# FROM 2D TO KUBI TO DOUBLES: DESIGNS FOR STUDENT TELEPRESENCE IN SYNCHRONOUS HYBRID CLASSROOMS

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This paper introduces the efforts of Michigan State University's Counseling, Educational Psychology, and Special Education/College of Education (CEPSE/COE) Design Studio to utilize robotic telepresence devices in synchronous hybrid learning classes for the Educational Psychology and Educational Technology (EPET) Ph.D. program. *Robotic telepresence devices* are digital devices that can be piloted from a distance for the purpose of interacting with people in a remote location. *Synchronous hybrid learning classes* refer to classes in which online and face-to-face students interact during shared synchronous sessions. This design case describes the context, technologies, and strategies used to integrate robotic telepresence devices in a synchronous hybrid learning class format. We conclude by discussing our insights gleaned from our existing designs for student telepresence in synchronous hybrid learning contexts.

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## INTRODUCTION

The driving purpose behind this design case was to combine online and face-to-face students in the same learning experience as comparable partners. There is a long history of courses that use a single medium for interaction, including face-to-face, distance education, and internet-based courses. While there are significant differences regarding interactions and potential pedagogical strategies with each of these formats, the fact that all of the participants experience the same constraints helps maintain the equity of student experience in class. In contrast, when a class uses more than one modality in the *same* learning experience, it introduces the real possibility of having two strata of student experiences: one stratum having richer access to the instructor and class interactions, and the other being more constrained.

### Context

This design case directly reflects a real need in our own work. The Educational Psychology and Educational Technology Ph.D. program at Michigan State University has two modes of the same program, one for on-campus students and one for hybrid students. On-campus students generally relocate to East Lansing, Michigan, for the duration of the program (generally four or more years). Of course, they use communication technology, such as email, for much of their work, but they are expected to come physically to classes, meetings, and events pursuant to their studies. In contrast, hybrid students are only expected to be in East Lansing for two weeks in each of their first four years in the program. From a distance, they can do everything else that is required of them, such as attending classes, meeting with their advisors, and even defending their dissertations.

While it would be conceivable to treat these two modes as *separate* but *equal* opportunities, we chose not to take that approach. Practically, we do not have sufficient personnel to offer everything we do in two separate modes. For example, we do not have sufficient faculty to teach every class twice, once for on-campus students and once for online students. Even more, philosophically we believe that our program is a richer program for everyone when we are integrating these

two populations of students. For example, we tend to have different populations of students in the two modes of the program. Those who move to campus make their primary work be their studies, and so they become immersed in the academic world. In contrast, hybrid students generally continue their full-time work in education, carrying out their responsibilities as teachers, administrators, consultants, and the like. Accordingly, these two populations have different perspectives on many issues of significance for their studies. Experience tells us that on-campus students tend to be more immersed in theoretical issues, while the hybrid students have a more active awareness of practical issues. Our ongoing expectation is that both groups of students gain through rich interactions with each other.

Combining these groups of students into the same learning experiences has proven to be a challenging task, a task that is beyond simply providing technology that connects the students who participate through the two modalities. Accordingly, exploring new ways to provide integrated and enriched learning experiences to both tracks of students is a vital interest to the authors and to the program as a whole.

The CEPSE/COE Design Studio is an in-house resource for the research, design, and support of technology-mediated learning contexts. It plays a significant role in addressing, and learning from, the challenges of implementing rich synchronous hybrid learning experiences. The authors of this paper are actively engaged in this program and the Design Studio. The first author is a professor at Michigan State University and Director of the Design Studio. The second author serves a dual role as a doctoral candidate in the Educational Psychology and Educational Technology (EPET) program at the same time that he serves as the Assistant Director of the Design Studio. The third and fourth authors are doctoral students in the EPET program with research interests in learning and instruction in technology-mediated contexts.

## The Challenge and the Goal

In the pursuit of synchronous hybrid classes, we have experienced significant challenges. Our commitment is to provide a comparable learning experience for all students, in whichever mode they study. Yet, this goal is surprisingly hard. One question that students ask speaks volumes for how students understand their own engagement in class. This occurs when there is live (synchronous) interaction involving both face-to-face and online students. Frequently, an online student will say, "I'm sorry to interrupt. Can I say something?" This question reveals an awkward reality, which is that the online students often think of themselves as existing in a secondary stratum. Indeed, the apologetic qualifiers in their statements suggest that they perceive their attempts at interaction as interruptions to the primary environment, namely, the physical space where the instructor is.

The goal of our teaching is that each student understands himself or herself as being among the primary participants in the class. Where there are limitations in their interaction, such as engaging digitally rather than physically, we want students to know that they are cared for and fully welcomed. Brophy (2000) states that "Productive contexts for learning feature an ethic of caring that pervades teacher/student and student/student interactions and transcends gender, race, ethnicity, culture, socio-economic status, handicapping conditions and all other individual differences" (p. 8). Engaging in class only through technology, as our hybrid students do, is perhaps something like coming to class with the aid of assistive technology such as a wheelchair. In the same way that we would not want a student to feel apologetic about the presence of their wheelchair, we do not want online students feeling awkward or intrusive in synchronous hybrid learning environments. Our goal is that we remove the sense of intrusion or limitation, so those with the assistive technology do not feel the need to apologize, and they are treated as full members of the learning environment.

## Social Presence

A theoretical framework that helps guide our design is that of social presence (Biocca, Harms, & Burgoon, 2003). Simply put, *social presence* is "the degree to which a person is perceived as 'real' in mediated communication" (Cobb, 2009, p. 241). From this perspective, a significant concern in synchronous hybrid teaching and learning is that students who join class via technology would not be as real as students who are physically present. Biocca et al. (2003) describe social presence as involving (a) copresence, (b) psychological involvement, and (c) behavioral engagement. When students feel copresent, they are aware of each other and feel that they are in the same place. Psychological involvement includes engagement in an interpersonal relationship in which there is mutual understanding. Behavioral engagement can include "eye contact, nonverbal mirroring, turn taking, and so forth" (Biocca et al., 2003, p. 465). Bringing these three factors together generates a context with a high social presence in which all participants are welcomed and valued as people, not merely an image on a display or a body in a seat.

Our goal is that we enable a comparable sense of social presence to both our on-campus and hybrid students. Initially, our thinking was that we would work to enhance the social presence of online students so that they experience the same level of belongingness and value as the face-to-face students. In many ways, this is a helpful model that accurately describes some of our courses. However, we have encountered times when face-to-face students have expressed that their own social presence was reduced due to the focus on online students to the extent that online students had a greater social presence than that of face-to-face students. As such, we are now seeking to avoid any

degradation of presence for either group, while working to enhance presence for both groups.

**The Story of This Design Case**

This paper describes our unfolding journey in pursuit of this goal. We have tried many things, with many failures and some seeming successes. With each iteration of our unfolding design, we describe our impetus for the new innovations, the innovations themselves, and the lessons learned, both good and bad.

In what follows, we will speak about participants as being either face-to-face or online. It should be noted that generally the students in the on-campus mode of our program took classes face-to-face and the students in the hybrid mode took classes online, although this was not required and it was not always the case. In fact, one of the rich learning experiences was for students (and instructors) to experience the class environment in the alternate mode as compared to their normal experience.

The information we report for this case came from multiple sources, depending upon the individual courses involved. We as authors of this paper were directly involved in several courses, either as students, technology navigators, or researchers. Our direct observations of the interactions in the class informed much of our thinking. In addition, we did pre- and post-surveys in many courses as well as several focus groups, and both face-to-face and online participants were included in these methods. The number of respondents, focus group participants, and hours of observation for the various studies are shown in Table 1. We found that all of these sources of information were useful, although focus groups and direct observations certainly provided the richest source of information that shaped our understanding most significantly.

## 2D TELEPRESENCE

**The Impetus**

In our initial efforts to implement synchronous hybrid course designs, we started with several courses in which comparable numbers of both hybrid and face-to-face students

had enrolled. Each of these courses had between 6 and 20 students. Since we had just a single faculty member to teach each of the classes, and these faculty members did not have the time to teach two separate sections of the course, we decided to pursue the vision of integrating both sets of students in the same learning experience. As mentioned earlier, this vision is what we call "Synchronous Hybrid" learning, although at the time we used the term "Synchromodal" (see Bell, Sawaya, & Cain, 2014).

The courses ranged in respect to content and pedagogical approaches, but all of them were graduate courses in education. Some of the courses included individuals at various locations who would join via videoconferencing on their own personal computer devices. Another course was essentially two classrooms on two different campuses that we chose to link together, again via videoconferencing. In this latter case, the instructor would alternate locations, sometimes teaching at MSU, and sometimes teaching at the other location.

For all of these courses, our goal was that students would have a comparable learning experience with comparable learning outcomes. It should be noted that the nature of these different graduate courses in education did not lend themselves to an easy direct comparison of outcomes, such as might be possible in courses where the intended educational outcomes lend themselves to assessment via objective testing. Consequently, our comparisons focused on observations by members of the Design Studio and reflections (through surveys and interviews) from the instructors and students.

**The Innovation**

Our approach for implementing synchronous hybrid learning in these courses was via videoconference technologies. In hindsight, we now refer to this as "two-dimensional telepresence" (2D). This is in recognition of the fact that online students in these approaches appear within the physical classroom in a 2D space on a screen that is fixed to a wall in the classroom. Moreover, online students experience the class from a fixed perspective on their own 2D displays. In short, our goal was that everyone could see and hear both ways, that is, online students could see the local classroom and hear what is being said, and face-to-face people could see online students (at least those who were speaking up) and hear what they say.

Figure 1 shows a typical setup for these classes. In this course, a central pedagogical strategy was for the instructor to guide a whole class discussion in which each student was expected to contribute to the group dialogue. Other courses gave a greater emphasis to lecture, whether by the instructor, individual students,

| MODEL | # OF COURSES | SURVEY | FOCUS GROUP | OBSERVATIONS |
|---|---|---|---|---|
| 2D | 3 | 10 | - | 95 hours |
| 2.5D Manual | 3 | 10 | - | 140 hours |
| 2.5D Auto | 2 | 55 | 12 | 100 hours |
| 3D | 1 | 22 | 12 | 50 hours |

**NOTE.** There was overlap in two courses across these models.

**TABLE 1.** Number of participants in data collection.

or guest presenters. Our initial approach was to display the videoconference session on a single large monitor in the room, and we would use a single camera to project the classroom experience to the online students.

We used various technologies to implement this 2D approach. In particular, we primarily used PolyCom and GoToMeeting. PolyCom promised the potential for multiple cameras, remote control of cameras, and rich video quality, while GoToMeeting made it possible for students without Polycom technology to join with free software and standard technology (i.e., a computer with a webcam, microphone, and headphones or speakers). We have also made use of Skype, Google Hangouts, Zoom, and Adobe Connect in connection with 2D approaches.

**The Successes**

Generally speaking, we were pleased that courses we offered using this 2D approach worked. That is, both instructors and students expressed that the intended and expected learning took place. There were headaches and glitches, but the consensus was that it was possible to teach and learn using this approach.

**The Failures**

Our general sense of success was mingled, however, with very clear indications that there were significant issues to address. The major troubles in our 2D approaches can be categorized under the headings Audio and Video. Embedded in these two problem areas are perceptual issues that relate to affective factors such as satisfaction, social presence, member autonomy, and transactional distance. While these

psychological factors will not be discussed in depth in this paper, we note them as key planning and motivational points in our efforts to innovate synchronous hybrid learning designs.

*Audio*

As we developed our 2D approaches, we learned that effective audio is both harder to manage and more fundamental than video. The latter issue, the fundamental nature of audio, now seems obvious to us in retrospect. When online students could see the classroom but could not hear anything, they felt completely left out. Hearing without seeing, on the other hand, enabled them to understand what was happening and follow along.

We had several failures with audio. In one case, we were meeting in a room that was overly hot because of having outside windows that were south-facing in warm months. One of our strategies to address this heat problem was to remove the diffuser from the air conditioning vent in the ceiling. This helped cool the room, yet at the same time, it resulted in online students hearing nothing but wind noise in the class. This experience introduced us to a persistent issue: knowing the experience of people "on the other end of the wire" is essential but challenging. To this day, we experience variations on this issue, such as when online people do not know how loud they are speaking, and they are unable to tell if they are essentially whispering or shouting unless someone tells them.

In another case, we had an audio channel that was designed to adapt automatically to the sound level in the room, which



**FIGURE 1.** A 2D Telepresence approach using a single camera and monitor.

seemed like a good idea. Unfortunately, when the room was quiet, the microphone sensitivity automatically went up until it picked up the sound of traffic outside the room, which was then more distracting to the online students than it was to the face-to-face participants who were physically close to the traffic. What is more, the time and attention required to address these audio problems were frustrating to some of the face-to-face students. That is, precious time in class was spent solving technical problems for the online students who could easily be viewed as costly intrusions into the face-to-face environment.

A constant concern with audio is feedback loops and echoes. Thankfully, technology has improved significantly since those early days in terms of echo detection and cancellation. We generally advised students to use headphones to reduce the likelihood of this possibility.

In one course, we had what we like to refer to as a "blender moment." One of our online students, while listening to class, decided to make a snack during class, one of the perks of being an online student! Unfortunately, this student forgot to turn off her microphone, so everyone ended up listening to the blender. It was not obvious to anyone what was happening at first, and even when it became clear where the sound was coming from, there was nothing they could do about it because the blender was too loud for that student to hear people trying to get her attention.

All of this taught us that paying attention to audio is a critical concern for synchronous hybrid courses. The human ear is a much more powerful instrument for discernment of different sounds, and for adjusting to louder and softer sounds, than the technology we could access and afford. Ensuring that the right voices can be heard, and that other noises do not distract, continues to be critical and challenging.

*Video*

In contrast to the issues with audio, we expected video to be a concern, and it was a concern, but not in the ways that we thought. We anticipated that bandwidth would be a big concern in having sufficient quality for the video signal. Rarely has that been an issue for us. Rather, we have wrestled both with displays and with cameras.

With displays, we tried to determine the best location to show the online students in the face-to-face classroom. We started by using a display in the front of the class. This was a simple choice at first because that is where a large screen display already existed in the room. Moreover, it seemed a good way to include more people in class, in effect extending the circle of students.

One of the failures regarding video was the realization that this approach tended to constrain the attentional capacities of the instructor. That is, the instructor could be in front and

look at the face-to-face students as he or she usually did in class, or could step back and be with the face-to-face students and look at the online students at the front of the class. It became apparent that putting the online students at the front of the class tended to lead to two modes in class: focusing on face-to-face students or focusing on online students. In fact, through surveys completed at the end of class, both face-to-face and online students expressed that online students were treated more as individuals in this class, and face-to-face students were treated more as a group. For example, online students were able to chat visibly, and their names always appeared with their chat entries, while face-to-face students did not have this opportunity. So everyone learned the names of online students more quickly than those of the face-to-face students. The instructor also gave priority to reaching out to online students individually, often calling on them by name, because of his or her concern that they feel included in the class. Moreover, psychologically, the online students each had their own location, while face-to-face students just were thought of as being in the classroom. Given these factors, it became clear that thinking about both online and face-to-face students in a comparable way was surprisingly challenging.

To address this issue, we moved the online students to the back of the class. We did so by putting a second large display in the class, referring to the rear display as the balcony. The front display returned to its former role as a typical projector for PowerPoint presentations or other documents. This approach helped the instructor think about all students at once. Unfortunately, it made the online students less visible to the face-to-face students. So the instructor could more easily think about both groups at once, but when an online student wanted to speak, all of the face-to-face students had to turn around. This approach also complicated the desire to share the PowerPoint that the instructor was presenting in the class since a different display was being used to communicate with the online students, and thus the screen share option of the videoconference technology was not able to share the presentation display.

In addition to the question of where to display online students, we wrestled with the question of where to place the camera that would present our local classroom environment to online students. Our first effort was to put the camera in the front of the room just above the main display. The rationale was to enable online students to see the face-to-face students, and when the instructor wanted to talk to the online students, he or she would naturally turn to look at the display and thus would also be looking at the camera by which those students would see him or her. The practical reason that was also significant was that the computer in the room that was part of the video teleconference was in the front of the room (connected to the primary display), so it was natural to include the webcam in that same location.

The obvious problem (in retrospect) was that online students spent most of the time seeing the back of the instructor's head. Moreover, we realized that this strategy effectively divided the attention of the instructor, that is, the instructor was paying attention either to the face-to-face students or to the online students, but not both simultaneously.

Our first attempt to address these problems was to move the camera to the side of the room. The idea was to enable online students to see both the instructor and the face-to-face students all the time. In fact, they were able to do so. The problem was that visually no one ever looked at the online students. There was nothing to see where the camera was, so no one ever looked there. So even when people were talking to the online students, it was not obvious that they were since there was never any sense of eye contact.

Our next attempt was to move the camera to the back of the room, which was very natural technically when we also moved the primary video conference display to the back of the room. The audio and video connections to the videoconference were both linked to a single computer in the back of the room. This approach, however, led to two new problems. First, the view of the instructor by the online students was not very good. Since there was a significant distance between the camera and the instructor, the instructor's face was not easily visible. Second, the online students would only see the back of the heads of the face-to-face students, relegating online students to being behind the last row of the classroom.

Eventually, we realized the value of including multiple devices in the classroom in the videoconference sessions. Doing so enabled sharing different perspectives and resources in the same channel at the same time. For the video display, we enabled mirroring the front display to the back so that both the instructor and the students could see the online students at the same time without turning around, thus making visual interaction with both face-to-face and online students more natural and more seamless. For the camera, we included one at the back of the room as well as at the front so online students could see both the instructor (albeit a distant view) and the face-to-face students.

The biggest concern with this approach was that only six video feeds could be shared at once using the videoconference tool we had at the time. This meant that including two video feeds from the classroom limited online student video feeds to four rather than five. Since we had more than five online participants, we already had the difficulty of deciding whose video feed would appear in the classroom. Taking away one of the five possible feeds simply made the problem worse.

### The Next Steps

As noted earlier, the courses we offered employing 2D Telepresence were successful in the sense that they enabled the courses to be taught and for the students to learn the required material. Our data suggested that online students' satisfaction was influenced by the idea that they would not have any access to the courses if they did not connect via 2D telepresence. Thus, from this perspective, the 2D Telepresence approaches we implemented were clearly better than nothing. At the same time, they certainly fell short of our goal of having face-to-face and online students be comparable partners in their learning experiences. This sense that we had not yet achieved parity for the online group, along with new ideas for potential innovations, led us to engage in a richer model for synchronous hybrid classes.

## 2.5D TELEPRESENCE: MANUAL

### The Impetus

In our 2D Telepresence model, we had enabled visual and auditory connections between face-to-face and online participants, although admittedly those connections were far from perfect. We were interested next in trying to figure out how to achieve a greater sense of social presence for online students, particularly in those courses that had a heavy emphasis on large group discussions. In particular, our hope was to bring the local reference point of an online student, which was outside the walls of the physical classroom, into the space occupied by face-to-face students. In other words, we wanted the online students to view the classroom from perspectives similar to those of face-to-face students, and we wanted the face-to-face students to feel as though the online students had taken a seat right next to them. We refer to this approach as manual two-and-a-half dimensional telepresence (2.5D). Cameras and displays would no longer be restricted to static positions on walls (2D); they would now come into the space of the classroom, among the face-to-face students and instructor but still lack the autonomy to move on their own (2.5D).

### The Innovations and Findings

*TriPad*

Our first innovation to support this closer integration of online and face-to-face students was to use what we called a "TriPad." This device was essentially an iPad on a tripod (see Figure 2), and its purpose was to provide us with a wireless movable camera. When this iPad was added to the class videoconference session, its camera view became the primary view of the classroom for online students. Now, instead of having our cameras mounted on the wall (as if the online students were sitting at the edges of the room), we could begin to give online students "the best seat in the
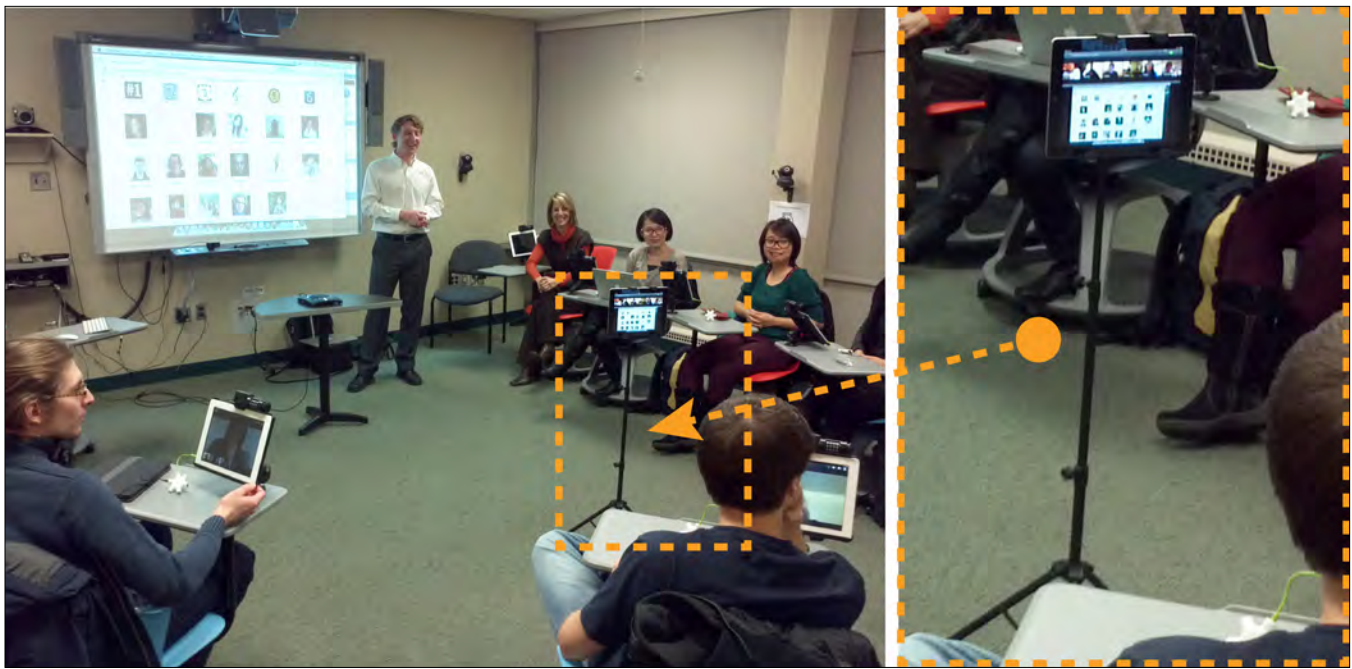
**FIGURE 2.** Manual 2.5D Telepresence approach using the "TriPad."

house" by putting the TriPad in the front center of the room facing the instructor. Furthermore, when a different person started to speak during class discussions, the TriPad could be moved to face that person, much like a face-to-face student would turn to face a different student speaking in the class. The face-to-face students largely ignored the picture on the iPad of the videoconference session because the view was limited to a set of barely visible thumbnail images of the online participants and the shared screen (see the inset in Figure 2). Again, the TriPad served simply as a way to provide an embedded view of the classroom to online students.

We found this approach to be effective for what it sought to accomplish. It did not help face-to-face students see the online students any better because it did not change the appearance of online students in the classroom. It did, however, mark our first attempt to provide a mobile and embedded perspective of the local classroom for online students.

At the same time, using the TriPad in class proved clumsy and a bit distracting. Turning one's head in class to look at others who speak is unobtrusive, whereas turning the TriPad was an obvious, overt action without a clear connection to what was happening in the classroom. It created a sense that "someone is watching us," where "someone" did not have a name or presence in the class (at least not connected with the viewing device). For face-to-face students, it is generally quite natural to have someone in class turn to look at them when they speak in class. This was not the case when using the TriPad; it became strange and distracting to have to point a device at people every time they took the floor. We also struggled with finding a good tripod that was portable, affordable, and stable. After multiple attempts (and one

shattered iPad display), we found a wheeled stand, something like an IV cart from a hospital that was relatively small and easily movable yet stable.

*Node chairs*

Our second innovation to support the closer integration of online students into the face-to-face environment aimed at supporting that integration in both directions: to help online students see the classroom better (as with the TriPad), and to help face-to-face students see the online students better. This innovation took place in a class that had just nine students with four being online. The class was largely dependent upon whole group discussions in which all students were to be active participants. To accomplish this, we attached iPads to movable student chairs, for which we used Node Chairs (see Figure 3). In addition, we had online students communicate 1:1 with these iPads on Node Chairs. This was a significant departure in how we envisioned interactions between people; our previous solutions for communication all involved multiple students connecting with each device, so these students had to share the same camera perspective and display space.

A key step in the implementation of this "iPad on Node Chair" solution was to have local "advocates," that is, face-to-face students who would be paired 1:1 with online students. It was the responsibility of the face-to-face student sitting in the chair with the iPad attached to move and swivel the chair so that the iPad would always be facing the center of the conversation in the class. A significant advantage to this approach was that whoever was at the center of the conversation in the class could see the online student looking

**FIGURE 3.** Manual 2.5 Telepresence approach using the "iPad on Node Chairs."

while also ensuring that all online students could hear all students (both face-to-face and online) in class. In addition, each audio connection was separate (because each online student was using a separate iPad), so troubleshooting was required for multiple video-conferencing points throughout the room. Finally, we sometimes had "absent advocates," that is, instances where face-to-face students turned their heads but left their iPads facing a blank wall or someone who was not speaking at the time. We realized this arrangement left online students unduly dependent on their advocates, and we needed to work out reliable yet unobtrusive means for online students to get the attention of their face-to-face advocates in the case of audio or video trouble.

directly at them. Moreover, each online student would appear much like the face-to-face students, with their heads being close to the same size and close to the same location as face-to-face students. Perhaps due to the collegial culture in this class, face-to-face students who served as advocates for online students did not express that this responsibility was problematic to them. However, this silence does not mean that this responsibility was without cost for these students.

In retrospect, we realize that one of the greatest benefits of this iPad on Node Chair approach was that online students began to have their own physical space in the classroom. When the instructor looked at the online student's iPad, it was clear to the online student and to the other students in the class that the instructor was, in fact, giving direct attention to this student. With our previous solutions, there was no visual way to distinguish the attention among multiple online people; when the instructor looked at the same display and camera for all online students, the view for every student (face-to-face and online) was identical.

Nevertheless, there were significant challenges with this approach. First, the online students now had a rather narrow view of the class. The iPad camera is not wide angle, so online students felt as though they had blinders on, unable to get a big picture of the class. We also struggled to ensure that everyone could hear online students when they spoke,

*Ad hoc*

Our third innovation actually took us by surprise, and we are still working to understand how to make use of it. That is, individual students in various classes have implemented manual 2.5D Telepresence solutions entirely on their own. For example, one class included more than 20 people and had a greater emphasis on a lecture with questions and answers. As such, students primarily needed to listen, and it was not as critical that they have the opportunity to talk with other students in the class. While this class was designed only for face-to-face students, at times one of the face-to-face students would be unable to come physically to class. That individual would ask someone who was going to be in class to initiate a Skype or similar video solution so that the absent student could listen and sometimes see and even be seen and heard in class. What is more, this strategy could be initiated without depending upon the instructor or other support personnel in the classroom, as the in-class students would simply use their laptop computer as the technology for this link.

We have many questions about this ad hoc approach, not the least of which are questions concerning privacy. At the same time, it provided an intriguing possibility for solutions that require nothing beyond the existing technology and people in a class, and no additional effort or attention of the instructor, to expand access to the physical classroom.

**FIGURE 4.** Autonomous 2.5D Telepresence approach using Kubi (device shown on the right).

## The Successes

*Social presence: Attention through 1:1 channel*

One of the biggest successes from 2.5D Telepresence came through the 1:1 student to device ratio. That is, when each online student had his or her own visual space in the classroom (for both presentation and perception), their sense of copresence in the class seemed significantly higher. Furthermore, an important example of behavioral engagement is the set of rules for the interruption. In our context of doctoral seminar courses, the conversation often moves quickly between speakers. It is not unusual for someone to interrupt another person in the middle of a sentence with a related idea. The instructor of the course in which this 2.5D Telepresence was first used commented that these rules of interruption, commonly and effectively used in face-to-face courses, actually translated well into this synchronous hybrid format. That is, students were able to see and hear each other as individuals and in the same space with such a degree of clarity that this kind of quick interplay between participants was possible. This stood in stark contrast to the common difficulty of multiple people speaking simultaneously in a phone conference, either without knowing they are doing it or without knowing who should take priority.

*Social presence: Closeness of embedded devices*

Another significant success in this use of 2.5D Telepresence is the benefit gained by bringing the teleconference devices into the same space occupied by the face-to-face students. When online students appeared in the midst of face-to-face students, the face-to-face participants reported that the online students were now a part of the class. For an analog comparison, we conceptualize this transition in terms of "having a seat at the table," rather than being "forgotten in the balcony or back row." Similarly, when online students could view the class from the perspective of face-to-face students in the class, rather than from a back wall, they felt more connected to the face-to-face students in the class.

## The Failures

As noted above, we continued to find significant limitations in the audio and video channels. The human capacity for seeing and hearing is so far unmatched by the technology we have been able to use. For instance, people can understand loud and soft sounds in close succession; they can distinguish wanted sounds from unwanted sounds; and they can adjust attention almost instantaneously. Each of these capacities is so natural for people that we hardly notice when we are doing them, whereas current technology does each of them much more poorly and slowly, if at all.

We also continued to be concerned about the lack of control that online students experienced regarding their own participation in class. Having a local advocate to help them was a good step, yet that local advocate had no direct way of knowing what the online student was experiencing. Without this direct feedback loop, adjusting and learning how to

offer a better experience to the online student was slow and challenging. Moreover, even when done well, we felt this local support did not empower the online student as an independent learner in the class. Finally, we suspected that by making and emphasizing local advocacy arrangements, we might have created the impression that online students were a kind of burden the face-to-face students had to bear.

**The Next Steps**

As a result of this experience with 2.5D Telepresence, we were very interested in the possibility of giving control of the experience to the online student. This meant an explicit transition from hosting videoconferences on behalf of the online students to giving the students access to telepresence devices they could control themselves. Thankfully, we were able to procure devices that provided this autonomous control, and we also were able to find instructors willing to experiment with this new technology in their classes.

## 2.5D TELEPRESENCE: AUTONOMOUS

**The Impetus**

Research from multiple directions led us to expect that, if we could give online students greater control of their presence in the physical classroom, we could improve their social presence and engagement in the class. First, research suggests that student achievement is higher when students have greater control over their learning experience (Eshel & Kohavi, 2003). Second, research suggests that embodied experiences (such as those for games involving virtual worlds) lead users to perceive themselves as being within that virtual world (Jarmon, 2009). So we expected that students who are embodied via robots would perceive themselves as having a greater presence in the classroom, and thus, they would perceive themselves as being more a part of that class. Finally, when students have a greater sense of their individuality (such as when they can behave and be perceived individually), they will have a greater sense of social presence, and thus avoid the problem of deindividuation (Annetta & Holmes, 2006). Accordingly, we chose to introduce various devices that would enable online students to control their own devices in the face-to-face classroom.

**The Innovation**

The device we experimented with for Autonomous 2.5D Telepresence was the Kubi, as seen in Figure 4. If an iPad in a 1:1 teleconference can be thought of as the online person's head, then the Kubi can be thought of as the online person's neck. That is, the Kubi enabled the online person to turn his or her head to face different parts of the physical classroom without the aid of anyone else.

What is more, the interface allowed for memorizing people's locations, so with a single click, the device could be turned

to face someone rather than having to make minor adjustments each time attention was turned. This technology thus allowed online students to see various parts of the classroom, and to be seen from different vantage points in the classroom. In addition, these students could express themselves in the classroom in a new way, namely, by directly expressing attention (via pointing their iPad screen and camera) to different individuals in the class.

One particular implementation of this approach involved a course with 12 online students and 3 face-to-face participants (the instructor, a student, and a teaching assistant). As with many of the courses in our work, this class also made extensive use of large group discussions led by the instructor. The class sessions in this course initially used a static 2D approach for communication between the online and face-to-face participants. Midway through the semester, we introduced two types of robotic telepresence devices: 10 desktop Kubis robots and 2 fully mobile Double robots. See Figures 5 and 6 for a comparison of the two approaches.

A central concern for the implementation of this innovation was the throughput required for the wireless interface. In particular, each of the 12 iPad-based video feeds of the online students required a separate video connection that not only used our wireless connection, but also required network bandwidth between our building and the Kubi server, which was in another state. We looked at the specifications of the Kubi (more than 1Mbps upload and download is suggested) as well as our wired and wireless networks. In talking with our local network support, we chose to add a second wireless access point, and then we experimented to see what would work. Because neither the wireless nor the wired network was dedicated only to our classes, we were, of course, dependent upon what other uses were occurring at the same time. Probably, because this course met in the evening, network throughput was not a significant problem for us.

**The Successes**

Response from students and instructors was very positive regarding this transition to the use of Autonomous 2.5D Telepresence. Upon introduction of the robotic telepresence devices, the online students reported a significant shift in their thinking. With these devices, they said, they began to think of themselves as actually being in the physical classroom rather than observing it from afar. The ability to control more aspects of their presence was a key part of this change in thinking. In addition, one face-to-face student observed that having online students appear on devices physically located the way other face-to-face students would have been located (i.e., in a semi-circle around the instructor), and having those online students able to turn on their own, made her feel like she was no longer "alone" in the classroom.

**FIGURE 5.** 2D Telepresence approach using Zoom videoconferencing on an 80" monitor.



**FIGURE 6.** Autonomous 2.5 / 3D Telepresence approach using Kubi and Double robotic telepresence devices.

Her sense of their presence as people, that is, their social presence, increased dramatically.

Students also continued to be enthusiastic about the "discernible attention" benefit of 2.5D Telepresence. That is, when the instructor turned to look at a student, that student was certain that he or she was the focus of the instructor's attention. We believe that awareness of attention was an important contributor to the students' report that their

relationship with the instructor grew more with the use of 2.5D Telepresence than with the 2D approach.

**The Failures**

At the same time, being on these robotic devices still fell far short of actually being in the classroom. Several things contributed to this shortfall. First, the audio continued to be a challenge. The volume for some people was too loud; for others, it was too soft. In both cases, those people were not

aware of how they were coming across. In addition, audio limitations made talking between two online students on telepresence devices (also known as a virtual-virtual connection) more challenging than talking between a face-to-face student and an online student (also known as a face-virtual connection). Moreover, even when the audio itself was not problematic, the audio was not stereo, so when online students heard a voice from a person who was not in their view, they did not know whether to turn left or right. Students reported that they learned in these situations to watch the Kubis on the other side of the classroom to see which way they turned in order to figure out the likely source of the voice.

In addition, the ability to see the class clearly continued to be limited. Of greatest concern was the narrow field of view offered by the iPad. The placement of the Kubis near the center of the room meant they could turn their attention more selectively to different areas of the classroom, but they were unable to see the classroom as a whole. As a result, students reported having a sense of wearing blinders, that is, they were able to see far less on the iPad (without turning) than they could with their naked eye. Moreover, because their field of vision was quite limited, they were quite uncertain as to whether others who were using Kubis could see them. Both factors certainly had a negative impact on social presence.

We also observed that when other students' Kubis were turned away from a student, all that was visible was the back of the iPad. In this situation, we once again felt discernible attention was in play. Online students who turned their Kubis to focus on one part of the classroom would essentially

disappear for other students who could only see the back of their device. In other words, the ability to give discernible attention in one direction meant losing discernible identity in other directions, given the nature of these robotic devices (see Figure 7).

Students also reported frustration with the slow turning speed of the Kubi. It is not as though the Kubi moves particularly slowly, except in comparison to turning one's eyes or one's head. So students reported thinking, "If that person I can't see isn't going to talk for too long, it isn't worth trying to turn my Kubi only to have the speaker change before I even see that person." They also reported wondering how distracting their own movement was, not knowing if it made a lot of noise in the physical classroom or whether people would be conscious of their movement.

Now that online students could control their own device in the physical classroom, however, they also realized that others could be drawing conclusions about the student based on what that device was doing. For example, students wondered if others would think they were staring too long at a single person simply from the positioning of their device. Conversely, if they did not turn to look at a speaker because they felt it was unnecessary to do so, students wondered if others would think they were not paying attention. We believe these concerns are a great success in disguise. The fact that students became concerned about what other participants thought about their movements revealed how richly they identified with that device; it extended and represented their presence in the classroom in a way that the 2D and 2.5D Manual approaches did not.



**FIGURE 7.** Students positioning their Kubis in different directions during an Autonomous 2.5D Telepresence session.

## The Next Steps

The obvious next step for us was to explore the potential for online students not only to turn their heads in class, but also to move about the room. At the same time, we continued to be aware of the challenges for visual and auditory channels of communication. We were able to acquire devices that provided this greater autonomy, as well as an instructor who was willing to experiment, so the next stage of this journey could begin.

## 3D TELEPRESENCE

### The Impetus

As noted above, giving online students greater autonomy regarding their in-class experience, while also integrating them more closely into the face-to-face context, seemed to have a dramatic impact on how they thought of themselves as students in the face-to-face class. Our expectation was that adding the ability for students not only to turn their heads but also to "walk around" the class would increase this impact. They would be less dependent on other people for their engagement, and thus they would think of themselves, and be thought of, increasingly as full participants in the class. In addition, they would have the ability to do more of what a full participant in a physical space might do, which is to move to another part of the class for various reasons, not the least of which is the ability to choose which people to talk with before, during, and after class. We refer to this mode of interaction as 3D Telepresence since students not only took up physical space in the classroom (via telepresence devices), but they also directly controlled their camera views and physical location.

### The Innovation

The device we used was the Double Robot. If a Kubi with an iPad can be thought of as a person's neck and head, then the Double Robot can be thought of as the person's body (see Figure 8). Essentially, it is a movable base (looking much like a Segway scooter) with a stick and an iPad at the top. The Double Robot is also height-adjustable, meaning online students could modify the vertical position of the iPad display and camera. The difference in the type of autonomous telepresence afforded by these two devices is important. For instance, when the Kubi was added to a small group discussion, or when a Kubi needed to be relocated, a face-to-face student would have to pick up that Kubi and



**FIGURE 8.** Two students position their Double robotic telepresence devices in front of the instructor as part of an Autonomous 3D Telepresence approach.

move it. With the Double, the online student could move without assistance.

## The Successes

Student enthusiasm was an obvious and immediate success in using the Doubles. Online students expressed great delight in their newfound ability to move about the classroom that they had previously only viewed from a static camera position. They reported not realizing how constrained they felt when they had no power to turn or move in the class until they actually had the ability to do so. It came as no surprise that this initial delight lessened over time, yet some of this effect continued.

Students also reported the significance of being able to move around the room. For example, if they did not have a good view of what was happening or who was speaking, students reported that they could simply move to another location in the room. This autonomous action is in contrast to having to ask someone to help them move, or, more commonly, to tolerate a less than ideal situation for engaging in class. They also found satisfaction in being able, literally, to go to the instructor after class and ask a question. Both face-to-face and online students expressed satisfaction in being able to adjust the Double Robot to a height suitable for standing or sitting conversations with others. Online students reported that being able to look at others at eye level made their interactions more natural and comfortable. And of course, they enjoyed strolling down the hall to the coffee shop!

When physical movement was required in a class, students expressed satisfaction in being able to move their device on their own, rather than being dependent upon someone to move it for them. They could manage it for themselves, and they appreciated the autonomy. In contrast, when the class broke up into small groups, the online students on the Kubis had to depend on face-to-face students to move their devices for them.

## The Failures

In addition to the enthusiasm for the Doubles, we also encountered some challenging problems.

*Driving anxieties*

First of all, there was a range of responses by online students to "driving the Doubles." Some seemed to take to it very naturally, immediately moving boldly around the room, while others were quite hesitant, worried that they might bump into something or someone. Anecdotally, there was a possible correlation between experience and enjoyment in playing first-person video games and confidence in driving the Doubles. In any case, some online students expressed that the extra complexity and cognitive load of managing

the Double were enough to make them prefer coming to class on the Kubis.

It is also important to note that face-to-face participants sometimes also felt this anxiety. Just as people have a sense of personal space in relation to other people, our students expressed a sense of personal space in relation to robots. Moreover, when the drivers of the robots found driving challenging, they would at times intrude on the personal space of face-to-face students, and some face-to-face students even expressed that there was something "creepy" about the robots getting too close to them.

*Narrow field of view*

Field of view also continued to be a significant concern. In fact, the Double had a narrower field of view than experienced on the Kubi. This was because the iPad in the Kubi could be mounted in landscape mode and thus allowed users to see a wide field of view, whereas the Double required that the iPad be mounted in portrait mode only. This narrower field of view made students feel more constrained, and it necessitated more movement in order to see the same limited field as the Kubi, which brought a greater cognitive load and more distraction.

*Unstable robots*

A few times, we actually had robots that became unstable. Whether it was because of something they rolled over on the floor or a poor network connection at an inopportune time, we had one robot fall over and that made people (both face-to-face and online) concerned. Unsurprisingly, these events made those who were hesitant to drive the Doubles even more hesitant.

## CONCLUSION

Our journey with synchronous hybrid courses and telepresence is far from over. From a technical perspective, we expect that the range and capability of available devices will continue to grow. At the same time, we expect that further experimentation, design, and reflection will open up new pedagogical strategies that will lead to increasingly effective synchronous hybrid experiences for both instructors and students.

The experiences and insights described in this design case have taught us that different contexts require different technologies and different strategies to reach their full potential for fostering meaningful learning interactions. We remain committed to investigating the complexity of solutions in different technology-mediated contexts rather than finding a single best solution that works everywhere or even in most settings. Furthermore, our exploratory journey from 2D to 2.5D to 3D telepresence is not meant to suggest that 3D telepresence is somehow a better or more evolved solution

than 2D or 2.5D designs. That being said, our goal of increasing perceptions of social presence while reducing cognitive load and distraction resulting from the telepresence devices continues to serve as a helpful framework. This goal involves selecting and developing appropriate technologies, and selecting and developing appropriate design strategies for face-to-face and online participants.

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