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Active Collaborative Learning Through Remote Tutoring: A Case Study With Students Who Are Deaf or Hard of Hearing

Austin U. Gehret[1], Lisa B. Elliot[2], and Jonathan H. C. MacDonald[3]

Abstract
An exploratory case study approach was used to describe remote tutoring in biochemistry and general chemistry with students who are deaf or hard of hearing (D/HH). Data collected for analysis were based on the observations of the participant tutor. The research questions guiding this study included (1) How is active learning accomplished in synchronous, remote tutoring for chemistry and biochemistry with students who are D/HH? and (2) Why might active learning be important to include in synchronous, remote tutoring for this student population? Findings included that (a) students approached remote tutoring with the same questions and materials they brought to in-person tutoring and (b) the degree to which tutoring materials could be imbedded into a remote session influenced the session's efficiency and the ability of students to actively participate in remote tutoring.

Keywords
remote tutoring, deaf, hard of hearing, Google Hangouts, chemistry, biochemistry

Higher education is increasingly leveraging technology to provide greater access to learning (Halverson & Collins, 2009), and this has been most visible through the rise in adoption of massive open online courses (MOOC; Daradoumis, Bassi, Xhafa, & Caballe, 2013). Though widespread, MOOCs focus more on universal distribution of information and less on the educational needs of the individual (Daradoumis et al., 2013). In contrast, in-person tutoring is an academic staple designed to assist in the individual needs of the learner and has a proven record of positively impacting academic performance (Cohen, Kulik, & Kulik, 1982), particularly with experienced tutors (Herppich, Wittwer, Nückles, & Renkl, 2014). It comes as little surprise that online tutoring platforms have started to emerge (Young, 2016) that combine traditional tutoring with current technologies.

Online Tutoring Research

Many current online tutoring services are entrepreneurial (Young, 2016). As such, research in this area tends to focus on user perceptions (Whetstone, Clark, & Flake, 2014) or student achievement with various platforms (Clark & Whetstone, 2014; Vasquez & Slocum, 2012). These tutoring enterprises address many academic disciplines and are used around the world. For example, a U.K. distance-learning institution offered online tutoring to supplement learning in the humanities. When students were surveyed, researchers found no difference in student perceptions of course quality (Richardson, 2009). Elluminate, a web-based software package piloted in the United Kingdom to provide synchronous, online tutoring with higher level mathematics was evaluated by students as easy to use and supportive of group problem-solving (Lissaman, Pomerai, & Tripconey, 2009). Engineering and computer science students working in remote laboratories in Hanover, Germany, received synchronous, remote mentoring without a significant impact on student motivation or task success (Bohne, Faltin, & Wagner, 2004). Remote tutoring has even been leveraged in test preparation. Middle school teachers in the Worcester Massachusetts School District used the online intelligent tutoring system ASSISTment to assess student progress toward state examination standards (Anozie & Junker, 2007). What these studies did not offer was any examination of the features that made the tutoring successful or dynamic for the stakeholders. Furthermore, none of these studies detailed any special features the platforms may have had for students with particular learning or communication needs, such as students who are deaf or hard of hearing (D/HH).

[1] Department of Science and Mathematics, National Technical Institute for the Deaf, Rochester Institute of Technology, Rochester, NY, USA
[2] Office of the Associate Dean of Research, National Technical Institute for the Deaf, Rochester Institute of Technology, Rochester, NY, USA
[3] British Columbia Provincial School for the Deaf, Burnaby, British Columbia, Canada

Corresponding Author:
Austin U. Gehret, Department of Science and Mathematics, National Technical Institute for the Deaf, 52 Lomb Memorial Dr., Rochester, NY 14623, USA.
Email: augnts@rit.edu

Online Tutoring for Students Who Are D/HH

Bryant (2011) conducted a pilot study with students who are D/HH to measure the efficacy of web-conferencing systems Adobe® Connect Pro 7™ and IdeaTools™ Video Hangouts chat to provide remote tutoring in English. While both systems had persistent technical issues related to video quality, each system included multiple channels that circumvented communication breakdown. This highlights the value of using an online tutoring platform with flexible communication modalities when remote tutoring this student population. Furthermore, several students who had never taken advantage of in-person tutoring elected to participate in remote tutoring (Bryant, 2011). This finding underscores the tendency of this student population to embrace web-based technologies. Contributing factors to this phenomenon may include the ability of these technologies to enhance both access to academic content (Lang & Steely, 2003) and to the quality of social interactions (Blom, Marschark, Vervloed, & Knoors, 2014). Thus, limited research with this student population suggests students who are D/HH can benefit from various forms of online learning.

Science, Technology, Engineering, and Mathematics Online Tutoring for Students Who Are D/HH

A fundamental problem for students who are D/HH is that at the postsecondary level, a "participation gap" in STEM has existed for years (Jenkins, 2009; Komesaroff, 2005). STEM careers remain a high priority in the United States (U.S. Department of Education, n.d.), and workers who are D/HH typically earn 31% more than those employed in other occupations (Walter, 2010). However, these jobs require an appropriate STEM education which is a persistent challenge for students who are D/HH. Contributing barriers include (a) a lack of support for STEM education at the elementary, middle, or high school level; (b) an overemphasis on literacy and language skills in early education; (c) a lack of exposure to STEM careers; (d) a lack of access services for STEM internships, classroom interpreters, and captioning specialists familiar with STEM vocabulary; and (e) a lack of a peer network for socialization and mentoring (Foster, 2009; Walter, 2009). In STEM fields, approximately 23% of all college students who are D/HH graduated with bachelor's degrees and between 1997 and 2006, and the pipeline shrank considerably at the graduate level: Only about 0.2% of new STEM PhDs were D/HH (Hoffer, Hess, Welch, & Williams, 2007).

Elliot et al. (2013) described efforts to provide synchronous, remote tutoring in STEM to students who are D/HH. They found that the anticipated technical challenges of remote tutoring could be mitigated if using wired Internet connections (no Wi-Fi) and good lighting conditions. Students and tutors alike reflected favorably on the ease of scheduling that remote tutoring provided, but an analysis of the specific tutoring exchanges that took place was not explored.

Active Learning

A description of synchronous, remote tutoring exchanges with students who are D/HH should be tempered by the fact that beneficial practices may not be readily transferrable due in no small part to the range of educational and communication backgrounds that exist for this student population. Students mainstreamed with hearing peers at the secondary-level experience a variety of facilitating or detracting factors to their academic success (Reed, Antia, & Kreimeyer, 2008). Even at residential institutions, teachers specializing in deaf education are challenged to satisfy an extensive list of knowledge and skills standards put forth in their initial preparation programs (Easterbrooks, 2008). Combined with these academic factors, the communication preferences and needs of this student population (Stinson, Liu, Saur, & Long, 1996) further complicate predictions of postsecondary academic success (Convertino, Marschark, Sapere, Sarchet, & Zupan, 2009).

An analysis of synchronous, remote tutoring exchanges with this student population might instead be well served through the lens of active learning. The heightened focus on assessment has pressured educators to become more innovative in how they teach with a de-emphasis on traditional lecture and increased emphasis on active learning (Miller, 2014). Synchronous online environments invite active learning and should be viewed more as learning laboratories than lecture halls (Finkelstein, 2006). The technology and diverse tools available within an online learning environment align more closely with a "learning by doing" view of education (Halverson & Collins, 2009). Several studies incorporating social media as a component of online learning invoke constructivist learning theories and the significance of students' active involvement in those environments to describe the learning process (Wankel & Blessinger, 2012). Students who are D/HH, like their peers who are hearing, reflect more favorably upon in-person tutoring experiences that are interactive and collaborative (Lang, Biser, Mousley, Orlando, & Porter, 2004; Orlando, Gramly, & Hoke, 1997).

Purpose of This Study

This study describes synchronous, remote STEM tutoring in biochemistry and general chemistry with students who are D/HH. While student comprehension improves in these disciplines when active learning experiences are incorporated (Dougherty et al., 1995; Minderhout & Loertscher, 2007), the guidance of a tutor should remain a critical component to active learning as knowledge acquisition can suffer in its absence (Kirschner, Sweller, & Clark, 2006). Thus, the research questions guiding this study as follows:

> **Research Question 1:** How is active learning accomplished in synchronous, remote tutoring for chemistry and biochemistry with students who are D/HH?
>
> **Research Question 2:** Why might active learning be important to include in synchronous, remote tutoring for this student population?

Table 1. Demographics of Student Participants.

Student	Program of Study	Course Supported	Term/Academic Year	College Experience (Terms)	Number of Sessions	Preferred Communication Style
A	Biochemistry	Biochemistry: Nucleic Acids	Spring[a] (2011–2012)	14	5	American sign language
B	Biology	Biochemistry: Conformation and dynamics	Fall[a] (2012–2013)	9	4	Simultaneous communication
		Biochemistry: Metabolism	Winter[a] (2012–2013)	10	2	
C	Chemical engineering	General and analytical chemistry III	Spring[a] (2012–2013)	2	1	American sign language
D	Laboratory science technology	General and analytical chemistry III	Spring[a] (2012–2013)	8	2	Oral communication
E	Biomedical sciences	General and analytical chemistry III	Spring[a] (2012–2013)	2	2	Simultaneous communication
F	Laboratory science technology	General and analytical chemistry I	Fall[b] (2013–2014)	9	3	Simultaneous communication
G	Biotechnology	General and analytical chemistry II	Spring[b] (2013–2014)	6	4	Oral communication

[a]Term occurred under an academic quarter calendar. [b]Term occurred under an academic semester calendar.

Method

Participants

All tutoring provided in this study supported chemistry or biochemistry courses taught by faculty who are hearing and who do not know sign language. Participants in this study were enrolled in these chemistry or biochemistry classes over the course of six academic terms spanning a little more than 2 years (see Table 1). The tutor's primary responsibility was to support all students who are D/HH enrolled in these courses (approximately 180 students) over this same time frame.

Students. Seven female students enrolled in baccalaureate biochemistry and chemistry courses participated in this study. One student participated twice for two different courses during two different academic marking periods (see Table 1). Students were eligible to participate in the study if they were D/HH and enrolled in an STEM major. Students were not required to have a specific means of preferred communication (see Table 1).

Tutor. The faculty member was hearing, formally trained in biochemistry, fluent in sign language, and experienced in conducting in-person tutoring with students who are D/HH. The tutor was knowledgeable with the content reviewed in remote sessions and communicated in all sessions using simultaneous communication (signing and speech at the same time). The faculty member was recruited by project staff to participate in the project with the support of the department chair and had no prior experience with remote tutoring.

Settings

The tutor conducted all remote-tutoring sessions from his campus office. Students participated in remote tutoring sessions from a variety of locations including nearby offices, student lounges and public areas across campus, and on- or off-campus housing. Most tutoring sessions occurred in the evening or during working hours as student schedules allowed. All remote tutoring sessions were conducted on a one-to-one faculty-to-student ratio and typically occurred middle to late in the academic term.

Procedure and Materials

The Google Hangouts (Google, 2016d) platform was chosen, in part, for its potential to accommodate diverse communication modalities through a range of synchronous functions including video, audio, and text-based discussions that are each common to many synchronous support platforms (Kear, Chetwynd, Williams, & Donelan, 2012; MacDonald, 2006; Tsuei, 2014). Remote sessions were all appointment based and scheduled through e-mail or using Google Calendar (Google, 2016a). The faculty member conducted all sessions using an iMac with built-in iSight camera, a wired Internet connection, and the Google Chrome web browser (Google, 2016b). Students used a variety of personal laptops (PC and Mac), Chromebooks, and either wired or wireless Internet connections and remote sessions ranged in length from 30 to 90 min. The faculty member used either a personal office whiteboard with the aid of the iSight camera or the online whiteboard application, Conceptboard (2016). Features used within Google Hangouts included chatting, drawing, microphones, and screen sharing (Google, 2016d). Google Drive (Google, 2016c) was used for uploading and sharing documents between student and tutor.

Research Design

The case study methodology was selected for this study as it met the three criteria defined by Yin (2009): (a) The focus of the study is to answer "how" and "why" questions, (b) the behavior of the students was not manipulated by the tutor, and (c) because we wanted to explore the context of the online tutoring conditions in depth as a contemporary phenomenon. Additionally, the study was designed as an exploratory case study because the tutoring situations did not have a clear, single set of outcomes (Baxter & Jack, 2008).

Results

Without prior remote tutoring experience, the tutor intended to model remote sessions as much as possible to in-person tutoring. To that end, if a remote session was able to flow with comparable pace of instruction to in-person tutoring, it was categorized as "efficient." Students approached remote tutoring as they would in-person tutoring by electing to focus each session around specific course assessments (homework assignments, journal articles, class problems). The ability of the Google Hangouts platform to allow collaboration on those assessments between tutor and student resulted in synchronous, remote tutoring with either "integrated" or "peripheral" materials.

Remote Tutoring With Integrated Materials

Previous work with students who are D/HH indicated that engagement within a remote tutoring platform, often achieved by active learning exercises such as homework, was critical for success with remote tutoring (Baker, 2010; Bryant, 2011). In this study, particular features of the web-conferencing platform did allow for active student participation. Each feature had the ability to "integrate" materials into the session, so that they were accessible to both parties. Integrated materials included document sharing, online homework programs, and online whiteboard applications.

Document sharing. A key feature of the remote tutoring platform was its ability to imbed files uploaded online (Google, 2016c) to remote sessions. Student A sought remote tutoring for an independent study in biochemistry focused on the structure and function of nucleic acids (DNA, RNA). The course instructor permitted the student and tutor to collaborate on take-home exams based on research articles related to the discovery of catalytic RNA (Cech, 1990), the identification of DNA as genetic material (Avery, Macleod, & McCarty, 1944), and RNA interference (Fire et al., 1998). Exam questions focused on empirical evidence authors used to formulate their conclusions; as such, the student was tasked with scouring through mounds of biochemistry jargon to identify key findings. By uploading the articles ahead of time, the tutor could share the articles with the student during the session allowing both parties to perform simultaneous key word searches. By virtue of this collaboration, reviewing journal articles proceeded with greater efficiency in synchronous, remote tutoring compared to in-person tutoring. Furthermore, as document sharing made the articles accessible to both parties, the student was placed in an active role for these sessions.

Online homework programs. In-person tutoring for general chemistry with students who are D/HH was heavily focused around online homework. Students D, E, and G all received remote tutoring for the online homework program MasteringChemistry™ (Pearson, 2016) in support of general chemistry courses (see Table 1). The topic of interest discussed in these sessions related to drawing organic molecules; Student G additionally requested session time to practice calculations on aqueous equilibria and thermodynamics. The online homework platform in this study was very sensitive to subtle drawing and calculation mistakes. Students who are D/HH would often overlook these subtle errors and become frustrated with the homework program. An application in the web-conferencing platform allowed the students to screen share their homework progress to the tutor in real time. When this function was enabled, the student's homework progress was displayed to the tutor in place of their video feed (see Figure 1). At the same time, the tutor's video feed was still visible to the student. Because each student used voice with or without signing (see Table 1), communication with the hearing tutor could be maintained under these circumstances. By directly observing the students' work in real time, the tutor intervened immediately when observing a drawing or calculation mistake. This real-time feedback is near impossible to replicate in-person because the tutor observes the student and their work asynchronously. As a result, these remote sessions were noticeably more efficient. Additionally, the students maintained an active role in these sessions because they were manipulating the homework module in the tutor's "presence" while receiving synchronous, remote tutoring.

Figure 1. An "integrated" remote tutoring session focused on general chemistry homework. The student could display their progress to the tutor by screen sharing the online homework webpage. The tutor was visible to the student the entire session.

Student D was a commuter student who had off-campus work responsibilities that routinely prohibited her from attending in-person tutoring. However, the student was able to take advantage of remote tutoring from her off-campus residence. Because this student was off campus, she was dependent on a wireless Internet connection that provided poor visual resolution with the video channel. Yet, the screen-sharing function still permitted the tutor to efficiently collaborate with the student on her online homework. Despite the video quality, the student requested a second remote session for the following day to receive additional assistance.

Online whiteboard applications. The use of whiteboards has been shown to be an advantageous academic practice for students who are D/HH (Marchetti, Foster, Long, & Stinson, 2012). Visually articulating STEM concepts with this student population has also been shown to be beneficial (Stinson, Elliot, & Easton, 2014). To take advantage of these benefits, an online whiteboard was incorporated to some remote sessions using the Conceptboard© application (2016), a stylus, and an iPad (for both parties). Students F and G each received remote tutoring using an online whiteboard for general chemistry (see Table 1). Student F requested practice drawing Lewis chemical structures and Student G requested practice with acid/base equilibria problems. Both topics require a deliberate, stepwise approach to a solution that the tutor would normally illustrate using traditional whiteboards for in-person tutoring. The instructor guided the students through the steps to solve their respective problems, and then the students repeated the procedure using the online whiteboard with the tutor intervening as necessary. The online whiteboard successfully provided active participation for the student; however, the efficiency of these remote sessions was noticeably reduced. Decreased efficiency was a result of the online whiteboard having intermittent syncing issues with the stylus. Additionally, the application would occasionally crash. Based on these factors, the potential benefit for active learning that an integrated tool could provide was offset by the decrease in efficiency it also brought to the remote session.

Remote Tutoring With Peripheral Materials

In contrast to the active learning opportunities available to supplement learning in general chemistry, most of the biochemistry courses tutored in this study were lecture driven and without formative assessments between exams. Students A and B approached these sessions, as was common for in-person tutoring, with a need for explanation or clarification on a range of advanced concepts (e.g., DNA replication, thermodynamics of metabolic reactions, derivation of the Michaelis–Menten model of enzyme kinetics). The tutor approached communicating these concepts, as he would during in-person tutoring, by using note-taker lecture notes and a whiteboard as visual aids to support what was spoken and signed. However, the use of tools remained peripheral to the platform in that only the tutor had direct access to either.

Projecting printed lecture notes. Incorporating physical lecture notes to a remote session was far more cumbersome than for in-person tutoring. For in-person tutoring, the tutor would describe a topic first and then supplement that explanation by directing the student's attention to the lecture notes section on that topic. To replicate this practice in remote sessions, the tutor elected to display the printed notes to the student by projecting them in front of the computer's camera (see Figure 2). As time had to be allowed for proper positioning and focusing of the material in the camera's field, this practice became far more time consuming compared to in-person tutoring. In these situations with Students A and B, the remote tutoring platform was inefficient at mirroring the tutor's practices for reviewing biochemistry lecture notes. Furthermore, the video quality of the remote session was dependent on the Internet connection used by the students and often limited video feed resolution. Conversations focused on defining complex scientific language and concepts new to the student required optimal video resolution for the student to acquire this knowledge. To guard against student misinterpretation of signed information or projected materials, text-based discussions, a feature of the platform, were liberally employed to help with these technical terms (see Figure 2).

Office whiteboard. With Student A, the tutor made a single attempt to illustrate a biochemical concept, DNA replication, using a native drawing application in the platform. Though syncing issues were not prevalent, illustration using a desktop mouse was even more challenging than a stylus and consumed half of the remote session. For subsequent sessions, the tutor elected to illustrate biochemical concepts using his office whiteboard. In order to achieve this, the iSight camera was repositioned to ensure both he and the whiteboard were in the camera's field (see Figure 3). Though this camera arrangement provided the most efficient manner in which to illustrate biochemical concepts, the continual repositioning disrupted the flow of the sessions contributing to their overall inefficiency.

Student B participated in the most remote sessions of any student in the project (see Table 1), and each of her sessions were supplemented with the use of an office whiteboard and printed lecture notes. Thus, this student was passively, rather than actively, acquiring all of the content during these remote sessions. Despite gaining the most experience with the platform, the student elected not to continue with remote tutoring for biochemistry support. Student B's reliance on peripheral tools in her sessions made her heavily dependent on visually receiving most information rather than actively participating in her learning.

Discussion

The current study was focused at analyzing synchronous, remote tutoring with students who are D/HH. In an effort to describe the interactions taking place in these sessions, two research questions guided this study:

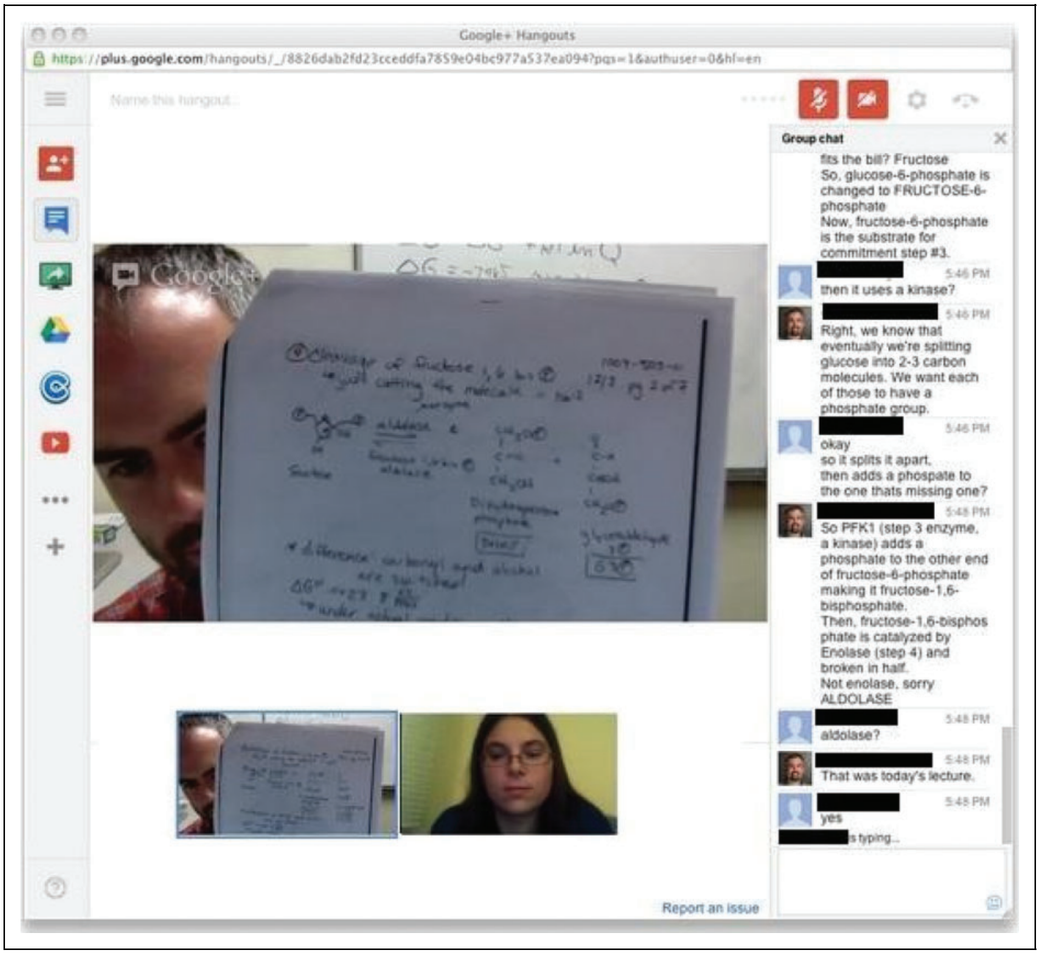

Figure 2. Visual aids incorporated into concept-driven biochemistry tutoring sessions in Google Hangouts. A copy of note-taker notes for students who are deaf/hard of hearing was used to aid in the explanation of glycolysis.

Research Question 1: How is active learning accomplished in synchronous, remote tutoring for chemistry and biochemistry with students who are D/HH?

Research Question 2: Why might active learning be important to include in synchronous, remote tutoring for this student population?

How Is Active Learning Accomplished?

Based on the experiences of the tutor in this study, students who are D/HH were more actively involved in the learning process when they were able to collaborate as part of the remote session. In this study, collaboration was achieved when educational materials were imbedded into a session and accessible to both the tutor and student. Students assumed an active, participatory role with their learning by completing some task (e.g., homework assignments, practice problems, exam questions, etc.) in addition to receiving instruction from the tutor. On the other hand, remote tutoring lacking opportunities for collaboration (e.g., projecting an office whiteboard or printed lecture notes) relegated the student to the role of passive observer.

Why Might Active Learning be Important to Include for This Student Population?

The favorable perception students who are D/HH retain for in-person tutoring with active learning (Lang et al., 2004; Orlando et al., 1997) likely extends to synchronous, remote tutoring because students approached both formats similarly. The efficiency of sessions and a student's dependence on visual communication might contribute specifically to their perceptions of remote tutoring.

Session efficiency. Because students who are D/HH approached synchronous, remote tutoring as they would in-person tutoring, they likely harbored the expectation the remote tutoring should proceed as efficiently as in-person tutoring. When the tutor made use of materials peripheral to the web-conferencing software (printed lecture notes, office whiteboards), the remote sessions were noticeably less efficient. Student B who participated in the most remote sessions (see Table 1) was also entirely reliant on peripheral tools for learning. It is possible that the peripheral materials reduced efficiency of these sessions to the detriment of effectively conveying information and

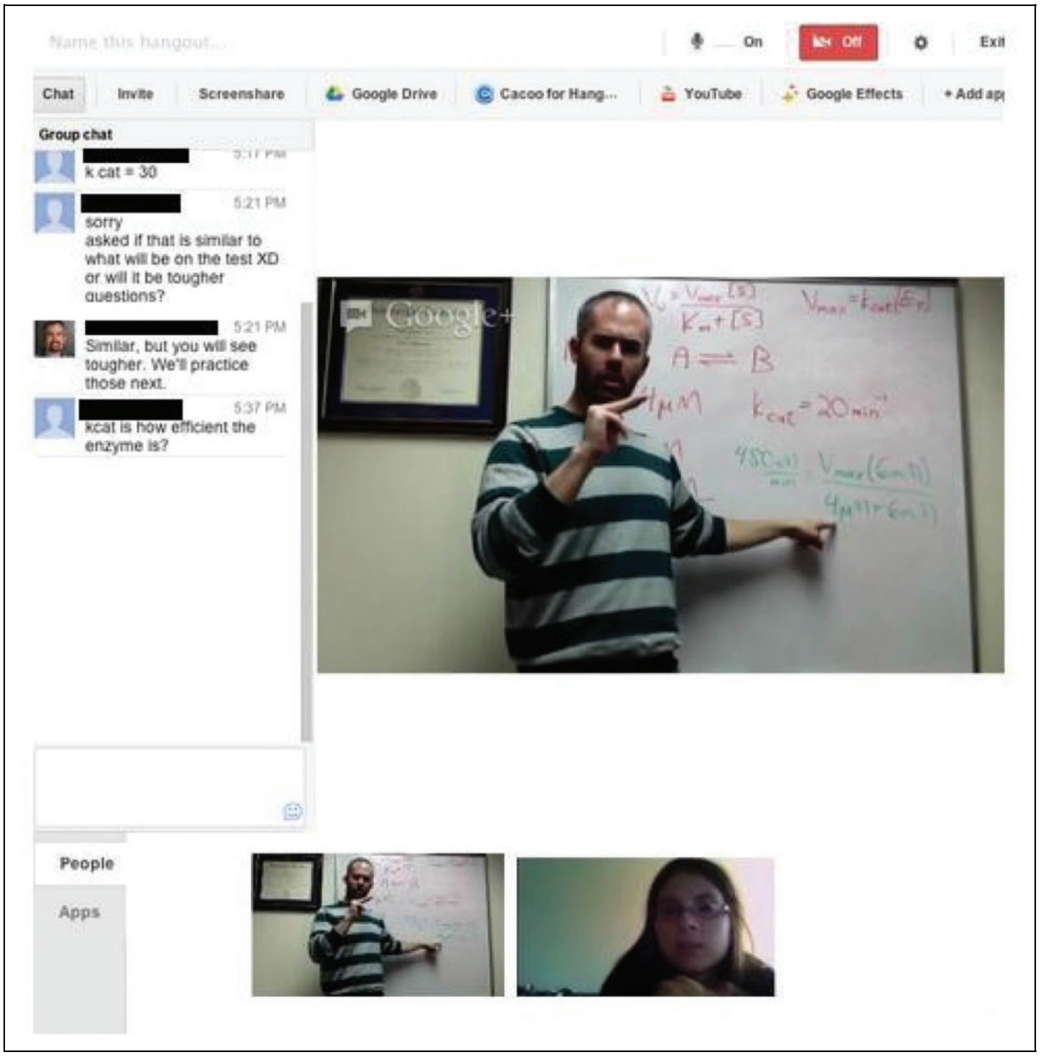

Figure 3. Office whiteboards were incorporated into Google Hangouts. The tutor made use of an office whiteboard for a remote tutoring biochemistry session to elaborate on the topic of enzyme kinetics. Signing was used in combination with the Hangouts chat feature to maintain seamless communication.

that this inefficiency contributed to the student's negative perception of remote tutoring.

On the other hand, remote tutoring with materials integrated with the platform (uploaded course documents, screen-shared online homework) allowed sessions to progress comparably or more efficiently than in-person tutoring. The case with Student D supported this observation. Despite poor video quality, collaboration with online homework was efficiently completed, and the student was eager to continue remote tutoring. The documented benefits of active learning in chemistry and biochemistry (Dougherty et al., 1995; Minderhout & Loertscher, 2007) appear to enhance the experience of remote tutoring for students who are D/HH too. The efficiency of remote tutoring with imbedded materials not only creates learning environments supportive of constructivist learning theories (Bonk & Cunningham, 1998; Lang et al., 2004) but also appears to enhance the "observability" (Rogers, 1995) of remote tutoring's effectiveness for students who are D/HH.

The tutor's choice of whiteboard also impacted the efficiency of synchronous, remote tutoring. Online whiteboards were tested in sessions with Students F and G during the third year of the study. As these whiteboards were integrated in the remote platform, they held potential for active learning opportunities. This potential was limited though by technical issues with the software and the tutor's ability to write efficiently with the stylus. The transition from a traditional to online whiteboard for illustration purposes has been shown to be nontrivial given the inherent loss in dexterity (O'Hanlon, 2007) and that clearly impacted these sessions too. At the same time, the alternative use of traditional whiteboards required the tutor to constantly reposition throughout a session. Thus, the efficiency traditional whiteboards provided the tutor were mitigated to an extent by the physical constraints of the remote session. In choosing how to implement whiteboards with synchronous, remote tutoring to students who are D/HH, efficiency should be an important consideration.

Student dependence on visual communication. Remote sessions lacking active learning components forced students to depend on the visual communication channel to acquire all knowledge. In sessions with active learning activities, students worked directly on course materials, were actively involved in developing knowledge, and were thus less dependent on visual communication with the tutor to acquire all information. Web-based distance education has already been shown to add distress to students when technical and communication issues arise (Hara, 2000). This issue is likely compounded with students who are D/HH as video speed can negatively impact sign language comprehension for different skill levels (Hooper, Miller, Rose, & Veletsianos, 2007). Thus, in addition to the fact that synchronous environments encourage active learning (Finkelstein, 2006), active learning in these environments might additionally provide a break from the demands of visually processing instruction for this student population, a practice common to mainstream classroom learning (Marschark et al., 2005).

Implications for Practice

In identifying a web-conferencing platform to provide remote tutoring to this student population, consideration should be given to the communication channels available within that platform. On occasions in this study when video quality became compromised, the platform could circumvent this issue with additional communication tools including built-in microphone features and text-based discussions. The ability of students to exercise choice in their means of communication is a strong draw to a remote tutoring program (Baker, 2010; Bryant, 2011) and students exercised those options throughout this study too.

Students also exercised choice in the materials they chose to utilize during remote tutoring including online homework, lecture notes, course worksheets, and research articles. A web-conferencing platform that has the resources for integrating these materials holds significant value but will likely be underutilized by a tutor inexperienced with the platform. Ostensibly, the tutor conducting a remote session is an expert in technology (McPherson & Nunes, 2004). However, the notion that any faculty member can serve as a remote tutor in their content area should be tempered by the fact that serving this role places them in a position outside of their comfort level (Bryant, 2011) and is best supported with prior training in the platform of choice (Doukakis et al., 2013). The faculty tutor in this study was able to leverage various tools to enhance student participation, and positively impact session efficiency, but only after gaining experience with the platform.

Finkelstein (2006) highlights five major functions served by synchronous online interactions: instruction, collaboration, support, socialization and informal exchange, and extended outreach. While extended outreach falls outside of formal instruction and therefore not applicable to this study, instruction was conducted both actively and passively through a variety of tools used by the tutor in all remote sessions. Socialization and informal exchange were ongoing in all sessions and through multiple modalities at the discretion of the student. Though these functions, as Finkelstein states, are the most challenging to quantify for their impact on learning, they would appear to be vital to any remote tutoring platform to help with the "transitioning" students need to undertake when asked to view a web-conferencing application as an education tool and not simply for social media purposes (Rubrico, 2012; Simoes & Gouveia, 2012; Truong & Zanzucchi, 2012). Support was an obvious function all students sought who took part in the study; however, the degree of support received appears to have correlated to some degree with the level of collaboration involved. As Finkelstein states, collaboration is a key element for a successful synchronous online learning environment that balances the roles of its participants. When collaborating, actual time spent on task is reduced. This was clearly evident in our study based on the efficiency of topic coverage for collaborative sessions. Furthermore, the support received is critical for retaining and motivating learners (Finkelstein, 2006). Thus, based on the findings in this study, collaboration should be regarded as central function of any remote tutoring platform targeted for supporting students who are D/HH.

In conclusion, synchronous, remote tutoring in STEM holds promise for academically engaging students who are D/HH. The best platforms for serving this population should have a solid infrastructure for integrating various educational materials to maximize active learning opportunities. Additionally, platforms with multiple channels for communication are best served to mitigate unanticipated technical issues. Under the tutelage of an experienced tutor using the remote platform, each of these features can be leveraged when most appropriate to accommodate the various educational needs of individual learners. In doing so, synchronous, remote tutoring holds great potential as a resource in the online educational toolkit.

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References

Anozie, N. O., & Junker, B. W. (2007). *Investigating the utility of a conjunctive model in Q-matrix assessment using monthly student records in an online tutoring system*. Presented at the Annual Meeting of the National Council on Measurement in Education (NCME), Chicago, IL.

Avery, O. T., Macleod, C. M., & McCarty, M. (1944). Studies on the chemical nature of the substance inducing transformation of pneumococcal types: Induction of transformation by a desoxyribonucleic acid fraction isolated from pneumococcus type III. *The Journal of Experimental Medicine*, *79*, 137–158.

Baker, S. (2010). Remote tutoring of deaf and hard of hearing students using web-based and video-based technologies. *Journal for Deaf Educational Technology*, *1*, 17–23.

Baxter, P., & Jack, S. (2008). Qualitative case study methodology: Study design and implementation for novice researchers. *The Qualitative Report*, *13*, 544–559.

Blom, H., Marschark, M., Vervloed, M. P. J., & Knoors, H. (2014). Finding friends online: Online activities by deaf students and their well-being. *PLOS ONE*, *9*, e88351. doi:10.1371/journal.pone.0088351

Bohne, A., Faltin, N., & Wagner, B. (2004). Synchronous tele-tutorial support in a remote laboratory for process control. In W. Aung (Ed.), *Innovations 2004: World innovations in engineering education and research innovations* (pp. 317–329). Potomac, MD: iNEER.

Bonk, C. J., & Cunningham, D. J. (1998). Searching for learner-centered, constructivist, and sociocultural components of collaborative educational learning tools. In C. J. Bonk & K. S. King (Eds.), *Electronic collaborators: Learner-centered technologies for literacy, apprenticeship, and discourse* (pp. 25–50). Mahwah, NJ: Lawrence Erlbaum.

Bryant, L. (2011). *Remote tutoring: A choice for deaf college students: An action research study*. Doctoral dissertation. Retrieved from http://hdl.handle.net/1802/16913

Cech, T. R. (1990). Nobel lecture. Self-splicing and enzymatic activity of an intervening sequence RNA from Tetrahymena. *Bioscience Reports*, *10*, 239–261.

Clark, A. K., & Whetstone, P. (2014). The impact of an online tutoring program on mathematics achievement. *The Journal of Educational Research*, *107*, 462–466. doi:10.1080/00220671.2013.833075

Cohen, P. A., Kulik, J. A., & Kulik, C.-L. C. (1982). Educational outcomes of tutoring: A meta-analysis of findings. *American Educational Research Journal*, *19*, 237–248. doi:10.3102/00028312019002237

Conceptboard. (2016). *Conceptboard*. Retrieved March 21, 2016, from http://conceptboard.com/

Convertino, C. M., Marschark, M., Sapere, P., Sarchet, T., & Zupan, M. (2009). Predicting academic success among deaf college students. *Journal of Deaf Studies and Deaf Education*, *14*, 324–343. doi:10.1093/deafed/enp005

Daradoumis, T., Bassi, R., Xhafa, F., & Caballe, S. (2013). A review on massive e-learning (MOOC) design, delivery and assessment. In F. Xhafa, L. Barolli, D. Nace, S. Vinticinque, & A. Bui (Eds.), *2013 Eighth International Conference on P2P, Parallel, Grid, Cloud and Internet Computing (3PGCIC)* (pp. 208–213). doi:10.1109/3PGCIC.2013.37

Dougherty, R. C., Bowen, C. W., Berger, T., Rees, W., Mellon, E. K., & Pulliam, E. (1995). Cooperative learning and enhanced communication: Effects on student performance, retention, and attitudes in general chemistry. *Journal of Chemical Education*, *72*, 793–797. doi:10.1021/ed072p793

Doukakis, S., Koutroumpa, C., Despi, O., Raffa, E., Chira, T., & Michalopoulou, G. (2013, October). *A case study of e-tutors' training program*. Presented at the 2013 International Conference on Information Technology Based Higher Education and Training (ITHET), Antalya, Turkey. Retrieved from http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=6671052

Easterbrooks, S. R. (2008). Knowledge and skills for teachers of individuals who are deaf or hard of hearing: Initial set revalidation. *Communication Disorders Quarterly*, *30*, 12–36. doi:10.1177/1525740108324043

Elliot, L. B., Rubin, B., DeCaro, J. J., Clymer, E. W., Earp, K., & Fish, M. D. (2013). Creating a virtual academic community for STEM students. *Journal of Applied Research in Higher Education*, *5*, 173–188. doi:10.1108/JARHE-11-2012-0051

Finkelstein, J. E. (2006). *Learning in real time: Synchronous teaching and learning online*. San Francisco, CA: Jossey-Bass.

Fire, A., Xu, S., Montgomery, M. K., Kostas, S. A., Driver, S. E., & Mello, C. C. (1998). Potent and specific genetic interference by double-stranded RNA in *Caenorhabditis elegans*. *Nature*, *391*, 806–811. doi:10.1038/35888

Foster, S. (2009). *Thematic notes from the PEPNet focus groups*. NTID Center on Access Technology. Retrieved from http://www.ntid.rit.edu/sites/default/files/cat/fosterReport.pdf

Google. (2016a). *Google Calendar*. Retrieved March 21, 2016, from https://www.google.com/calendar

Google. (2016b). *Google Chrome*. Retrieved March 21, 2016, from https://www.google.com/chrome/browser/

Google. (2016c). *Google Drive*. Retrieved March 21, 2016, from https://www.google.com/intl/en/drive/

Google. (2016d). *Google Hangouts*. Retrieved March 16, 2016, from https://hangouts.google.com

Halverson, R., & Collins, A. (2009). *Rethinking education in the age of technology: The digital revolution and schooling in America*. New York, NY: Teachers College Press.

Hara, N. (2000). Student distress in a web-based distance education course. *Information, Communication & Society*, *3*, 557–579. doi:10.1080/13691180010002297

Herppich, S., Wittwer, J., Nückles, M., & Renkl, A. (2014). Addressing knowledge deficits in tutoring and the role of teaching experience: Benefits for learning and summative assessment. *Journal of Educational Psychology*, *106*, 934–945. doi:10.1037/a0036076

Hoffer, T. B., Hess, M., Welch, V., & Williams, K. (2007). *Doctorate recipients from United States universities, summary report 2006*. Retrieved from University of Chicago, National Opinion Research Center website: http://www.nsf.gov/statistics/doctorates/pdf/sed2006.pdf

Hooper, S., Miller, C., Rose, S., & Veletsianos, G. (2007). The effects of digital video quality on learner comprehension in an American Sign Language assessment environment. *Sign Language Studies*, *8*, 42–58. doi:10.1353/sls.2007.0029

Jenkins, H. (2009). *Confronting the challenges of participatory culture: Media education for the 21st century*. Cambridge, MA: MIT Press.

Kear, K., Chetwynd, F., Williams, J., & Donelan, H. (2012). Web conferencing for synchronous online tutorials: Perspectives of tutors using a new medium. *Computers & Education*, *58*, 953–963. doi:10.1016/j.compedu.2011.10.015

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching. *Educational Psychologist*, *41*, 75–86. doi:10.1207/s15326985ep4102_1

Komesaroff, L. (2005). Category politics: Deaf students' inclusion in the ''hearing university.'' *International Journal of Inclusive Education*, *9*, 389–403. doi:10.1080/13603110500138301

Lang, H. G., Biser, E., Mousley, K., Orlando, R., & Porter, J. (2004). Tutoring deaf students in higher education: A comparison of baccalaureate and sub-baccalaureate student perceptions. *Journal of Deaf Studies and Deaf Education*, *9*, 189–201. doi:10.1093/deafed/enh020

Lang, H. G., & Steely, D. (2003). Web-based science instruction for deaf students: What research says to the teacher. *Instructional Science*, *31*, 277–298. doi:10.1023/A:1024681909409

Lissaman, R., Pomerai, S. de, & Tripconey, S. (2009). Using live, online tutoring to inspire post 16 students to engage with higher level mathematics. *Teaching Mathematics and Its Applications*, *28*, 216–221. doi:10.1093/teamat/hrp028

MacDonald, J. (2006). *Blended learning and online tutoring: A good practice guide*. Aldershot, England: Gower.

Marchetti, C., Foster, S., Long, G., & Stinson, M. (2012). Crossing the communication barrier: Facilitating communication in mixed groups of deaf and hearing students. *Journal of Postsecondary Education and Disability*, *25*, 51–63.

Marschark, M., Pelz, J. B., Convertino, C., Sapere, P., Arndt, M. E., & Seewagen, R. (2005). Classroom interpreting and visual information processing in mainstream education for deaf students: Live or Memorex®? *American Educational Research Journal*, *42*, 727–761.

McPherson, M., & Nunes, M. B. (2004). The role of tutors as a integral part of online learning support. *European Journal of Open, Distance and E-learning*, *7*(1).

Miller, M. D. (2014). *Minds online: Teaching effectively with technology*. Cambridge, MA: Harvard University Press.

Minderhout, V., & Loertscher, J. (2007). Lecture-free biochemistry. *Biochemistry and Molecular Biology Education*, *35*, 172–180. doi:10.1002/bmb.39

O'Hanlon, C. (2007). Board certified. *T.H.E. Journal*, *34*, 30–34.

Orlando, R., Gramly, M. E., & Hoke, J. (1997). Tutoring deaf and hard of hearing students: A report of the National Task Force on Quality of Services in the Postsecondary Education of Deaf and Hard of Hearing Students. *PEPNet2*. Retrieved from http://www.pepnet.org/sites/default/files/48Tutoring Deaf and Hard of Hearing Students.pdf

Pearson. (2016). *MasteringChemistry*. Retrieved March 21, 2016, from http://www.pearsonmylabandmastering.com/northamerica/masteringchemistry/

Reed, S., Antia, S. D., & Kreimeyer, K. H. (2008). Academic status of deaf and hard-of-hearing students in public schools: Student, home, and service facilitators and detractors. *Journal of Deaf Studies and Deaf Education*, *13*, 485–502. doi:10.1093/deafed/enn006

Richardson, J. T. E. (2009). Face-to-face versus online tutoring support in humanities courses in distance education. *Arts and Humanities in Higher Education*, *8*, 69–85. doi:10.1177/1474022208098303

Rogers, E. M. (1995). *Diffusion of innovations* (4th ed.). New York, NY: Free Press.

Rubrico, J. G. U. (2012). Computer-aided learning and task-based learning: Engaging learners in contextualizing grammar. In L. A. Wankel & P. Blessinger (Eds.), *Cutting-edge technologies in higher education: Vol. 6B. Increasing student engagement and retention using social technologies* (pp. 179–209). Retrieved from http://www.emeraldinsight.com/doi/pdfplus/10.1108/S2044-9968(2012)000006B009

Simoes, L., & Gouveia, L. B. (2012). Influence of psychological variables on the academic use of Facebook. In L. A. Wankel & P. Blessinger (Eds), *Cutting-edge technologies in higher education: Vol. 6B. Increasing student engagement and retention using social technologies* (pp. 121–158). Retrieved from http://www.emeraldinsight.com/doi/full/10.1108/S2044-9968(2012)000006B007

Stinson, M. S., Elliot, L. B., & Easton, D. (2014). Deaf/hard-of-hearing and other postsecondary learners' retention of STEM content with tablet computer-based notes. *Journal of Deaf Studies and Deaf Education*, *19*, 251–269. doi:10.1093/deafed/ent049

Stinson, M., Liu, Y., Saur, R., & Long, G. (1996). Deaf college students' perceptions of communication in mainstream classes. *Journal of Deaf Studies and Deaf Education*, *1*, 40–51.

Truong, M., & Zanzucchi, A. (2012). Going beyond the traditional essay: How new technologies are transforming student engagement with writing outcomes. In L. A. Wankel & P. Blessinger (Eds.), *Cutting-edge technologies in higher education: Vol. 6B. Increasing student engagement and retention using social technologies* (pp. 263–288). Retrieved from http://www.emeraldinsight.com/doi/full/10.1108/S2044-9968(2012)000006B012

Tsuei, M. (2014). Mathematics synchronous peer tutoring system for students with learning disabilities. *Journal of Educational Technology & Society*, *17*, 115–127.

U.S. Department of Education. (n.d.). *Science, technology, engineering and math: Education for global leadership*. Retrieved March 3, 2016, from http://www.ed.gov/stem

Vasquez, E., & Slocum, T. A. (2012). Evaluation of synchronous online tutoring for students at risk of reading failure. *Exceptional Children*, *78*, 221–235. doi:10.1177/001440291207800205

Walter, G. G. (2009). *Testing the concept of a virtual alliance for postsecondary level STEM students who are deaf and hard-of-hearing: Summary of PEPNet focus groups*. NTID Center on Access Technology. Retrieved from http://www.ntid.rit.edu/sites/default/files/cat/walterReport.pdf

Walter, G. G. (2010). *Deaf and hard-of-hearing students in transition: Demographics with an emphasis on STEM education*. NTID Center on Access Technology. Retrieved from http://www.ntid.rit.edu/sites/default/files/cat/Transition demographic report 6-1-10.pdf

Wankel, L. A., & Blessinger, P. (2012). New vistas in higher education: An introduction to using social technologies. In L. A. Wankel & P. Blessinger (Eds.), *Cutting-edge technologies in higher education: Vol. 6B. Increasing student engagement and retention using social technologies* (pp. 3–16). Bingley, UK: Emerald Group Publishing Limited.

Whetstone, P., Clark, A., & Flake, M. W. (2014). Teacher perceptions of an online tutoring program for elementary mathematics. *Educational Media International*, *51*(1), 79–90. https://doi.org/10.1080/09523987.2013.863552.

Yin, R. K. (2009). *Case study research: Design and methods*. Los Angeles, CA: Sage.

Young, J. R. (2016, February 9). Boom in online tutoring means another cost for many students. *The Chronicle of Higher Education*. Retrieved from http://chronicle.com/article/Boom-in-Online-Tutoring-Means/235236

Author Biographies

Austin U. Gehret is an assistant professor at Rochester Institute of Technology. He provides direct instruction in biotechnology and tutoring in chemistry and biochemistry to students who are D/HH. He advises students who are D/HH in independent biochemistry research.

Lisa B. Elliot is research associate professor at Rochester Institute of Technology. Her research involves the intersection of technology and education, particularly around education issues related to students who are D/HH.

Jonathan H. C. MacDonald is a teacher at British Columbia School for the Deaf. He is an alumnus from the Master of Science in Secondary Education of Students who are Deaf or Hard of Hearing program at Rochester Institute of Technology.