"if the limiting reagent doesn't reach an equilibrium, the reaction will have to stop....never stops."* EX 2 - Kamila: *"So the conditions of equilibrium, I guess we kind of answered that, where if there's a limiting reagent, the reaction stops. And then if there's not a limiting reagent, the reaction keeps on going, I guess because it's continuous meaning."*

ELs Interviews Analysis

During the transcription and when first listening to each interview, analytical memos were made for making sense of the data and keeping a record of ideas and questions that came up during this process (Saldaña, 2016). The EL students' challenges discussed in previous studies were used as priori codes to define smaller chunks in interviews transcripts. For example, all interview questions around the English proficiency topic were grouped together as a chunk. with a specific topic. In the next step, each chunk around a topic was analyzed by doing a constant comparison analysis. In this technique, the data were reread several times and separated into meaningful chunks. Similar meaningful chunks were grouped together and descriptions were written for that group. Finally, the categories were reviewed and general themes were identified (Phelps, 1994). Findings from interviews were used for triangulation purposes and to make sense of the reasons for the observed differences between EL and non-EL students' engagements in group-level joint knowledge construction.

Results and Discussion

Frequency of Talk Turn

After transcribing the small group breakout room conversations, we observed that the total talk turns over 20 classes for non-ELs (N=4) were 564 and for ELs (N=5) were 295. The results of analysis show that EL students had fewer talk turns than their non-EL peers (X^2 (1) = 156.514, $p < .001$). King (1994) and Sedova et al. (2019) concluded that verbalizing ideas and discussing them with other learners has a positive effect on students' learning and helps them to have a higher level of achievement. Our findings showed that EL students faced a challenge in terms of engaging in small group conversations that ultimately might impact their learning and achievement negatively.

Discursive Moves that can Lead to a Shared Understanding

The difference between EL and non-EL contributions in group-level joint knowledge construction was determined through the analysis of small group conversations based on the SIDM framework. The result of the analysis revealed that EL and non-ELs were different in terms of the frequency of engagement in discursive moves that can lead to a shared understanding through a joint knowledge construction in a POGIL-based general chemistry class (See Figure 3.3).

Figure 3.3

Frequency of key discursive moves for non-ELs and Els

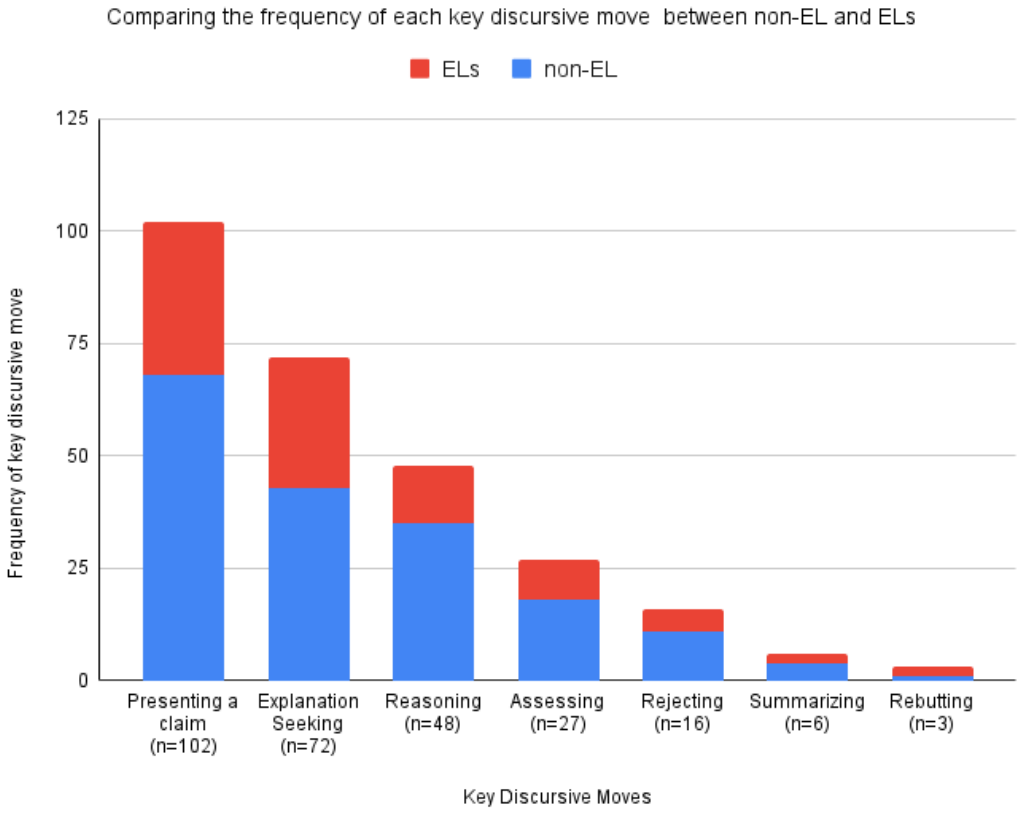
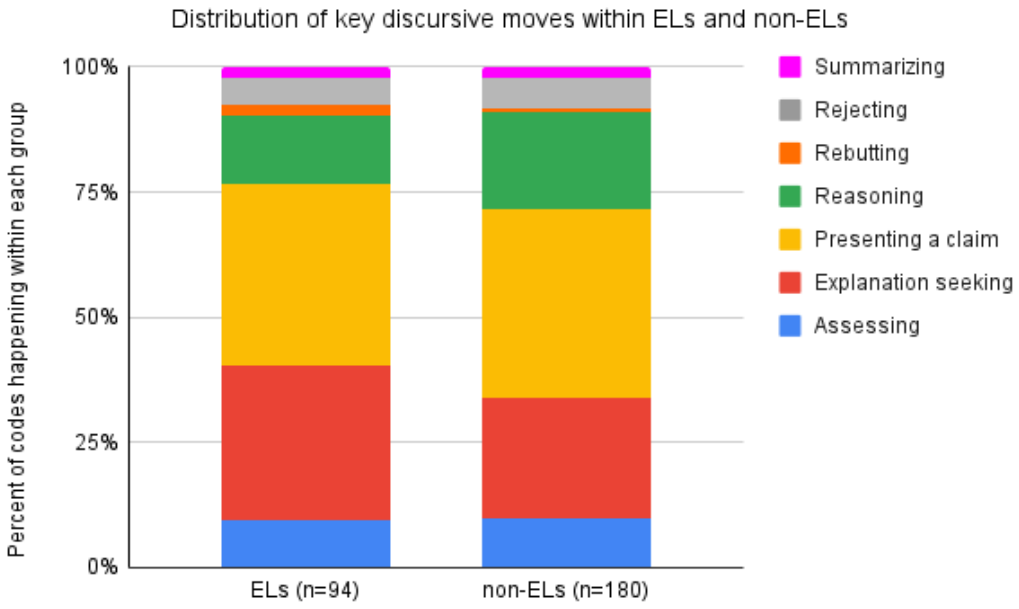


Figure 3.3 shows that for non-EL groups the total frequency of key discursive moves was higher than EL group (X^2 (1) = 50.065, p < .001). For instance, non-EL students had a much higher frequency for "presenting a claim" and "Reasoning" than EL-students. Both of these moves are necessary for engaging in scientific arguments and these data show that EL students engaged in these discursive moves less frequently. Argumentation is one of the process skills that is necessary for understanding the nature

of science and for acting like a scientist (Kulatunga et al., 2014). Previous studies showed that the absence of argumentation can decrease science learning (Kulatunga et al., 2013; Aydeniz et al., 2012). Students who engage in scientific argumentation indicate a deeper understanding of scientific phenomena (Murphy et al., 2018). Not engaging in such discursive moves can indicate missed opportunities for joint knowledge construction. Although the frequency of codes was different between EL and non-EL students in this study, the distribution of codes within each group was similar with a few differences (see Figure 3.4). For instance, 36.2% of EL's key discursive moves and 37.8% of non- EL's key discursive moves were "Presenting a claim", which is similar. This pattern is observed for other key discursive moves as well (e.g., "Assessing", ELs =10%, non-ELs = 9.6%). Thus, this suggests that the challenge was not with the EL students' ability to engage with the discursive move but with how frequently they engaged with the discursive move in their small group conversations. To see every single participant's engagement in key discursive moves, see the graph in Appendix E.

Figure 3.4

The distribution of key discourse moves within non-EL and EL groups.



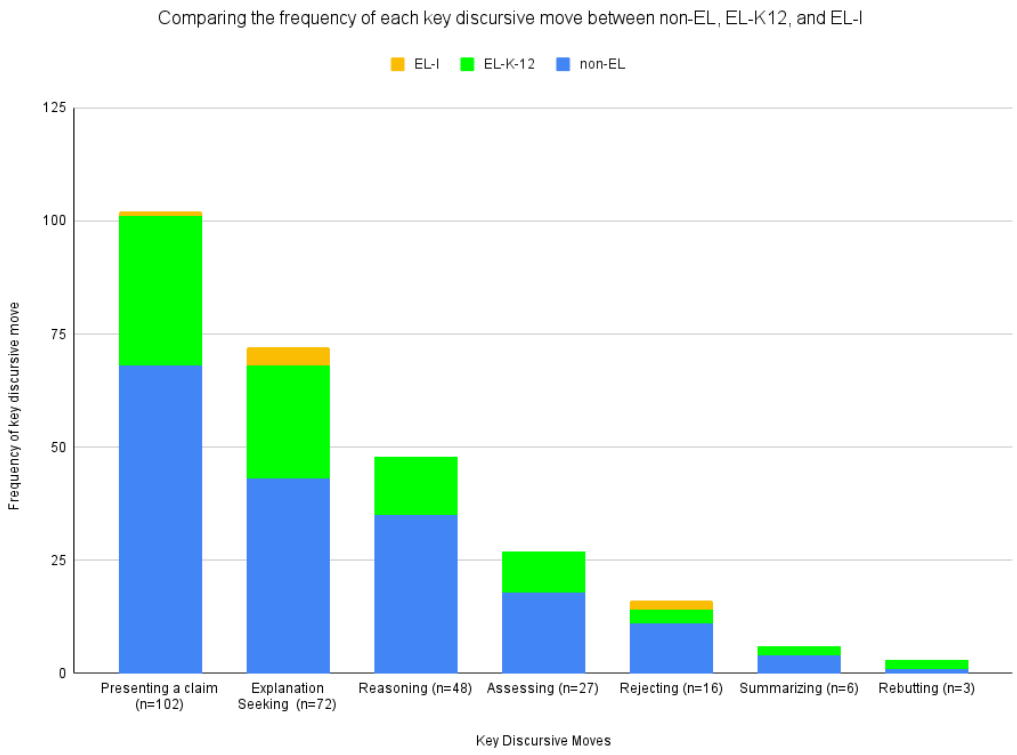
Redefining the EL Population

A closer look at the data and students' educational backgrounds showed that there were two subgroups among the EL population. Some EL students were international students who came to the U.S. on a temporary "non-immigrant" status to complete their college-level education while other EL students immigrated to the U.S. when they were much younger and completed their K-12 education in the U.S. system. We defined these subgroups as EL-international (EL-I) and EL-K-12 respectively. In table 3.1, all names starting with N are non-ELs, names starting with K are EL-K-12, and names starting with I are EL-I.

The total talk turns over 20 classes for non-ELs (N=4) were 564, for ELs-K12 (N=3) were 279, and for ELs-I (N=2) were 16. Findings showed that non-EL, EL-I and EL-K-12 students were different in terms of the total number of talk turns in the small group conversations (X^2 (2) = 247.375, $p < .001$). The frequency of engagement in key discursive moves between non-EL, EL-I and the EL-K-12 participants was also compared (See Figure 3.5). EL-I students were less frequently engaged in joint knowledge construction key discursive moves than both EL-K-12 and non-EL participants. Figure 3.5 shows the frequency of all codes was much lower for EL-I students than for their EL-K-12 and non-EL peers (X^2 (2) = 75.717, $p < .001$). In the EL-I population, utterances that require a justification for sharing an idea or critiquing others' ideas such as "Reasoning" and "Rebutting" were completely absent.

Figure 3.5

Frequency of key discursive moves for non-EL, EL-K-12, and EL-I

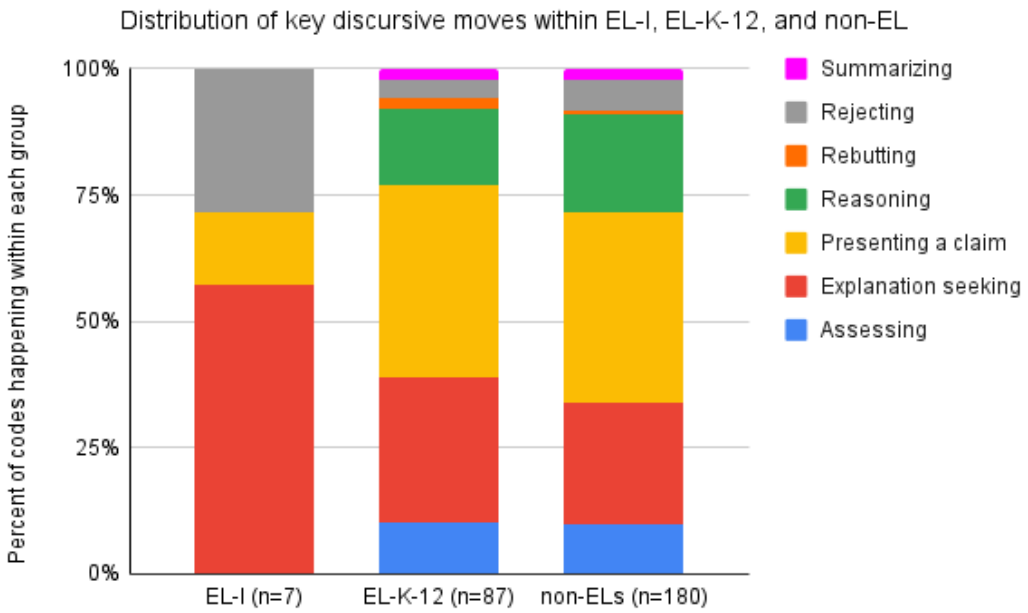


The distribution of key discursive moves was compared between EL-I and EL-K-12 (See Figure 3.6). This chart indicates that the distribution of joint knowledge construction key discursive moves for EL-I was different from EL-K-12 and non-EL students. From the analysis, the distribution of codes for EL-K-12 and non-ELs are similar but EL-I is different. Most discursive moves such as summarizing, rebutting, reasoning, and assessing were not used by EL-I students. For instance, within EL-I population "Explanation seeking" has the biggest portion of the distribution (more than 55%), which means when EL-I are engaged in discourse, they are mostly asking questions. The

remainder of their distribution complement the “Explanation seeking” code, which is to either reject the answer presented to them (Rejecting) or present their answer (Presenting a claim). However, for EL-K-12 and non-EL groups “Explanation seeking” constitute about 28% and 24% of their key discursive moves respectively.

Figure 3.6

The distribution of codes within EL-I, EL-K-12, and non-EL



Reasons for Differences between EL-I and EL-K-12

Analysis of the ELs’ interviews indicated that the English proficiency and cognitive processing time are two factors that could explain the differences observed within EL population.

English Proficiency

In this study, all EL participants reported that their first language was not English. Considering only this factor leads to grouping them together as a separate case from the native speakers (non-ELs). However, the findings of this study (Figures 3.3 and 3.5) showed that this feature is not enough for grouping them and other factors such as English proficiency and time spent in the US education system should also be taken into account when grouping students. The data from the interview helped us to better understand the current English proficiency of students from their perspectives and how long each participant has been in the US education system. All EL-K-12 participants finished their entire K-12 education in the US but EL-I finished their K-12 education in their home country and moved to the US for their college-level education. While the first language of all EL participants was not English, they held different perceptions of their English proficiency. All EL-K-12 (e.g. Karla & Kamila) rated their proficiency between 8 to 10 (on a scale of 1 to 10) but EL-I (Isabel & Isaac) chose 4 and 5.

Karla (EL-K-12)*: "Well, I would say my proficiency is like a 10 right now."*

Kamila (EL-K-12)*: "I'd say like, an 8, maybe because I work so hard."*

Isabel (EL-I)*: "I'm an international student, actually. I'm from Kenya. So I moved here for undergraduate on a scholarship… Okay, I can say 5."*

Isaac (EL-I): *"Well… I would say 4."*

Another interesting point that came up during the interviews was related to the skills that ELs think need more improvement. All EL-K-12 mentioned that they need some improvement in their listening but they do not see this as a barrier to group participation.

> Kiana (EL-K-12): *"I don't think it influences my group participation, because I feel like in groups, we all kind of use the same language, you know, we're all coming from high school, we all just use the language that we're comfortable with."*

EL-K-12 participants do not perceive their English to be a barrier to their group participation and they do not have any worries to be judged based on their English. However, what EL-I students experience in the class is different. Both EL-I participants mentioned that they need improvement in their English speaking skill and they were worried about other students' judgment of their accents. Not being fully proficient in English and fear of being judged by others can be valid reasons for not speaking up during small group conversations and engagement in joint knowledge construction process. For instance, Isabel said,

> *"Sometimes I feel like I'm not comfortable speaking because of my English… Some people understand and others don't. So you don't know like, if someone will judge you or…"* She also stated *"if, like if he or she asked me a question, and then I answer most of the time, he or she says, I can't hear you. That's when you feel like more uncomfortable."*

Isaac, another EL-I, also mentioned that the English that he had learned in his country is British English, and the way that they pronounce words is different. He mentioned, *"When you get the idea that how to pronounce those words you are fine…"* He said when he came to the US he had that problem but after a while, he figured it out, and now he is fine.

Being in the US education system and residing in an English-speaking country for a long time helped EL-K-12 to be proficient in English and familiarize them with the education system. For instance, Karla mentioned that the time of being in the environment helped her to overcome the language difficulties

> *"…my parents are immigrants. … But, I did go to elementary school here and high school everything…I had more trouble with it in elementary school, but I was in ESL classes for a long while. And then I think I picked up on it pretty quick. I was raised here, so it made it easier for me."*

Kamila, an EL-K-12, also mentioned,

> *"I grew up only in Spanish. And then it was very hard, because I remember starting kindergarten, all I spoke was Spanish. And at that time, there weren't very large, like ESL groups. So I basically had to teach myself English…which is already very hard...."*

Kiana another EL-K-12 participant mentioned

> *"...I started first grade in the US and they originally wanted to put me in kindergarten again here, since I didn't speak English... first grade, it was hard. I know like they've gotten better at dealing with now they call like English second learners. I remember originally, it was called English language learners. And there wasn't that much of a program...I think what helped me a lot as a kid to learn English, I read a lot. I always wanted to get into the library. I was always reading like chapter books…"*

A difference between EL-K-12 and EL-I is the age at which they started dealing with language barrier issues. All EL-K-12 started learning English at very young ages

(elementary level) and many received help from special programs at their schools. Also, being in an English-speaking country helped them to speak English fluently. However, for EL-I the situation was different. They encountered language issues at older ages and they needed to overcome their difficulties mostly on their own. This finding matches the Sheng et al. (2011) study that claimed different factors such as how long an EL student has been in an English-speaking country and their age when they relocated to that country play a major role in EL-K-12 students' English proficiency. Curtis and Millar (1988) also claimed that the longer duration (8 years) of being in an English-speaking country helped EL students to overcome an achievement gap that they were experiencing during the first few years.

Even though, EL-K-12 students feel more confident about their English proficiency and they do not see that as a barrier for group conversations it does not mean that their experiences are similar to non-EL students in terms of using English and they are not experiencing any issues. For instance, Kamila, an EL-K-12, who rated her English as 8 mentioned how sometimes switching between Spanish and English can be a struggle:

> *"…for me, if… if I were to be on a phone call right before, like, lecture…, and then I walked in, like, I've walked in some times and started talking to Casey [One of her group members] in Spanish, I'm like, Whoa, sorry. And it's, it's just kind of like a switch. So I wouldn't say that my English is like at a perfect 10. Because there are times where I know the word for what I'm trying to say in Spanish. And I'm completely blanking on like what I'm trying to say in English which happens more often than you think with how good my English is…"*

Processing Time

The interview also revealed that there was not enough time to work on the assigned questions. For instance, Isabel said:

> *"Sometimes we have like a minimal time. For example, the instructor often gives us five minutes. And then we do some of them, like, asking someone, and then before that time and before he or she answers… I can see that being an issue... if you are given like, five minutes, and then you have like, two questions or one question to discuss, you cannot, you can't like, you don't have that time to like, ask another question, no."*

For EL students who are not proficient in English, reading the prompt in English, processing the information and making sense of it, putting the ideas in a coherent way, and translating them into English take longer time than non-ELs. 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 question.

Conclusions

Learning happens through social interactions and it is more likely for a student to internalize knowledge at a higher level when they talk through concepts. Therefore, it is important that all students, regardless of their backgrounds, have conversations with other learners. However**,** our analysis indicated that ELs are less likely to contribute in small group conversations compared to their non-EL peers and their talk turns is lower. ELs

engaged less frequently in discursive moves that can lead to a shared understanding through joint knowledge construction. This challenge needs to be addressed to help EL students' learning. To offer a learning environment that benefits diverse students equitably, it is important to make sure all students are engaged in activities and actions that improve their learning. Also, it is important to note that the EL population cannot be viewed as homogenous since those whose first language is not English have different educational experiences. Our data show that, the amount of time spent in the US education system is a differentiating factor between the subgroup populations of ELs. For instance, international students and those who had K-12 education in the US were different in how they participated in small group conversations.

Implications

Instructors should take into consideration the benefit of students participating in verbal interaction rather than just listening. There might be missed opportunities of a higher level of knowledge construction for EL students who are not engaged in joint knowledge construction key discursive moves. Our findings suggest that EL students need more time to be able to share their arguments in their groups. Therefore, instructor should consider pacing out the time. For instance, instructors could use formative assessment to determine if ELs in their classes are getting adequate processing time and are able to engage in group conversations. Our data suggest that while EL students represent a growing population in our undergraduate STEM courses, there might be nuances that accounts for differences in their contributions to small group conversations. This finding can inform researchers studying the EL population that relying only on the

fact that English is not their first language or categorizing them with other minorities is not sufficient in understanding their needs. More information about ELs backgrounds can help with gaining a better understanding of their experiences. Researchers should consider that the EL student population might need to be redefined and that different subgroups with different needs might exist among them. The results of this study can also be informative for instructors who have EL students in their classes that EL-Is might need special support for engaging more in group interactions compared to those ELs who had enough time to cope with challenges related to language and culture.

Future Research

In the present study, students' outcomes and how engaging in group conversations might impact their course grades were not investigated. In future research, it would be valuable to the field to see how students' engagement in small group conversations will impact their grades and success in finishing the course. Doing more research on the assessment component of active learning will help educators to design assessments that reinforce the importance of interacting with other learners to externalize ideas. If instructors can highlight the positive role of externalizing ideas in students' outcomes in the class and includ this in their class assessment, it can lead to more buy-in from students to engage in group conversations.

There is also a potential for doing more research considering the conceptual framework used in this study to talk about knowledge construction process in a POGIL class (See figure 3.2). This study focused on Externalization and Objectivation components and how these steps were different for the EL population. The reason for focusing on these

two components was related to the hypothesis that in externalizing ideas and having conversations with other learners, language plays an important role. However, in other steps of the knowledge construction process in a POGIL class language matters as well. For instance, typically, the model is a written paragraph that students need to read and understand. Therefore, still there are other components of learning in a POGIL class that might create a different experience for EL students. Future studies can consider other components such as Prior knowledge and Internalization and how different types of POGIL models (e.g., written models, graphs, demonstration) might impact EL students' small group conversations. This will help to see if a certain model can facilitate small group interactions among EL students.

ELs at the undergraduate level were the subjects of this study. There are EL students at the graduate level in the US. The future research should examine the classroom and research experiences of this group of EL students at American universities. Similar to the undergraduate level, EL-I students also exist amongst the EL students at the graduate level. Graduate EL-I students obtained their bachelor's degrees in another country and came to the US to get their master's or doctorate degrees. It would be interesting to compare their experiences with EL-I students at the undergraduate level and see if starting education in the US at different levels (and most probably at different ages) impacts their experiences. Research is an important part of the graduate school experience, so it is important to investigate whether this experience addresses or creates any challenges for graduate EL students.

Limitations

The first limitation of this study is related to the nature of our method, discourse analysis that focuses only on students' verbal interactions. It is clear that there are other non-verbal ways of externalizing (e.g., body language) the thoughts and ideas that were not captured in this study. The second limitation is a potential bias based on the identity of some of the researchers who are themselves ELs. This has implications for interpreting and analyzing the data. By discussing the finding and sharing the data with other researchers in the group, we tried to reduce the impact of the personal experiences of EL researchers on the data. The third limitation of this study is the fact that this data comes from a single university and a particular classroom. Thus, results of the study cannot be generalized to other settings without replication of similar analysis in diverse settings and institutions but are potentially transferable to other situations that share similar characteristics.

REFERENCES

Adams, A., Jessup, W., Criswell, B. A., Weaver-High, C., & Rushton, G. T. (2015). Using Inquiry to Break the Language Barrier in Chemistry Classrooms. *Journal of Chemical Education*, *92*(12), 2062–2066.

Amineh, R. J., & Asl, H. D. (2015). Review of constructivism and social constructivism. *Journal of Social Sciences, Literature and Languages*, *1*(1), 9-16.

Aydeniz, M., Pabuccu, A., Cetin, P. S., & Kaya, E. (2012). Argumentation and students' conceptual understanding of properties and behaviors of the gases. *International Journal of Science and Mathematics Education*, *10*(6), 1303-1324.

Bauer, C. F., Daubenmire, P. L., & Minderhout, V. (2019). Not just a good idea, POGIL has a theoretical foundation. In S. R. Simonson (Ed.), *POGIL: An Introduction to Process Oriented Guided Inquiry Learning for Those Who Wish to Empower Learners,* (pp, 3-22). Stylus Publishing.

Chi, M. T., & Menekse, M. (2015). Dialogue patterns in peer collaboration that promote learning. *Socializing intelligence through academic talk and dialogue*, 263-274.

Cole, R. S., Lantz, J. M., & Ruder, S. M. (2019). The Process. In S. R. Simonson (Ed.), *POGIL: An Introduction to Process Oriented Guided Inquiry Learning for Those Who Wish to Empower Learners,* (pp, 42-68). Stylus Publishing.

Curtis, S., & Millar, R. (1988). Language and conceptual understanding in science: A comparison of English and Asian language speaking children. *Research in Science & Technological Education*, *6*(1), 61-77.

Draskovic, I., Holdrinet, R., Bulte, J., Bolhuis, S., & Leeuwe, J. V. (2004). Modeling small group learning. *Instructional Science*, *32*(6), 447-473.

Driscoll, M. P. (2005). *Psychology of learning for instruction (3 ed.)*. Boston: Pearson.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences, 111*(23), 8410-8415.

Goldenberg, C. (2008). Teaching English language learners: What the research does-and does not-say.

Hoffman, M. M., & Richardson, S. (2019). Team construction and accountability. In S. R. Simonson (Ed.), *POGIL: An Introduction to Process Oriented Guided Inquiry*

Learning for Those Who Wish to Empower Learners, (pp, 113-140). Stylus Publishing.

Ing, M., Webb, N. M., Franke, M. L., Turrou, A. C., Wong, J., Shin, N., & Fernandez, C. H. (2015). Student participation in elementary mathematics classrooms: The missing link between teacher practices and student achievement? *Educational Studies in Mathematics*, 341-356.

Jackson, M. O. (2010). Social and economic networks. In *Social and Economic Networks*. Princeton university press.

Kahu, E. R. (2013). Framing student engagement in higher education. *Studies in higher education*, *38*(5), 758-773.

King, A. (1994). Guiding knowledge construction in the classroom: Effects of teaching children how to question and how to explain. *American educational research journal*, *31*(2), 338-368.

Kuh, G. D. (2009). What student affairs professionals need to know about student engagement. *Journal of college student development*, *50*(6), 683-706.

Kulatunga, U., Moog, R. S., & Lewis, J. E. (2014). Use of Toulmin's argumentation scheme for student discourse to gain insight about guided inquiry activities in college chemistry. *Journal of College Science Teaching*, *43*(5), 78-86.

Kulatunga, U., Moog, R. S., Lewis, J. E. (2013). Argumentation and Participation Patterns in General 615

Chemistry Peer-Led Sessions. *J. Res. Sci. Teach.*, *50* (10), 1207–1231. https://doi.org/10.1002/tea.21107

Lee, O. (2005). Science education with English language learners: Synthesis and research agenda. *Review of Educational Research*, *75*(4), 491–530.

Lo, S. M., & Mendez, J. I. (2019). Learning-The evidence. In S. R. Simonson (Ed.), *POGIL: An introduction to process oriented guided inquiry learning for those who wish to empower learners*, (pp, 85-112). Stylus Publishing.

Lombardi, D., Shipley, T. F., & Astronomy Team, Biology Team, Chemistry Team, Engineering Team, Geography Team, Geoscience Team, and Physics Team. (2021). The curious construct of active learning. *Psychological Science in the Public Interest*, *22*(1), 8-43.

Markic, S., & Childs, P. E. (2016). Language and the teaching and learning of chemistry. *Chemistry Education Research and Practice*, *17*(3), 434-438.

Moon, A., Stanford, C., Cole, R., & Towns, M. (2017). Decentering: A characteristic of effective student–student discourse in inquiry-oriented physical chemistry classrooms. *Journal of Chemical Education*, *94*(7), 829-836.

Murphy, P. K., Greene, J. A., Allen, E., Baszczewski, S., Swearingen, A., Wei, L., & Butler, A. M. (2018). Fostering high school students' conceptual understanding and argumentation performance in science through Quality Talk discussions. *Science Education*, *102*(6), 1239-1264.

National Research Council. (2012). *Discipline-based education research: Understanding and improving learning in undergraduate science and engineering*. The National Academies Press

Nennig, H. T., States, N. E., Montgomery, M. T., Spurgeon, S. G., Cole, R. S. (2022) Student Interaction Discourse Moves: Characterizing and visualizing student

discourse patterns. *Disciplinary and Interdisciplinary Science Education Research*. (Submitted).

Otter.ai. (2022). https://get.otter.ai/interview-transcription/.

Patton, M. Q. (2014). *Qualitative research & evaluation methods: Integrating theory and practice*. Sage Publications.

Phelps, A. J. (1994). Qualitative methodologies in chemical education research: Challenging comfortable paradigms. *Journal of Chemical Education, 71*(3), 191-194.

Qualtrics (2022) [Computer Software]. Provo, Utah: Qualtrics

Redmond, P., Heffernan, A., Abawi, L., Brown, A., & Henderson, R. (2018). An online engagement framework for higher education. *Online learning*, *22*(1), 183-204.

Reid, J. W., Gunes, Z. D. K., Fateh, S., Fatima, A., Macrie-Shuck, M., Nennig, H. T., ... & Talanquer, V. (2022). Investigating patterns of student engagement during collaborative activities in undergraduate chemistry courses. *Chemistry Education Research and Practice*, *23*(1), 173-188.

Ruder, S., Brown, P. J., & Stanford, C. (2020). Developing POGIL Materials: Writing and Refining Activities for a Spectrum of Content Areas. *Journal on Excellence in College Teaching*, *31*(1), 195-228.

Saldaña, J. (2016). *The coding manual for qualitative researchers*. Sage.

Sedova, K., Sedlacek, M., Svaricek, R., Majcik, M., Navratilova, J., Drexlerova, A., ... & Salamounova, Z. (2019). Do those who talk more learn more? The relationship between student classroom talk and student achievement. *Learning and instruction*, *63*, 101217.

Sheng, Z., Sheng, Y., & Anderson, C. J. (2011). Dropping out of school among ELL students: Implications to schools and teacher education. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, *84*(3), 98–103.

Smith, T. J., McKenna, C. M., & Hines, E. (2014). Association of group learning with mathematics achievement and mathematics attitude among eighth-grade students in the US. *Learning Environments Research*, *17*(2), 229-241.

Stetsenko, A., & Arievitch, I. (1997). Constructing and deconstructing the self: Comparing post-Vygotskian and discourse-based versions of social constructivism. *Mind, Culture, and Activity*, *4*(3), 159-172.

Temi. (2022). https://www.temi.com/.

Terry, N. P., & Irving, M. A. (2010). Cultural and linguistic diversity: Issues in education. *Special Education for All Teacher*, *5*, 109–132.

van Aalst, J. (2009). Distinguishing knowledge-sharing, knowledge-construction, and knowledge-creation discourses. *International Journal of Computer-Supported Collaborative Learning*, *4*(3), 259–287.

Vincent-Ruz, P., Meyer, T., Roe, S. G., & Schunn, C. D. (2020). Short-Term and Long-Term Effects of POGIL in a Large-Enrollment General Chemistry Course. *Journal of Chemical Education*, *97*(5), 1228–1238.

Vygotsky, L. (1978). Interaction between learning and development. *Readings on the development of children*, *23*(3), 34-41.

Walker, L., & Warfa, A.-R. M. (2017). Process oriented guided inquiry learning (POGIL) marginally effects student achievement measures but substantially increases the odds of passing a course. *PloS One*, *12*(10), e0186203.

Warfa, A. R. M., Roehrig, G. H., Schneider, J. L., & Nyachwaya, J. (2014). Role of teacher-initiated discourses in students' development of representational fluency in chemistry: A case study. *Journal of Chemical Education, 91*(6), 784-792.

Warfa, A. R. M., Nyachwaya, J., & Roehrig, G. (2018). The influences of group dialog on individual student understanding of science concepts. *International journal of STEM education, 5*(1), 1-14.

Washburn, G. N. (2008). Alone, confused, and frustrated: Developing empathy and strategies for working with English language learners. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 81*(6), 247–250.

Webb, N. M., Franke, M. L., Ing, M., Wong, J., Fernandez, C. H., Shin, N., & Turrou, A. C. (2014). Engaging with others' mathematical ideas: Interrelationships among student participation, teachers' instructional practices, and learning. *International Journal of Educational Research, 63,* 79-93.

Wilson, K. (2020). Balancing the Disruptions to the Teaching and Learning Equilibrium—Responsive Pedagogic Approaches to Teaching Online During the Covid-19 Pandemic in General Chemistry Classes at an Arabian Gulf University. *Journal of Chemical Education, 97*(9), 2895-2898.

Yin, R. K. (2015). *Qualitative research from start to finish*. Guilford publications.

CHAPTER FOUR: STUDY TWO

A hybrid POGIL class: Student engagement in small group conversations when joining in person and remotely

(Manuscript will be submitted to the Journal of Chemical Education)

Abstract

In today's educational system, distance education plays a major role. This approach does, however, raise some doubts regarding its effectiveness in engaging students. According to the transactional distance theory, there is a psychological separation between students and their instructors in distance education, called transactional distance, which prevents students from being engaged and interacting. In other words, transactional distance is a social and communications gap among students and the instructor that can create a space of potential misunderstandings. Bringing active learning approaches to the online class is being suggested by literature to reduce the transactional distance. A hybrid Process Oriented Guided Inquiry Learning (POGIL) class with half of the students attending in person and the other half participating remotely was discussed in this study, along with some evidence that designing such an environment was possible. The analysis of students' interactions and conversations, however, revealed that even the active learning approach in this design was not able to eliminate the transactional distance among remote students, as they were less engaged in group conversations when joining remotely. Among the reasons cited by the course instructor and student participants for the observed patterns are more distractions in

remote classes, difficulties in engagement caused by the nature of online classes, and lower levels of accountability. Analysis at an individual level revealed that the pattern we observed for the whole class was not the same for each individual student and some students were more engaged in conversations when they joined remotely. In discussions about the perceived reasons for this finding, students and the instructor pointed out that sometimes students' individual characteristics and attitude toward the course could have a greater impact on how they participated in small group discussions than the learning environment or whether they were in person or remote. Considering more research on students' individual features, group dynamics, facilitation, and task types may be useful for understanding the reasons behind these observed patterns and optimizing the learning experience in online settings in the future.

Key Words: Hybrid POGIL, transactional distance, engagement, small group conversations

Introduction

In recent years, an increasing number of students are attending online distance education (Poll et al., 2014). The transactional distance theory claims a psychological separation between the instructor and students in distance education (Moore, 1993). Therefore, there is some level of skepticism about the effectiveness of online education as compared to in-person instruction in terms of productive students' engagement. Educators who believe that learning is a social process that happens through interactions with other learners might be concerned with the lower level of interactions in distance education and ultimately the way that this lower level of interactions influences student

learning (Jaggars & Xu, 2016; Paulsen & McCormick, 2020; Trespalacios et al., 2021). Not having adequate interactions and collaborations among students is an issue because social interactions among learners and the instructor is the key component of learning as explained in learning theories such as social constructivism or situated learning (Vygotsky, 1978; Lave & Wenger, 1991). It is important to see what kind of online learning environment facilitates students' engagement and consequently decreases the transactional distance. Previous studies agreed that designing online courses based on the idea of active learning can encourage students' interaction and engagement in dialogue (Brent et al., 2021; Khan et al., 2017).

Process-Oriented Guided Inquiry Learning (POGIL) based instruction is a socially mediated active learning strategy used widely in chemistry (Cole et al., 2019; Warfa & Walker, 2017). POGIL is designed based on social constructivism and interacting with other learners. Engaging in small group conversations is an important step of the learning process in POGIL classes that helps them reach a shared understanding. Although there are several valuable studies on the positive impact of POGIL courses on students' learning and achievement (Vincent-Ruz et al., 2020; Walker & Warfa, 2017), few studies have investigated online or hybrid POGIL classes (Reynders & Ruder, 2020). Therefore, this study focused on a novel-designed hybrid POGIL general chemistry class and investigated students' contributions in small group conversations. This study investigated whether a hybrid version of POGIL will create a transactional distance among students that might impact students' small group conversations.

Background/Literature Review

Distance education is an instructional method where time and geography constraints prevent in-person contact between student and instructor (King et al., 2001). Getting a degree through distance education is becoming more popular because it allows for students to pursue their education regardless of where they live and, in some cases, gives them the freedom to learn at their own pace (de Oliveira et al., 2018). In today's educational system, online and internet-based distance education is well established (Paulsen &McCormick, 2020). As of 2016, more than 25% of higher education students reported taking at least one online course (Allen & Seaman, 2016). In spring 2020, the transition to emergency remote teaching (Al-Taweel et al., 2020; Hodges et al., 2020) was an immediate action in response to the COVID-19 pandemic that made all students at K-20 levels experience taking online courses.

Despite the growing availability of online education all over the world, there is a level of skepticism and uncertainty regarding the quality of this type of education, especially in terms of the social interactions among students and instructors (Trespalacios et al., 2021). Paulsen and McCormick (2020) mentioned that online education falls behind other modes of education in terms of student collaboration and engagement which ultimately can impact students' achievement negatively (Jaggars & Xu, 2016).

The transactional distance theory (Moore, 1993) claims there is a psychological separation between the instructor and students in distance education called transactional distance. Three factors including dialogue among students and the instructor, structure of the course, and autonomy of students influence this separation. The core idea of

transactional distance theory is about having dialogue among students and the instructor in a learning environment and the notion that as the amount of dialogue increases (students talks to their peers and the instructor more frequently), the transactional distance decreases (Gorsky & Caspi, 2005). In this theory, a relationship between dialogue and structure and autonomy is considered. In highly structured courses, where there is less chance for accommodating or being responsive to each learner's individual needs, there is less chance for learners to have a dialogue with the instructor and other learners which ultimately will lead to more transactional distance. In the same regard, the learners' autonomy during the learning process determines the extent of the dialogue that happens among learners and the instructor. In other words, less autonomy for the learner will lead to less dialogue and a higher level of transactional distance. Previous studies (e.g., Khan et al., 2017; Poll et al., 2014) highlighted the role of student discussion in online classes and Maddix (2012) argued that the level of discussion that happens in an online course can determine the course success and effectiveness in terms of students' learning.

Taken together, these studies suggest, to increase students' achievement and the effectiveness of online classes, it is vital to create a context that encourages students' collaborations and interactions (Jaggars & Xu, 2016). In some learning theories such as social constructivism, social interactions among learners and the instructor is the key component for learning. Assuming that an online learning environment cannot provide a proper context for social interaction will lead to questioning the quality of learning in these environments. However, it is important to remember that similar to in person

classes, different instructors will choose different pedagogies and course designs for online courses. Some instructors might offer more teacher-centered online classes while others offer student-centered online classes.

Brent et al. (2021) and Khan et al. (2017) claimed that all active learning strategies that are used in face-to-face classes for increasing students' interaction can be used in online courses as well. Collaborative activities, discussion boards, debates, peer learning/teaching, and team project assignments are some recommendations by previous studies for increasing students' interactions and social presence which helps learners to know their peers are real people who can provide them with more support in the course (Brent et al., 2021; Khan et al., 2017). Additionally, previous studies mainly revealed that synchronous online classes provide a more proper context for students' engagement and interactions (Tan et al., 2020; Hurst, 2020; Wenzel, 2020). They indicated that synchronous online classes accommodate the social presence by providing the context for student connection, communication, and sharing their opinions in real-time. Hearing and seeing their peers and the instructor "live" allow students to receive an immediate response to their questions and insights about the course material, and also personalizes interactions among members of the learning environment (Cobb, 2009).

Combining online and face-to-face aspects to create a hybrid learning environment is another approach that is suggested by some studies for increasing student engagement and interaction. For example, Poirier (2010) discussed how a hybrid learning environment is helpful in terms of students' interaction and engagement. Shea et al.

(2015) also concluded that a well-designed hybrid class has promising results in terms of students' engagement and learning.

As a result of reviewing previous literature, a better understanding was gained of what has been done to address the transactional distance and encourage more interaction in online education. Generally speaking, most previous studies agreed that designing online courses based on the idea of active learning can encourage students' interaction and engagement in dialogue that ultimately decreases the transitional distance. Additionally, previous studies mainly revealed that synchronous online classes provide a more proper context for students' engagement and interactions relative to asynchronous classes (Wenzel, 2020; Hurst, 2020).

Although reviewing the previous studies indicate that bringing active learning ideas into online courses is feasible, many active learning approaches have not been examined in online contexts to see if they help with decreasing the transactional distance issue through enhancing students' interactions and dialogue. Another important point that needs to be considered is the focus on students' engagement. As Redmond et al. (2018) introduced an online engagement framework, students' engagement has different aspects (e.g., behavioral, emotional, and cognitive engagement) and might be influenced by some factors such as students' personality (Zhang et al., 2020). Engaging in verbal interactions with other learners in distance education is one of the aspects of engagement that the majority of the previous studies did not explore. Therefore, conducting more research to examine different online course designs and focusing on students' conversations can contribute to this field. Being able to design a distance course that can provide a context

for students to engage in conversations, will help with decreasing the transactional distance and will lead to a higher level of learning.

This Study

Based on previous studies, it is possible to design online classes that have positive outcomes in terms of student engagement. This study focuses on a class that was designed by combining both in person and remote approaches to be able to compare students' engagement in small group conversations in these two formats. The course was designed based on utilizing POGIL as an active learning strategy and a synchronous remote portion happening simultaneously with an in person portion. Having both remote and in person formats in one class can give us more empirical evidence about whether this way of structuring a remote active learning environment might be helpful to facilitate productive small group conversation and reduce the transactional distance. Using this specific design helps with controlling for variables such as the course content, the instructor, and individual differences (by switching remote and in person sessions among students). The following research questions guided this study:

1. How different is students' participation in small group conversations during in person and remote portions of a hybrid POGIL-based general chemistry class?
    - Are individual students likely to show the same patterns as the whole class?
2. What are reasons that may explain the observed differences between students' participation in small group conversations during in person and remote portions of a hybrid POGIL-based general chemistry class, if any?

Methods

Research Design

In this exploratory case study, qualitative cross-case analysis was done to compare different cases including students' small group conversations when they attended remotely and students' small group conversations when they attended in person sessions (Patton, 2014). The students were the same in both cases, and we compared their contributions in small group discussions when they joined in person and remotely. This design was chosen to do an in-depth study on each case's experiences in a hybrid POGIL-based course and compare cases.

Context

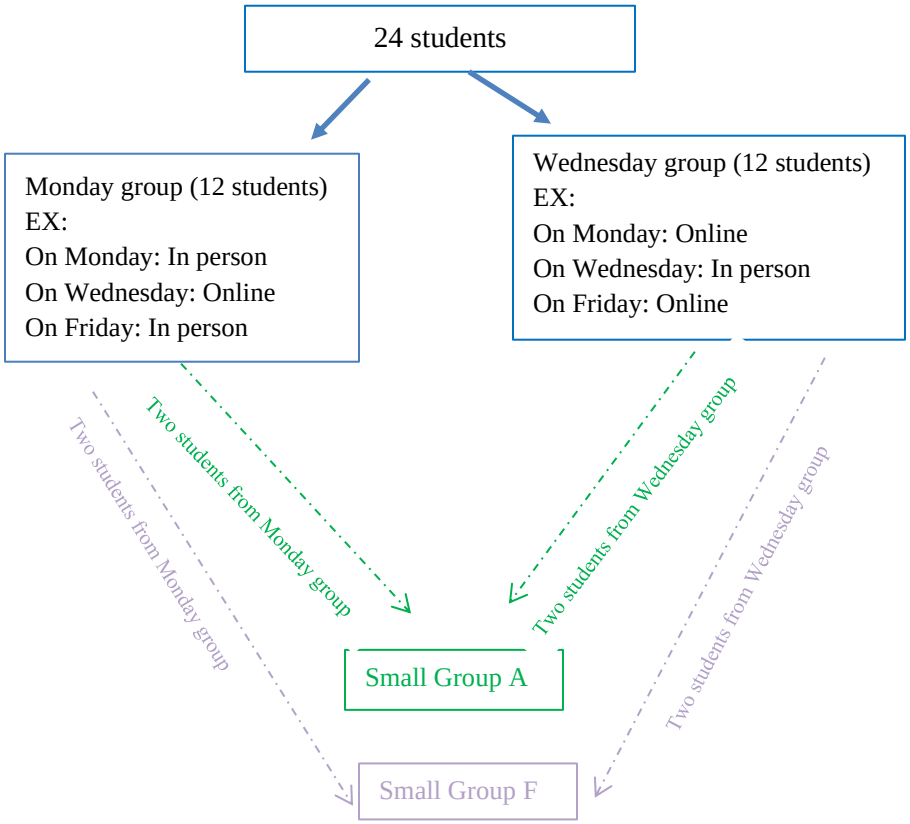
In this study, the data was collected during the COVID-19 pandemic during the Spring 2021 semester in a hybrid General Chemistry class with an enrollment of 24 students at a southeastern R2 university. Each class session was 55 minutes and there were three class meetings each week on Mondays, Wednesdays, and Fridays. This course mainly utilized POGIL and students worked in groups of four to complete the POGIL activities in addition to whole-class conversations and interactive lectures. The instructor was a faculty member with more than twenty years of experience in teaching chemistry and an experienced POGIL trainer. In this context, the instructor maintained components of an in person POGIL-based class such as working collaboratively on the POGIL activity, assigning each student to a small group of 3 or 4, and small group facilitation.

In this hybrid class, half of the students were in the Monday group (i.e., they were in person on Mondays and the rest of the class joined via Zoom) and the other half were

in the Wednesday group (i.e., they were in person on Wednesdays and the rest of the class joined via Zoom) (see Figure 4.1). Monday and Wednesday groups would switch places every other Friday to be in person or join via Zoom. For splitting the class into two groups with equal numbers of people in each, the instructor used the alphabetically ordered class list and assigned the first half of the names on the list to the Monday group and the rest to the Wednesday group. For small group conversations, the instructor sent the students to pre-assigned breakout rooms containing two students who were present in the class and two students who were remote that day. Students who were in person were also expected to bring an electronic device to join the Zoom meeting to be able to work with their remote peers. Usually, the group conversations lasted five to twenty minutes, and in each class one or two small group conversations happened. While students were working on the activity in their small groups, the instructor checked in with groups, answered their questions, and provided them with feedback by joining each breakout room. Additionally, if someone in class needed help, the instructor spoke directly with them at their desk. Each group had an iPad to share the screen so the instructor was able to see each group's progress through the activity and monitor their responses. After most of the groups had completed the assigned section of the POGIL, she invited all students back to the main Zoom space and reviewed the important or challenging points considering what she noticed and observed in most groups. Sometimes by calling on some groups the instructor created a whole-class conversation. If there was a common problem for most groups the instructor gave a mini-lecture on that topic.

Figure 4.1

The process of grouping students



Six small groups in total (Group A, B, C, D, E, F), in each group four students (two students from Monday group and two students from Wednesday group)

Participants and Recruitment Process

All students in this class were invited to participate in the study during the second week of the class. 22 students (6 males and 16 females) out of 24 consented to participate in the study and they provided us with their demographic information by taking a short survey on Qualtrics (Qualtrics, 2020). Appendix B shows the survey questions that

students answered. All data collection was approved by the university Institutional Review Board (IRB protocol number: 19-2253).

Data Collection

Zoom meeting recording

To work on the POGIL activities, students were sent to their small groups in breakout rooms. A laptop was used for each breakout room to record the students' oral conversations and their written communications through the chat function of Zoom. The recorded videos were saved on password-protected laptops and later stored on a secure server accessible only by the researcher for transcribing and analysis. All breakout rooms were recorded starting from the second week of the class until the end of the semester. However, only class recordings after the fourth week were used for analysis purposes because the group compositions stayed the same. All recordings were transcribed using online services such as TEMI or Otter (Otter.ai, 2021; Temi, 2021). Transcripts were double-checked and edited if needed.

Fieldnotes

One of the researchers was present in all class sessions to write field notes. The class schedule was used to know which students were scheduled to be in person and which of them were remote. Sometimes students did not follow the schedule and showed up in the class in person the day that they were expected to join remote or vice versa. Also, several students needed to be quarantined during the semester (due to the COVID-19 infection or exposure to the virus), so they needed to join the class via zoom for about

2 weeks. Therefore, besides zoom recordings, the field notes were an important source of data to check who was in person or remote.

Instructor Interview

After analyzing small group conversations, the course instructor was interviewed via Zoom in Aug, 2022 to probe their perceptions of the observed difference between remote and in person students' contribution to the small group conversations as well as possible reasons behind those differences and to inform an understanding of relevant findings from the fieldnotes and Discourse Analysis. See Appendix F-a for interview questions.

Student Interview

After analyzing small group conversations, two student participants (Rose and Kiana) were interviewed via Zoom in Sep, 2022 to learn more about their experiences in the class and their perceptions of the reasons behind what we observed. After 15 months of completing that hybrid POGIL course, only two students agreed to help with this interview. See Appendix F-b for interview questions.

Data Analysis

Small group conversations

To compare the students' conversations between when they joined the class remotely and in person, discourse analysis was done. Breakout room recordings were used to analyze students' small group interactions qualitatively and the way that they engaged in the group conversation in remote and in person sessions was compared. Student Interaction Discursive Moves (SIDM), is the analytical framework that was used

in this study (Nennig et al., 2022). This framework was chosen because it allows a detailed analysis of students' conversations and their discourse moves.

In the SIDM framework, there are two units of analysis; ‘conversational turns’ and ‘utterances’. The first unit, ‘conversational turn’, is defined as every time a different person begins speaking. The second unit of analysis, ‘utterances’ is used when a ‘conversational turn’ includes multiple moves and cannot be characterized by assigning only one code. Therefore, the second unit of analysis is used to break down the turn and assign one code to each piece (Nennig et al., 2022). Each code contains 3 levels including the type of interaction, primary intent, and nature of utterances. The first layer of the framework, type of interaction, characterizes how students broadly interact with each other and identifies when students are working independently, interacting with the instructor, conversing about the task, conversing off-task about the course in general or off-task about their personal lives, and finally if the students are not engaged at all with the class. Primary intent describes for what purpose the student is speaking and captures the temporal nature of a conversation from beginning to end. Nature of utterance highlights the nature of students’ primary intent by further characterizing in what ways students displayed a specific behavior (Nennig et al, 2021).

Using the SIDM framework, all students' conversations were analyzed and the results were used for quantifying and comparing the quality of student engagement in group discussions when they joined the class remotely and in person. To analyze the quality of students’ small group discussions, previous research was used for identifying the key discursive moves that can lead to constructing knowledge. For instance, some of

the verbal interaction that can lead to knowledge construction includes explanations, justifications, inferences, hypotheses, interpreting and evaluating of new ideas, sharing, critiquing, and testing ideas at different levels (King, 1994; Van Aalst, 2009). In the next step, each key discursive move was matched with one of the codes of the SIDM (see Appendix C) framework considering the definitions provided by the codebook (Nennig et al., 2021). The frequency of each key discursive move was compared between when students joined the class remotely and in person. Table 4.1 shows examples of these discursive moves (assessing, explanation seeking, presenting a claim, reasoning, rebutting, rejecting, and summarizing) mentioned by our participants.

Table 4.1

Examples of discursive moves that can lead to a shared understanding through joint knowledge construction process.

Discursive moves that can lead to a shared understanding	Code definitions	Example
Assessing	Determining if the strategy addresses all aspects of the problem/task and is functional or if an answer makes sense	EX 1 - Nancy: “I believe your answer is right for 1” EX 2 - Noah: “Yeah I was going to say it should probably be a little lower than 1500.”
Explanation Seeking	Requesting to share ideas, seeking an initial answer to a question or how to think about a problem, or requesting backing to a claim	EX 1 - Nadia: “How do you know when you have to flip the reaction?” EX 2 - Kamila: “So Nina, how did you decide that?”

Presenting a Claim	Suggesting an idea (may be tentative in nature)	EX 1 - Kiana: “is a guess but it dissolved so” EX 2 - Noah: “Okay so I think we can say that we can speed up reactions by heating them up”
Reasoning	Thinking through the problem/scenario or justifying or supporting an idea with scientific reasoning	EX 1 - Karla: “For the first one, it’s because it is a gas” EX 2 - Nina: “...because sodium chloride is held together by an ionic bond, which isn't a real bond. So, I guess as soon as it can get apart, it will. And that's kind of the idea of entropy is that if it can spread out, then it's going to”
Rebutting	Rejecting an assertion supported with reasoning	EX 1 - Nina: “I don't think... I don't know that we can say that yet. Because it remains constant within the concentration of NO changes. And the rate changes so that in the next one NO stays the same and H_2 changes and the rate changes.” EX 2 - Maria: “I'm not sure because salt dissolves in it no matter what”
Rejecting	Explicitly voicing disagreement with an utterance	EX 1 - Noah: “I don’t think so, I’m pretty sure equilibrium is met when the reaction proceeds in both directions at the same rate” EX 2 - Karla: “I don’t think so then. Remember she said that would decrease probability of it being the right orientation”
Summarizing	Summarizing ideas or steps to solve a problem that arose from the conversation	EX 1 - Nina: “ if the limiting reagent doesn't reach an equilibrium, the reaction will have to stop....never stops.” EX 2 - Kamila: “So the conditions of equilibrium, I guess we kind of answered that, where if there's a limiting reagent, the reaction stops. And then if there's not a limiting reagent, the reaction keeps on going, I guess because it's continuous meaning.”

Interviews

The instructor and students interviews were also analyzed as another source of data and for the purpose of triangulation to make sense of the observed pattern of

students' engagement in small group conversations (See Appendix F-a and F-b for interview questions). The instructor and student interviews were transcribed using an online transcribing service, Temi. Considering the idea of transactional distance theory and how and why remote classes can influence students' engagement, interviews were analyzed and the related quotations were presented in the findings and discussion section.

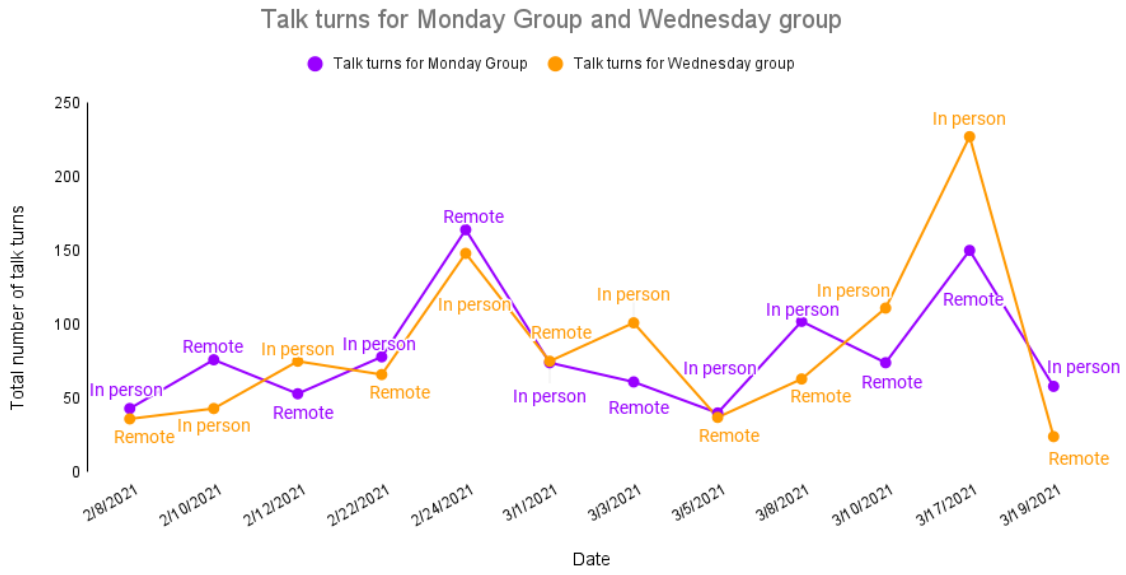
Findings and Discussion

Comparing the Monday and Wednesday group

Due to the fact that Monday and Wednesday groups had different students, we needed to see if their contributions to small group conversations were different. Therefore, the number of total talk turns and the key discursive moves were compared between the Monday and Wednesday groups. Figures 4.2 and 4.3 show these comparisons:

Figure 4.2

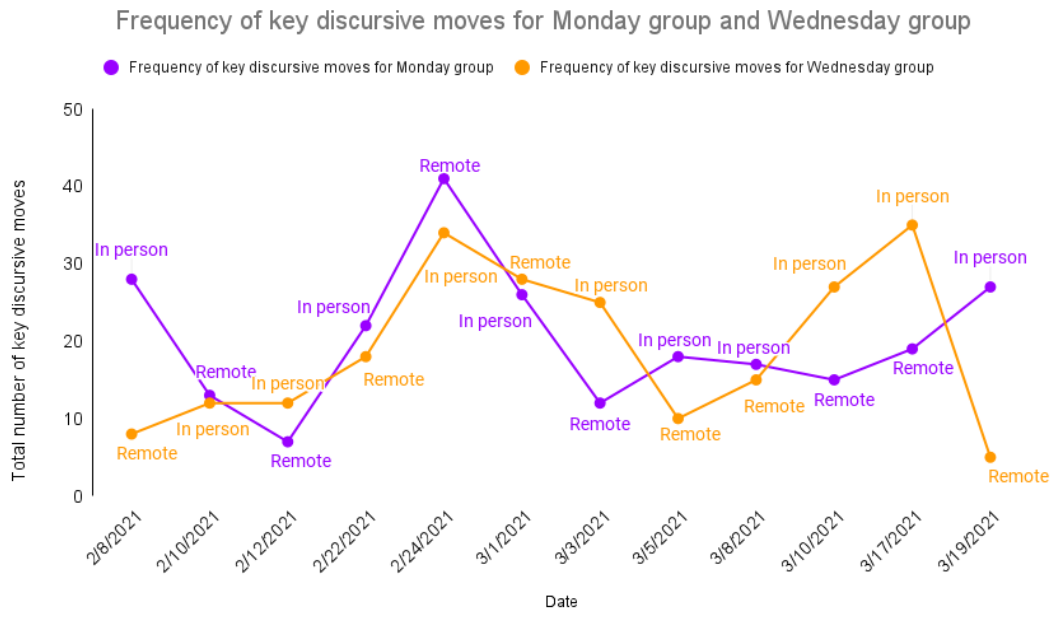
Total talk turns for Monday and Wednesday group



Both Monday and Wednesday groups do not follow a consistent pattern of talk turns. It can be seen in Figure 4.2 that on some days the Monday group has a higher frequency of talk turns, and on other days the Wednesday group has a greater number of talk turns. Comparing the frequency of key discursive moves between the Monday and Wednesday groups also showed there is not a consistent pattern for any of them (see Figure 4.3). The result of a t-test also indicated the difference between Monday and Wednesday groups in terms of the frequency of talk turns ($t(19) = -0.137$, $p = 0.893$), and the frequency of key discursive moves ($t(22) = 0.335$, $p = 0.74$) was not statistically significant

Figure 4.3

Frequency of key discursive moves between Monday and Wednesday groups



These comparisons show that students in the Monday and Wednesday groups do not have different contributions to small group conversations. For some dates the Monday group has a higher frequency of talk turns or key discursive moves and for the rest of the dates the Wednesday group had higher frequencies. This study has therefore controlled for students' differences such as their content knowledge, and their attitude toward the course. As a result of this comparison, we felt confident that if any differences were observed between remote and in-person students' conversations, it would not be

because there were two different groups of individuals participating in conversations, regardless of the type of learning environment.

Comparing the remote and in person portions of the hybrid course

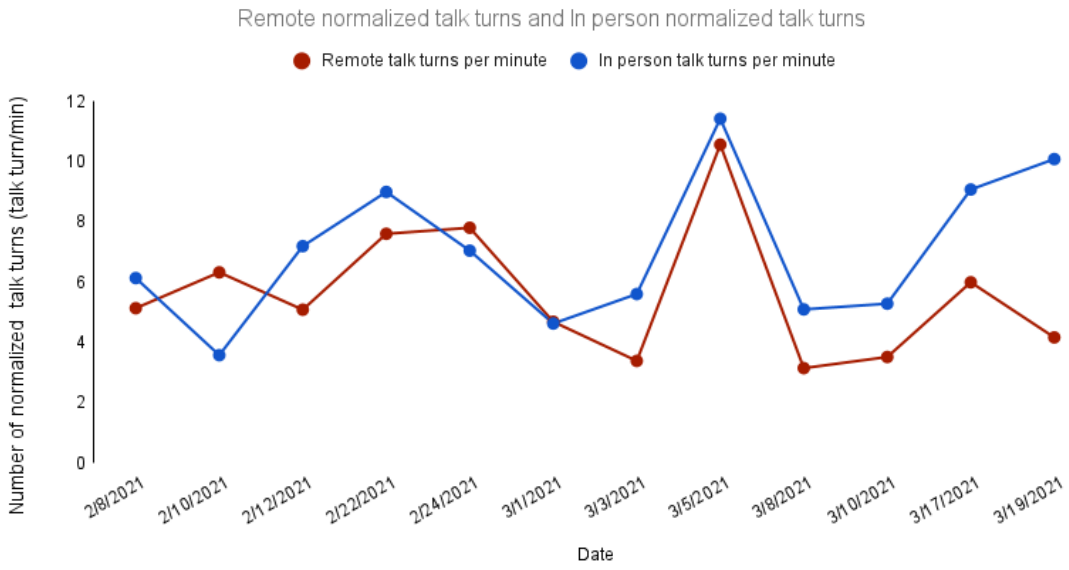
a) Number of talk turns

The number of talk turns for remote and in person portions of the classes were compared. Figure 4.4 shows this comparison. In this figure, the red line represents the frequency of talk turns for remote students over the semester and the blue indicates the frequency of talk turns for in person students. Over the semesters the amount of time that students were given to work on group activities in breakout rooms were different. Thus, to remove the effect of time on the number of talk turns, the data was normalized. For normalizing the data, the amount of time students spend in breakout rooms on each date was calculated and the number of talk turns was divided by that time (in minutes) to calculate the number of talk turns per minute for each date. The normalized data makes it easier to compare talk turns between different dates (see Figure 4.4).

As figure 4.4 shows, for 10 out of 12 classes, the total talk turns of in person students are higher than the talk turns for remote students. Two classes where remote students have higher frequency of talk turns belonged to the Monday group.

Figure 4.4

Normalized talk turns for remote and in person students over 12 classes of a hybrid course



The normalized data shows that both remote and in person students had the maximum number of talk turns per minute for 3/5/2021 class. A paired t-test (a paired t-test was done because the students in both remote and in person groups are the same people) showed that the number of talk turns for remote and in person portions of the hybrid class over 12 classes were statistically different ($t(11)= -1.481$, $p=.04$, Cohen's d= 0.475).

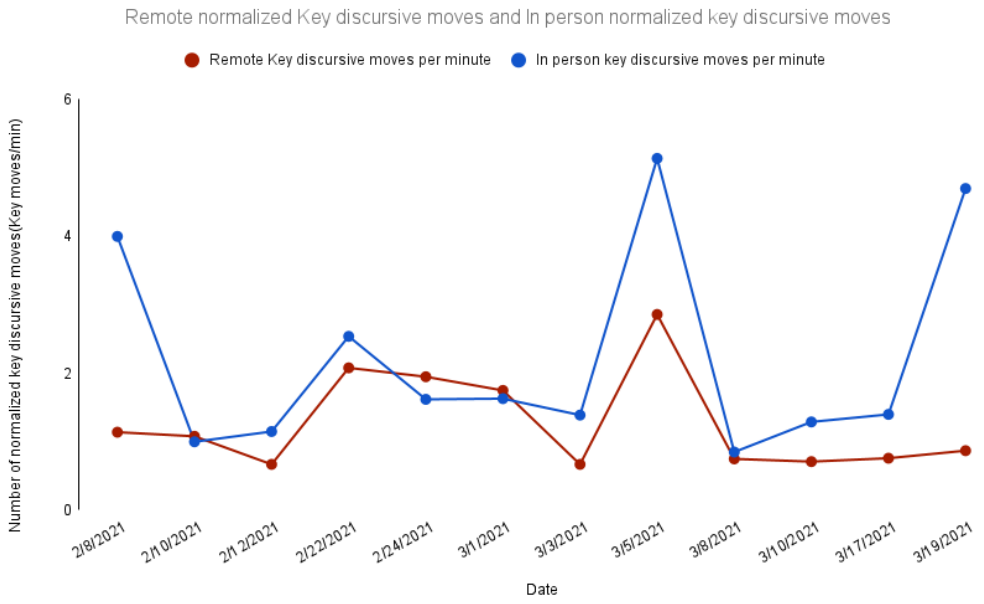
b) Frequency of key discursive moves

The total number of key discursive moves was also compared between remote and in person portions of the hybrid class. Figure 4.5 shows the result of this comparison. In

this figure, the red line represents the frequency of key discursive moves for remote students over the semester and the blue indicates the frequency of key discursive moves for in person students. The number of key discursive moves was also normalized to remove the effect of time. In order to normalize the data, the number of key discursive moves was divided by the amount of time students spent in breakout rooms on each date (in minutes). As Figure 4.5 indicates, for the majority of classes in person students have a higher frequency of key discursive moves than the remote students. In a few dates that the frequency of key discursive moves is higher for remote students (e.g., 3/1/2021), the difference between the frequencies for remote and in person students is minimal.

Figure 4.5

Normalized key discursive moves for remote and in person students over 12 classes of a hybrid course.



Looking at the normalized data helps to make an accurate comparison between different dates. For example, 3/5/2021 has a high frequency of key discursive moves. Additionally, there are 3 dates including 2/8/2021, 3/5/2021, 3/19/2021, that indicated a biggest difference between the frequency of key moves between remote and in person students. A closer look at the POGIL activities assigned to students in these three days it turned out that on 2/8/2021 and 3/19/2021, the POGIL model was a class demonstration. For each class demonstration, the instructor did an experiment and asked students a few questions regarding that. However, the whole process of demonstrations was

broadcasting for the remote students, the data shows that in person students were more engaged in small group conversations focused on demonstrations.

Using a paired t-test, a statistically significant difference between the remote and in-person portions of the hybrid class over 12 classes was found ($t(11)=-1.96$, $p=.025$, Cohen's d = 0.802).

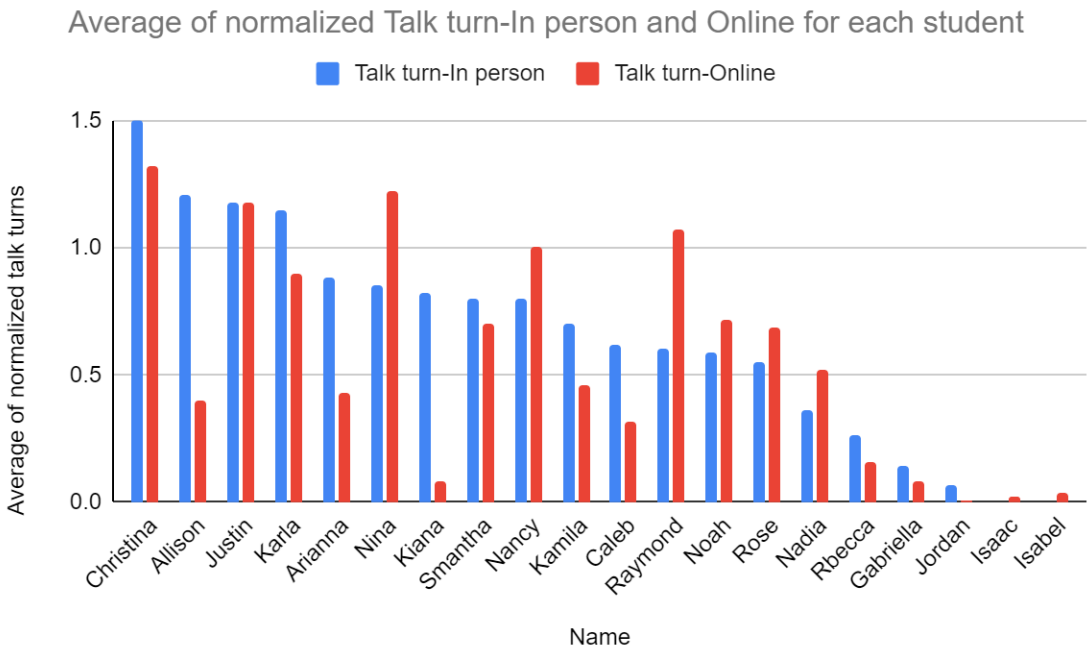
A closer look at each student

As discussed above, looking at the class as a whole showed students are less engaged in small group conversations when they are remote. The question arises, however, as to whether the same pattern is present for each individual student. As a result, we analyzed the data at an individual level in order to see how each student contributed to small group conversations remote and in person.

In Figure 4.6 An average of normalized talk turns for 12 classes is shown.

Figure 4.6

Average of normalized talk turns for each participant



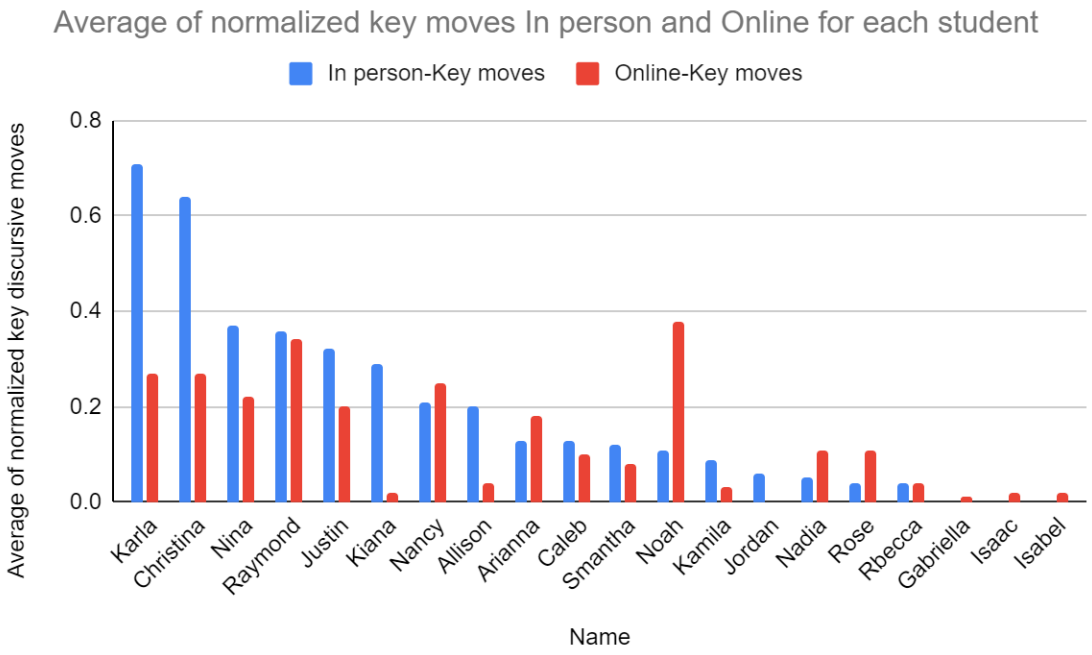
For different students, there is a different pattern in terms of how engaged they are in small group discussions when joining the class remotely or in person. The majority of students have a higher average of talk turns when they joined the class in person which is matches the general pattern that we found for the whole class data set. However, there are some students, such as Nancy and Raymond, who talked more frequently when participating remotely. There are also a few students, such as Justin, that their average of normalized talk turns in remote and in person classes are pretty similar. Figure 4.6 indicates that regardless of the general patterns that were observed in the class, individual students might have different patterns of engagement in small group conversations.

According to transactional distance theory, being less engaged in dialogue in distance education might be due to the physical separation that leads to a sense of distance, which opens the door for misunderstandings between the teacher and the students, as well as among student peers (Wengrowicz et al., 2014). Through having conversations with other learners, students can explore and address the misunderstandings that might be created due to transactional distance. Findings from Figure 4.6 showed that even in the same learning environment different students might experience different levels of transactional distance. Therefore, it seems there should be other factors that can impact the sense of distance that different students might feel in the remote portion of the class.

An average of normalized frequency of key discursive moves for 12 classes is shown in Figure 4.7.

Figure 4.7

Average of normalized key discursive moves for each participant



This figure also shows that some of the students, such as Karla and Christina, were more engaged in key discursive moves in in person classes, but some were more engaged, such as Noah and Nancy, when joining via Zoom. Also, there are a few students such as Raymond who engaged in key discursive moves pretty similar in remote and in person classes.

As seen from Figures 4.6 and 4.7, the highest number of talk turns and key discursive moves during the semester is related to in person classes.

Instructor Interview

The data from the interview helped us to understand the observed difference between remote and in person students' contribution to the small group conversations. When we asked about the instructor's expectations of seeing differences between remote and in person students' contributions to a small group conversation, she discussed her logic for designing such a hybrid class and how she was curious to see if this design will help with higher level of students' engagement compared to 100% online classes that she taught before. She indicated that establishing relationships with students and having time to know them is important in teaching as she stated *"...personal interactions…so much of the job is just, uh, trying to build some sort of relationship with the students so that they will let you teach them…If they hate you, if they don't trust you, if they think you're wasting their time, how you gonna teach them anything?".* In order for students to interact and engage in group discussions, the instructor believes that creating a classroom community is important. She pointed out from her experiences of teaching 100% online classes she knew that building community with remote students was hard and this could happen easier in in person classes than remote classes *"... the people separated from me, I have a harder time building a community with [and] they'll have less communication [with the instructor]"*. She commented that having students in class physically present even for a few classes to be able to meet the instructor and other students in person would help build the community to some extent so then when they joined the class remotely, it would be easier to connect to them and interact with them. That is why based on her previous experiences during the outbreak of the COVID-19 pandemic, she considered switching between remote and in person students to have enough time to build

relationships with students. Therefore, a hybrid design was chosen to make sure that students could see the instructor and some of their peers in person at least for half of the classes so they could establish relationships with them *"My hope was that since I saw all of them in person, some of the time that we would have enough of a relationship to, to make the online communication effective, the zoom online communication effective".* This aligns with the notion of transactional distance and psychological separation in distance learning and how the instructor attempted to reduce transactional distance in her class.

The instructor also considered in person students as a mediator for a better connection to those who joined the class remotely *"I would say in general I expected the in-class students to help manage the online environment …the idea of having our group split that way was in part to take care of sidebar conversations and things that I want to say* [that in person students can communicate to their remote peers]*".* Additionally, this shows that the instructor thought that there was a perceived lower level of separation between in person students and the instructor compared to remote students. Therefore, she used in person students to reduce the separation between herself and remote students.

The instructor mentioned that in her hybrid class, the community was built to some extent but maybe not enough. In her view, the nature of remote classes contributed to the lack of sense of community:

> *"…so that community did happen. um, but maybe not enough to overcome just the awkwardness. Maybe it's not even awkwardness if, if, if you and I are on zoom and we have two people in the room [those] are in the room together… can go back and forth at each other… a lot easier than I can interject. And when I do*

interject, y'all all gotta stop and go What, what was that you said? And a lot of people don't want that kind of attention."

In response to a question about whether the instructor believes the observed pattern for the whole class will be the same for each student, she indicated that remote sessions might have different effects on different students depending on their personalities:

"... I really believed it would be more of a personality thing than a position thing. That's what I noticed. I noticed that the personalities of the students were just magnified…for a student who wants to hide and we know there are lots of them in a gen chem class, zoom is a gift. Cause it's so easy to hide."

She mentioned for students who are comfortable talking to their peers and the instructor the type of learning environment will not make a huge difference. She also stated that if students kept their cameras on, it seemed that they were bringing the instructor to their house and it could reveal some aspects of their personal lives to the class that might help with creating a better sense of community:

"It changed the nature of our relationship because suddenly I'm in your home and so are your colleagues, so are your friends, if you turn your camera on now, you know a lot of things about me you didn't know before."

Regarding the reasons why the class as a whole was less engaged in group conversations when they were on Zoom, the instructor pointed out that students needed to put in more effort for remote interactions, which was making it harder for them: *"You*

gotta work harder, distance education in general. I think you have to work harder to build community, to feel a part of things". Furthermore, she explained that when someone was remote and others were in class, this feeling of not being a focal point was natural: *"I think in general, being on the zoom while there are other people in the room makes us feel like we're in a separate, we're a step away from the class…So the responsibility for carrying on the class was happening in the room".*

Distraction was another reason for less engagement in remote classes from the instructor's perspective:

> *"Distraction. I'm in the class, but I'm not really in the class. And people want to… multitask, even though it's not really a thing you can do. Uh, but they love to do it. So my attention is not really all here... I got a hundred other things I can do here. So I got a whole other computer. I could keep working on something else over here…I could, you know, be paying bills… chasing my kid".*

Distraction in in person classes was harder because everyone could see what each person did, and there might be consequences such as being called out. However, behind a black screen it would be easier to be distracted.

Student Interviews

Student interviews were conducted to learn about students' experiences in hybrid classes and how they perceive the reasons for the observed patterns of students' small group interactions when joined the class in person and remotely. The student, Rose, in response to the question whether she engaged in small group conversations differently

when she joined the class remotely and in person, stated that the type of learning environment did not affect her participation in small group discussions. Rose's actual engagement in small group conversations matched her perception of her participation, and the analysis indicated that joining remotely did not negatively impact her participation. According to her, students' personalities influenced the way they engaged in small group conversations, and it was because of her personality that she wanted to complete the task whether remote or in person: *"personally… I try to get what I need to get out of… whether it was to answer a question or trying to figure something out".* From Rose's perspective students' personalities play a more important role in the way they interact in small groups than being remote or in person. Therefore, she thinks if someone is less engaged in small group conversation it is related to her/his personality. She mentioned that the reason for some remote students being less engaged in group discussions was because remote classes provided the context for those who were not willing to engage *"sometimes people just use any excuse they can if they don't wanna engage" and* "*it's easy for people to hide*" in online environments. Rose also mentioned that accountability in remote classes was less than in person classes which was another reason for some students being less engaged in remote classes: *"…they don't have, uh, as much accountability behind the computer, then they would be in front of…a class or the instructor."* Rose noted that because of the differences that exist amongst students' personalities and accountability, we might see different patterns of small group engagements at the individual level compared to the general observed pattern at the class level.

Another student, Kiana, shared her experiences about the hybrid classes. Similar to Rose, Kiana also thought that "students' attitudes" toward the course and individual features of students were more important factors influencing their engagement in small group conversations and it did not have anything to do with being remote or in person. As an example of what she meant by attitude toward a course, she compared her participation in a remote psychology class with the chemistry class. While both courses were remote, she said she was more engaged and active in the psychology class than in the chemistry class since psychology is her favorite subject.

However, she believed students might be distracted and less focused in remote classes, which can lead to a lower level of engagement in remote classes:

> *"...when you're there in person. I think it's easier to pay attention. It's easier to understand the explanations. It's easier to not get distracted cuz you're in a classroom environment. So in the same time, like if you're at home, like you might not, like you might get easily distracted or you're just not really in the mindset of like being in class."*

As for the hybrid class, she explained that there was no difference between being remote or in person because students were communicating through Zoom in both cases, so from her perspective the learning environment was the same and it did not influence her group participation: *"... if you were in person, you weren't talking to other people that were like in person, even if they were in person, you were still talking on the zoom. So it wasn't really different."*

However, looking at Kiana's actual engagement in small group conversations revealed that, contrary to what she thought, she was less engaged when she joined the class remotely.

Kiana also mentioned that distraction and not paying attention were the main possible reasons for a low level of engagement for some students when joining the class remotely. Additionally, she said remote classes gives the students an easier option for not interacting than in person students that was similar to what Rose mentioned:

> *"Somebody might be distracted or if like you're on zoom, somebody doesn't wanna talk, they might just mute themselves or like turn their camera off. Like in person you can't mute yourself. I mean, you can sit there and not say anything, but you're more actively there…they could like have the zoom open and be working on another class or asleep or whatever. So I think that's just really, it is that you can't control them as much as if they're in the class. If they're in the class, they're in the class, like they're more kind of forced to participate. I mean they can still sit there and be quiet or be on their laptop doing something else. But they're more in that classroom space. When they're at home, they don't have to act like they're in clas*s."

Conclusions and Implications

In this study, it was generally observed that students who joined the hybrid class remotely were less likely to participate in small group discussions that might be due to the higher level of transactional distance in the remote portion of the course. It is

consistent with the transactional distance theory that due to the transactional distance, it is expected that students in distance education have less dialogue compared to students who interact in person (Moore, 1993; Gorsky & Caspi, 2005). Additionally, since different patterns were seen among individual students' engagement in talk turns and key discursive moves in remote and in person classes, this study concluded that students may respond differently to distance education and engage distinctively in group conversations. Student engagement in group conversations is not solely determined by one variable, but is influenced by multiple variables, such as student personality and learning environment. Considering some factors related to students' personality, emotions, and attitudes by interviewees as reasons behind the observed patterns in students' engagement in small group conversations, highlighted the fact introduced by Redmond et al., 2018 that student engagement has different aspects such as behavioral and emotional and how students' emotions and personalities might influence behavioral engagement (Zhang et al., 2020). Therefore, more research needs to be done to investigate how to design and facilitate courses differently for students considering their specific characteristics and emotions in order to maximize engagement. More research is also required to understand other possible explanations as to why the number of talk turns and key discursive moves are less for the majority of students when they are not physically present in the class. Group dynamics and facilitation may be important factors to be considered in future studies to optimize learning in online environments and enhance students' engagement when joining the class remotely. In addition, it could be interesting to investigate what kinds of activities and tasks could be transferred most effectively to a remote format to engage students in small-group discussions. Finally, as Brent et al. (2021) and Khan et al. (2017)

predicted, this study also provided evidence that bringing active learning to distance education is possible, even though there is a space for improving students' engagement and interactions. In particular, findings of this study indicated that designing a hybrid POGIL chemistry class is possible and can be considered as an option by instructors.

Future Research

In this study, the background of students (e.g., ethnic, racial, educational, socioeconomic status) was not considered. Considering the contextual nature of learning and how students' backgrounds might impact their learning experiences, it would be interesting to investigate how different groups of students respond to the remote learning environment in terms of collaborative engagement and discussions with their peers. This approach can help with designing remote classes that benefit all students equitably.

The theme in many studies in distance education is about the comparison between in person and distance education and how they can create remote classes that are more similar to in person courses. However, it would be helpful to adopt a different perspective in distance education research and see whether remote classes can be inspiring to design more effective in person courses in terms of students engagement. For example, the results of this study indicated that some students were more engaged in small group conversations when they joined remotely. It would be valuable to do studies on this group of students and find out what are the reasons behind the observed patterns. The findings of that research can be informative for in person classes and will help design in person classes with some features of a remote class (e.g., letting students communicate through

chat even if they are present in the class) that might help those who do not prefer face-to-face interactions.

Limitations

First, students' experiences of the remote and in person portions of this hybrid setting cannot be generalized to those who are taking 100% online or 100% in person courses. In our setting, all students had been present in class physically for half of the sessions so their experience could be different from those who took online courses without being in the class physically even once. Our participants had the chance of visiting the instructor and half of their peers in person which is not the case for students who take 100% online courses.

Second, participants of this study did not choose to be in an online environment; they were forced because of the COVID-19 pandemic to enroll in online classes. These participants might perceive remote classes differently and behave differently in an online environment than those who opt to enroll in online courses.

Another limitation is related to the data collection process. It was not possible to start recording the breakout rooms exactly at the same time because there were 6 laptops for recording that needed to be joined to each breakout room. Due to a delay in joining breakout rooms and recording, a few seconds of some groups' conversations might be missed, which can affect the total number of talk turns and the frequency of key discursive moves.

REFERENCES

Allen, I. E., & Seaman, J. (2016). *Online report card: Tracking online education in the United States*. Babson Survey Research Group. Babson College, 231 Forest Street, Babson Park, MA 02457.

Al-Taweel, D., Al-Haqan, A., Bajis, D., Al-Bader, J., Al-Taweel, A. M., Al-Awadhi, A., & Al-Awadhi, F. (2020). Multidisciplinary academic perspectives during the COVID-19 pandemic. *The International Journal of Health Planning and Management, 35*(6), 1295-1301.

Brent, R., Prince, M., & Felder, R. (2021). Promoting and managing student-student interactions in online STEM classes. *International Journal of Engineering Education*, *37*(3), 797-813.

Cobb, S. C. (2009). Social presence and online learning: A current view from a research perspective. *Journal of Interactive Online Learning, 8*(3).

Cole, R. S., Lantz, J. M., & Ruder, S. M. (2019). The Process. In S. R. Simonson (Ed.), *POGIL: An Introduction to Process Oriented Guided Inquiry Learning for Those Who Wish to Empower Learners*, (pp, 42-68). Stylus Publishing.

de Oliveira, M. M. S., Penedo, A. S. T., & Pereira, V. S. (2018). Distance education: advantages and disadvantages of the point of view of education and society. *Dialogia*, (29), 139-152.

Gorsky, P., & Caspi, A. (2005). A critical analysis of transactional distance theory. *Quarterly review of distance education, 6*(1).

Hodges, C. B., Moore, S., Lockee, B. B., Trust, T., & Bond, M. A. (2020). The difference between emergency remote teaching and online learning.

Hurst, G. A. (2020). Online group work with a large cohort: challenges and new benefits. *Journal of Chemical Education*, *97*(9), 2706-2710.

Jaggars, S. S., & Xu, D. (2016). How do online course design features influence student performance? *Computers & Education*, *95*, 270-284.

Khan, A., Egbue, O., Palkie, B., & Madden, J. (2017). Active learning: Engaging students to maximize learning in an online course. *Electronic Journal of E-Learning*, *15*(2), pp 107-115.

King, A. (1994). Guiding knowledge construction in the classroom: Effects of teaching children how to question and how to explain. *American educational research journal*, *31*(2), 338-368.

King, F. B., Young, M. F., Drivere-Richmond, K., & Schrader, P. G. (2001). Defining distance learning and distance education. *AACE Review (Formerly AACE Journal)*, *9*(1), 1-14.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge university press.

Maddix, M. A. (2012). Generating and facilitating effective online learning through discussion. *Christian Education Journal*, *9*(2), 372-385.

Moore, M. G. (1993). Theory of transactional distance In D Keegan (ed) Theoretical Principles of Distance Education pp. 22–38 Routledge. *New York.*

Nennig, H. T., States, N. E., Montgomery, M. T., Spurgeon, S. G., Cole, R. S. (2022) Student Interaction Discourse Moves: Characterizing and visualizing student

discourse patterns. *Disciplinary and Interdisciplinary Science Education Research*. (Submitted).

Otter.ai. (2021). https://get.otter.ai/interview-transcription/.

Patton, M. Q. (2014). *Qualitative research & evaluation methods: Integrating theory and practice*. Sage Publications.

Paulsen, J., & McCormick, A. C. (2020). Reassessing disparities in online learner student engagement in higher education. *Educational Researcher*, *49*(1), 20-29.

Poirier, S. (2010). A Hybrid Course Design: The Best of Both Educational Worlds. *Techniques: Connecting Education and Careers (J1)*, *85*(6), 28-30.

Poll, K., Widen, J., & Weller, S. (2014). Six instructional best practices for online engagement and retention. *Journal of Online Doctoral Education, 1*(1).

Qualtrics (version August 2020) [Computer Software]. Provo, Utah: Qualtrics

Redmond, P., Abawi, L. A., Brown, A., Henderson, R., & Heffernan, A. (2018). An online engagement framework for higher education. *Online learning*, *22*(1), 183-204.

Reynders, G., & Ruder, S. M. (2020). Moving a large-lecture organic POGIL classroom to an online setting. *Journal of Chemical Education*, *97*(9), 3182-3187.

Shea, J., Joaquin, M. E., & Gorzycki, M. (2015). Hybrid course design: Promoting student engagement and success. *Journal of Public Affairs Education*, *21*(4), 539-556.

Seaman, J. E., Allen, I. E., & Seaman, J. (2018). Grade increase: Tracking distance education in the United States. *Babson Survey Research Group*.

Tan, H. R., Chng, W. H., Chonardo, C., Ng, M. T. T., & Fung, F. M. (2020). How chemists achieve active learning online during the COVID-19 pandemic: using the Community of Inquiry (CoI) framework to support remote teaching. *Journal of Chemical Education*, *97*(9), 2512-2518.

Temi. (2021). https://www.temi.com/.

Trespalacios, J., Snelson, C., Lowenthal, P. R., Uribe-Flórez, L., & Perkins, R. (2021). Community and connectedness in online higher education: A scoping review of the literature. *Distance Education*, *42*(1), 5-21.

van Aalst, J. (2009). Distinguishing knowledge-sharing, knowledge-construction, and knowledge-creation discourses. *International Journal of Computer-Supported Collaborative Learning*, *4*(3), 259–287.

Vincent-Ruz, P., Meyer, T., Roe, S. G., & Schunn, C. D. (2020). Short-Term and Long-Term Effects of POGIL in a Large-Enrollment General Chemistry Course. *Journal of Chemical Education*, *97*(5), 1228–1238.

Vygotsky, L. (1978). Interaction between learning and development. *Readings on the development of children*, *23*(3), 34-41.

Walker, L., & Warfa, A.-R. M. (2017). Process oriented guided inquiry learning (POGIL) marginally effects student achievement measures but substantially increases the odds of passing a course. *PloS One*, *12*(10), e0186203.

Wengrowicz, N., Dori, Y. J., & Dori, D. (2014). Transactional distance in an undergraduate project-based systems modeling course. *Knowledge-Based Systems*, *71*, 41–51.

Wenzel, T. (2020). Collaborative group learning in remotely taught analytical chemistry courses. *Journal of Chemical Education*, *97*(9), 2715-2718.

CHAPTER FIVE: CONCLUSIONS

It has long been the focus of chemistry education to assist students in acquiring a deep understanding of the concepts, practices, and ways of thinking in chemical sciences (National Research Council [NRC], 2012). Active learning strategies have been demonstrated to be beneficial in supporting students in these domains in several recent reports (e.g., Freeman et al., 2014; NRC, 2012). Rather than having passive listeners, active learning environments aim to keep students engaged in the learning process, and it is critical for all students to contribute in interactions with their peers through verbalizing their thoughts, which may lead to a deeper understanding and more quality learning (Freeman et al., 2014; Driver et al., 2000; Sedova et al., 2019). In order to engage students in the learning process, it is vital to remember the contextual nature of learning environments and how factors, such as the type of learning environment and people who are present, can lead to different outcomes (Lave & Wenger, 1991; Closs et al., 2022). Thus, it is crucial that all approaches used in the classroom benefit all students equitably, regardless of students' differing backgrounds. Considering the idea of equity in classrooms, this dissertation had two main foci: (1) exploring how English Learner (EL) students, a growing population in the US educational system, experience active learning classes (POGIL) in introductory undergraduate chemistry, (2) examining how a specific design of an active learning approach (i.e., POGIL) works when students join the learning environment remotely.

In chapter two, two systematic literature reviews were conducted; first, on common problems that ELs encounter in science classes and second, on strategies for increasing students' engagement in distance education. Reviewing the previous literature

on EL population (e.g., Lee, 2005; Harrison & Shi, 2016; Alfred, 2003; Bergey et al., 2018) assisted with creating a list of possible issues that this student population might have in classrooms (e.g., unfamiliarity with norms of the US classrooms, not being proficient in English, fear of being judged and not being accepted by their peers) and previous studies' (e.g., Pappamihiel, 2002; Mohr & Mohr, 2007; Washburn, 2008; Buck et al. 200; Blumenfeld et al., 1996) suggestions to address those issues (e.g., engaging them in active learning). These findings were used to inform our research questions, sampling frame, data collection approach, and analytical frameworks. The literature review on students' engagement provided valuable information on different formats of distance education (e.g., synchronous and asynchronous) and some factors for increasing student engagement in distance learning environments (e.g., bringing active learning approaches into distance education) (Redmond et al., 2018; Brent et al., 2021; Skylar, 2009; Tan et al. 2020; Reynders & Ruder, 2020). These findings guided the development of our research questions, sampling frame, data collection approach, and analytical framework. In particular, findings from the literature review led us to focus on a particular active learning approach in a hybrid POGIL-based environment, the verbal interactions of students in the hybrid course, and to compare the quality of students' conversations when they joined the class in person versus remotely.

In chapter three, we discussed the experiences of the EL population in POGIL chemistry class. After analyzing students' small group conversations and conducting interviews with EL participants, the following research questions were addressed: 1) what differences exist, if any, between EL and non-EL students' contributions to small group conversations and the group-level knowledge construction in a POGIL-based general

chemistry class? 2) what differences exist, if any, within the EL population in terms of contributing to small group conversations and the group-level joint knowledge construction in a POGIL-based general chemistry class? what might be accounting for any differences that are observed?

Social interactions can create learning opportunities, and students are more likely to internalize knowledge through social interactions than when they receive a didactic instruction (Sedova et al., 2019). It is therefore crucial that all learners have conversations with each other, regardless of their backgrounds. Our analysis revealed that ELs are less likely to participate in small group conversations and have fewer talk turns than their non-EL peers. In terms of joint knowledge construction, ELs engaged less frequently in key discursive moves that can lead to a shared understanding. Consequently, it is evident that EL students face a challenge that needs to be addressed in order to support their learning. In our study, we observed a distinct difference between the subgroup populations of ELs based on the amount of time they had spent in the US educational system. The interviews conducted with ELs demonstrated that their age when they first came to the US influenced their English proficiency and cognitive processing time—two factors that could explain the differences observed within the EL population (Sheng et al., 2011; Torres & Zeidler, 2002; Curtis & Millar, 1988). For instance, in small group discussions, international students and those ELs who had K-12 education in the US contributed differently. International students encountered language issues at older ages, and they had to overcome their difficulties mostly on their own. Thus, they are not usually as proficient as their EL peers who completed their K-12 education in the US. The process of reading the materials in English, making sense of the information, putting

the ideas together in a coherent way, and translating them into English can take much longer if the students are not proficient in English. This process creates a higher cognitive load for EL students and might prevent them from engaging in small group conversations and externalizing their ideas. Generally, it is important to provide a learning environment in which all students are engaged in activities and actions that enhance their learning in order to provide a learning experience that benefits diverse students equitably. Therefore, more research is needed to understand how EL students can be encouraged to engage in group conversations. In addition, those whose first language is not English may have different educational experiences, so it is important to consider that the EL population cannot be viewed as homogenous; therefore, highlighting a need for more research in redefining this population.

In chapter four, we discussed a hybrid POGIL chemistry class that combined both in-person and remote approaches to compare how students engaged in small group conversations within each format. Three research questions were investigated: 1) how different is students' participation in small group conversations during in person and remote portions of a hybrid POGIL-based general chemistry class? 2) are individual students likely to show the same patterns as the whole class? 3) what are the reasons for the observed differences between students' participation in small group conversations during in person and remote portions of a hybrid POGIL-based general chemistry class, if any?

This study revealed that students' engagement in small group conversations was influenced by their learning environment, with the majority of students who joined remotely being less likely to participate. When compared with the students joining in

person, remote students had fewer talk turns and key discursive moves. Lower levels of engagement in small groups' conversations in the remote portion of the class might suggest a greater degree of transactional distance. More distraction in remote classes, difficulties in engagement because of the nature of remote classes, and lower level of accountability were among the reasons cited by the course instructor and student participants for the lower level of engagement in remote classes. As the instructor and student participants predicted, the pattern we observed for the whole class was the same for the majority of the class but not for each individual student. For example, some students were more engaged in small group conversations when they joined the class remotely, or some students' contributions in small group conversations were the same in both in person and remote classes. Different personalities and attitudes toward the course were the reasons mentioned by interviewees about the different patterns that existed among individual students. They pointed out that students' individual characteristics and attitudes toward the course could sometimes have a greater impact on how they participated in small group discussions than the type of learning environment or whether they were in person or remote. Introverts, for example, might not engage in small group conversations regardless of whether they are in person or remote. There was evidence in this study that bringing active learning to distance education is possible, even though there is a space for improving students' engagement and interactions. Observations demonstrated that students responded differently to the same course design. Further studies should examine how to make changes to the design or facilitation of distance education to ensure that all students engage in interactions and to optimize learning in remote learning environments.

This dissertation highlighted the benefits of students participating in verbal communication and that lack of participation may result in missed opportunities for higher levels of knowledge construction. Therefore, instructors should consider engaging all students in verbal interactions, regardless of students' backgrounds (e.g., being EL or non-EL) or the type of learning environment (e.g., in person or remote classes). Overall, the dissertation contributed to the literature by highlighting the importance of the learning environment design, its interaction with students' individual features and backgrounds, and how this interaction impacts students' behavior and experiences in the classroom. It is important to recognize that different students might have different experiences in the same context, so we, as educators, need to be aware of and meet these learners' needs. In other words, not everyone brings the same sets of tools; thus, we need to support the diversity of tools rather than focusing on one set. By adopting this approach, we may accomplish having equity in our classrooms and that learning environments will benefit all students regardless of their backgrounds.

REFERENCES

Alfred, M. V. (2003). Sociocultural contexts and learning: Anglophone Caribbean immigrant women in US postsecondary education. *Adult Education Quarterly*, *53*(4), 242-260. (n.d.).

Bergey, R., Movit, M., Baird, A. S., & Faria, A. M. (2018). Serving English Language Learners in Higher Education: Unlocking the Potential. American Institutes for Research.

Blumenfeld, P. C., Marx, R. W., Soloway, E., & Krajcik, J. (1996). Learning with peers: From small group cooperation to collaborative communities. *Educational researcher*, *25*(8), 37-39.

Brent, R., Prince, M., & Felder, R. (2021). Promoting and managing student-student interactions in online STEM classes. *International Journal of Engineering Education*, *37*(3), 797-813.

Buck, G., Mast, C., Ehlers, N., & Franklin, E. (2005). Preparing teachers to create a mainstream science classroom conducive to the needs of English-language learners: A feminist action research project. *Journal of Research in Science Teaching*, *42*(9), 1013–1031.

Closs, L., Mahat, M., & Imms, W. (2022). Learning environments' influence on students' learning experience in an Australian Faculty of Business and Economics. *Learning Environments Research*, *25*(1), 271-285.

Curtis, S., & Millar, R. (1988). Language and conceptual understanding in science: A comparison of English and Asian language speaking children. *Research in Science & Technological Education*, *6*(1), 61-77.

Harrison, J., & Shi, H. (2016). English language learners in higher education: An exploratory conversation. *Journal of International Students*, *6*(2), 415-430.

Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences*, *111*(23), 8410-8415.

Lave, J., & Wenger, E. (1991). *Learning in doing: Social, cognitive, and computational perspectives. . Legiti- mate peripheral participation.* Cambridge University Press.

Lee, O. (2005). Science education with English language learners: Synthesis and research agenda. *Review of Educational Research*, *75*(4), 491–530.

Mohr, K. A. J., & Mohr, E. S. (2007). Extending English-language learners' classroom interactions using the response protocol. *The Reading Teacher, 60*(5), 440–450.

National Research Council. (2012). *Discipline-based education research: Understanding and improving learning in undergraduate science and engineering*. The National Academies Press

Pappamihiel, N. E. (2002). English as a second language students and English language anxiety: Issues in the mainstream classroom. *Research in the Teaching of English*, *36*(3), 327–355.

Redmond, P., Abawi, L. A., Brown, A., Henderson, R., & Heffernan, A. (2018). An online engagement framework for higher education. *Online learning*, *22*(1), 183-204.

Reynders, G., & Ruder, S. M. (2020). Moving a large-lecture organic POGIL classroom to an online setting. *Journal of Chemical Education*, *97*(9), 3182-3187.

Sedova, K., Sedlacek, M., Svaricek, R., Majcik, M., Navratilova, J., Drexlerova, A., ... & Salamounova, Z. (2019). Do those who talk more learn more? The relationship between student classroom talk and student achievement. *Learning and instruction*, *63*, 101217.

Sheng, Z., Sheng, Y., & Anderson, C. J. (2011). Dropping out of school among ELL students: Implications to schools and teacher education. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, *84*(3), 98–103.

Skylar, A. A. (2009). A comparison of asynchronous online text-based lectures and synchronous interactive web conferencing lectures. *Issues in Teacher education*, *18*(2), 69-84.

Tan, H. R., Chng, W. H., Chonardo, C., Ng, M. T. T., & Fung, F. M. (2020). How chemists achieve active learning online during the COVID-19 pandemic: using the Community of Inquiry (CoI) framework to support remote teaching. *Journal of Chemical Education*, *97*(9), 2512-2518.

Torres, H. N., & Zeidler, D. L. (2002). The effects of English language proficiency and scientific reasoning skills on the acquisition of science content knowledge by Hispanic English language learners and native English language speaking students. *The Electronic Journal for Research in Science & Mathematics Education*.

Washburn, G. N. (2008). Alone, confused, and frustrated: Developing empathy and strategies for working with English language learners. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas*, *81*(6), 247–250.

APPENDICES

Appendix A (Study #1): EL Interview Questions

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? 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? 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?) 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?
6. Tell me about your experience working on POGIL activities as an EL/non-EL? Tell me about the challenges you experience when working on POGIL tasks. In what ways could POGIL activities be modified to help you to participate more in group conversation? 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). In which of the Speaking, Reading, Listening, or writing do you think need more improvement? 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 ELs or with your non-ELs peers?
9. Our classes are recorded on Panopto. 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?

Appendix B (Study #1 and Study #2): Qualtrics 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.

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

o No

o Yes

The research procedures to be conducted are clear to me.

o No

o Yes

I confirm that I am 18 years or older.

o No

o Yes

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.

o No, I do not consent

o Yes, I consent

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 don'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 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).

What is your name?

_____

Last Four Digits of MTSU ID#:

_____

How old are you?

_____

What are you studying at MTSU?

_____

1. Gender Identification:

o Female

o Male

o Other

o Prefer not to say

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

_____

2. Race:

o American Indian or Alaska Native

o Asian/Asian American

o African/African American

o Hawaiian/Pacific Islander

o White/Caucasian

o Other

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

_____

3. Ethnicity:

o Hispanic or Latino or Spanish Origin

o Not Hispanic or Latino or Spanish Origin

4. Are you an international student?

o Yes

o No

5. Is English Your First Language?

o Yes

o No

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

6. **What language did you learn first?**

o Spanish

o Chinese (Cantonese or Mandarin)

o Italian

o Russian

o Other

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

_____

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

o Yes

o No

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

o Yes

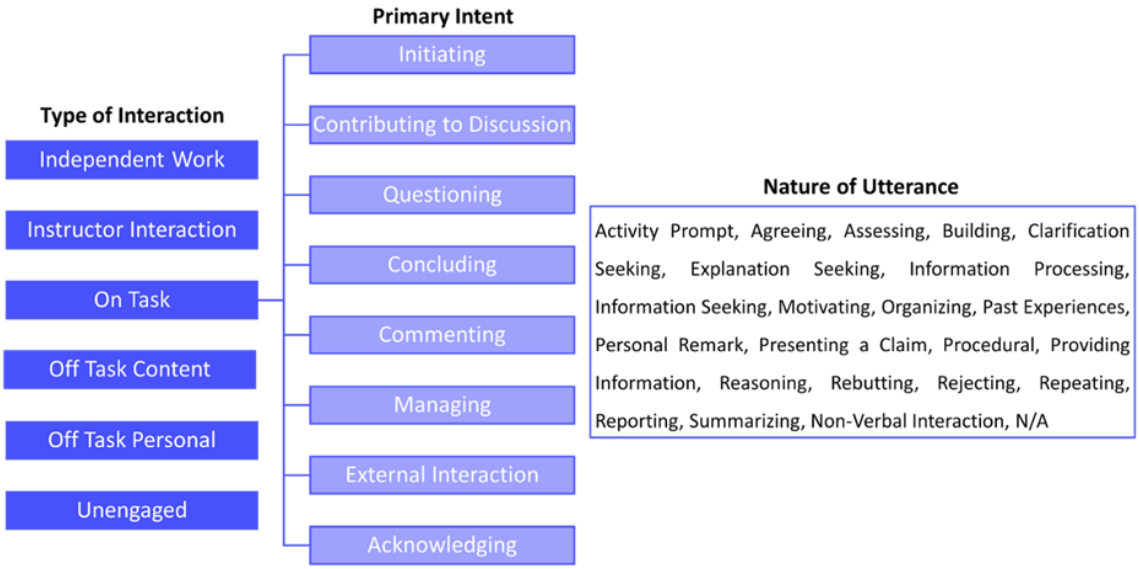
o No

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

_____

Appendix C (Study #1 and Study #2): SIDM codebook

Analytical framework for analyzing student discourse. Primary intent describes for what purpose the student is speaking and captures the temporal nature of a conversation from beginning to the end. Nature of utterance highlights the nature of students' primary intent by further characterizing in what ways students displayed a specific behavior.



Code Tables

Description and examples of discourse moves. Abbreviations of each discourse move are in parenthesis. Student quotations are italicized with bolded quotes corresponding to specific discourse moves.

1. Type of Interaction

Describes students' interaction during small group activities

Category	Definition

Independent Work (Ind W)	Students are not conversing with each other but are actively working through the problem (ex. no feedback from peers, writing stuff down, using a calculator)
Instructor Interaction (Inst I)	Interactions with the instructors about class content or administrative matters
Off-Task Content Related (Off C)	Students engaging in conversation that deviates from their assigned task but is still related to class content
Off-Task Personal (Off P)	Students engaging in conversation not related to class content (ex. personal experiences)
On-Task (On)	Students are actively conversing with each other on the assigned task
Unengaged (U)	Not participating in classroom activities or engaging with peers (ex. sitting, using a phone)

2. Primary Intent

Describes for what purpose the student is speaking

Discourse Move	**Definition**
Acknowledging (AL)	Recognizing a stated utterance that does not meaningfully contribute to the conversation
Commenting (CM)	Personal remarks, the judgment of activity/class, or utterances of how students understand the material or future plans to work on material
Concluding (C)	Statements that serve as a consensus and ends the question answering process
Contributing to Discussion (RC)	Responses that contribute to the completion of activity
External Interaction (EI)	Interactions that take place with someone who is not a member of the group or instructor
Initiating (I)	Students begin to work on the activity prompt
Managing (MG)	Management of time, works tasks, and student roles or utterances related to getting started to begin the activity
Questioning (Q)	Utterances that require member(s) to respond during the activity (does not include questions regarding the management of time or work tasks)

3. Nature of Utterance

Describes the manner at which students engage in a specific discourse move

Discourse Move	**Definition**	**Key Features**

Activity Prompt (AP)	Reading the activity prompt out loud	• Repeating given text at any point during the discussion
Agreeing (A)	Voicing agreement to a previous utterance	• Does not just include repeating an utterance • Clear indication of agreement to another's utterance • Confirmation to a question
Assessing (AS)	Determining if the strategy addresses all aspects of the problem/task and is functional or if an answer makes sense	• Reflecting on the degree to which strategy is addressing the question/task • Provides evidence of determining whether a strategy or response is functional/correct • Not related to analyzing answer options
Building (B)	Completing an incomplete utterance or expanding on an utterance with more detail or adding additional claims. (This is coded along with another code to describe the nature of the building utterance)	• Finishing an incomplete thought • Can be done by self or another student • Descriptor code does not have to be the same as the original utterance that is being built upon
Clarification Seeking (CL)	Requesting to seek clarification of what another student said or what is being stated or confirming their interpretation is correct	• Asking to repeat an utterance • Asking for more information on a previous utterance • Asking for a reworded statement • States an idea followed by a request for feedback/agreement
Explanation Seeking (E)	Requesting to share ideas, seeking an initial answer to a question or how to think about a problem, or requesting backing to a claim	• Seeking the process for how to complete/solve a problem • Why/How questions • Asking for rationale/reasoning for an utterance
Information Processing (IP)	Evaluating, interpreting, or transforming given information (students trying to make sense of given information)	• Includes the information that is being processed related to the task • Does not include one-word phrases (um, so, uh, then)

Information Seeking (IS)	Requesting for more information needed to solve the problem such as conversion factors, definitions, or rules	● Asking for pieces of information to complete a procedure to solve a problem ● Does not include asking for the process of how to solve a problem ● Does not include asking for the answer ● What questions
Motivating (M)	Providing encouragement to group members	● Positive reinforcement ● Appreciating group collaboration or individual ideas
Organizing (O)	Getting ready to work on the task, making sure members are working on the correct task, keeping up with discussion, or assignment of student roles/tasks	● Can happen at any point in the discussion ● Does not have to be related to question content ● Utterances are related to the whole group and not oneself
Past Experiences (PE)	Describing experience(s) with science	● Does not have to be academic/class-related ● Should be in the past tense
Personal Remarks (PR)	Describing current state of being, or how they feel about the activity, prompt, something they need to complete or other comments not related to completing the task	● Can be on task ● Not related to solving the focus of the problem
Presenting a Claim (PC)	Suggesting an idea (may be tentative in nature)	● Does not have to be the final answer ● Cannot be framed as a question
Procedural (P)	Describing how to solve the problem. This can include the calculational process	● Calculation or conceptual process ● Not just stating a formula ● Does not have to be the entire process ● Can be stating how an individual solves a problem
Providing Information (PI)	Conveying an idea that is needed to solve the problem (ex. Conversion factors, definitions, rules, formulas, data) or move the conversation forward	● Presenting pieces of information to help solve a problem ● Is not the answer to a problem ● Response to an utterance that does not have to be scientific

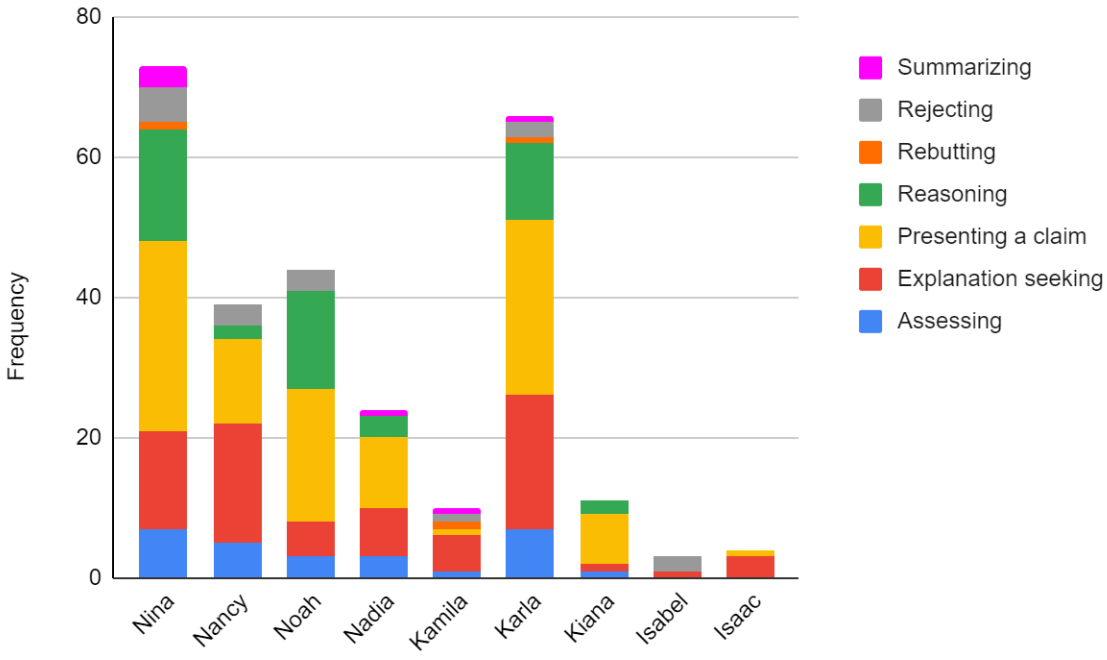
Reasoning (RS)	Thinking through the problem/scenario or justifying or supporting an idea with scientific reasoning	• Evidence of thought process in reaching a conclusion • Presenting a rationale to explain why a claim is true • Does not have to be about the answer to the task • Does not have to be requested
Rebutting (RB)	Rejecting an assertion supported with reasoning	• Clear indication of disagreement of a previous utterance • Must include a clear rationale for why the utterance was incorrect or reasoning for an alternate claim • Does not include rebutting the ideas from oneself
Rejecting (RJ)	Explicitly voicing disagreement with an utterance	• Clear indication of disagreement of a previous utterance • Statement of disagreement or • Statement of alternate claim/response • Does not include rationale
Repeating (RP)	Revoicing an utterance that has been previously stated	• Restating an utterance or information that the person has previously uttered • Due to lack of hearing or understanding
Reporting (RT)	Revoicing an idea or feedback to move the conversation forward	• Restates a claim, information, or reasoning that was provided previously (text, instructor, peer, etc.) • Should be attributed to the source • Would not be a restatement due to lack of hearing or understanding.
Summarizing (SM)	Summarizing ideas or steps to solve a problem that arose from the conversation	• Represents a consensus process that typically incorporates ideas from multiple respondents • Clearly wrapping up how an answer was arrived at • Appears at the conclusion of the dialogue for a particular task • Can be a final answer or an intermediate step

Non-Verbal Interaction (NVI)	Contributing to the completion of the activity by engaging in conversation without words	• Seen in video data • Clear indication that a student is pointing towards something
Not Audible or Applicable (N/A)	Utterances that are inaudible due to static or are not appropriately described by any of the proposed codes	• Audio cannot be heard to code properly • Cannot fit into any other nature codes

Appendix D (Study #1): POGIL Activities Used in the Course

Topic of Activity
Colligative Properties
Intermolecular Forces - The Interactions Between Molecules.
Introduction to Chemical Equilibrium
Acid-Base Equilibrium: Buffers
Mechanisms and Kinetics
Rate of Chemical Reactions: Kinetics.
Thermodynamics - Why Chemical Reactions Happen?
Thermodynamics Part II: The Rest of The Story.
Units of Concentration & Colligative Properties.
Electrochemical Cells
Balancing Oxidation-Reduction Reactions
Electrochemistry
Worksheet on Electrolysis

Appendix E (Study #1): Frequency of Key Discursive Moves for Each Participant



Appendix F (Study #2): Interview Questions

a) Instructor interview

1- Did you expect to see differences between online and in person students' contributions to small group conversations before the semester began? Why?

2- Did you observe any differences between students' contributions to small group conversations in the online and in-person portions of the hybrid class during the semester?

3- Our findings show that online students were less likely to engage in small group conversations. From your perspective, what could be the cause of this difference?

4- We looked at the class as a whole and we did not examine individual students' engagement in small group conversations. Is this pattern likely to be seen for each student individually as well?

5- Did you use different facilitation strategies for online and in-person students? Please explain.

6- Did you interact more with online students or in-person students? Why?

b) Student Interview

1- Please tell me about your experience attending the class online and in person. Which one did you prefer? Why?

2- Did you engage in small group conversations differently when you joined the class online and in person? Why?

3- Did you experience any difficulties/challenges in engaging in small group conversations when you were online?

4- Was the instructor’s interaction with you different when you joined the class online and in person? If so, did that influence the way you contributed to small group conversations? Please explain.

5- Our findings show that online students were less likely to engage in small group conversations. From your perspective, what could be the cause of this difference?

6- We looked at the class as a whole and we did not examine individual students' engagement in small group conversations. Is this pattern likely to be seen for each student individually as well?

Appendix G (Study #1 and 2): IRB approval letter

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

MIDDLE TENNESSEE STATE UNIVERSITY

IRBN001 - EXPEDITED PROTOCOL APPROVAL NOTICE

Thursday, August 25, 2022

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	6/30/2023	Date of Approval	6/11/19	Recent Amendment	8/25/22
Sample Size	100 (ONE HUNDRED)				
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	Contact information allowed. Audio or/and video recording are permitted for data collection. Approved to use informed consent for verbal recruitment
Restrictions	Mandatory ACTIVE informed consent using MTSU tempate; the participants must have access Part A of the informed consent. 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. 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)

IRBN001 Version 2.0 (overlay) Revision Date 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 6/30/2023 (Refer to the Continuing Review section below); REMINDERS WILLNOT 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 (6/30/2023) by obtaining a continuation approval prior to 6/30/2023. 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	Requisition 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 Shiavone, 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 Shiavone, M Akter, S Berryhill, J. Reid, S. Zakher, O. Ayangbola and K. Aboulyamin.	
Third Year	The IRB has granted an additional year to account for the loss of time due to the 2020-21 lockdowns (IRBCR2023-157).	
Final report	5/31/2023	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 Shiavone (jas2ta - CITI33000069) and Johann Mejia (adb2ev - CITI 33642204) have been approved to join the research team	IRBA2020-060

Date	Amendment(s)	IRB Comments
10/16/2019	Amy Phelps (amy.phelps CITI31797802) and Demet Kirbulut (CITI33739947) are added to the investigating team.	IRBA2020-066
12/06/2019	Anika Chowdury (atc4g - CITI8683231) 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 IRBCR2020-059
06/25/2020	Joshua Reid (jwr4k: CITI5610010) is added to the protocol.	IRBA2020-161
07/30/2020	Permitted to continue data collection with modified class structure that includes "hybrid" class sections with virtual interactions involving the platform Zoom.	IRBA2021-173 IRBA2021-212
08/20/2020	The informed consent will be administered via a Qualtrics link (on file). The investigating team is updated.	IRBA2021-216 IRBA2021-220 IRBA2021-225
02/03/2021	Changes to data collection to allow hybrid methods are approved. This was done to address challenges due to COVID-19.	IRBA2021-231 IRBA2022-266 IRBA2022-296
02/16/2021	Student worker Sylvia Zakher (swz2a - CITI9879058) is added to the protocol.	IRBA2022-306 IRBA2022-313 IRBCR2022-157
02/24/2021	Student worker Oluwatobiloba Ayangbola (ota2g - CITI8211312) is added to this protocol.	IRBA2023-382
03/09/2021	Karolin Abouelyamin (ka6f - CITI9959130) is added to this protocol. A new student interview protocol is added.	
q04/06/2021	A new interview protocol is added,	
07/23/2021		
10/04/2021	Fatima Kaya (CITI575996) is added to the protocol. A new instrument is approved.	
10/21/2021	An altered interview is approved (questions on file).	
11/23/2021	An altered interview is approved (questions on file). Refer post-approval action section below for more information.	
08/19/2022	An altered interview is approved (on file). .	
08/25/2022		

Other Post-approval Actions:

Date	IRB Action(s)	IRB Comments
08/19/2022	This protocol has been given an administrative extension by ONE (1) year to account for the 2020-21 COVID-19 lock downs. .	IRBCR2023-157

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.

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