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

Shaghayegh Fateh[a], Oluwatobiloba Theresa Ayangbola[d], Joshua W. Reid[b], Sylvia W. Zakher[d], Zubeyde Demet Kirbulut Gunes[c], Amy J. Phelps[d], Aspen Malone[a], Gregory T. Rushton[a,d*].

[a] Tennessee STEM Education Center, Middle Tennessee State University, Murfreesboro, TN 37131, USA

[b] Department of Biological Sciences, Texas Tech University, Lubbock, TX, 79409, USA

[c] Department of Mathematics and Science Education, Gazi University, 06560, Ankara, Turkey

[d] Department of Chemistry, Middle Tennessee State University, Murfreesboro, TN 37131, USA

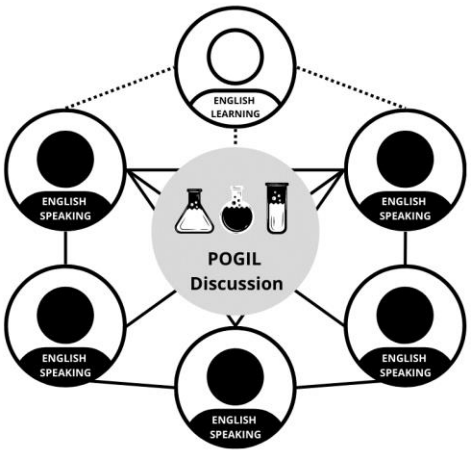
For editorial correspondence contact Gregory T. Rushton, Ph.D. at grushton@mtsu.edu

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 approach, 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. These challenges can impact this group of students' learning and achievements. Previous studies have discussed that learning chemistry can be more challenging for EL students due to the critical role of language in learning. We argue that ELs use 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 in our sample, ELs were less likely to engage in

discursive moves than non-ELs. This difference may result in missed opportunities for a shared understanding and joint knowledge construction. In addition to differences between EL and non-EL students in our samples, we also found differences between EL students who attended K-12 schools in the United States compared to international EL students. Implications for future studies of these possibly distinct EL populations are considered.

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.[1] Kahu has conceptualized student engagement as a multifaceted and complex construct that helps explain student outcomes (e.g., persistence, success, achievement) and is typically regarded as a proxy for student participation.[2,3] One aspect of engagement is collaboration that focuses on peer learning through discussion and group work.[4] Collaborative engagement is fostered through active learning approaches that provide students with opportunities to interact and socially engage with each other.[4] In active learning environments, students construct their own understanding of a concept through meaningful engagement with others in course activities.[5,6] 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 that 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.[7] Previous studies have discussed the positive impact of this approach on students' learning when implementing the POGIL approach in both chemistry and non-chemistry contexts.[8, 9] However, the impact of the POGIL approach on diverse populations of students (e.g., gender, race, language, ethnicity, etc.) is one of the understudied areas in POGIL research.[10] The United States is becoming increasingly diverse, and the population of English Learners (ELs), students whose first language is not English, has been increasing rapidly in American classrooms due to the influx of immigrant students since the beginning of the 20th century.[11, 12] Due to this increase in heterogeneity in chemistry classrooms, the importance of understanding the needs of underrepresented students, such as ELs, becomes more crucial. There are a few studies that considered the importance of language in learning chemistry and how engaging with English in addition to the technical language and content of chemistry can be more challenging for ELs compared to English native speakers (non-ELs).[13-15] 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. There is therefore a need to investigate ELs' experiences in chemistry classes. The research literature is scant on how ELs navigate the aspects of the POGIL experience. This is important to understand so these EL students are not at a disadvantage in their learning of chemistry. This study was designed to investigate ELs' experiences in a POGIL-based classroom by focusing on their small group conversations. Verbalizing ideas is a crucial step in the learning process, which is why small group work is a critical part of the POGIL approach.[16] 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 compare ELs' and non-ELs' discourse and engagement in moves that lead to a shared understanding at the group level through joint knowledge construction. Joint knowledge construction is 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.[17] 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, between EL students who attended K-12 schools in the United States compared to international EL students in terms of contributions to small group conversations and group-level joint knowledge construction in a POGIL-based general chemistry class?

CONCEPTUAL FRAMEWORK AND BACKGROUND

Social Constructivism

Vygotsky's social constructivism theory explains the learning and development process based on three critical assumptions.[18] The first assumption is that the learner is not a passive receiver of external influences and information. The second assumption is that knowledge is constructed at the social level and a higher level of mental processing happens through social interactions.[7, 19, 20] This is so learners can construct ideas and solutions that they would not be able to reach individually.[19] The third assumption focuses on the vital role of language as a mediator in the learning process. Vygotsky argues that verbal communication and one's thoughts are closely related. Talking through a concept helps promote a faster and higher quality internalization of newly learned knowledge. [20, 21] While simply being present in a talk intensive learning environment and listening to actively participating peers is beneficial for learners because it allows for internalization of the knowledge to some extent, there is a stronger link between the frequency and the quality of one's own talk and their individual achievement.[21-23] Based on these arguments, all students should speak with high quality and frequency in group conversations to maximize learning.

Small Group Interactions

Small groups are superior to large groups when it comes to constructing knowledge.[24] Small groups allow more students to be engaged in conversations and have shown to have a positive impact on STEM majors' persistence, achievement, and attitudes.[25] Encouraging ELs to interact with their peers in small group conversations is one of the practices suggested by Goldenberg to provide ELs with more support, opportunities to share their ideas, and practice in academic conversations in a safe

environment.[26] Despite knowing about the positive effects of small group conversations for students' learning, little is known about how ELs engage in small group conversations in college classes.

POGIL

POGIL activities are aligned with the tenets of social constructivism and are designed based on a learning cycle that includes exploration, invention, and application phases.[27] 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 1) posits knowledge construction via a process that includes knowledge Internalization, Externalization, Objectivation, Legitimation, and Reification.[28] 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.[29] 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 by adopting a new perspective on the topic (Transformation).[30] In small groups, students can express their new knowledge verbally or in a symbolic way such as 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.[17] POGIL is a cooperative learning strategy that requires that learners reach a shared understanding.[31] Working in small groups provides the context for hearing others' ideas and perspectives. 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. Students can still construct knowledge on their own; however, through social interaction and engaging in conversations with others, the learning will likely be deeper.[17, 32] The emerging knowledge is then considered and vetted by the instructor through either small group facilitation or whole class conversation (Legitimation) to solidify

the concepts in students' minds (Reification). This cyclic process can happen several times during a single POGIL class.

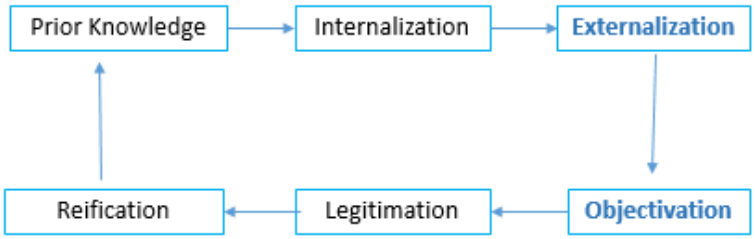


Figure 1. The learning process in a POGIL-based classroom designed based on social constructivism.

To study the internal process of knowledge construction, the external aspect of it must be interpreted and analyzed.[30] Verbal expressions through discourse is one of the accepted forms that can provide insight to the researcher.[33] Students externalize their ideas in the group discussion with their peers to 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" (Ref 17, p. 24). Verbalizing thoughts also contributes to joint knowledge construction that leads to shared understanding. 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.[17, 32] In this study, we focused on ELs' engagement in small group conversations (the Externalization and Objectivation steps in Figure 1). We investigated the ELs' 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). This was to see whether the Externalization and Objectivation components of the learning process occurring in a POGIL class are different for the EL and the non-EL groups as well as the EL subgroups.[30, 34-36] Findings from previous studies on ELs, primarily done in K-12 STEM classes, showed that ELs face some challenges such as having low English proficiency, fear of being judged, or feelings of not being valued and socially accepted.[37, 38] These challenges can affect ELs' interactions in group settings 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 ELs in this sample 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.[39] There are two cases: ELs (made up of ELs who attended K-12 in the US and international 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.[40]

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 an experienced POGIL trainer faculty member with more than twenty years of experience teaching chemistry. Each class session was 55 minutes. There were three class meetings each week on Mondays, Wednesdays, and Fridays. This course used POGIL-inspired activities in addition to some whole-class conversations and interactive lectures. Students were randomly assigned to work in six small groups, each composed of four students, to complete the POGIL-inspired activities (see Table 1). The groups that were studied are highlighted within the table. 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 the groups and answered their questions. After most of the groups had completed the assigned section of the POGIL-inspired activity,

the instructor invited all students back to the main Zoom space. The instructor then reviewed the important and/or challenging points by selecting examples of students' work to create a whole-class discussion.

Table 1. Group Composition

Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
4 non-ELs	4 non-ELs	3 non-ELs 1 EL	1 non-EL 2 ELs	4 non-ELs	2 non-ELs 2ELs

Participants and Recruitment Process

All students in this class were invited to participate in the study during the second week of the class. They were offered modest extra credit as an incentive to participate. They provided researchers with their demographic information through a short survey on Qualtrics.[41] The demographic information was used to determine which groups contained at least one EL student. These groups were to be included in this study. Out of total six groups (N=24) presented in class, there were three groups that had at least one EL student. We focused on these three groups (N=12). However, the data related to three students who were members of these 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 2 summarizes the participants' demographic information (N=9). Pseudonyms were assigned for all participants. Names beginning with N were non-EL students, K were EL students who attended K-12 schooling in the U.S., and I were international EL students. All data collection was approved by the university Institutional Review Board (IRB protocol number: 19-2253).

Table 2. Demographic Information

Participant Name	Gender	EL	First Language	International Student
Nina	Female	No	English	No
Noah	Male	No	English	No
Nancy	Female	No	English	No
Nadia	Female	No	English	No
Karla	Female	Yes	Arabic	No
Kiana	Female	Yes	Farsi then Turkish	No

Kamila	Female	Yes	Spanish	No
Isaac	Male	Yes	Unspecified	Yes
Isabel	Female	Yes	Unspecified	Yes

All five EL students were invited for an interview via email, and all of them agreed to participate in this part of the study. The interviewees' time was compensated with electronic gift cards at a rate of $10 per hour. A brief description of each participant who was interviewed is provided below.

Karla

Karla indicated in the consent form that she is an EL student. She was in group four. She picked up English from her neighbors and at school. She began her education by enrolling in an English as a Second Language (ESL) program. She is an immigrant's child, and Arabic is her first language.

Kamila

Kamila indicated in the consent form that she is an EL student. She was in group three. She came to America when she was five years old and grew up speaking Spanish as her first language. According to her interview, she taught herself English. Kamila had to return to El Salvador approximately halfway through the semester due to the health of one of her family members.

Isabel

Isabel is an EL student who indicated on the consent form that she is an international student. She was in group six. She is from Kenya and came to the United States on a student visa to pursue her undergraduate degree. She sees her English language skills as a barrier to her learning in the US.

Kiana

Kiana indicated in her consent form that she is an EL student. She was in group six. She attended pre-school in Iran, kindergarten in Turkey, and first grade in the United States. She is the daughter of immigrants and is trilingual, speaking Farsi as her first language, Turkish as her second, and English as her third. Kiana missed many classes during the semester.

Isaac

Isaac is an EL student who indicated on the consent form that he is an international student. Isaac is from Kenya who came to the United States on a student visa to pursue his undergraduate degree. He was in group four.

DATA COLLECTION

Multiple data sources (interviews and small group Zoom meeting recordings) were used for studying each case and answering the research questions.[40] Discourse analysis was used for making sense of students' group conversations, and a constant comparison approach was used for analyzing the ELs' interviews.[42, 43]

Zoom Meeting Recording

To work on the POGIL-inspired 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 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. All recordings were transcribed using online services such as Temi or Otter.[44, 45] 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 depending on how detailed the interviewee was 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 so the audio and video could be recorded. They were transcribed using Temi or Otter.[44, 45] The interview protocol (see supporting information), which included open-ended questions, was designed based on previous literature that discussed ELs' experiences in class conversations and possible factors that influence their interactions. 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. Questions were modified

accordingly. For example, 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. This is 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 for 20 classes were transcribed and analyzed. The results of the analysis were used to quantify the number of talk turns per student and to evaluate how often each student was engaged in specific discursive moves. These values were used to identify the differences between ELs and non-ELs and between K-12 and international ELs within the EL sample. Due to the small sample size, we provided descriptive statistics of this specific sample with these data. The Student Interaction Discursive Moves (SIDM) framework (see supporting information) was used to analyze students’ small group conversations. This framework was chosen because it allowed a detailed analysis of students' conversations and discourse moves. In the SIDM framework, there were two units of analysis; ‘conversational turns’ and ‘utterances.’ The first unit, ‘conversational turn,’ was defined as every time a different person began speaking. The second unit of analysis, ‘utterances’ was used when a conversational turn was too large to be coded by assigning only one code. Therefore, the second unit of analysis was used to break down the turn and assign one code to each piece.[42] This process has been summarized in figure 2.

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.[30, 34] Warfa in two studies indicated that some discursive moves such as asking for confirmation and clarifying ideas, agreeing or rejecting with reasoning, and seeking group

consensus helped students reach a collective understanding.[35, 36] Each key discursive move was matched with one of the natures of utterance codes of the SIDM framework based on the definitions provided by the codebook.[42] Only codes matching the key discursive moves including presenting a claim, explanation seeking, reasoning, assessing, rejecting, summarizing, and rebutting 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 as well as K-12 ELs and international ELs to answer our research questions. Table 3 shows examples of our participants using these discursive moves (presenting a claim, explanation seeking, reasoning, assessing, rejecting, summarizing, and rebutting).

Table 3. 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
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"
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?"
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"
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."
Rejecting	Explicitly voicing disagreement with an utterance without any reasoning	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.”
Rebutting	Disagreeing with 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.”

ELs Interviews Analysis

First, analytical memos were made as a record of ideas and questions that came up during the transcription process of each interview.[46] The EL students’ challenges discussed in previous studies were used as *a priori* codes to define smaller categories for the interviews’ transcripts. For example, all interview questions about the English proficiency topic were grouped together as a category. The transcripts were used for doing a constant comparison analysis. The data were read to identify recurring themes. The data were then reread to further categorize these themes. These categories were then grouped. This was done until the data was coded into the least number of distinct sections possible. These groups were reviewed and related back to the research question.[43] The findings from the interviews were used for triangulation purposes and making sense of the reasons for the observed differences between EL and non-EL students’ as well as K-12 ELs and international ELs engagements in group-level joint knowledge construction.

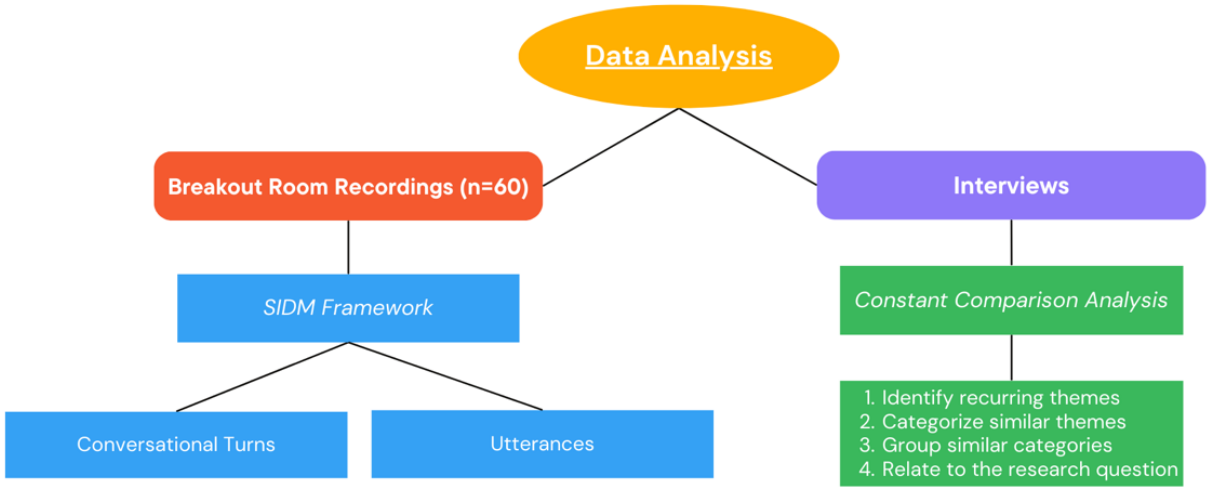


Figure 2. The data analysis process for the recordings and interviews.

RESULTS AND DISCUSSION

Number of Talk Turns

After transcribing the small group breakout room conversations, we observed that the total talk turns for 20 classes for non-ELs (N=4) were 564 and for ELs (N=5) were 295. Our analysis indicated that EL students had less talk turns than their non-EL peers. King and Sedova 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.[30, 21]

Discursive Moves that can Lead to a Shared Understanding

The results revealed that while 66% of non-EL students engaged in key discursive moves, only 34% of EL students did. Figure 3 shows the difference between EL and non-EL students' contributions in group-level joint knowledge construction based on the SIDM framework.

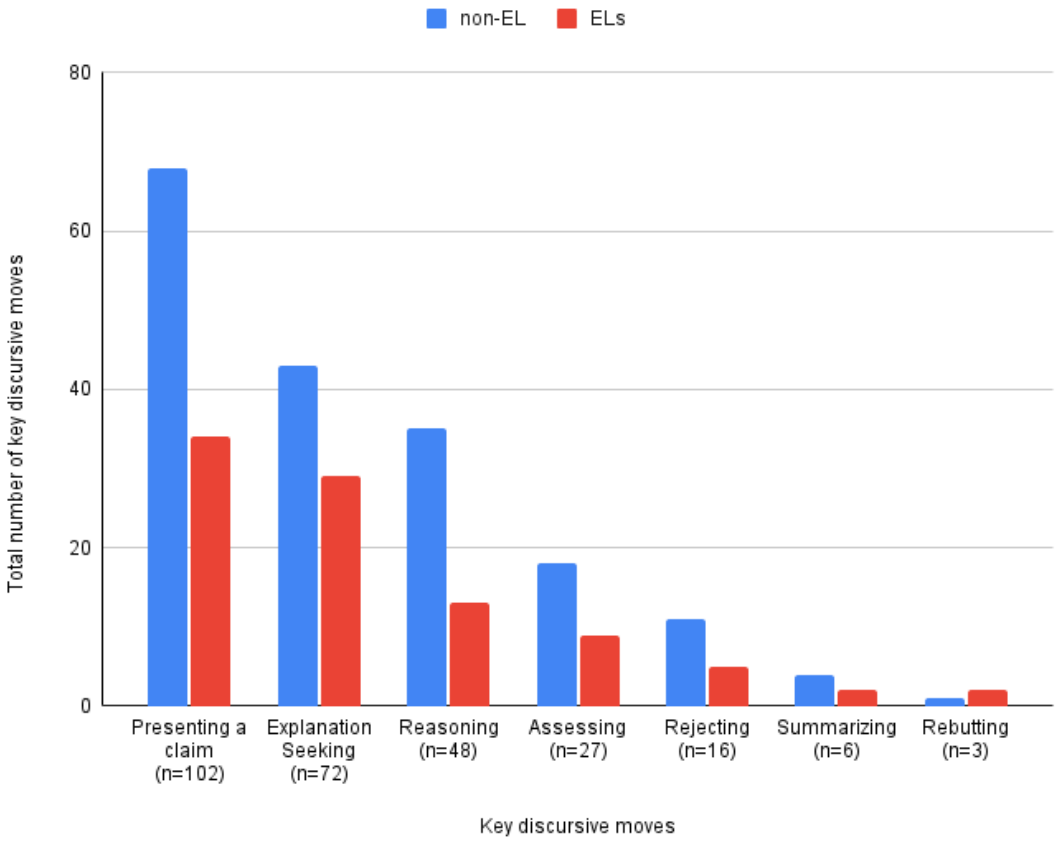


Figure 3. Total number of key discursive moves for non-ELs and ELs

Non-EL students had a higher number 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.[47] Previous studies showed that the absence of argumentation can decrease science learning.[48, 49] Students who engaged in scientific argumentation indicated a deeper understanding of scientific phenomena.[50] Not engaging in such discursive moves can indicate missed opportunities for joint knowledge construction. Although the number of codes were 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 4).

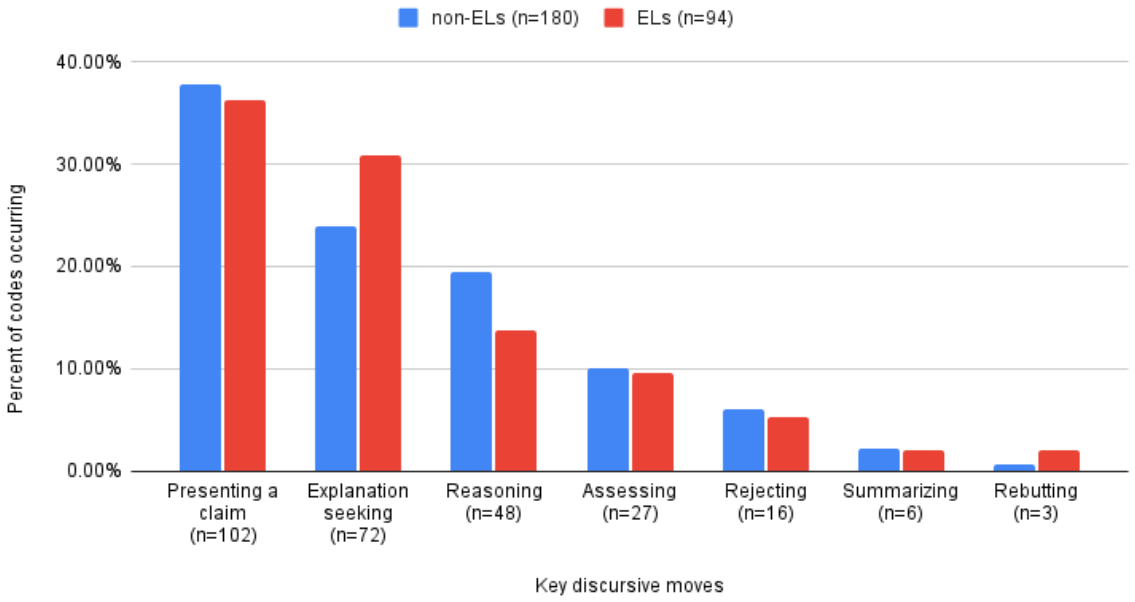


Figure 4. The distribution of key discourse moves within non-EL and EL groups.

For instance, 36.2% of ELs' 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 Figure 5.

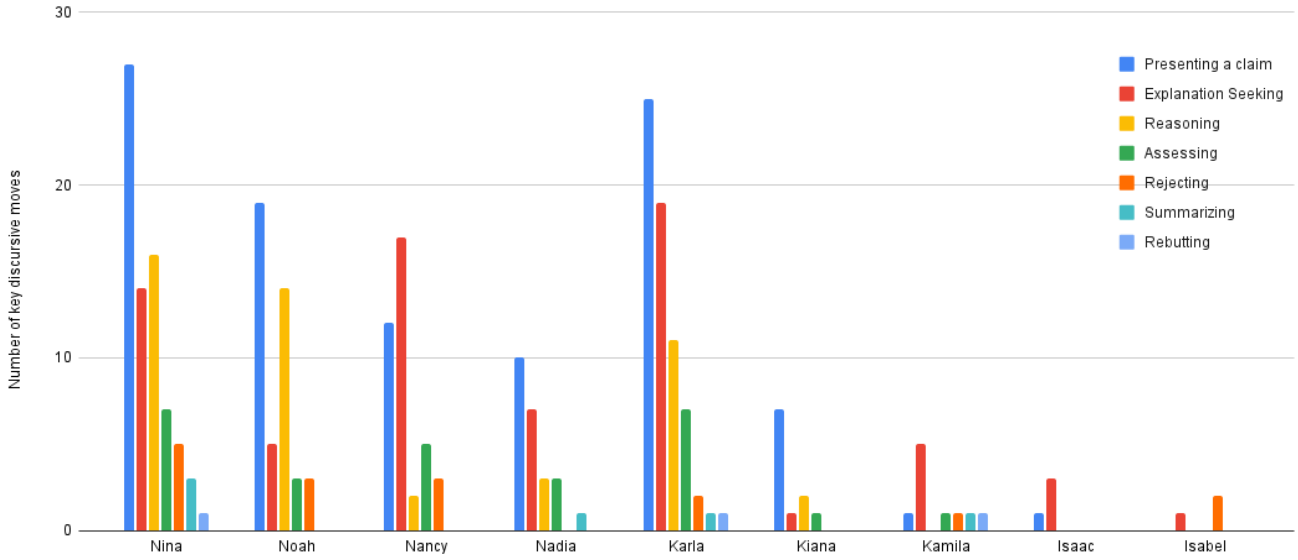


Figure 5. Number of key discursive moves for each participant

Figure 5 shows the quantity and distribution of discursive move types by participants. Non-EL students showed similar numbers of key discursive moves. However, the EL population had more variation in the number and distribution of key discursive moves. Total number of moves by the EL population ranges from less than five to more than twenty. For instance, Karla's use of the presenting a claim discursive move was higher than ten. Likewise, each non-EL participant used the same move more than ten times. In contrast, each EL student apart from Karla presented a claim less than ten times. Therefore, Karla's main discursive move is more similar to those displayed by non-EL students than those displayed by the EL population. Within the EL-Population, Isaac and Isabel used only two types of discursive moves each and engaged in fewer discourse moves overall compared to all other participants.

Redefining the EL Student Group

A closer look at the data and students' educational backgrounds showed that there were two subgroups among the EL sample. Some EL students were international students who came to the U.S. on a temporary "non-immigrant" status to complete their college-level education. Other EL students

immigrated to the U.S. when they were much younger and completed their K-12 education in the U.S. system. Students within these two subgroups differed significantly in their self-evaluation of their English language proficiency. This data is represented in Figure 6 below. Due to this difference, discourse moves were analyzed separately for each subgroup. We defined these subgroups as EL-international (EL-I) and EL-K-12, respectively. In Table 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.

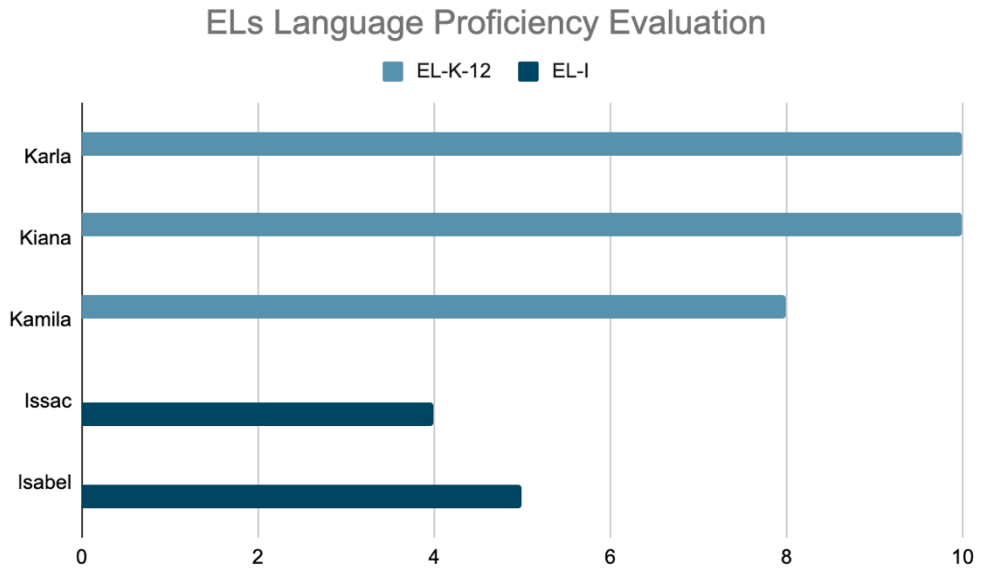


Figure 6. EL-Students Language Proficiency Based on Self-Evaluations

The total talk turns for 20 classes for non-ELs (N=4) were 564, for ELs-K12 (N=3) were 279, and for ELs-I (N=2) were 16. Within the EL-K-12 subgroup, Karla contributed the majority of the talk turns. Kiana and Kamila, two other EL-K-12 students, contributed less talk turns, possibly due in part to less consistent class attendance. The total number of each key discursive moves between non-EL, EL-I and the EL-K-12 participants were also compared (See Figure 7). EL-I students were less frequently engaged in joint knowledge construction key discursive moves than both EL-K-12 and non-EL participants overall. In the EL-I subgroup, the utterances that require a justification for sharing an idea or critiquing others' ideas such as "Reasoning" and "Rebutting" were completely absent.

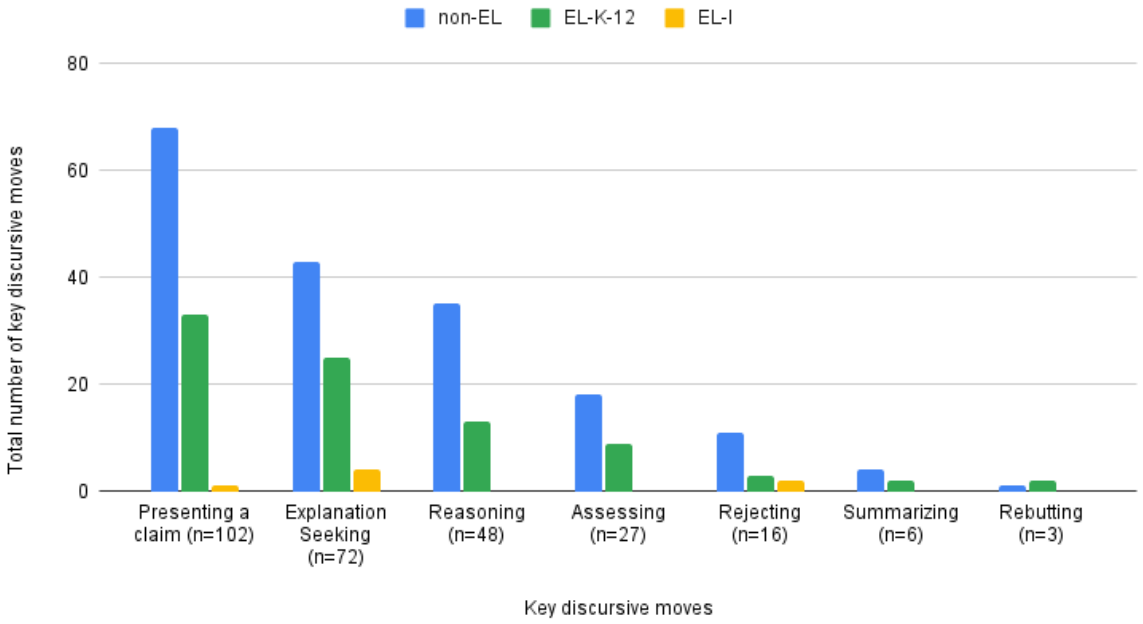


Figure 7. Total number of key discursive moves for non-EL, EL-K-12, and EL-I

The distribution of key discursive moves was compared between EL-I, EL-K-12, and non-EL participants (See figure 8). 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 the EL-I subgroup, "Explanation seeking" has the biggest portion of the distribution (more than 55%). This means when EL-I were engaged in discourse, they were mostly asking questions. The remainder of their distribution complements the "Explanation seeking" code. This is in the form of either rejecting the answer presented to them (Rejecting) or presenting their answer (Presenting a claim). However, for EL-K-12 and non-EL groups, "Explanation seeking" constitutes about 28% and 24% of their key discursive moves, respectively.

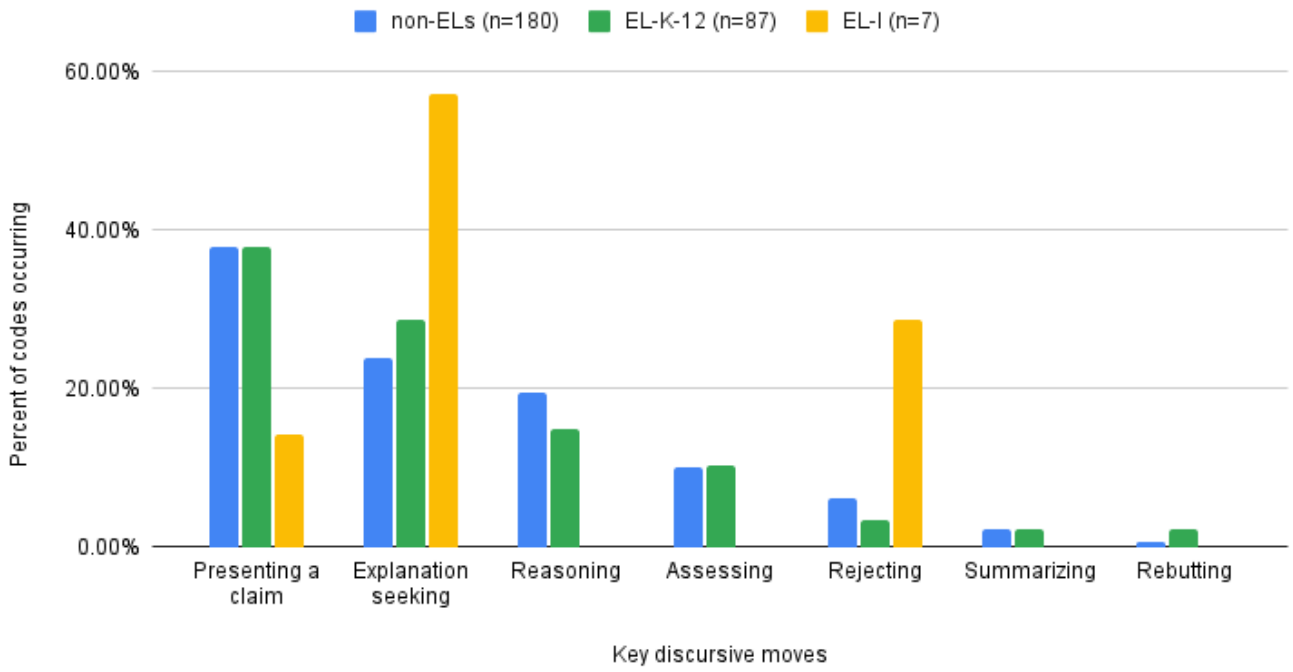


Figure 8. The distribution of codes within EL-I, EL-K-12, and non-EL

REASONS FOR DIFFERENCES BETWEEN EL-I AND EL-K-12

English Proficiency

In this study, all EL participants reported that their first language was not English. Considering only this factor led to grouping them together as a separate case from the native English speakers (non-ELs). However, the findings of this study (Figures 5, 6, 7 and 8) showed that this feature still resulted in a heterogeneous group. Other factors such as English proficiency and time spent in the US education system might also be considered when grouping students. The data from the interviews 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; whereas, EL-I finished their K-12 education in their home country and then 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-12s (e.g., Karla & Kamila) rated their proficiency between 8 to 10 (on a scale of 1 to 10) while EL-Is (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 thought needed more improvement. All EL-K-12 mentioned that they needed some improvement in their listening, but they did 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 did not perceive their English to be a barrier to their group participation, and they did not have any worries about being judged based on their English. However, EL-I students' class experience was different. Both EL-I participants mentioned that they needed 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 the 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 the English that he had learned in his country was British English, and the pronunciation of 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 this problem but after a while, he figured it out.

Being in the US education system and residing in an English-speaking country for a long time helped EL-K-12s' proficiency in English and familiarization with the education system. For instance, Karla mentioned that the time spent in the environment helped her 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…"*

One difference between EL-K-12 and EL-I students is the age at which they started dealing with language barrier issues. All EL-K-12s 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 learn to speak English fluently. However, the situation was different for EL-Is. They encountered language issues at older ages and needed to overcome their difficulties mostly on their own. This finding matched Sheng's 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.[51] Curtis and Millar's also claimed that the longer duration (8 years) of being in an English-speaking country helped EL students overcome an achievement gap that they were experiencing during the first few years.[52]

Even though EL-K-12 students felt more confident about their English proficiency and did not see it as a barrier for group conversations, it does not mean that their experiences were similar to non-EL students in terms of using English. They were still experiencing issues. For instance, Kamila, an EL-K-12, rated her English as 8 and 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…"*

There could even be differences among EL-K-12 students. For instance, in Figure 5, Karla's engagement in key discursive moves seemed different from the other EL-K-12 students. This may result from her English proficiency since she rated her English as 10. Due to our small sample size this difference may or may not be representative of the population; additional research is needed to determine this.

CONCLUSIONS

Learning happens through social interactions. It is more likely for a student to internalize knowledge at a higher level when they talk through concepts. Therefore, all students, regardless of their backgrounds, should have conversations with other learners. This idea is supported in Vygotsky's social constructivism theory as well as in previous studies that reveal the benefits of collaborative learning. [8, 9, 18] While previous studies did not specifically analyze ELs, the results for our sample showed that ELs were less likely to contribute to small group conversations compared to their non-EL peers. ELs engaged less frequently in discursive moves that can lead to a shared understanding through joint knowledge construction. Being engaged in conversations has been known to lead to success for STEM majors. [25] EL students might have faced a challenge in engaging in small group conversations that could impact their learning and achievement negatively. 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 that improve their learning. Moreover, the EL sample could not be viewed as homogenous due to the different educational experiences of the students. Our data showed that the amount of time spent in the US education system is a differentiating factor between the K-12 and international subgroups of our EL sample. This result is in line with a study that showed students who spent more time in English speaking countries had similar experiences (e.g., achievement) with the native English speaking students.[51, 52] In this study, international students and those who had K-12 education in the US were different in how they participated in small group conversations. Previous studies have indicated the impact of English proficiency on students' experiences in science classes.[37] Our interview data showed that English proficiency was an important factor for students' verbalization of their ideas.

IMPLICATIONS

Instructors should consider the benefit of students participating in verbal interaction rather than just listening. There might be missed opportunities of higher-level knowledge construction for EL students who are not engaged in joint knowledge construction key discursive moves. Perhaps EL students need more time to be able to share their arguments in their groups. Therefore, instructors should consider pacing out the time to allow for this. For instance, instructors could use formative assessment to determine if ELs in their classes are receiving adequate processing time to be able to engage in group conversations. Our data suggest that there might be nuances that account for differences in ELs' contributions to small group conversations. This finding may suggest for researchers studying additional EL samples 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 contribute to gaining a better understanding of their experiences. Researchers should further study whether the EL student population needs to be redefined because 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. 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.

LIMITATIONS

The first limitation of this study is related to the nature of our method in which discourse analysis focused only on students' verbal interactions. There are other non-verbal ways of externalizing (e.g., body language) thoughts and ideas that were not captured in this study. The second limitation was a potential bias of researchers who are themselves ELs. This has implications for interpreting and analyzing the data. By discussing the findings 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 these data come from a single university and classroom with a small number of participants. Therefore, the differences between EL-I, EL-K-12, and non-EL students should be taken with caution. This study performed descriptive statistics due to the small sample size. Additional studies with larger sample sizes are needed to generalize these findings to the population. Lastly, using self-assessment of language proficiency allows for bias by asking students to self-evaluate skills. Further studies might choose to use an English proficiency test given to all students, not just ELs, to better understand group composition and its influence on students' discourse engagement.

ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available on the ACS Publications website at DOI: 10.1021/acs.jchemed.XXXXXXX.

- Interview questions; Qualtrics consent form; SIDM codebook; POGIL-inspired activities used in the course; Number of key discursive moves for each person (PDF, DOCX)

AUTHOR INFORMATION

Corresponding Author

*E-mail: gregory.rushton@mtsu.edu

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