Interaction Patterns in Synchronous Online Calculus and Linear Algebra Recitations

Dr. Greg Mayer
Georgia Institute of Technology
gsmayer@gmail.com

Dr. Cher Hendricks
University of West Georgia
cher@westga.edu

Abstract

This study describes interaction patterns observed during a pilot project that explored the use of web-conferencing (WC) software in two undergraduate distance education courses offered to advanced high-school students. The pilot program replaced video-conferencing technology with WC software during recitations, so as to increase participation in the program from schools systems unable to afford the equipment that the established model required. We report on the experiences of 16 high-school students who had enrolled in this pilot through survey, focus group, and quantitative log data. Despite technical challenges that the participants and teaching assistant encountered, students in the pilot demonstrated they were able to succeed in this alternate format. Implications for the design of online group work are discussed.

Acronyms

DCP = distance calculus program
HS = high school
LI = log-in
TA = teaching assistant
WC = web-conferencing
WCR = Wimba Classroom
VC = video-conferencing

Introduction

The Georgia Institute of Technology, in collaboration with various school systems in Georgia, has been offering sophomore college level courses via distance learning to advanced high school students through its Distance Calculus Program (DCP) since 2005 (Morley et al., 2009). The program now annually enrolls over 300 high school students from roughly 30 different schools that are geographically spread out across Georgia. Many of those students live too far away from the university to attend lectures and recitations on campus; providing instruction through the use of distance learning has always been a more viable format for administering this program.

Overall, the DCP has been a success: program enrollment numbers have steadily increased since 2005, and the high school students that complete the DCP receive, on average, higher grades than the Georgia Tech students who complete the same courses on campus. The program has also been an effective recruitment tool for attracting academically advanced students in the state to Georgia Tech (Morley et al., 2009). Nonetheless, over the years, opportunities for refining the DCP have been identified. Currently, students connect to lectures and recitations through video-conferencing (VC) equipment. Costs to the school systems for technical assistance been a modest $100/semester per student, plus an additional equipment fee that is roughly $7,000 per school. Although these costs are capped at $3,000 per school and $15,000 per school district, they can be prohibitive for some schools and school districts that have a small number of students who would like to enroll in the program. Moreover, the VC equipment does not have a shared whiteboard that students can write on, which limits the interactions that students can have with other students, the teaching assistants, and lecture content. Synchronous group work between students at different high schools using the VC equipment is not possible.

This report describes the results of a small pilot project aimed at addressing these challenges through delivering recitations to a small group of advanced high school students using a web-conferencing tool, Wimba Classroom (WCR). The project aimed to answer the questions: How do high school students in live, synchronous recitations connecting through web-conferencing software (a) interact with the technologies they use, (b) interact with other students, and (c) interact with their teaching assistant? These questions were explored to help us track and support the students in our pilot to be successful, and also to characterize an alternate delivery model of the Distance Calculus Program recitations that would rely on web-conferencing software. Our work is based on the experiences of 16 students in one section of the DCP that connected to recitations over a nine-month period using WCR. Although this software is being phased-out in January 2015 and our sample size is relatively small, we hope that describing the interaction patterns that these students exhibited may help other educators who are considering the implementation of group work using web-conferencing software and also help researchers trying to understand the mechanics of group work in synchronous online learning environments.

Literature Review

The past two decades have seen a rapid expansion of online courses, programs, and schools at the K-12 level (Barbour, 2009,2010, 2012; Wicks, 2010). Among the forces driving the growth of online learning are policy initiatives targeted at expanding educational opportunities for all students and meeting particular needs for schools where administrators have difficulty finding teachers for high level and/or Advanced Placement (AP) courses (Johnston & Barbour, 2013; Rice, 2006). Alongside reports of success in some of these initiatives (e.g., Barbour, 2012; Barbour & Mulcahy, 2006; Watson, Murin, Vashaw, Gemin, & Rapp, 2010), several key challenges and unanswered questions have emerged. One such challenge resides in concerns surrounding student isolation and lack of socialization in the virtual environment. For example, a recent study by Johnston and Barbour (2013) of the Florida Virtual School (FLVS) examined the performance and perceptions of high school students in online advanced placement courses. FLVS students felt that some classes were "better" in the traditional classroom settings because of their preference for "student-to-student exchanges and class discussions" (p. 25).

Many online K-12 programs have found methods for incorporating significant student-student and student-teacher exchanges (Barbour, 2012; Wicks, 2010). Web conferencing (WC) tools, for example, are one example of a technology that virtual high schools in North America are now using to build online community and enable interactions between students and teachers. Elluminate, Wimba Classroom, and Adobe Connect are current examples of WC software that enable simultaneous communication through audio, text chat, shared white board, desktop video, and computer desktop or application sharing.

Reports on the use of Wimba Classroom (WCR) can be found at the undergraduate level (Carrington, Kim, & Strooper, 2010; Divine & Kimmins, 2010; Huijser et al., 2008; Rogers, 2011), at the graduate level (Betts, 2009; Martin et al., 2012), in health sciences education (Velaitis, 2007), and in library workshops and programs

(Fletcher, 2008; Tagge, 2009). One theme that can be clearly identified in the educational literature on WCR, and other WC software, is the array of technical challenges that students and facilitators encounter. Laubach and Little (2009) describe the complexity in dealing with these issues:

> *Many years of system design and implementation has convinced otherwise rational observers that electronic systems are breeding grounds for gremlins – unexplainable equipment and program failures. A system as complex as Wimba requires the cooperation of many subsystems: the hardware and software of the instructor computer, the university network, the Internet, the Wimba servers, the student's Internet provider, and the student computer. (p. 60)*

Because there are many subsystems at play, it can be difficult to determine the source of unanticipated program failures. Additionally, as there may be no way for a facilitator to determine if and when participants encounter such failures, some degree of responsibility is placed on participants to resolve their own technical issues and/or seek assistance when necessary.

Another theme that can be found in the literature on WC in learning software is the characterization of interactions that students have with other students and with their instructors. These interaction patterns have been used to identify teaching strategies that promote learning in online synchronous learning environments (Bower & Hedburg, 2009; Martin et al., 2012). For example, Martin et al. conducted a study on the interaction patterns within a synchronous virtual classroom by surveying graduate students and interviewing an instructor in an instructional technology program in the southeastern United States. The strategies recommended by the participants in their study and their archive analysis led to a set of "implications for those who are considering teaching synchronously using the virtual classroom or adding synchronous components to asynchronous courses," (p. 227) listed in their paper.

The Distance Calculus Program

Morley et al. (2009) provides a detailed description of the organization of this program, but the salient aspects of the DCP that are relevant to this study are described in this section.

The DCP consists of two semester-long courses; the first focuses on infinite series and introductory linear algebra, and the second focuses on multivariable calculus. From Monday to Friday, 8:05 am to 8:55 am, high school (HS) students enrolled in the DCP gather in classrooms in their respective schools for live, synchronous lectures and recitations mediated through VC equipment. On Tuesday and Thursday mornings, students are subdivided into recitation sections where TAs solve problems and answer questions that students may have.

Courses in the DCP are taught simultaneously to undergraduate and HS students. The HS students either complete proctored tests and final exams on campus with the on-campus students, or they write them at their schools whereupon a school staff member will proctor and mail or fax the completed tests to the instructor and TAs to be graded. Quizzes are 50 minutes long and are held during recitations. In the 2012-13 academic year, four quizzes were administered in the fall semester, and another four quizzes were administered in the spring semester.

Both local and distance students can use their VC equipment to pose questions to the instructor and TAs, and all students can see and hear the answers. When a student at a remote site wants to address the TA or instructor, he or she may press a particular button on the VC equipment, at which point the student is shown on large screens in the lecture hall and can converse with the TA or instructor. There is no way for students at different HS to work in groups with each other during recitations and lectures using the VC equipment.

Lectures are also offered via a live webcast. Students in the pilot section, who did not have access to VC equipment, were expected to view lectures in this way. Those students viewing the lectures through the webcast can pose questions to their instructor through an instant messaging system. Finally, all lectures and recitations are archived using Tegrity software.

Data Collection

We used a variety of data collection methods to explore our research questions. To gather data on student perspectives we held a set of roughly ten-minute group interviews (Table 1) during the last three recitations (R28, R29, R30) of the Spring 2013 semester. To protect student identities, the names of each student and their schools were replaced with a two-letter code. The first letter represents the school they were attending. For example, there were six students from school A and Af is a student from that school.

Table 1

Students who were logged into Wimba during three group interviews held in the last recitations of the Spring 2013 semester.

	School A						School B			School C			School D		School E	School F
Recitation	Aa	Ab	Ac	Ad	Ae	Af	Ba	Bb	Bc	Ca	Cb	Cc	Da	Db	Ea	Fa
R28	✓		✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
R29	✓					✓		✓	✓	✓	✓		✓	✓	✓	
R30										✓						✓

To explore how students interact with the WC software, we analyzed WCR's log-in (LI) report. Every time a student enters or leaves the WCR environment, his or her name and the time/date is archived in a database that can be downloaded as a CSV file. The LI data does not provide information on how engaged students were during recitations or whether students attended the recitations. We analyzed the LI data to see if the patterns in it could help us characterize when students might have experienced technical issues.

Other sources of data included a video archive that captured the recitations using Tegrity software. WCR also has an archiving feature that will record the audio/video of each session, but Tegrity was used in the experimental section to ensure consistency across all sections. The TA also recorded his recitation experiences in a journal, including some of the technical issues that were encountered by students during recitations, which helped provide further data that could be used to prepare this report.

Recitation Structure

The sixteen students who participated in the pilot were those students who could not have otherwise participated in the DCP because the VC equipment could not be made available at their schools. The same sixteen students completed the two DCP courses from August 2012 to the end of April 2013. Over this nine-month period, one TA facilitated 60 recitations for these students using WCR.

It can be difficult to write mathematical expressions on a white board without a graphics tablet (Carrington et al., 2010). Therefore, the TA and all students in the pilot were lent $65 "Wacom Bamboo Splash" tablets for the entire duration of the DCP so that students and the TA could more easily write on the board. An earlier report describes how students in face-to-face learning environments found these tablets hard to use at first but managed to get used to writing with them over time (Hrepic, 2011).

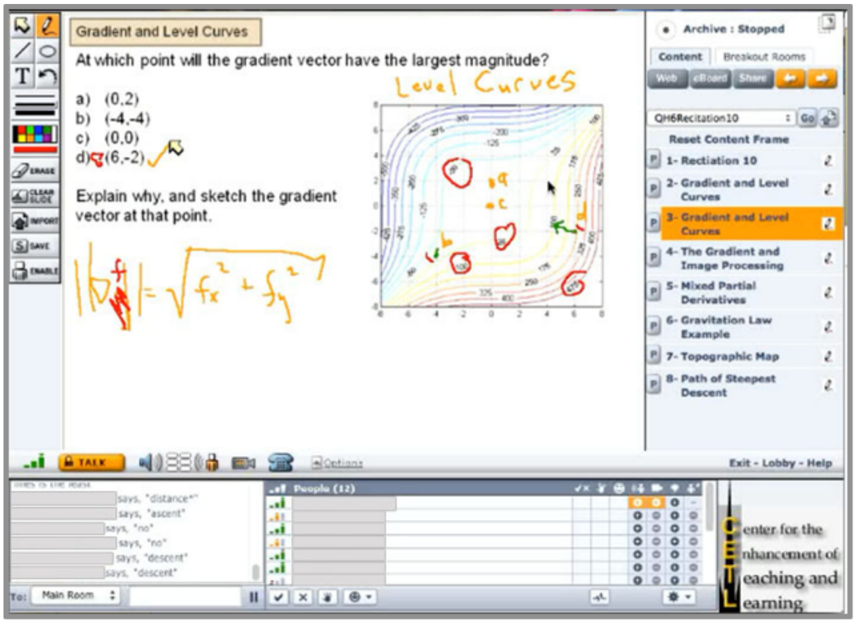
To help ensure that students were prepared for the recitations, the TA contacted all of the students in the pilot in August via email to (1) encourage them to install necessary software for the tablet and WCR, (2) suggest they log into WCR before the first recitation to ensure that they could do so, and (3) give each student an opportunity to meet the TA in WCR to ensure that they could log into the software and knew how to communicate with the TA. The TA met seven of the sixteen students in Wimba before the first recitation for these reasons. Additional time was spent in the first recitation on how to use and communicate with WCR, and in later recitations as issues arose.

The WCR Environment

Figure 1 shows a screen capture of the Wimba Classroom environment during Recitation 10 of the Spring 2013 semester (personal identifiers have been redacted with grey boxes). A set of PowerPoint slides was made in advance of each recitation that contained problems that were explored. The particular slide shown in Figure 1 incorporates a multiple-choice question from Schlatter's ConcepTests (2002), which students answered anonymously by writing on the board. Students annotated the diagram and corrected mistakes that the TA made, which then provided a basis for further questions the TA could ask. As shown in the figure, some of the questions related to this problem that the TA asked were answered with the text chat.

WCR has a polling feature that has been found useful in a similar context (Fletcher, 2008). This feature was avoided because the mathematical notation that could be incorporated into these polls was limited to those contained in the set of Unicode characters, and also because images cannot be displayed on the same slide that contain polls. As such, multiple-choice questions, rarely used, were prepared on PowerPoint slides so that students could indicate their answers by typing them in the text chat window or indicating their answers by writing on the white board.

Figure 1: A "screen shot" of a recorded recitation demonstrating the layout and features of the Wimba Classroom environment.



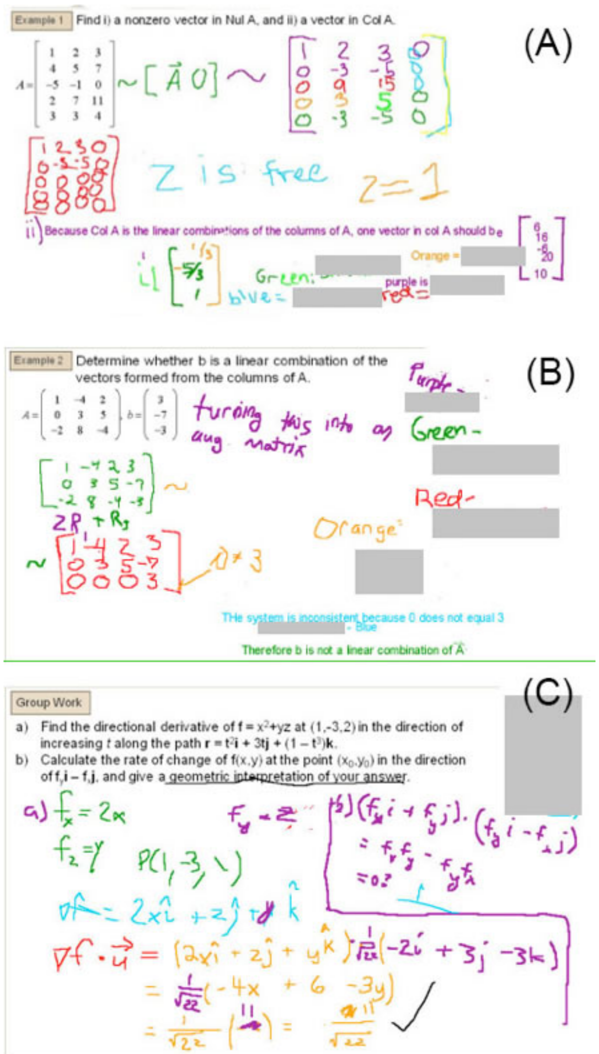
Not shown in Figure 1 is the video feed of the TA. Students received a video and audio feed of the TA, but the TA did not have a video feed of the students. Students who had a microphone could use it to speak to the other participants in the recitations.

WCR breakout rooms were used to facilitate group work in 26 of the 60 recitations. During group work, students in a recitation session moved out of a "main" room and into "breakout" rooms where students worked in groups of four or five to solve a set of problems on a shared whiteboard. While students were working in groups, the TA moved between breakout rooms to interact with students. There is no mechanism in WCR to identify who writes what, so students were encouraged, but not required, to write in different colors and to write their initials on the board in their color.

Student-Student Interaction Patterns

Schools C and D were located geographically close to each other, so the five students from those two schools always met in the same physical location during recitations. These students also often worked together in the same group, and because they were in the same physical room they were able to discuss their solutions without using WCR. Samples of their group work are shown in Figure 2.

Figure 2: Samples of group work from (A) Recitation 17 of Fall 2012, (B) Recitation 11 from Spring 2013, and (C) Recitation 12 from Fall 2012. Students in consisted of the five students from schools C and D. Blue = Ca, Green = Cb, Orange = Cc, Purple = Da, Red = Db.



In comparison to other groups, the TA observed that students from schools C and D would often take more time before they started writing on the board, but when they started writing, each student would write on the board at the same time in a way so that each color would be represented on the white board. Their solutions tended to include fewer errors than the other groups. During Recitation 30, all students were asked:

> *During group work other students are writing on the board. How did you decide what to write?*

Student Ca responded in the text chat:

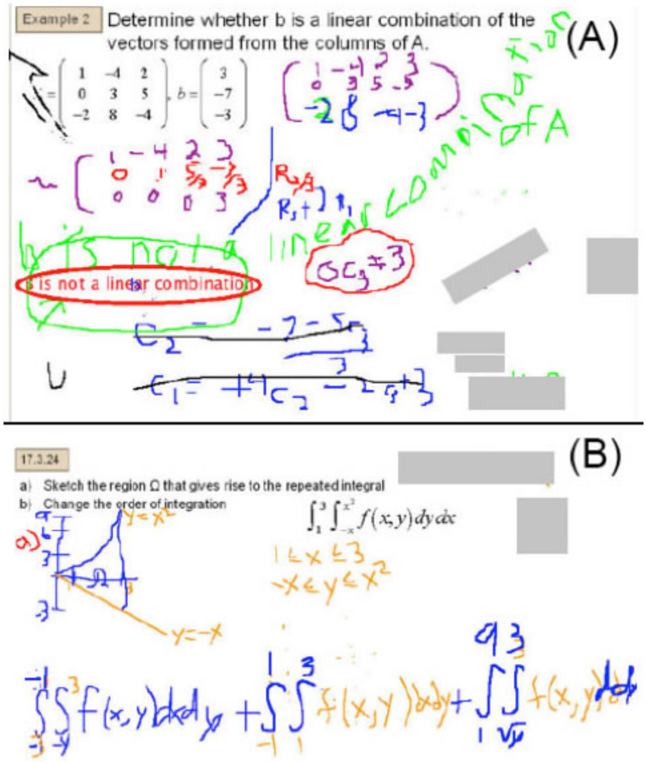
> *Ca: "I thought it was helpful to be able to discuss the problems face to face because we were able to figure them out together and then determine what each person would write"*

The description that Ca provided is consistent with the solutions presented in Figure 2. Another pattern that was observed was described in Recitation 30 by student Fa, in response to the same question was:

> *Fa: "I worked the problem the night before usually. i would either start the problem off or skip to the next line of it and help whoever was writing it put it on the board"*

The description that Fa provided is consistent with the solutions in Figure 3, which provides examples where this student helped complete problems and fix errors in the work of other students. Figure 3A points to other interaction patterns. Students Ba, Bc, and Af may have contributed to the solution of the given problem, but there is no way, based only on the white board writing, to determine the extent to which they did.

Figure 3: Student solutions to group work problems from (A) Recitation 12 of the fall semester, and (B) Recitation 21 from the spring semester. Student Fa wrote in green in (A) and blue in (B).



Student-Technology Interaction Patterns During Group Work

A set of questions were asked during the interview to explore how students interacted with the WCR software. In Recitation 28, students were asked:

> *What are some of the things you had to do this semester in order to resolve technical issues?*

Responses written on the white board were "logging back into wimba a lot," "restart wimba," and "restarting computer," and "being moved to the lobby." Students also responded to this question in the text chat:

> *Af: Java*
> *Bb: could write at random times*
> *Bb: couldn't*
> *Ca: java*
> *Ea: java*

The TA then asked "Was moving into breakout rooms a problem for some of you?" Responses were provided in the text chat

> *Ea "sometimes"*
> *Ba "not today but before yes"*

During R29, the TA asked:

> *What factors made it difficult to work in groups in Wimba?*

Only two responses were provided: on the whiteboard a student wrote "Java" and "getting into breakout rooms."

An online survey conducted in February 2013 asked students what technical problems they encountered. The survey was opened after recitation 14 and closed before recitation 15. Eight students completed the survey, so we cannot draw conclusions about the experiences of all 16 students, but we can describe the experiences of some of the students in the pilot and use the data to confirm the conclusions that came out of the group discussion.

Table 2

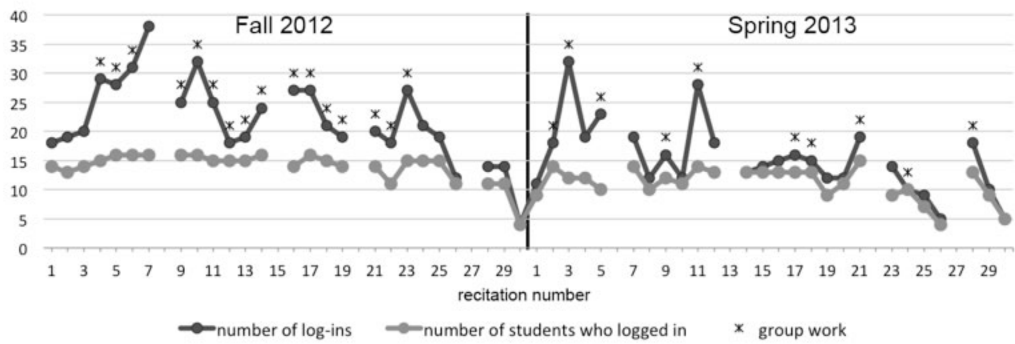
Responses to "Please indicate which of the following technical problems you have encountered during recitations since the beginning of January."

Number of Responses	Technical Problem
8	difficulty logging into Wimba
6	slow Internet
4	difficulty moving in or out of a breakout room within Wimba
3	difficulty writing on the white board
3	difficulty seeing the teaching assistant
2	issues related to computer's operating system
1	difficulty hearing the teaching assistant clearly
1	issues related to the Wacom Tablet you use or share
1	issues related to your computer hardware
0	difficulty using Wimba text chat

Table 2 gives us a sense that students experienced issues related to communicating with other participants and with moving in and out of breakout rooms. Some of these issues could be related to their Internet connections, computer hardware, or operating system problems. Although students described how they resolved technical issues by logging in/out of Wimba or restarting their computer, the group discussion and online survey did not give a sense of how often students needed to leave the Wimba environment. However, the extent to which students logged in and out of Wimba can be characterized using the LI report that Wimba generates.

The log report was processed to isolate the LIs from students in the pilot that occurred at any time between 6:00 am and 9:00 am on mornings that recitations were held. Figure 4 below displays the number of students who logged in during recitations and the number of times that a LI was made for each recitation. Because some students logged-in multiple times during recitations, the number of log-ins was equal to or greater than the number of students who logged-in for every recitation. Gaps correspond to recitations when quizzes were held: quizzes took up the entire recitation, and nine of the sixteen students did not have access to a computer during the quizzes. Also shown are recitations that incorporated group work, which are marked with a star.

Figure 4: Number of LIs and number of students who logged in during every recitation.



There are a number of reasons why a student may log-in multiple times during a recitation. For example, Wimba Classroom requires a Java plug-in to be installed on the host computer. A day prior to Recitation 3 in the Spring 2013 semester, a Java update had been released. This particular Java update was mandatory, and there was no message in WCR telling students that they needed to update their version of Java. Students who were using a device that did not have the update could log into WCR, but the software would not function properly, causing some confusion throughout that recitation.

Grade Data

All quizzes were graded by the instructor and the TA. Final exams were graded by the instructor and a pool of TAs. Grade weightings for both semesters are shown in Table 3.

Table 3

Grade weightings for students in the pilot and for the other students in the DCP.

	Students in the WC Section	Students not in the WC Section
Homework	10%	10%
Final exams	25%	25%
Quizzes	60%	65%
Group work in recitations	5%	NA

Despite the unanticipated technical issues encountered throughout the term, the 16 students in the experimental section received grades that were similar to the final grades obtained by the students in the VC sections (Table 4). Grades were not used to evaluate the delivery format of the VC sections. Comparisons of final grades between the two groups are complicated because the two groups had different TAs, the recitation curriculum was not identical, and grade weightings and the technologies that were used in these sections were different. Additionally, the VC final grades from the Fall 2012 and Spring 2013 were not normally distributed (Shapiro-Wilk test for normality, p values less than 2.2 × 10-16 and equal to 8.5 × 10-10, respectively, calculated using R). Data in Table 4 are only presented to demonstrate that, on average, students in the WC section did not receive lower grades than their peers in the VC sections.

Table 4

Shown are the number of students (N) and the mean final grades and standard deviations (SD) among the students who completed the DCP in the Fall and Spring 2012-13 semesters. Grades and SDs are expressed as percentages.

	Fall 2012			Spring 2013		
Format	N	Mean	SD	N	Mean	SD
Web Conferencing (WC)	16	96.5	5.3	16	90.3	11.4
Video Conferencing (VC)	296	96.2	4.2	290	87.4	8.6

Discussion

One goal of this study was to characterize interaction patterns in an alternate delivery model of the Distance Calculus Program recitations that relied on WC software. To this end, our study focused on exploring how students interact with other participants and how students interact with the technologies they use during their recitations.

Student – Student Interaction Patterns

The interview data contains descriptions of the strategies that students used while collaborating with their peers in WC. The five students who connected to recitations from the same physical location decided to use WCR as a means of presenting results that were established outside of the software in a face-to-face setting. Their use of the WC software shifted the format of the recitations away from a fully online to a more "blended" learning environment that incorporates some face-to-face interactions. In contrast, student Fa, who was geographically isolated from all other students in this study, needed to interact with the WC software and his peers to both solve and present solutions to others. These interaction patterns are more similar to those observed in other fully online synchronous online learning environments, such as those labeled under the "knowledge construction" dimension (Hou 2011, p. 1462), or those labeled under the "on-task" dimension (Orvis, Wisher, Bonk, & Olson, 2002, p. 789).

Student – Technology Interaction Patterns

Although students were trained on how to use the WC software at the beginning of the program, discussions of technical challenges were threaded into the discussion of many recitations throughout the year. Other reports on synchronous online learning environments have found that technical issues are incorporated into discussions throughout the duration of courses (Hou 2011; Laubach, & Little 2009; Orvis, et al., 2002). One resource that some web-conferencing software offers that may help online teachers and teaching assistants identify and troubleshoot technical issues is the log report that some web-conferencing software offers. Log reports do not indicate why a student logs in or out during a session, but it can identify students that might be struggling with their system and need additional technical support; if a student has needed to log in and out multiple times during a single recitation, that student may benefit from additional support from an instructor or TA to provide a reminder that they may benefit from updating their Java, trying using a different web browser, or to explore whether connecting over a wired connection is possible.

Implications

Comparing final grades obtained by students in the WC section versus those obtained by students who utilized VC during their recitations, we have no evidence that students in the WC format were unable to succeed in the DCP. Moreover, we were able to identify challenges unique to possible future implementations of a WC recitation format. For example, students in schools C and D, located within close geographical proximity to each other, always connected to recitations in the same physical room. These students preferred to work together during group work activities so that they could communicate without the WC software. However, when these students worked on their group work activities offline, the TA had no opportunity to provide support for their learning during these activities.

Secondly, technical issues encountered by the TA and students presented further implications to the DCP. Students who connect to recitations via VC are not expected to address technical issues they encounter: they have facilitators and university staff who are responsible for resolving them. In the WC format used in this pilot, the TA required additional time to instruct students on how to use the software in ways that were not possible in the VC technologies (such as how to communicate with other students and move in and out of breakout rooms) and to address unanticipated technical issues. Moving forward, if the DCP adopts a particular recitation model that utilizes WC software, it may be that the TAs responsible for facilitating these sections would need to be allotted additional time to address these issues.

Conclusions

Our study was limited by its small sample size, the fact that only the format of the lectures was not studied, and because Wimba Classroom will soon no longer be supported. However, we were able to identify a number of strengths, challenges and opportunities that future implementations of this format that could be considered. The use of web-conferencing software allowed students who were attending schools unable to afford the VC equipment to participate in the DCP. Moreover, average final grades obtained by students in the WC format were not lower than those found in other sections, and students in our study demonstrated that they were able to collaborate in ways that were not possible with the traditional format that utilizes video-conferencing technology. We were able to identify particular challenges that characterize this alternate delivery model, namely the inability for the TA to monitor and engage in the face-to-face student-student interactions that occur between students connecting from the same physical location, and that students and teaching assistants are responsible for addressing additional technical issues that students and TAs in the traditional VC format did not have to field. The Wimba log-report was identified as a tool that can be used to troubleshoot technical issues that arise during recitations, and although WCR will no longer be supported soon, other web-conferencing tools, such as Adobe Connect, support this feature. Ultimately, we hope that describing the experiences that the 16 students in the pilot section will help guide the delivery of future offers of other similar online program initiatives.

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