International Journal *of* Designs for Learning
2023 | Volume 14, Issue 1 | Pages 62-69

LEARNING FROM DESIGN FAILURES: A VIRTUAL MATHEMATICS TUTORING PROGRAM

Janet Mannheimer Zydney & Casey Hord, *University of Cincinnati*

In this design case, we describe our first attempt to create a virtual mathematics tutoring program for students with learning disabilities. We describe in detail how the design was motivated by the pandemic which forced schools into remote learning, how a university and school collaborated on the design, the rationale for our design decisions, and aspects of the design that did not meet the intended outcomes. Three interrelated design failures included problems with flexible scheduling, challenges seeing students' work, and inconsistent use of a collaborative, communication tool. Pervasive to all these failures were underlying communication issues associated with being remote. We share our experience learning from and altering our design of these features for the future.

Janet Mannheimer Zydney is a professor of instructional design and technology at the University of Cincinnati, School of Education. Her research interests include online learning, blended synchronous learning, and computer-supported collaborative learning.

Casey Hord is an associate professor of special education at the University of Cincinnati, School of Education. His research interests include developing mathematics interventions for struggling students and designing and implementing math tutoring programs.

https://doi.org/10.14434/ijdl.v14i1.35222

INTRODUCTION

Prior to designing this virtual program, we had a successful in-person mathematics tutoring program that paired pre-service special education teachers with high school students who struggled in mathematics due to learning disabilities (Hord & DeJarnette, 2020). Then, the COVID-19 pandemic hit, shutting schools down, and even after schools re-opened, our pre-service teachers were not allowed into the buildings to tutor. However, tutoring was needed more than ever as the year away from in-person schooling caused even wider achievement gaps, especially in subjects like mathematics (Bailey et al., 2021). Moreover, our pre-service teachers needed to gain experience working with kids even though they were not allowed in the school buildings. This prompted us to figure out how to shift our in-person approach online. The aim of this design case is to describe several interrelated design failures in detail and to share our experience learning from these failures to improve upon the design.

DESIGN CONTEXT AND TEAM

Initially, our design team consisted of the two authors of this paper:

- **Janet** (first author) is an instructional design and technology professor with experience in providing technology-based scaffolding in mathematics. She led the technology aspects of the project.
- **Casey** (second author) is a special education professor with experience in designing and implementing math interventions for struggling learners and preparing education majors to be teachers. He led the math curriculum and teaching strategies parts of this project.

We both work at the same university, located in a midwestern city. Our university's School of Education offers a special education program, which provides its pre-service teachers with opportunities to tutor students with disabilities. We have utilized math tutoring programs for the last 8 years to prepare college students to be teachers and to provide extra support to students in local schools. As a part of our special

education program, we have around 25 tutors in schools per year tutoring as a part of their coursework. From these students, we usually select around five tutors to specialize in Algebra 1 tutoring based on their teaching interests and performance in mathematics education courses. During the pandemic, we had difficulty finding placements and shifted this tutoring requirement to a voluntary, resume-building experience.

In response to the need to provide tutoring to students remotely (due to COVID-19 at the time and eventually to meet students' needs in remote locations), Casey consulted with Janet on how to create a virtual version of his existing tutoring programs. We met initially to brainstorm how to combine our knowledge and skill sets to address the challenges presented by COVID-19 to deliver tutoring to students remotely. We thought we could combine principles from the teaching of mathematics to struggling learners with instructional technology for teaching virtually. After discussing a rudimentary plan, Janet contacted a local school that she had collaborated extensively with in the past on other research projects.

This suburban high school enrolls about 630 students with approximately 9% of students identifying as having a disability. In prior years, National Honor Society students offered tutoring to students in high school. However, with the COVID-19 pandemic, the school saw a great need for additional support in math, especially helping students in algebra. Students' performance on state achievement test scores in 2021 indicated that 43.6% of students scored below the proficient level in algebra. Given this need, the school was happy to work with us and the superintendent introduced us to school personnel to collaborate with on this project. Pseudonyms are used throughout the article to protect individuals' identities.

- **Natalie** is a guidance counselor at the high school and coordinated the administration of finding students who needed tutoring and obtaining permission from parents.
- **Steve** is the network /software supervisor for the school district and helped coordinate the logistics for the technology needed and provided troubleshooting for technology problems.
- **Kelly** is the media technology specialist for the school district and helped facilitate the distribution of the cameras used for the tutoring program.

With this group, we discussed the needs of the school and the best ways to contribute to the learning of the students.

Finally, our team expanded to include tutors. Casey hand-selected tutors from his teacher preparation courses for special education majors on how to teach students with mild-to-moderate disabilities. Casey targeted education majors based on their performance in class as well as their preparedness and demonstrated reliability to be trusted with the education of youth in need of support. He found five tutors altogether; however, only three were needed by the school. The tutors who joined the team were the following college students:

- **Meredith** was a junior, special education major who had tutored previously in person during her sophomore year. She worked with Ariel, a ninth grader who struggled in algebra.
- **Robert** was a junior, special education major who had no prior tutoring experience. He was doing well in an online class he was taking with Casey and mentioned in a homework assignment his interest in eventually working in a high school setting, so Casey thought this tutoring experience would be a good fit and invited him to participate. Robert worked with Mike, a ninth grader who struggled in algebra.
- **Jill** was a junior, special education major who had tutored previously in person during her sophomore year. She worked with Rachel, a tenth grader who wanted to achieve better in geometry.

Each member of the team brought a different type of expertise and background to the project which helped the entire team think through all the logistical and technological challenges associated with implementing a virtual tutoring program for the first time.

INFLUENCES ON THE DESIGN

Pedagogical Influences

Based on his in-person tutoring experience, Casey trained the tutors using a method that combines principles from special education, math education, and cognitive psychology. The method was not adjusted for virtual tutoring since we were unsure whether changes would be necessary for tutoring within this new learning environment.

The specific tutoring strategies included questioning, off-loading techniques, making connections, and using visuals. For example, the tutors learned strategies for asking the right kinds of questions to students to provide support when needed or a push when ready for a challenge (DeJarnette & Hord, in press). The tutors also learned how to teach students to store information on scratch paper in strategic ways to lighten the load on memory and processing (see offloading; Risko & Dunn, 2010). The tutors gained skills in ways to help students connect new and challenging information to skills and concepts familiar to them. This approach makes unfamiliar and complex concepts easier for students to think about and apply to their work (see connections between long-term memory and working memory; Ericsson & Kintsch, 1995). Finally, the tutors learned how to combine gestures with what they were saying to the students to make the

math more accessible. For example, the tutors learned to strategically point with their finger, while speaking about different parts of drawings, algebraic notation, graphs, etc. (see overlapping visuals; Hord et al., 2019). All of these strategies can make math easier for students to learn when they are struggling.

Technological Influences

The technological design consisted of three main design goals:

- Create a flexible environment for students and tutors to meet at a convenient time and place.
- Determine a way for tutors to see how students worked through problems in realmtime so they could provide in-the-moment scaffolding.
- Create a community for tutors to share experiences and collaborate.

Flexible environment

One of the advantages of virtual tutoring is that it can be scheduled at a time and place that is convenient for both tutors and students. We learned from others doing virtual tutoring that being flexible is one of the key elements for success (Kier & Clark, 2020). To address the goal of creating a flexible environment for tutoring, we decided to have the tutors use WebEx video conferencing to schedule individual 1-hour, weekly tutoring sessions with their students. The tutors were already familiar with using WebEx in their undergraduate classes, so they just needed additional instruction on how to host their own meetings. We debated about having one session altogether with tutors and students meeting in breakout rooms as this would mimic more closely how Casey had tutored in person, but we thought it would be more appealing to give tutors and students the opportunity to schedule their sessions when it worked best for their schedules. To determine the best time for students, Casey spoke individually on the phone with parents and then had the tutors follow up to coordinate schedules.

Seeing student work in real time

An important aspect of tutoring in mathematics is the ability to provide in-the-moment support as students are working through problems. We knew from our in-person tutoring the importance of using visuals to support students' thinking processes as they engaged with challenging mathematics (Hord & DeJarnette, 2020). We looked at what others were doing on virtual math tutoring and found research at the college level that recommended using synchronous technology with interactive whiteboard capabilities (Johns & Mills, 2021). However, when discussing this idea with the undergraduate tutors, Robert brought up a good point that this would not be ideal for writing algebraic equations because of the dexterity needed to write with a mouse. Then we had a breakthrough. For our research on in-person tutoring, Casey used small document cameras (See Figure 1) to record students working through problems to assess ways to improve our tutoring.

We had several of these cameras available to us and thought that this would provide the needed visual solution. Students could simply connect these document cameras to their computers, and this would enable the tutors to see the students working through the problems on scratch paper.

Building a community

In prior years, tutors worked all together providing tutoring as a pullout during math class, with Casey providing in-the-moment support to the tutors as needed. This support included assisting with logistical or communication issues or more complicated academic issues the tutors could not resolve on their own. After each tutoring session, tutors completed a reflection individually through a survey for research purposes and to troubleshoot any tutoring issues.

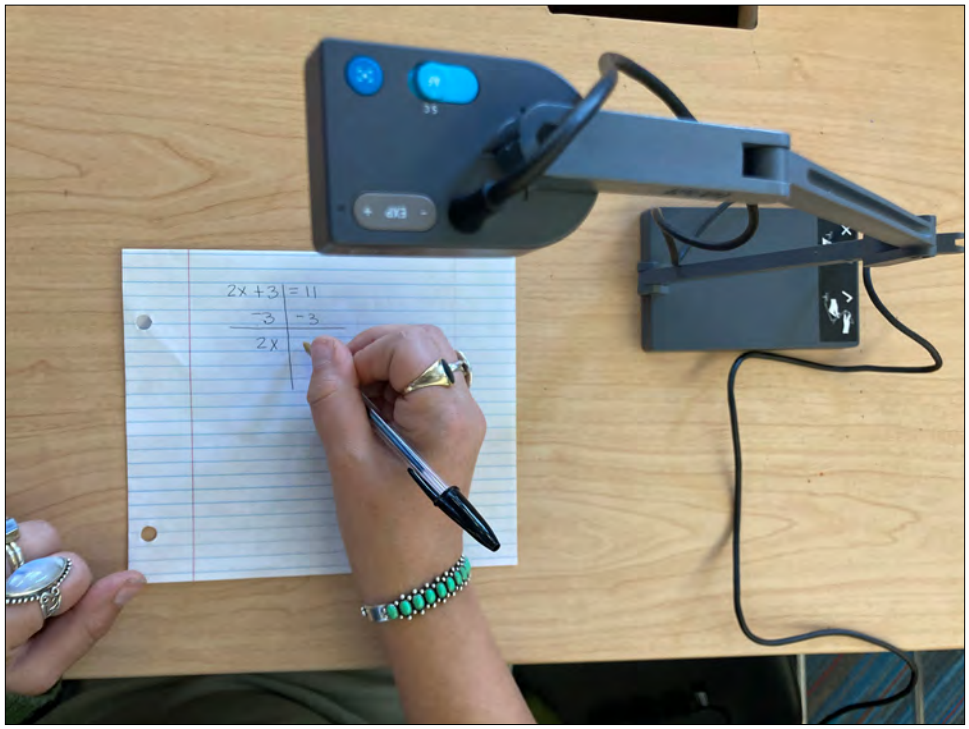

FIGURE 1. Student using document camera.

Since we would not all be together for virtual tutoring, we wanted a way for the tutors to connect asynchronously. Other researchers had suggested using asynchronous technology for reflection and sharing resources (Kier & Clark, 2020). Janet had experience using Microsoft Teams to build a learning community in her online classes (Ergulec & Zydney, 2019) and thought this might be a useful tool for these purposes. Microsoft Teams would enable the group of tutors to reflect together, share their experiences, troubleshoot similar problems, and exchange resources.

START UP LOGISTICS

The first step was to find students to participate in the program. Casey worked with Natalie to identify students who could benefit from the program. However, Natalie had challenges finding students motivated to participate. Even though the students needed the help, they did not have the wherewithal to participate given all the demands in dealing with the pandemic. She suggested expanding the program to include geometry, which we thought was a good idea. While students were being identified, the tutors obtained the necessary background checks required by the school.

After Natalie identified students who were likely to benefit from the program, Casey spoke on the phone briefly with students' parents to learn about the students' academic needs and the best time/place for tutoring (e.g., difficult academic subjects, tutoring in school or at home, characteristics as learners, etc.). Then, Casey arranged for tutors to speak on the phone with their students' parents to build trust and make final arrangements on tutoring times, academic content, and potential teaching strategies based on their children's needs and strengths.

The next step was to develop a detailed plan for the distribution, testing, and training needed for the cameras. Janet worked out a plan with Steve to have the cameras distributed through the school library. Students who would be tutored at home would check out a camera after bringing a Take Home Agreement signed by them and their parent or guardian. Based on the agreement that the school uses for their laptop program, Janet designed the Take Home User Agreement that enumerated the student's responsibilities for taking care of the camera and the consequences for lost or damaged devices. For students who would be tutored during the school day, the cameras would be distributed to their study hall teachers and would be kept in the classroom for students to use during the tutoring sessions. The idea behind keeping the cameras in the classrooms was to reduce the amount of potential wear and tear on the cameras from students storing them in their lockers and carrying them around in their backpacks.

Janet delivered the cameras to the school, and Steve tested out the cameras to make sure they would work with the

FIGURE 2. One-page handout for connecting camera to laptops.

school laptops. He then gave them to Kelly who oversaw the distribution of the cameras. Meanwhile, Janet developed a short, one-page training handout on using and storing the cameras. Janet shared the handout with Steve as well as the tutors to pass along to the students. See Figure 2 for the handout.

The final logistical step was to create a Microsoft Teams environment in which the tutors could collaborate. Janet created a new Team and added the tutors and Casey as members. She organized the Team with several channels (i.e., sections within a Team to organize conversations by topics), including Introductions, Technology Tips, Video Recordings, and Weekly Reflections. In Introductions, everyone posted about themselves to begin building rapport with one another. Technology Tips provided a space to add training materials on using WebEx and the cameras as well as troubleshoot any technology issues at the school. Video Recordings offered a private space to upload recordings from the tutoring sessions that could be used for later analysis in a research study. The Weekly Reflections channel offered a place for tutors to post a reflection after each tutoring session, as shown in Figure 3. Janet moderated the weekly reflection postings by asking tutors follow-up questions or highlighting when tutors had experiences that might be helpful to other tutors.

DESIGN FAILURES

While we had moments of successful tutoring experiences when tutors excelled at teaching and the students improved their understanding, there were several design failures that

FIGURE 3. Screenshot of the Weekly Reflections channel in Microsoft Teams.

made tutoring more difficult, including problems with flexible scheduling, challenges seeing students' work, and inconsistent use of Teams. Pervasive to all these failures were underlying communication issues associated with being remote. When communicating virtually, we did not have the benefit of simply walking with a teacher between classes or talking with a teacher in the classroom to sort out logistical challenges; we had to rely on email communication with school personnel, who were extra busy with adjusting to new ways of teaching and safety protocols required during a pandemic. This often created a lag in communication and inefficiency in solving problems. Although we were collaborating with a number of school personnel, we were missing a main teacher contact onsite who could troubleshoot and make quick adjustments in real time if tutoring did not go as planned. These communication issues contributed to each of the design failures, as will be explained in the sections that follow.

Problems with Flexible Scheduling

Although one of the benefits of virtual tutoring is to be able to tutor at a time and place convenient for the student, our design was almost too flexible. Tutors made individual arrangements to meet with their students, but this required that the student remember to log on at a particular day and time. This resulted in a pattern of "no shows" for tutoring. In some cases, students logged on to tutoring at the right time, were prepared to work, and benefitted from the tutoring session. For example, Robert reflected on the success he had with one student: "he always seemed like he left at least understanding everything a little bit better which I was always happy about."

Other times, things did not work out as well. Several times tutors waited in vain for students to log on. Robert wrote in his weekly reflections about this problem:

> *Just wanted to let you know that Mike did not show up for our tutoring session today. I went ahead and sent him a follow up email and copied his mom onto it, let me know if there is anything else that I should do!*

After getting in touch with his mom, the situation improved for a couple of weeks but then the student started not showing up again. On other occasions, students cancelled last minute. Jill explained: "There have been like a couple weeks, where she was like I don't really have anything, I don't really feel like we need to meet."

These scheduling issues are not easy to fix when communicating virtually because the tutors could not just walk to the classroom and talk with the teacher to figure out why the student did not show up. Are they absent? Did they forget? Or, do they not need help that day? There was no way for tutors to know until they reached the students later by email. This was never really an issue for in-person tutoring because the teacher would typically send the student to the tutoring session, or the tutor could just walk to the classroom and bring the student to the tutoring session. And, If the student was absent or needed to work on something else at the time, the teacher could just simply pick another student who could use some help that day. We learned that not having someone onsite to troubleshoot and make quick adjustments presents challenges with virtual tutoring.

Students also had the flexibility of choosing a place for tutoring. One chose to work from home, while the others choose to work during the school day. The problem was that sometimes the place that the student chose did not have reliable Wi-Fi connections and that also created issues regarding communicating effectively. For example, Meredith explained:

> *It just was tough meeting, just the wi-fi for some reason was really bad in the room she was in um, and so just it'd be slow like connectivity or, or she would just email saying like it's really slow today so like the call wouldn't really work so you're not really getting to me because of that.*

Not having a dedicated space in the school for tutoring proved problematic. Tutoring in a consistent place would enable us to test out the internet connections and have someone onsite that can troubleshoot technology issues as they happen.

Challenges Seeing Students' Work

Although there were some positives of using the cameras to see students' work in real time, for the most part, this solution did not meet its intended outcome. For example, sometimes the math problems students were working on were online, and the students needed to be able to share both their screen and the work they were doing on scratch paper simultaneously and this proved frustrating as explained by Jill:

> *We were doing AIR practice tests, last Tuesday. And that's all online and some of the problems were super long, so I was trying to figure out or she was trying to figure out how she could show the camera; so that I could look at the problem but there wasn't enough space for me to be able to see what she was doing, So I couldn't correct her if I needed to.*

Another issue was only the student had a camera and not the tutor, which made it challenging for the tutors to show how to work through a problem, as Jill went on to explain: "when you're in person, obviously, you can just gesture to things you can tell them where to write things but online it's very different and finding out like the best way to be able to show your work to [them]."

In some cases, we had difficulty getting document cameras distributed to the students, due to the underlying communication issues. After testing the cameras, Steve dropped off the cameras to Kelly in the library. The student working from home picked up the camera as planned. Kelly delivered the other cameras to the study hall teachers. Janet let the tutors know that the cameras had been delivered. The tutors inquired with their students about the cameras, but the students did not seem to know where the cameras were. After following up a couple of times with the students, the tutors gave up. It was almost like we were playing a game of telephone with each person passing along the message, resulting in the message never actually making it to the students who needed it.

The lack of cameras made tutoring more challenging for the tutors because tutors could not watch the students work through problems in real time and had instead they had to awkwardly hold up their paper to the camera (see Figure 4).

Robert explained, "I could never really like see his scratch work to see if he was really understanding everything, to the extent that he should have."

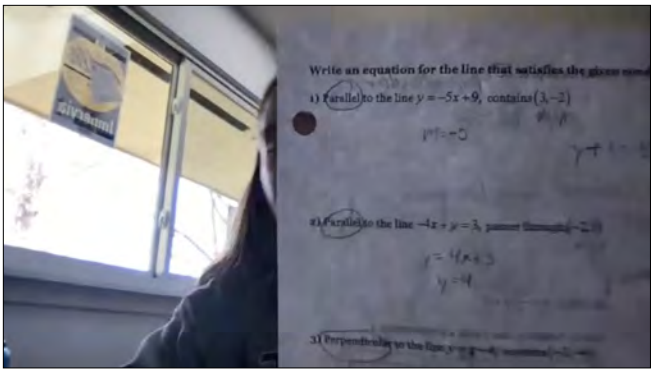

FIGURE 4. Student showing work on camera.

Kelly suggested that next time instead of distributing the cameras to the teachers to keep the cameras in the library and arrange for the students to participate in the tutoring sessions from there.

Inconsistent Use of Teams

The goal of using Teams was to create a place for tutors to share their experiences and troubleshoot problems with one another. The tutors appreciated the idea of using Teams. For example, Meredith noted: "I think Teams is like nice, neat and like to see like how other people's experiences are going, so I think that's like a helpful thing for sure." However, the Teams environment was underutilized and often not updated without prompting from us. Meredith explained, "I was just not very good updating it; I think. I just had trouble like a few times in a row meeting with her, and then I didn't get into a rhythm of it." Robert agreed that scheduling issues got in the way of getting into a routine of posting. It was also problematic that only the team members from the university were part of the Teams environment. It may have been more utilized and helped overcome some of the communication issues if everyone on the design team were using the same communication tool.

UNEXPECTED DISCOVERIES

Not having the document cameras to see students' work in real time led to one unexpected discovery. It forced the tutors to find other creative ways to teach students that may have been even more successful than ways they had used when tutoring in person. For example, when Jill was having trouble showing the student how to work through a problem, she asked the student to show her how to do the problem instead. The student excelled at talking the tutor through the problem (using gestures, other visuals, and effective verbal language). See Figure 5 for an example of student gesturing.

This method of communication seemed to provide a great opportunity for a conversation that Jill might not have sought if she was able to use methods she often used when tutoring in person, such as gesturing over the student's

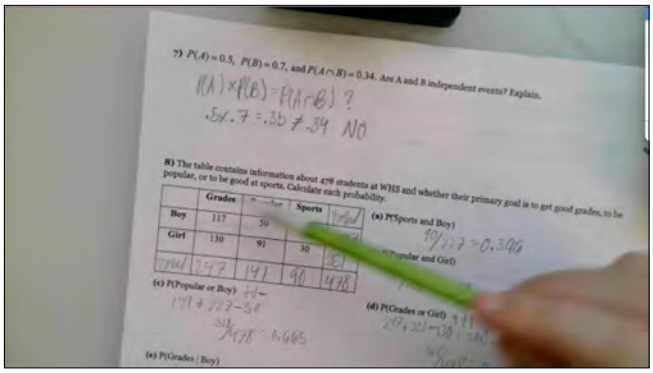

FIGURE 5. Video of student gesturing over WebEx.

paper. This key adjustment made by Jill out of necessity is a catalyst for future research on asking students to teach tutors as a way to demonstrate their understanding of mathematics. This technique is recommended by the National Council of Teachers of Mathematics (2014), and we have now found a great context for using this approach.

Another unexpected discovery was the level of connections the tutors formed with their students. For example, Robert revealed:

> *I was actually kind of surprised because I mean like I was a freshman guy at one point I would have not been as easy to talk to as he was. I think he was always really comfortable during the sessions, and it made it easier for me um, with it being virtual.*

And, Jill who tutored a student from home also became close with the parent:

> *Um I talked to [the parent] a lot. She, as soon as I like emailed her, she emailed me back, we like exchanged phone calls. We talked on the phone for like an hour and a half. She was basically giving me the whole rundown of like why, how Rachel was like, what she's looking for.*

The tutors mistakenly believed that being virtual would make it harder for them to get to know their students, but in reality, they ended up getting to know them as well, and maybe even better, than meeting in person.

DESIGN FOR THE FUTURE

With virtual tutoring, we have realized that we need a staff member at the physical location of the tutoring. Of course, this presents more difficulty when virtually tutoring students who are at home. But, at schools in our future work, we will designate a staff member to sort out logistical issues that arise such as when students do not log onto the computer. We have learned that intermittent, brief, face-to-face conversations between tutoring staff and teachers at the school can quickly resolve issues as they occur.

In addition to having a designated staff member, having a reserved space for tutoring is needed. Kelly suggested that next time we do virtual tutoring, we have students work from the media center in the library, which has reliable internet and someone on staff to troubleshoot issues.

In addition, instead of tutoring on a volunteer basis, the tutors will go back to how tutoring worked before the pandemic when it was a requirement for a class. As part of their homework, tutors will be required to tutor 15 hours a semester (1 hour per week). During the class, they will talk about the students they are tutoring and relate their field experiences to the academic content (e.g., working memory, cognitive load, IQ testing, teaching school subjects, etc.). So, much of the training and knowledge sharing will take place during class time.

Instead of using document cameras, Kelly suggested that we try using the Jamboard app (See Figure 6). The app can be downloaded on a tablet, and then the student can take

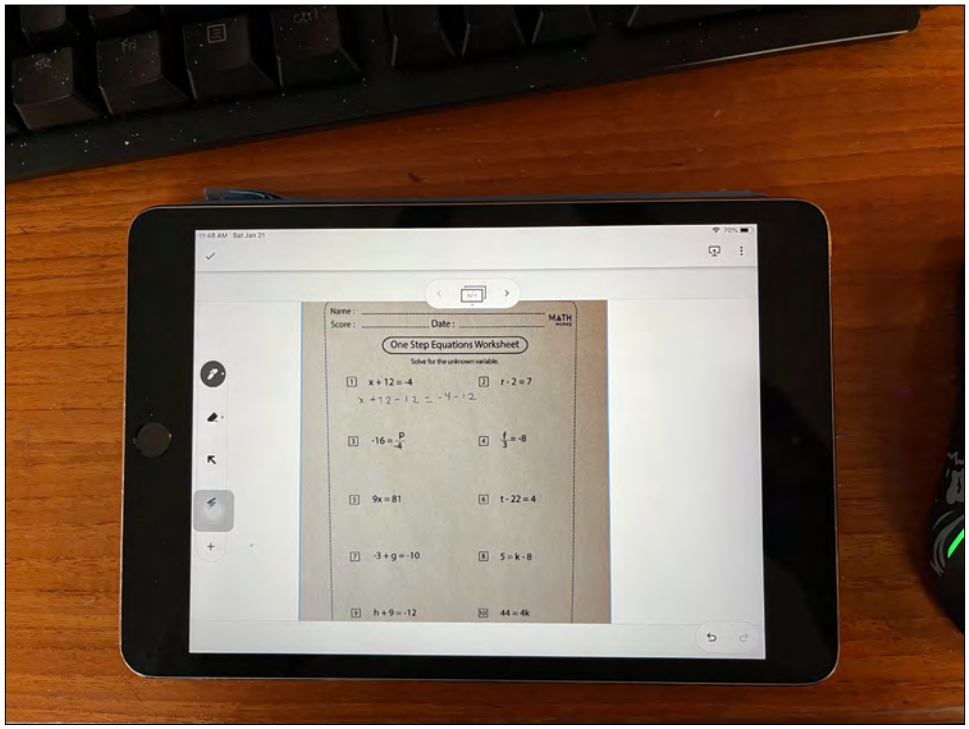

FIGURE 6. Jamboard app on iPad.

a picture of their worksheet or a screenshot of an online problem. Both the tutor and student can then write on the problem together. By using stylus pens, writing out algebraic equations feels quite natural. The tutor can watch the student work through the problem in real time and provide needed in-the-moment scaffolding, and the tutor can also demonstrate how to work through the problem. Although tutors will not be able to gesture in the same way that they can in person, there are tools within the app that allow for highlighting which we think will be useful for these purposes. For example, tutors can quickly highlight or color code parts of problems and then quickly change things back to their original state. Students can add visuals like arrows and then delete the arrows as needed with the click of a button.

Microsoft Teams still seems to have potential, especially if everyone gets into a routine of using it and both university and school personnel are added as members. The tutoring sessions themselves could happen within Teams, which would enable everything to occur in the same place, increasing the likelihood of usage. However, if a school has a different collaborative tool that they are already using, this may be a better option.

CONCLUSION

At times, students had cameras, logged on at the right times, worked hard on their math, and the tutors excelled in their work as well. But, all these pieces coming together did not occur as frequently as we expected based on our experience tutoring in person. The reasons tutoring was not always successful stemmed from three interrelated design failures, including problems with flexible scheduling, challenges seeing students' work, and inconsistent use of Teams. This interfered with the intended design outcome of creating a flexible community of tutors that could help one another in providing in-the-moment support to students. There was no one person responsible for these design failures; rather, there were too many people with specific jobs along with a lack of coordination and communication among everyone involved.

The key takeaways for other designers interested in designing virtual tutoring programs are establishing regular and consistent communication, using the same platform for everyone to communicate, and establishing norms for frequency of communication. Rather than working with several school personnel, finding one person who can coordinate all pieces on site and having a dedicated space for tutoring is essential.

Although this design instantiation was not a complete success, we discovered new ways to tutor and uncovered innovative technology solutions to help students visualize mathematics remotely, which we plan to use in the future.

REFERENCES

Bailey, D. H., Duncan, G. J., Murnane, R. J., & Au Yeung, N. (2021). Achievement gaps in the wake of COVID-19. *Educational Researcher*, *50*(5), 266-275. http://doi.org/10.3102/0013189X211011237

DeJarnette, A. F., & Hord, C. (in press). Mathematics questioning practices of pre-service special education teachers providing algebra tutoring for students with learning disabilities. *Teacher Education and Special Education*. https://journals-sagepub-com.uc.idm.oclc.org/doi/epub/10.1177/08884064211073573

Ergulec, F., & Zydney, J. M. (2019). A design case for implementing a collaborative strategy for online teams. *International Journal of Designs for Learning*, *10*(1), 25-34. https://doi.org/10.14434/ijdl.v10i1.24120

Ericsson, K. A., & Kintsch, W. (1995). Long-term working memory. *Psychology Review, 102*, 211–245. https://doi.org/10.1037/0033-295X.102.2.211

Hord, C., & DeJarnette, A. F. (2020). Perspectives on Algebra I tutoring experiences with students with learning disabilities. *Learning Disabilities: A Contemporary Journal, 18*(2), 177-192. https://eric.ed.gov/?id=EJ1281076

Hord, C., Kastberg, S., & Marita, S. (2019). Layering visuals to empower struggling students. *Australian Mathematics Education Journal, 1*(2), 6-10.

Johns, C., & Mills, M. (2021). Online mathematics tutoring during the COVID-19 pandemic: Recommendations for best practices. *Primus, 31*(1), 99-117. https://doi.org/10.1080/10511970.2020.1818336

Kier, M., & Clark, K. (2020). The rapid response of William & Mary's School of Education to support preservice teachers and equitably provide mentoring to elementary learners in a culture of an international pandemic. *Journal of Technology and Teacher Education, 28*(2), 321-327. https://www.learntechlib.org/primary/p/216153/

National Council of Teachers of Mathematics. (2014) *Principles to actions: Ensuring mathematical success for all*. Reston, VA: Author.

Risko E. F., & Dunn, T. L., (2010) Storing information in-the-world: Metacognition and cognitive offloading in a short-term memory task. *Consciousness and Cognition, 36*(1), 1-74. https://doi.org/10.1016/j.concog.2015.05.014