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Overcoming Barriers for Implementing International Online Collaborative Assignments in Chemistry

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Overcoming Barriers for Implementing International Online Collaborative Assignments in Chemistry

Abstract
Organic chemistry students at two universities, one in Canada and the other in the United States, connected using video conferencing software as learning partners for six online collaborative assignments. Mixed-methods analysis of interviews, surveys, and student-written reflections was used to identify barriers that students encountered during the international online collaborative assignments. Students described the barriers of their experience with online collaborative assignments in terms of course pedagogy or chemistry concepts, social interactions, and technology. Results were compared and supported by additional data sources. Students were successful at overcoming most barriers, demonstrating real-world problem-solving and a high degree of resiliency. Persistent barriers were identified and resolved by faculty through revisions to design and implementation.

Les étudiants de chimie organique de deux universités, l'une au Canada et l'autre aux États-Unis, ont communiqué les uns avec les autres en tant que partenaires d'apprentissage grâce à un logiciel de vidéoconférence pour six travaux collaboratifs en ligne. Des analyses à méthodes mixtes d'entrevues, d'enquêtes et de réflexions rédigées par les étudiants ont été employées pour identifier les obstacles que rencontrent les étudiants quand ils participent à des travaux collaboratifs internationaux en ligne. Les étudiants ont décrit les obstacles rencontrés lors de leur expérience avec les travaux collaboratifs en ligne en termes de pédagogie du cours ou de concepts de chimie, d'interactions sociales et de technologie. Les résultats ont été comparés et soutenus par d'autres sources de données. Les étudiants ont réussi à surmonter la plupart des obstacles, ce qui démontre qu'ils ont été capables de résoudre des problèmes dans le monde réel avec un niveau élevé de résilience. Des obstacles persistants ont été identifiés et résolus par les professeurs qui ont révisé le concept du cours et sa mise en oeuvre.

Keywords
organic chemistry, collaborative/cooperative learning, communication, chemical education research, international, distance, online, blended, disciplinary language

Cover Page Footnote
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Students of organic chemistry commonly attempt rote memorization as a means to successfully complete the course. This method undertaken by the student often prevents them from developing a deeper level of understanding of the material and has been found to lead to poor long-term memory retention (Bhattacharyya & Bodner, 2005; Laszlo, 2013). These factors possibly account for the inability of graduates to adequately communicate with their peers and other professionals using disciplinary language (Bhattacharyya & Bodner, 2014; Bhattacharyya & Harris, 2017).

Chemistry has been described as a professional language used to express complex natural phenomena through an integration of representations, such as words, formulae, equations, and illustrations (Laszlo, 2013; Lemke, 1998; Markic, & Childs, 2016). As with learning any language, there are inherent challenges associated with learning the language of chemistry. One common challenge during language learning is the formation of an interlanguage (Selinker, 1972). Interlanguage is a dialect that develops between learners which is incorrect or incomplete but is understood by each of the individuals (Selinker, 1972). Although these individuals may be able to communicate with one another, the idiosyncrasies engrossed in their developed interlanguage may limit their ability to communicate with other students or professionals (Markic & Childs, 2016; Song 2012). We previously found that communication between local peers does not inhibit interlanguage formation and may instead enhance its formation (McCollum, 2015). In contrast, communication between remote peers may hinder the development of interlanguage by removing the shared classroom experience, requiring students to use more accurate terminology in order to be understood (McCollum, 2015; Skagen, McCollum, Morsch, & Shokoples, 2018).

The American Chemical Society (ACS) 2018 Strategic Plan notes that

> globalization of the chemistry enterprise continues, with students, members, and other chemistry-related professionals … . This trend provides an opportunity to restructure and/or diversify information and knowledge-based solutions to meet regional and international needs and to establish a globally based workforce. (p. 3)

Canadian graduates will similarly be entered a globally based workforce. Half of Canadian university students desire international learning experiences, but only 3% participate in study abroad before graduation (AUCC, 2014). Thus, we began designing a set of highly personal learning interactions between international peers, making it possible for all students to gain an internationalization at home (IaH) experience during post-secondary training. These learning interactions would increase access to international learning relative to the barriers associated with study abroad for both Canadian and American students.

As with any language training, local or international students need opportunities to practice their new skills; active-learning strategies can provide such opportunities. Active-learning strategies, such as flipped classrooms, reposition students from passive participants to involved agents of their own learning, and can facilitate both concept and language development (Bonwell & Eison; Chickering, 1991; Chickering & Gamson, 1987; Flynn, 2015; McCollum, 2016; Prince, 2004; Seery, 2015; Seery & Donnelly, 2012). Collaborative learning, a form of active learning pedagogy (Crimmins & Midkiff, 2017), involves students working together in small groups to achieve a common learning goal (Barkley, Major, & Cross, 2014; Prince, 2004; Smith & MacGregor, 1992). Collaborative learning methods aim to "develop autonomous, articulate, thinking people" through social construction of knowledge (Smith & MacGregor, 1992). Learning activities in collaborative learning settings are designed to intentionally provide learning opportunities to students (Barkley et al., 2014). Implementation of a collaborative learning setting can positively impact student engagement, attitudes, and persistence for diverse student populations (Barkley et al., 2014)

Collaborative learning is not restricted to the classroom (Dooly, 2008; Zhu, 2012). Online conferencing between remote learners has been used for collaborative learning in second language training (Hauck & Stickler, 2006). Collaborative learning activities and knowledge construction can be enhanced by group interactions within online learning systems (Zhu, 2012), and student interest in learning can be stimulated by the exchange and negotiation of ideas (Dooly, 2008). However, it involves a new set of multimodality literacies compared with face-to-face learning in a classroom such as proficiency with online video conferencing software while simultaneously navigating social interactions with a stranger.

The goal of this study was to identify the barriers that students encounter when engaging in online collaborative assignments (OCAs) with an international peer. The research questions of the study were the following:

(1) What are the barriers that students experience during online collaborative chemistry communication practice with an international partner?
(2) What strategic approaches can, and should, be implemented to reduce barriers that students experience during online chemistry communication practice with an international partner?

While many of the identified barriers will be unsurprising to the reader, they were not obvious barriers to the study participants. For this reason, this work has value in compiling the barriers that student participants identified so as to guide future implementation. Instructors need to take the time to clearly communicate to students that these barriers will exist and, as we will demonstrate, students are capable of overcoming them.

Method

Theoretical Framework

The theoretical framework for this study was phenomenography. It is a qualitative methodology which strongly focuses on participant descriptions of a particular phenomenon (Marton, 1981). Phenomenography states that there are a limited number of quantitatively different ways a given phenomenon can be experienced or perceived (Booth, 2008; Marton, 1981; Marton, 1994). Whereas our goal for the study was to identify the barriers that students encounter when engaging in OCAs with an international peer, phenomenography provided a framework to study these barriers from the perspective of students experiencing the OCAs. By collecting data that represents the student voice, until saturation is achieved, we can generate the associated outcome space (Åkerlind, Bowden, & Green, 2005; Andretta, 2007; Booth, 1997). Examples of phenomenographic analysis in the Scholarship of Teaching and Learning (SoTL) / chemistry education research can be found elsewhere (McCollum, Sepulveda, & Moreno, 2016; McCollum, Fleming, Plotnikoff, & Skagen, 2017; Skagen et al., 2018).

International Experience

While a collaborative learning experience can be initiated between remote peers within the same country, we chose to organize the project as an international experience. This permitted students to connect with peers in another country without the typical costs of studying abroad. International experiences expose learners to diversity of cultures and new viewpoints and ideas, which encourages them to rethink and re-evaluate their own ideas, and encourages critical thinking (Dooly, 2008; Zhu, 2012). With students advocating for opportunities to network with chemists outside their country of origin (Lafranzo, 2017), online video conferencing software appears to be a promising tool to provide an international networking experience while facilitating chemistry language training, and course content practice through collaborative learning between unfamiliar remote peers (Skagen et al., 2018).

Participants

Approval for the study was obtained from the Human Research Ethics Board / Institutional Review Board of both universities. A total of 122 Organic Chemistry I students, 57 in Western Canada and 65 in Central US, were invited to participate in the study. Data was only included for those who completed and provided consent on all three surveys throughout the semester (n_{Canada} = 31, n_{US} = 44). Student demographics were similar in the two courses: 70% female (Canada) and 74% female (US); mean age of 21 (Canada) and 22 (US). Differences between the universities include: (1) the American university offers both undergraduate and graduate programs, while the Canadian university offers only undergraduate programs; and (2) that the US offers a major in Chemistry (15% of US participants were Chemistry/Biochemistry majors), while the Canadian university did not offer a major in Chemistry at the time of the study.

Course Design

In a flipped classroom, students are expected to engage with learning materials before coming to class, and instructional time is focused on active participation in group work and problem solving (Bergmann & Sams, 2012, 2014). Pre-lecture resources can reduce in-lecture cognitive load and diminish differences in achievement between students with prior knowledge of chemistry compared to students lacking this prior knowledge (Seery & Donnelly, 2012). Both classrooms in this study employed variations on flipped pedagogy as described elsewhere (McCollum, 2016; McCollum et al., 2017; Morsch, 2016; Morsch & Lewis, 2015).

The American classroom used pre-lecture instructor-created videos for pre-class preparation, as well as open-education textbook LibreTexts, which served as the resource for reading assignments (Allen et al., 2015; Larsen et al., 2017; Rusay, Mccombs, Barkovich, & Larsen, 2011). Students were expected to engage with these materials prior to class, verified with quizzes at the beginning of class. The American students were required to have iPads for the course, enabling them to draw, name, and visualize molecules with the ChemDraw app. The iPads also allowed use of Socrative web app as a classroom response system. More information on the American classroom pedagogy is reported elsewhere (Morsch, 2016).

The Canadian classroom also used a flipped classroom method. A traditional print textbook was used, as well as physical molecular model kits, and OWLv2 online homework system from Nelson Cengage. Peer leaders attended classes to support the team-based active learning (Gosser

& Roth, 1998). Other classroom interventions included 15-minute academic reading circles (ARCs) at the start of class (Daniels, 2002; Seburn, 2015; Shelton-Strong, 2012), iClicker questions during class, and open-response multiple-attempt (ORMA) group quizzes (McCollum, 2016). More in-depth information on the Canadian classroom pedagogy is reported elsewhere (McCollum et al., 2017).

The American and Canadian classes had different examination schedules; the American classroom had three in-term exams and a final, while the Canadian classroom had one in-term exam and a final.

Online Collaborative Assignment Design

Reorganization of curricula for the two courses for sufficient alignment was necessary before any topics could be selected for the OCAs. Several difficulties were encountered in aligning the curriculum. The American university had a semester start date two weeks prior to the Canadian university, the universities had different national holidays, and the Canadian university had a reading week, while the American one did not.

Similar learning objectives that could be scheduled to align between the two universities were selected for the project. Examples of these learning objectives are shown in Table 1. OCAs were then developed based on revised shared learning objectives and overarching course topics as shown in Table 2. Some revisions to the learning objectives were required to unify our approach and learning objectives for the OCAs. The shared learning objectives for some of the OCAs are also presented in Table 2. Negotiating these shared learning objectives did not require that a university's learning objectives were "lowered" to match the other university. Rather, in some instances the depth of course content at one university (reflected through the learning objectives) was increased to provide closer alignment. In other cases, the shared OCA learning objectives reflected the existing overlap of course content.

The OCAs were designed with a collaborative learning foundation intended to encourage students to practice written and spoken chemical language, as well as foster an international experience in social construction of knowledge. The OCAs require that students work together to solve a problem requiring a number of skills including oral communication and correct disciplinary language. There were five objectives which factored into the design and development of the OCAs (Skagen et al., 2018):

(1) Promote the development of chemistry-based language skills through chemistry communication practice with a peer.
(2) Enhance conceptual understanding of course content through social construction of knowledge.
(3) Foster mutual accountability and interdependence with an international chemistry peer and provide opportunities for feedback on the relationship dynamics.
(4) Require partners to discuss chemistry concepts verbally using standards within the discipline, to explore similarities and differences in how concepts can be described.
(5) Include questions that require learners to summarize, and self-evaluate, their learning in organic chemistry.

Table 1
Sample Learning Objectives for Organic Chemistry at the American and Canadian universities and Shared Learning Objectives for the Online Collaborative Assignments

Topic	Sample Learning Objectives Before Alignment Between Universities		Sample Learning Objectives of OCAs After Alignment Between Universities
	Canadian University	American University	OCAs
Nomenclature	- Identify, name, and sketch simple and branching alkanes, alkenes, and alkynes (up to 20 carbons on main chain) according to the IUPAC system. - Identify, name, and sketch aliphatic carboxylic acids, aldehydes, alcohols, amines, and halogenated hydrocarbons. Identify, name, and sketch aliphatic and cyclic ketones.	- Use the IUPAC system to name organic molecules (up to 10 carbons). - Recognize the major functional groups, including alkanes, alkenes, alkynes, alcohols, ethers, alkyl halides, aldehydes, ketones, amines, carboxylic acids, esters, amides, thiols, sulfides, disulfides, thioesters, phosphate esters and acid halides.	- Identify, name, and sketch hydrocarbons (up to 10 carbons on main chain) according to the IUPAC system. - Provide example molecules for common organic functional groups.
Stereochemistry	- Identify, name, distinguish, and generate structures for enantiomers and diastereomers of a compound. - Identify meso compounds. - Name and differentiate between geometric stereoisomers using the cis/trans and E/Z systems, applying the Cahn-Ingold-Prelog rules when required. - List chiral and achiral properties. - Generate and interpret Fisher projections.	- Recognize chiral compounds. - Determine configuration of the stereocenter, and name chiral compounds. - Classify pairs of compounds as enantiomers, diastereomers, or a different class of isomer. - Draw chiral compounds using perspective drawings and Fisher projections. - Describe the relation between the stereochemistry of a product and the reaction mechanism.	- Identify compounds as chiral or achiral. - Identify stereocenters within chiral molecules. - Determine the configuration of stereocenters, and name chiral compounds using the Cahn-Ingold-Prelog rules. - Sketch and name the enantiomer and all diastereomers of a chiral compound. - Generate Fisher projections of chiral compounds.

Table 2
Topics Selected for Online Collaborative Assignments

Assignment	Topic
1	Naming alkanes and functional groups
2	Drawing cyclohexane
3	Stereochemistry
4	Reaction coordinate diagrams
5	Nucleophilic substitution reactions
6	Elimination reactions

Students were assigned a partner from the other university, with the majority of groups retaining the same partners from start to finish. However, some groups were rearranged due to withdrawals from the course. In some instances, students were paired in groups of three due to unequal enrollment at the two universities. A typical OCA consisted of approximately six questions based on the assignment topic (Table 2). Students reported spending about 60 minutes preparing for the online meeting, 30-60 minutes during the meeting, and 45 minutes writing the final assignment submission and individual reflection. Students completed the OCAs outside of class time using online video chat software such as Skype or Google Hangouts. A notable difference in student tasks between universities was the requirement for American students to record and submit the video meetings using Kaltura CaptureSpace Desktop Recorder. The Canadian students did not have this responsibility. Students provided consent for their video submissions to be retained by the two professors in a secure location accessible only by the research team for up to five years. OCAs were graded for: (a) meaningful participation, as verified by spot-checks of the video recordings, (b) grading of the submitted assignments on the basis of completion, and (c) and meaningful responses to the reflection questions. Collectively, the six OCAs were worth 5% of the total course grade.

The OCAs were deployed at the two universities simultaneously, with complementary versions given to each student in the partnership. An example question from OCA 5 is provided in Figure 1, which illustrates a nucleophilic substitution reaction provided to the Canadian partner. Students would generate the full reaction mechanism and then prepare a written description of each step. This description included the IUPAC name of reactants and products, explanations of any reaction intermediates, and details on the electron flow in each step. During the online meeting, the Canadian student would read their prepared description to the US partner. The US student would then sketch the mechanism based on the description and show their scheme to the Canadian student. If the US and Canadian student schemes did not match, the Canadian student would inform their partner. Without revealing the original reaction or their prepared mechanism structure, the Canadian partner would initiate a discussion of their work. Partners would identify any misconceptions on either side and collaborate to identify a shared answer. After this question, the roles would then be reversed, and a new question would be attempted.

Without grading support from teaching assistants, it was not possible for the instructors to monitor or evaluate all student meeting preparation materials for correctness. Rather, the purpose of the collaborative learning design was intended for peer feedback to support both learners. Peer feedback as a valuable learning tool has been well established (Li, 2010; van der Pol, van der Berg, Admiraal, & Simons, 2008; van Popta et al., 2017). As shown in Figure 1, if the student that did preparation for a particular question was not able to get their partner to generate a matching response, the two students were expected to collaborate to resolve the error.

The first assignment generated many questions on what materials were required for submission (e.g., work from only the local student versus copies of all answers from both partners). We have refined our assignment instructions to reduce the number of student queries. Very little assignment troubleshooting was required beyond the first assignment. However, as students reported particular barriers in class, instructors provided suggestions about how to overcome these barriers.

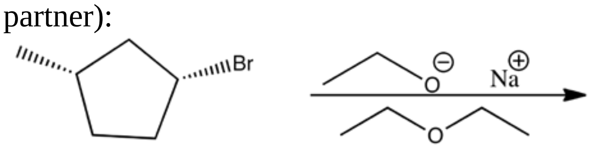
Canadian Student Version	US Student Version
Before meeting with your partner: • Review the nucleophilic substitution reaction below. Don't show it to your partner. • Sketch the full reaction mechanism, then write a description using appropriate chemistry terminology and IUPAC nomenclature for each step. During your meeting: • Read your description of the reaction mechanism to your partner. • They will attempt to draw the mechanism based on the description. • Your partner will then show you their drawing. • If it does not match the original, both partners should check their work and continue attempting to match their mechanisms using proper chemistry terminology and IUPAC nomenclature in their discussion. Your reaction is (don't show it to your partner): 	During your meeting: • Your partner will read their description of a reaction mechanism based on a reaction that only they have been given. • You will attempt to draw the mechanism based on the description. • You will then show your drawing to your partner. • If it does not match the original, both partners should check their work and continue attempting to match their mechanisms using proper chemistry terminology and IUPAC nomenclature in their discussion.

Figure 1. An example question from the online collaborative assignment on nucleophilic substitution reactions.

Data Sources

Data was collected during the Fall 2016 semester and sources included student interviews, surveys, student written reflections, instructor field notes, US student video recordings of OCA meetings, and associated written assignments. Surveys were issued at the beginning of the semester, the middle of the semester, and the last week of classes. The surveys captured demographic information including age, gender, grade point average, and intended major. The surveys also included open-response questions that invited students to reflect on various aspects of their OCA experience.

To avoid potential ethical conflicts due to the dual-roles of the instructors/researchers, all interviews were conducted by research assistants. Interviews were conducted during the last two weeks of the semester with 25 participants (n_{Canada}=10, n_{USA}=15). The semi-structured interview prompts included the topic of barriers. The objective was to explore what barriers the students' experienced when preparing for the OCAs, meeting with their partner, or completing the written assignments. The interview questions and surveys have been reported elsewhere (Skagen et al., 2018).

Thematic Analysis

Data was collected in the form of small group interviews until saturation was achieved, and the observed variation of experiences organized into the outcome space (Åkerlind et al., 2005; Andretta, 2007; Booth, 1997). Student interviews were transcribed, and subsequently coded following the practices of thematic analysis (Braun & Clarke, 2006; Saldana, 2009). Each interview was coded by two or more team members. According to principles of phenomenographic analysis, the coding process was iterative and comparative in nature: patterns in qualitative data were identified and categorized into several broad themes, each with their own subthemes, which encompassed all identified patterns. This type of coding process ensures interrater reliability as divergent coding schemes by individual members were identified, discussed, and resolved by the full team. The emergent themes from the interviews were then compared to faculty field notes, student video recordings of OCA meetings, and the associated written assignments, to triangulate results. Triangulation involves using "multiple methods, data sources, and researchers to enhance the validity of research findings" (Mathison, 1988, p. 13).

Results and Discussion

The outcome space for this study included categories of impact, barriers, resources, and collaborative learning approaches (Skagen et al., 2018). In this paper, we focus on the barriers students reported experiencing during the OCAs. The sub-themes associated with barriers are listed in Table 3. Participant descriptions of experiences that match each of these sub-themes were analyzed to identify specific barriers and determine if these barriers were unintentional, avoidable, or if they were desired learning opportunities. All participant quotes are attributed to a student from Canada (C) or America (A), using an identifier that includes their country, a participant identifier, and the student's course grade.

Table 1
Sub-themes Related to Barriers Students Experience During the OCAs that Emerged from Thematic Analysis of Participant Interviews

Sub-theme	Description
Content and Pedagogy	Barriers related to chemistry course content or pedagogy
Social Interactions	Barriers related to personalities and time management
Technology	Barriers related to hardware, software, and networks

Barriers of Chemistry Content and Pedagogy

One of the challenges in learning any new language is the ability to effectively express the message you are trying to convey. The challenge of using chemistry language was described by some students. Consider the following quote from one student participant:

> You just have to be really specific. What you're trying to convey to them. Because you have to say, 'this is cyclohexane' so they don't just write a hexane. Or, 'this is a diol', instead of just saying 'there's an OH here and an OH here'. You've got to be really specific in what you tell them. … I guess we overcame that by just talking to each other. Even if we couldn't figure out what the other one was saying, we would try to coach them into it. (A-9-B)

In previous semesters, students struggling to use proper chemistry terminology would commonly say to their instructor 'but you know what I mean'. The experience of discussing chemistry with a remote peer enabled this student to appreciate the value of correctly using specific nomenclature in order to be understood by their partner. This barrier to effective communication is an important learning opportunity facilitated by the OCAs. Discovering the specificity required in using chemistry terminology can promote deeper understanding and appreciation for communication which requires deliberate and specific language choices (Airey & Linder, 2009; Lemke, 1998; Zhu, 2012).

Students reported the barrier of having a partner whose class was behind in the curriculum. This perceived experience of having a mismatched level of knowledge compared to their peers led to frustration when attempting to complete the collaborative assignments. One student noted,

> One of the challenges I found was, sometimes we were on two different chapters and so we would be discussing things that they had yet to learn or we had yet to learn. The majority of the time it was they had yet to learn. In some aspects, it was frustrating not necessarily because we were still teaching but we weren't on the same level. (C-2-B)

Despite similar descriptions from some students, the two instructors had planned the course schedule to ensure that all related content was covered in class before release of an assignment. As such, these descriptions of experience were unexpected. Considering that students at both campuses described this experience, sometimes for the same assignment, the instructors were not the ones who were behind schedule. This observation may be interpreted in terms of Attribution Theory, with students attributing the behavior of their partner in terms of an external cause (the course instructor) (Weiner, 1972).

The instructors have discussed what interventions they can implement to better encourage students to be prepared for the OCAs. One simple approach that works is to consider how they would feel if their partner is not prepared for the OCAs. Additionally, the American campus has introduced in-class academic reading circles which encourages students to be prepared to discuss the content with local peers, thus increasing the probability that they are ready for the OCAs.

Barriers of Social Interactions

Social interactions presented an array of barriers, with navigating the task of scheduling meetings comprising a large portion of this barrier. The most commonly reported barrier related to scheduling was the 1-hour time zone difference between the two universities. Students reported that for their first meeting both students would be waiting for their partner at 8pm. However, 8pm Mountain Time was already 9pm Central Time. The American student would logout frustrated before their Canadian partner would log on at 8pm local time. One student said:

> Because if they wanted to meet at eight their time that was nine your time. And so, having that hour difference sometimes made a big difference into where they were going to be like at what point of the day they were in, what time you were in. (A-6-B)

While this barrier may be obvious to professionals, it is novel to students who have never had experience arranging meetings with people in different time zones. The 1-hour time difference initially caused missed meetings and confusion but was resolved by the second assignment. In subsequent implementation of OCAs, all instructors identified time zone issues as a common scheduling challenge, almost completely eliminating this barrier. This demonstrates that instructor awareness and communication to students regarding barriers can have a positive impact, reducing potential barriers faced by the students.

Another scheduling challenge experienced by students pertained to group size. At the start of the term, class size was similar, and most students were in pairs, with only a few triads. However, as class numbers changed during the semester, this led to different numbers of students at the two universities. To remedy this, the instructors constructed some groups of three students, and one group of four, so that everyone would have at least one international partner. Students reported that with a larger group size there was increased difficulty in scheduling.

Another barrier experienced by students occurred when one partner was not prepared for the online meetings. Each assignment had components for individual preparation. Despite this, some students described how their own lack of preparation going into the assignments, or the lack of preparation from their partners, affected their experience and feeling of success in the assignments. The following quote was from a student whose partner was unprepared:

> [My partner] in Illinois, she always left it [her preparation] until the video started, and she would do all of the questions during it. That’s why it would take 2 hours. So then, it’s just like ‘ugh why! It's not hard. It’s three questions!’ Yeah, and so, it was really frustrating. (C-3-A)

Contrast this with the following comment from a student on the other side, who was the unprepared partner:

> Interviewer: How did you feel when you weren't prepared for the assignments?
> Student: "I just felt kind of lost. I think it was the chair structures that I was still confused on and they were trying to help me, but I just wasn't getting it. They just moved on and I was still like 'what?' you know. Still kind of lost. So, I did feel like I was behind them or I was holding them back. So, it just wasn't great when I didn't do it beforehand. (A-9-B)

Student preparedness appeared to play a large role in the students' feeling of success in their assignments, which is a known factor for online learning environments (Parkes, Stein, & Reading, 2015). Students who had unprepared partners expressed frustration. One student (C-8-B) even described it as "chaos" when their partner was unprepared, and students who were aware of their personal lack of preparation expressed feelings of guilt. Despite this, as partners developed a relationship and a sense of accountability towards each other, they became better prepared for their meetings and this barrier was eliminated for most participants. Feelings of accountability and high motivation for preparation have been linked to increased student success (Debacker & Nelson, 2000; Hibbard, Sung, & Wells, 2016). The development of strong relationships between partners was reported in instructor field notes. Our original plan was to change partners after Assignment 3, with the intention that partnership changes would reduce the development of interlanguage between international partners (Selinker, 1972). However, when the partnership change was announced to the class there was a near-revolt. One student stood up and loudly proclaimed, "You can't take my partner from me!" Both instructors held a vote in their class, and both populations overwhelmingly voted to maintain partnerships. The instructors agreed to leave the partnerships unchanged for the remainder of the term. While this did influence the experimental design of our study, we argue that it is important to respond to student feedback during the learning process as advocated by the Students as Partners research community (Cook-Sather, Bovill, & Felten, 2014). Furthermore, video recordings of the online meeting revealed that no substantial use of interlanguage occurred during the six online meetings, and thus our decision to allow partnership to continue did not undermine our objective to minimize interlanguage. This result may have changed if the number of meetings was greater, or the time length of meetings was longer. It is valuable to note that students reported going to their textbooks or other resources during the online meetings to find the appropriate terminology for their conversations, demonstrating student understanding of the importance of shared disciplinary language.

Surprisingly, personality differences did not appear as a significant category of experience. We consider this an impressive demonstration of professional attitude among participants (Paterson, Higgs, Wilcox, & Villenuve, 2002; Skagen et al., 2018). One group required restructuring due to a non-responsive partner, which was resolved with a single email from the local course instructor. The other issue was more complex and required a group reassignment into a triad. The two American students in this triad completed a group interview together. They noted the following:

> We actually got to work together because [name]'s partner didn't respond to her. We got to work together and our partner was like really responsive. He answered every email that we had. I think we kind of got lucky. I've heard horror stories from other people. I think ours just like went really smooth, it was a positive outcome. (A-5-C)

Despite what this student said about horror stories from other students, most partnerships functioned well. Only two groups out of 57 in Fall 2016 required some level of instructor intervention. Some other groups expressed challenges of unprepared partners on the first assignment, but students reported that this improved through the 6 assignments.

Barriers of Technology

One category of experience that was common to almost every participant was the barrier of poor Wi-Fi bandwidth. Some comments were brief but full of emotion, such as “We learned not to trust the WiFi” (A-9-B), “So many dropped calls” (C-1-B), or “We would just have to mime the entire time” (C-2-B). For some participants, their study habits involved specific environments such as their dorm room, which they did not vary even when confronted with poor Wi-Fi. One noted, “I’m usually in my dorm, and the Wi-Fi was awful there. In my room, … It’s comfortable.” (A-9-B) In contrast, other students described their experience with Wi-Fi as a motivator for adaptation. One student stated,

> [My partner], she lives in the dorms and sometimes the Wi-Fi is messed up in there, so she just did it from the library after that. Oh, and lags, sometimes the videos would lag. Sometimes it would be really bad. There’d be no words at all and then there’d be the next words, and I’m like ‘I have no idea what you said, I missed half your sentence’. (A-6-B)

Some students, without reliable Wi-Fi, reported being unable to focus on their communication practice. One partnership reported turning to multi-platform communication methods, using the video software for visual information and text messaging to replace the unpredictable audio.

Video chat software creates high demand on internet bandwidth, often resulting in poor video transmission (Rehn, 2017; Xu, Yu, Li, & Liu, 2012). This is especially true during times of high internet traffic, such as during the school day, where internet connection speeds can drop even further (Bassi, Radice, Bruccoleri, Erba, & Mazzanti, 2016). This problem was further exasperated by the Canadian university undergoing Wi-Fi upgrades, which slowed down the system (Pike, 2016). With internet bandwidth predicted to double over the next few years, the emphatic concerns of OCA participants may become a non-issue (Cisco, 2017). In our case, the Canadian university Wi-Fi upgrade is now complete and student ratings of the Wi-Fi signal strength during the second year of using OCAs, on a scale of 1 “terrible” to 5 “amazing”, across the OCAs was 4 ± 1. While we do not have data from the first year of using OCAs for comparison, this demonstrates that students are generally considering the Wi-Fi reliable and no longer a barrier to the experience.

During the second implementation of the OCAs, each student was asked to rate their Wi-Fi experience for each of the six online meetings. A clear majority (76%) rated all of their meetings as having the WiFi work “very well” or “extremely well”. Only 9% of students rated the Wi-Fi as working “slightly well” or “not well at all”.

Participant comments regarding the video recording software, Kaltura CaptureSpace Desktop Recorder, revealed two distinct categories of experience. Consider the following statement from a Canadian partner describing their American partners’ struggles: “Sometimes it [the software] wouldn’t record, or he would be on mute the entire time, so there was a lot of difficulties.” (C-1-B)

This student's experience with muted audio from their partner revealed an unanticipated hardware issue. When the headphone jack was in use the device would mute the onboard microphone in favor of the headphone microphone, as is found with Apple wired headphones. Students that were using a different brand of headphones were sending no audio signal to their partner. Troubleshooting with their instructor helped to resolve this barrier.

One 'C'-level participant expressed frustration with the technology barriers:

> I didn't really feel like I learned that much because there was so much technology issues that I was freaking out about that the whole time. Like 'am I even going to have anything to turn in'. I didn't care about getting the right or the wrong answers I just wanted to get it done quickly because the computer could turn off at any second. So, it was more stressful than beneficial to me. (A-2-C)

This student's description suggests cognitive overload as they struggled to manage the new course concepts, peer interactions, and the video recording software (Çakiroğlu & Aksoy, 2017; Sweller, 1994). In contrast, other participants described initial struggles to be a normal element of a new technology-enabled experience. One student noted,

> Kaltura, the recording software, was fine. The first time it [the collaborative meeting] was a little bit slower because I had to figure out how to turn it [the recording software] on. Other than that, one time we had our Skype disconnected because of problems on her end with her computer, but that's just basic trouble shooting. It wasn't too bad. (A-10-A)

Compared with the WiFi barrier, which was a concern of almost every student and out of the instructor's control, software barriers only occurred for some American participants and their Canadian partners, and reports only identified the recording software as a barrier. In contrast, the video conferencing software was never reported as a barrier to the experience. We interpret the small number of participants that experienced software barriers in terms of a proactive intervention by the US instructor. Prior to the first OCA meeting, he organized a training session for the students with the university information technology department. Despite only taking 30-minutes of class time, the training appears to have served the needs of most students. Additionally, the relatively few comments about software barriers reflects the confidence of modern digital students, who are commonly identified as being well prepared to handle technology (Parkes et al., 2015). Survey data aligns with this interpretation, with 77% of participants reporting prior experience with video chatting software and 88% of participants rating the online video chatting experience as "moderately easy" or "easy.". Clearly, while technological barriers, such as Wi-Fi bandwidth, were frustrating for students, most participants did not consider the technology difficult to use.

Resolving Barriers

Students described some barriers to their experience of the OCAs, which could be organized into categories of chemistry content and pedagogy, social interactions, and technology. Despite these barriers, participant interviews revealed initiative and problem-solving behaviour that enabled students to overcome most barriers. For example, rather than giving up when their online meeting was frustrated by lagged video, one partnership resolved poor Wi-Fi connectivity by having a student move to a different room closer to the internet router. Another student quickly moved to their roommate's laptop when their computer crashed.

Instant messaging was employed by many participants to improve scheduling conversations. Text messaging would allow them to arrange meetings on short notice without worrying that their partner wasn't checking emails. Other participants solved scheduling difficulties by planning in advance. For example, one student noted,

> We just had to figure it out. You plan ahead. Send each other your schedules, [identify] what times work for everyone. Then, if worse comes to worse, we did it late, like ten o'clock. That's how you got it done. It wasn't bad. (C-5-B)

General and chemistry-related communication barriers were overcome through persistence. Partners would adjust their word choices, refine their explanations, and use internet searches to verify their chemistry understanding. Students were surprised by subtle differences in English language use between Canada and the United States. One student stated,

> You don't realize how many different words people in the US use as opposed to us. Sometimes I would say a word and they'd be like 'Huh? What are you talking about?' Eventually it would be okay. [I would] dummy it down, [and] figure out what kinds of words [I can] use that make sense. (C-5-B)

Another participant described how their experience of barriers related to chemistry course content resulted in meaningful interactions with their partner:

> I'm not going to lie. Sometimes I didn't know what the heck they were talking about, especially if they learned something different from you, or they were ahead. It's a learning experience, because you didn't know what that was before, but now you do. Yeah, it was hard. It was hard. We would just figure it out by talking to each other. Them talking to us, us talking to them. … I think the most meaningful stuff was doing the problems and seeing 'okay, they got the same answer as me, so I must be doing something right. Either that or we're all wrong. And then we need to ask [professor's name]'. I think the best conversations when one of us got something wrong. That's when the most growth happened. 'I learned something I'm going to remember that now. I'm not going to do it wrong again.' You finally have that click moment where you're like "I finally get it. I'm not stupid'. (A-9-B)

This student's experience aligns with our goal for the international online collaborative learning assignments. Learning is hard work. Yet, it is through the struggle of communicating with a learning partner that knowledge co-construction occurs. We are pleased that students were able to overcome many unintentional barriers of the OCAs, and that the intended chemistry communication practice with inherent challenge of chemistry knowledge acquisition was realized. This year, we have revised some of our implementation to reduce other barriers that shaped student experiences. For example, before assigning international partnerships, we now have students complete an availability survey and use that information to identify pairs of students in different countries that have similar availability for meetings.

Challenges and Limitations

Design of the international online collaborative assignments involved changes to the course content and schedules to reflect differences in topics, holidays, and start and end dates, at the two universities. These negotiations took time, creativity, and reached beyond the two collaborating faculty members to include other organic chemistry instructors in their departments. Trust between the collaborating faculty was foundational. An on-going mutual commitment to the initiative was necessary, with both instructors keeping to the agreed-upon schedule so that all students would see a topic before the associated assignment was released.

Classes involved in this study were relatively small (approximately 60 students). In addition to the software training provided at the American university, there was a significant time commitment from both faculty to resolve changes to class enrollments or manage the rare unresponsive student. Online collaborative assignments in larger classes would likely have additional barriers as faculty are less available to assist individual students with troubleshooting. However, many of these large classes also have several teaching assistants that could assist with the process.

As a qualitative study, this research aims to reveal the barriers that students encounter when engaging in international online collaborative learning. It does not endeavor to quantify improvement in student communication accuracy or chemistry understanding. Future research on international collaborative learning facilitated through video conferencing software should focus on measuring this impact.

Implications

We anticipated that students would find the experience of international OCAs challenging. Analysis of student surveys, reflections, and interviews identified variations in the ways that students experienced the assignments and revealed the barriers that students can encounter when engaging in international online collaborative learning for organic chemistry. Barriers to be avoided are deviating from the content schedule, which leads to students being unfamiliar with assignment content, and assigning larger groups, which increases the scheduling complexity for students. Pre-emptive software training can reduce technology barriers.

Other barriers are not in the control of the instructor: Wi-Fi bandwidth, and non-responsive or unreliable partners. Support from stakeholders, such as campus IT teams in the case of Wi-Fi, may be an option for resolving these barriers. We also no longer have students collect and submit recordings of their online meetings. This has simplified the experience for students, permitting them to focus on the content and interpersonal interactions rather than worrying about technology issues with the recording software. Data emerging from the subsequent deployment of OCAs reveals that students are still engaging in meaningful learning experiences. Complaints about non-responsive partners are currently handled through the instructors. This has become a limitation as the collaborative learning initiative has begun to expand to include other institutions. The research team is currently developing software to automate some aspects of the OCA coordination.

Another set of barriers are intentional learning experiences: chemistry language and course content, and scheduling between partners including time zones. Strategic approaches and existing supports were identified and implemented to assist students with improving their chemistry content knowledge and communication confidence through online collaborative learning. Although students identified scheduling issues as a barrier, they also described it as a professional obligation, demonstrating professional growth. To avoid issues where students in two different times zones both log-on at 7pm local time, instructors now advise the students to account for time zone differences when scheduling meetings. Prior knowledge of potential barriers to students can aid faculty engaging in international collaborative learning initiatives in avoiding unintentional obstacles and keep students focused on the intended learning objectives.

It should be noted that the OCAs were worth only 5% of the course grade. We wanted the students to find value in learning collaboratively with others, as opposed to primarily completing the assignments for marks. Our data shows that students will both engage in the experience and troubleshoot the associated barriers without significant faculty intervention. There does not appear to be any need to increase the weighting of the OCAs. We suspect this is due to Social Comparison Concern (Festinger, 1954). It has shown that students will often put in more effort when confronted with a peer, in particular if they believe they can improve their own performance relative to a peer.

Although we did not report quantitative data regarding student outcomes in this manuscript, we have previously reported the impact of the OCAs on student confidence in communication (Skagen et al., 2018). While this took effort for the faculty to implement the OCAs for the first time, the second implementation was significantly easier as the materials were already created and available for use, and the faculty were more familiar with the process. Additionally, relative to the instructor effort, the benefits to students in terms of professional identity formation were substantial and substantiated our efforts (Skagen et al., 2018).

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