Broadening Participation for Remote Communities: Situated Distance Telepresence

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ABSTRACT

Our work is concerned with how embodied communication involving speech and gestures may be mediated through mobile tele-robotics and augmented reality to support hands-on distance mentoring. Following work in the psycholinguistics of embodied communication (e.g., meaning is expressed through gesture, gaze, and speech), a four design-implement-test-deploy-evaluate study was undertaken. We investigated whether and how powerful multimodal language to support explanation and mentoring may be mediated over distance through the designs.

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Sidebar 1: Multi-modal Communication and Distance Mentoring

- **Face-to-face Mentoring:** Face-to-face mentoring is facilitated through powerful embodied cues and resources (e.g., white boards, impromptu demonstrations, illustrative diagrams.
- **Means of Analyzing of Facilitated Communication:** Multi-modal communication theory furnishes lenses by which we may analyze the mentoring communication facilitated by the technology to determine if and how the technology supports effective distance mentoring.

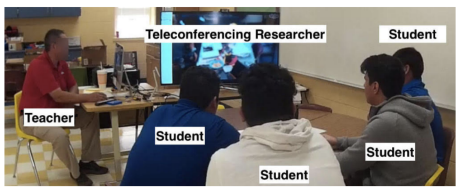

Figure 1: In this pilot research, the college students at Texas A&M University met daily with the students at a far-rural high school at the Texas-Mexico border via video teleconference to provide instruction, mentorship, and guidance, hence engaging in a kind of distance apprenticeship where the college engineering students serve as 'More Knowledgeable Others' (MKOs) both in the role of instructors [15] and more knowledgeable peers [28].

KEYWORDS

Communities of Practice, Zone of Proximal Development, Maker Movement, Micro-Manufacture, Public School, Apprenticeship

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INTRODUCTION

Human language is multimodal, given how our body is engaged in communicative acts through gestures that include our arms, hands, posture, and head (e.g., gaze serving as a communicative nexus for managing turn-taking and directing attention) [16, 26]. Consideration to multi-modal communication is relevant to supporting distance mentoring of hands-on content for two reasons (Sidebar 1). One exemplar case for the need for such a approach can be seen in Okundaye et al. work on college student mentoring rural high school students in Maker technology and manufacturing processes (Figure 1) [20, 21]. Our work seeks to illustrate how the coupling of telepresence robotics with augmented reality may serve to situate mentors‘ gestures in the workspace with mentees.

RELEVANT BACKGROUND

Need for Remote Mentoring

There is a need to equip our students with a fluent grasp of technology and a flexibility of mind to acquire new competencies [8, 27] necessary to engage increasingly technology-infused world of work and life. Currently, there are challenges with the broadening of STEM experiences, leading to bottleneck of school resources (e.g., only 50 % of high schools in the US offer Calculus and only 63% offer Physics [4]) (Sidebar 2). Such asymmetry of STEM experiences could result in lower participation for certain sections of the population (e.g., students of color and rural communities) [18]. One solution proposed is the use of distance learning (Sidebar 3). Students may be better able to direct their energy toward educational goals, and are more likely to graduate if they have access to anchoring relationships with a web of supportive mentors [10]. For physically-predicated content that requires significant hands-on learning, more situated learning approaches are needed [37] (Sidebar 4).

Need for Embodied Communication Support

On-demand videos services (e.g.,YouTube, Khan Academy) provide flexibility in learning time,location, and features (e.g., pausing and reviewing). Likewise, teleconferencing tools (e.g., Skype), tutors and students can engage one another visually and audibly in real time. One challenge that remains of is the

Sidebar 2: Challenges associated with broadening of STEM participation

- **Shortage of Teacher Specialization in STEM:** There is a shortage of instructors and mentors in STEM attributed to fewer teachers specializing in science sub-fields [4].
- **Teachers' Confidence and Familiarity with STEM:** Even when teachers are willing to integrate STEM approaches, there may be challenges in technology, understanding, time, planning, or confidence [11, 31].

Sidebar 3: Benefits of Distance Learning (DL) in the Classroom

- DL could spur engagement in collaborating on questions or in-class problems with online mentors [2].
- DL serves to support the 21st century skills of creating, communicating, and collaborating inherent in contemporary work. [32?]
- DL can encourage students to better articulate and achieve educational goals through access to anchoring supportive mentors [10].

Sidebar 4: Physical Proximity Demands in Maker Based Learning

Physical skills and actions become critically important when the instructor has to show, demonstrate, move about, point, and guide. Vygotsky's social development theory and the zone of proximal development (ZPD) [35] state that knowledge and meaning are socially constructed, and that the student learns within communities [5]. A certain degree of closeness and fluidity in interaction is required for mentors to effectively function as MKOs [37].

Sidebar 5: Intrisic Physical Elements critical to Maker Education

- Materializing children's thinking to design and engineering concepts requires physical representation. [1].
- Learning physical skills for electronics and physical construction comes from "playful, exploratory, iterative style" of tinkering [30].
- The inherent physicality of Making is a key impediment to online sharing of digital designs that require physical manifestation grounded in specific tools and processes [17].

case of physical proximity (Sidebar 4). One notable example is in physicality of Maker-based learning, as is evident by the fact that Makerspaces, workshops and camps usually become the orbital centers for Making (Sidebar 5). With respect to these issues in the consideration to distance learning and physical mentorship, two technologies, telepresence robotics and augmented reality, in the supporting instruction are discussed in sidebar 6.

METHODOLOGY: THREE-YEAR LONGITUDINAL PILOT STUDY

Our ongoing NSF EAGER pilot project [20, 21, 25] on Making and micro-manufacturing, is conducted along the Texas-Mexican border that are typically severely under-resourced [19, 36]. The study provides insights into the challenge of distance mentoring in STEM for rural communities. In addition, it provides the educational context in which we investigate technology support of distance mentoring. Our pilot project investigates how high school students are exposed to a combination of Making [9, 22] and rudimentary engineering skills, knowledge, and practice through a novel distance apprenticeship program [20, 21, 24]. Students in the program produce instructional science kits for use in local elementary school classrooms . A primary component of our 3-year longitudinal pilot was a 'distance apprenticeship' where STEM college students met daily with and mentored the high school team via video teleconference (Figure 1,Sidebar 7). The analysis used the grounded theory approach. Open coding was performed on all data sources, and a set of common axial codes were developed from triangulation of the open codes from all sources.

METHODOLOGY: ROBOT STUDY PILOT

Based on early results from our EAGER pilot, we implemented an initial tele-presence robot design for a second pilot study. We built our design from a base Mobile Robotic Telepresence (MRP) platform that features a web-based interface for navigation, a display screen for the 'head' that contains a camera, and tilt control for the 'head display' (Figure 2). The robot also has a close-in downward-looking camera for collision avoidance. We augmented the robot with an arm camera to provide a close-in view of the student's workspace that is displayed to the mentor. A similar camera is available to the mentor to do demonstrations that may be displayed on a display mounted on the mid-section of the robot. Figure 3 shows this initial design with the display mount on the robot. We conducted a series of three Maker workshops in which high school students constructed a 'LED candle' with an LED mounted on top of a segment of PVC pipe on top of a laser-cut base. The students had to learn both in-screen design skills with the TinkerCAD [34] online design software, and the physical fabrication skills of soldering of wires and applying heat-shrink. The conditions in the sessions were with the mentor/instructor: 1. Physically present; 2. Interacting via large screen video teleconference; and, 3. Interacting via the telepresence robot (Figure 3). For consistency, the same person mentored all three sessions.

FINDINGS: THREE-YEAR LONGITUDINAL PILOT STUDY

From the student's perspective, we found that feedback cycles for help, information, instruction and guidance tend to be long and delayed (Figure 4). One exemplar of this can be seen as students needed to manipulate the camera being used for teleconferencing or their work extensively for soldering an electronics board (Student 1:"If he was physically present we could just call him over to see and we wouldn't have to waste as much time camera flipping so that he could be able to see and we wouldn't have to waste as much time redoing the camera."). From the instructor's perspective, a very common theme was that management of students, providing instruction and guidance was challenging due to lack of co-presence (Figure 3). One example, during student demonstrations, the instructor engaged in extensive speech to have the students spatially manipulate the object in such a way that he or she can make proper assessments (e.g., "Turn it the other way. No not like this, I mean like that.").

FINDINGS: ROBOT PILOT STUDY

We summarize our results where we compared sessions 2 and 3 against session 1 (assuming physical presence is the most effective). In the video teleconference case, the mentor was able to go through the 'instruction phases' of the workshop where he used screen sharing to show how to use TinkerCAD, and he used a prepared video to demonstrate how to solder wires and apply the heat shrink. The session did not allow the students to share individual screens with mentor, and this capability might have enabled the mentor to diagnose the problem the students were having, but this sharing would have to be synchronized with each student's speech (e.g., is the student having difficulty with the CAD view control or does she want to thicken the design component).

In session 3, the mentor was better able to diagnose the problems students had even when they were not able to describe the situation precisely. In one example a student was having difficulty scaling an object in TinkerCAD, and because the mentor had navigated the robot behind the student, he was able to say 'You want to grab the black box and drag it'. He could do that only because he could observe that the black box control points were clearly visible to the student and that the student had repeated tried to drag the edge of the object with his mouse.

CONCLUSION

Our work addresses the concerns for the nexus of technological innovation and access-ability in education and learning, this through coupling Making skills and knowledge with engineering foundations of manufacturing, including process and production planning, and industrial distribution and inventory management (basic supply chains). Tele-mentoring brings together human-computer interaction, psycholinguistic multi-modal interaction, distance learning, and robotic tele-presence to enable remote mentors to support learning in the rural/remote communities.

Sidebar 6: Potential technologies to support distance mentorship

- **Mobile Telepresence Robots:** Mobile Robotic tele-Presence (MRP) is a form of telepresence robot applied in on hands-on mentoring and instruction [14]. MRPs have been employed for language tutoring [13], operating room teaching and monitoring by surgeon [33], and to teach medical-surgical nursing skills [29].
- **Augmented Reality (AR) for Mentorings:** From its inception, education and training has been a major application area for AR [3]. AR provides contextual information for learning across a range of subject areas like mathematics [12], physics [7] and often through 'gamification' of learning [6, 23]. Currently, use of AR to support educational communication is far less studied.

Sidebar 7: Components of Distance Apprenticeship Study

Three main data sources were used for that analysis:

- Oral and written reflections from the undergraduate and graduate student mentors
- Semi-structured interviews with the high school students on experience during teleconference sessions and physically co-present sessions at authors' university.
- Recordings of selected video conferencing sessions.

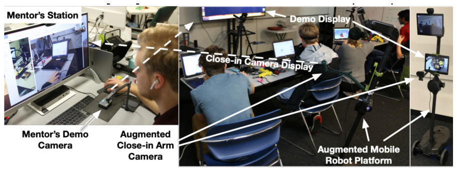

Figure 2: Initial MRP design

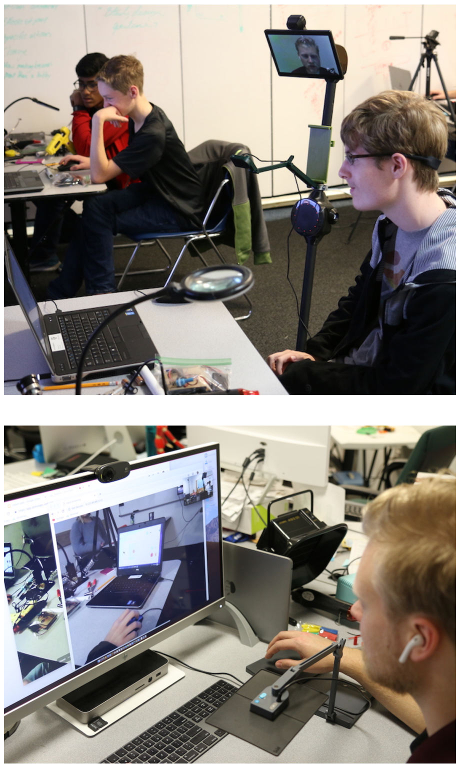

Figure 3: Example of MRP use in session.

SELECTION AND PARTICIPATION OF CHILDREN

Children were selected through a self-selected pool of high school students. Interested students and their parents were given informed consents issued by the researchers’ university IRB. Informed consent states explicitly that audio and video recorded data would be collected. Students for the longitudinal study participated in the study as part of a high school technology course credit. Participants of the tele-presence robot study engaged in one of three half-day studies.

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Students' Perspective
Feedback Cycles
Difficult to get instructor's attention
Difficult to obtain immediate or quality responses
Extraneous Effort for Communication
Need for extensive movement and manipulation of the camera by one or multiple students
Need to move work-in-progress for demonstration
Instructor's Perspective
Classroom Management
Difficult to gain class overview and close-ups
Difficult to maintain student focus on task
Difficult to get specific students' attention
Complexity of Instruction
Need for repetitive instructions
Need for overt/precise step-by-step guidance
Difficult to guide exploration by students
Long dialogue to convey spatial manipulations

Figure 4: Perspective Codes

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