Robot-Enhanced Telepresence of Remote Teachers for Effective Distance Learning

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***Abstract*—While distance learning becomes increasingly popular today, its effectiveness is limited due to the lack of physical interaction between participants. This limitation is a result of physical disconnection caused by current teleconference technology. In this paper, we outline a teleoperated robotic system which enables remote teachers to physically interact with local students via a humanoid robot. This system empowers remote teachers by creating their telepresence, which in turn improves the communication between teachers and students in distance learning. We quantitatively verify that telepresence, provided by our teleoperated robotic system, enhances learning experience in distance learning. Thus, our experiment advances the understanding of the importance of physical interaction in distance learning.**

I. Introduction

Distance Learning (DL) is conducted by instructors to remotely provide students with study materials through various online forms with the aid of tele-conference technology, such as a video call software, which allows virtual face-to-face interaction [1]. Both educators and students worldwide have moved to DL to continue education in the wake of the COVID19 pandemic. Moreover, before the recent events, online learning was growing in popularity as educational resources have never been more accessible[2][3][4]. The unprecedented convenience of knowledge exchange brought by DL has brought multiple forms of interactions between remote teachers and students in DL, such as “inquiry interventions” [5], conversational interaction [6][7], and online interaction when teachers manage classes [8]. However, the effects of lacking physical interaction (PI) between students and teachers needs investigation.

PI is a non-verbal way to exchange information through body language such as pointing, gesturing, and eye gaze. The physical disconnection from current teleconference makes it difficult for clear instructions, especially when it comes to relaying essential intangibles such as social interaction norms and hands-on experiences [9]. Students are aware of these differences and have lower satisfactory learning outcomes [10], which could lead to them being less motivated, persistent, and productive/focused. Ultimately, the difficulty of developing engaging distance learning curriculum with students’ lack of enthusiasm for the format would prevent the widespread adoption of the current DL strategies.

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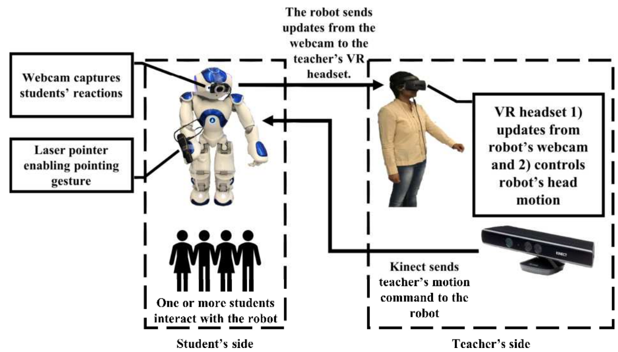


Fig. 1 This teleoperated robotic system transmits human body movement data to the robot via a Kinect camera, and directs the real-time updates captured by the robot’s webcam to the VR headset worn by the teacher. Students will obtain educational information from the robot while they have direct interactions with it. Therefore, the robot can give students a concrete sense of teachers’ presence.

Therefore, there is a need to empower remote educators with ability for PI in DL settings with students. With this idea an investigation of a remote teacher system using a teleoperated robot to give instructions was conducted. The goal of this work is to quantitatively determine the effectiveness and differences of using a teleoperated robot to advise the student compared to a teleconference style of teaching. The contributions of this work are as follows:

1. Determining the efficacy and preference of teachers and students of a teleoperation setup through surveyed responses. Determining both the preference of the teachers and students is critical in the outcome of the overall effectiveness of DL.
2. Experimentally evaluating the effectiveness of PI has on short term learning outcomes. The goal is to determine if the involvement of PI allows users to convey and receive information more effectively than traditional teleconference learning styles.

II. Related Work

Teachers and students have both expressed discontent with remote teleconference style learning [11]. Students often feel anxious, and uncomfortable to ask questions to further their own understanding in this style of communication which lead to undesirable outcomes such as disinterest, low motivation, and ultimately higher drop-out rates [12][13]. The lack of PI is a major point of the discontent, especially those in STEM subjects. It tends to be challenging for teachers to explain and for students to grasp scientific concepts in a traditional DL environment [10],[14]. These fields often require physical experiments to illustrate core concepts and have students gain first-hand experience[15]. Without these experiments, students would lose the opportunity to physically experience phenomena of natural sciences. Students' involvement is important to maximize their learning outcomes.

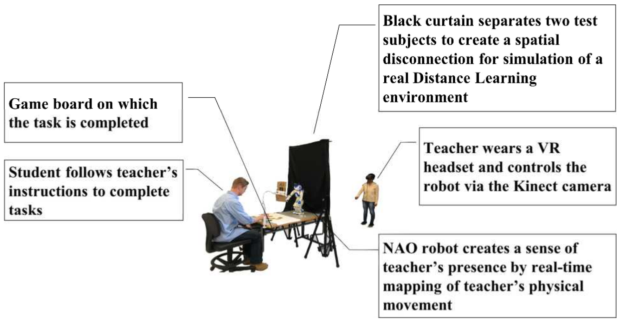


Fig 2. The workspace setup for the experiment. A remote teacher gives instructions to a student through a teleoperated robot. This robot is replaced with a laptop for the traditional teleconference setup. The workspace presented in front of the student is task they will complete.

The lack of PI leads to lower student involvement. Students often experience difficulties staying attentive to instructions and report lower involvement, where there has been effort to identify and alleviate this issue [16][17][18]. Simple gestures, such as pointing, can help recapture attention of students and convey large amounts of information [19]. Although gesturing can help with complex communication, such gestures appear ambiguous on screens without tele-embodiment [20][21]. Alternatively, students have been given technology to improve their own physical involvement through ways to gain the teachers' attention [10][22]. This system immerses students in a remote, interactive environment where communicating with teachers is relatively more efficient compared to the traditional, virtual environment [23][24]. In spite of the more interactive environment, PI between students and teachers remains difficult to carry out since gestures like pointing are still challenging to achieve. A next step in richer immersion is to include robotic technology.

III. Methods

A. System Components and Setup

A traditional teleconference style of learning is used as a baseline with a webcam between the student and the instructor. This will be compared to the alternative strategy of a teleoperated NAO robot being used as the intermediate interface between students and instructor (shown in Figure 1). The instructor is outfit with a Windows VR headset that relays a webcam feed from the robot for real-time visual feedback. An Xbox Kinect is used to obtain body gesture motion for the instructor so the robot can emulate the instructor arm and head motion. The robot is also outfit with a laser pointer to explicitly denote a desired location. A student has the robot placed in front of them on a table within their workspace. The task they are working on is also displayed on the table in Figure 2. In total, 20 subjects participated, where each person assumed both roles as teachers and as students. The order of these roles was randomly assigned.

Two tasks will serve as experimental setup to test the contributions discussed earlier. The first is an interactive assembly task to see how PI has on the involvement for hands-on activities. The second is a memorization quiz style task to see if the spatial information that PI creates help students retain information.

1) The Interactive Assembly Task

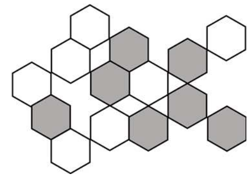


Fig 3. An example of a map layout. The shaded tiles indicate a position filled with a specific piece determined by the teacher's instructions. The white tiles indicate an empty position. The teacher must adequately describe the location and correct tile to place.

The instructor is given a random map configuration with instructions on how to appropriately assemble it (an example is displayed in Figure 3). There is a randomly sorted group of tiles with different patterns that must be placed in the correct position. The instructor is tasked with giving commands to help the student build the map. The instructor must inform the student when the assembly action is incorrect and must give another instruction to help them assemble the map. The completion time, number of mistakes, and number of clarifications the students needed were recorded. After assembly, both the teacher and student answered a survey questionnaire which can be found in the Appendix.

2) The Memorization Task

A random preset map configuration was laid in front of the student. A sequence of facts about the map (what each tile represents, and available routes between tiles) is presented to the student. The instructor is to explain the importance of each component before a five-question "true or false" quiz is given to the student. Afterwards, both the teacher and student answered a survey which can be found in the Appendix.

IV. Results

We recruited ten pairs of volunteers (20 subjects in total) to participate in our experiment. One of them is a full-time teacher while the rest are all high school or college students. Each pair of participants did four sets of tasks as they switched between two setups (tele setup and robot setup) and two different roles (student and teacher), where each set of tasks composed task 1 and task 2. One pair of subjects, thus, provided us with four sets of data. In total, we have obtained 40 observations.

A. Objective Data Collected in Task 1

Fig. 4a shows the distributions of time spent in accomplishing the assembly task in the robot setup and the tele setup respectively. One outlier in the tele setup is removed in the plot for a better visual representation. The median of two distributions are roughly the same, around 92 seconds. However, the minimum and maximum timing in the robot setup are substantially lower than those of the tele setup. The p-value of these two distributions is 0.0810, approaching the borderline of being statistically significant. Therefore, we conclude that users spend a noticeably less amount of time completing task 1 with the aid of the teleoperated robot.

Table I indicates the total number of clarifications, picking and placing mistakes in task 1. These results suggest that, in the tele setup, students tend to have more questions to clarify, and make more attempts to place a card in the desired location. The number of clarifications in the tele setup is almost 6 times as many as that of the robot setup, and the number of placing mistakes is more than doubled in the tele setup. The number of picking mistakes are about the same in both setups. This similarity arises from the fact that picking a certain type of the Catan card is a relatively easy task when participants are familiar with the card names and their corresponding appearances.

B. Objective Data Collected in Task 2

Fig. 4b shows the quiz scores that participants obtained in each setup after they attempted task 2. Although the two distributions share the same median of 4, the scores in the robot setup ($\sigma = 1.35$) are more scattered compared to those in the tele setup ($\sigma = 0.605$). Despite this dissimilarity, the p-value of the two distributions is 0.5204, indicating that the two distributions are not significantly different from each other. This observation suggests that learning outcomes, represented by their retention rates, are not largely influenced by the different setups of DL in a lecture-style scenario.

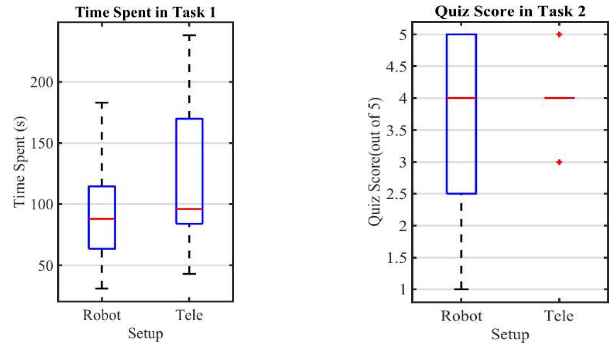
TABLE I. NUMBER OF CLARIFICATIONS, PICKING AND PLACING

Setup	Clarification	Picking Mistakes	Placing Mistakes
Robot	5	8	27
Tele	29	6	57

C. Subjective Data in Task 1 and 2

Fig. 5 shows the participants' responses to the subjective questionnaire. Refer to Appendix A for the list of subjective questions for teachers and students respectively. Test subjects were asked these subjective questions after each completion of a task depending on their roles. These subjective questions are classified as positive questions and negative questions. A positive question evaluates to what extent a participant agrees with a positive statement such as "I'm satisfied with task completion." A negative question reflects how much a participant agrees with a negative statement like "It feels difficult to clearly express myself." Fig. 5a presents their opinions when they played the role of a student while Fig. 5b shows their thoughts as a teacher in DL. The red boxes indicate participants' responses to the positive questions in the questionnaire. A higher score for the positive questions means that particular setup contributes largely to the effectiveness of DL, as they feel more comfortable and confident about using that setup to complete the given task. Conversely, a more negative score for negative questions, shown in Fig. 5 as blue boxes, indicates that setup is adversely affecting the effectiveness of DL, since participants feel more uneasy or hesitant to use that setup to do the task.

Analyzing students' responses to the subjective questions for the two setups in task 1, we find that the positive scores for the robot setup have higher median and minimum values. The average of the positive scores for the robot setup is 8.3% higher than that of the tele setup. The negative scores of the robot setup has a smaller interquartile range and slightly less negative values for all the key indicators of the population. Particularly, the average of the negative scores for the tele setup is 16.7% more negative than that of the robot setup. These observations show that students generally prefer the robot setup in a task where hands-on activities are involved.



(a) (b)

Fig. 4 (a) shows experimental results of task 1. The left box plot shows the total time spent to complete task 1 in the robot setup (min = 31, 25th percentile = 63.5, median = 88, 75th percentile = 114.5, max = 183) and the right one shows that in the tele setup (min = 43, 25th percentile = 84, median = 96, 75th percentile = 169.75, max = 238). These statistics show that users spend less time completing task 1 in the robot setup. The p-value is 0.0810. In (b), the left box plot shows the students' task 2 quiz scores in the robot setup (min = 1, 25th percentile = 2.5, median = 4, 75th percentile = 5, max = 5), and the right one shows that in the tele setup (min = 3, 25th percentile = 4, median = 4, 75th percentile = 4, max = 5). The p-value is 0.5204

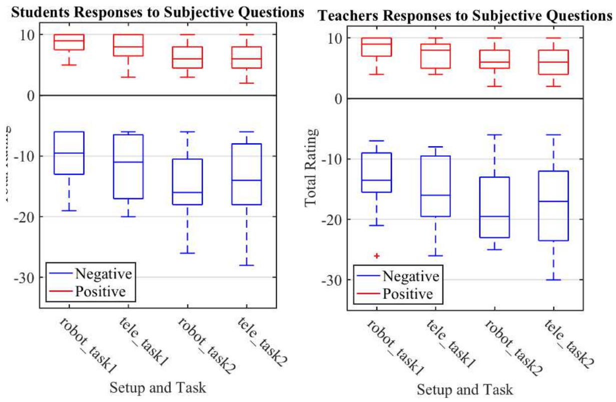
Teachers' responses show a similar trend. With higher upper quartile, median and lower quartile values of the positive scores for the robot setup in task 1, it is shown that teachers are more inclined to use the robot setup to teach in this task. Teachers' less negative scores for the robot setup in task 1 also indicate the same preference. The plot shows that teachers' negative scores for "robot task1" ($\sigma = 4.79$) is less scattered than that of the tele setup ($\sigma = 5.74$), and the 25th percentile of the robot setup in task 1 is substantially less negative in comparison with the same indicator in the tele setup. These results indicate that our teleoperated robotic system is well-liked by both students and teachers in task 1.

In contrast, the robot setup becomes less welcomed in task 2. Students rated the two setups with similar positive scores in task 2, and they even gave the robot setup a worse rating in the negative questions, as indicated by the more negative median and upper quartile values. The median of the negative score for the robot setup in task 2 is 14.3% more negative than that of the tele setup. The 75th percentile of the task 2 negative score in the robot setup is 31.3% more negative compared to that of the tele setup. This trend reveals that students do not find the teleoperated helpful in a lecture-style memorization task in DL, and they prefer the traditional tele setup to the robot setup for this type of tasks. Teachers' opinions suggest a similar preference as they gave more negative scores to the robot setup after completing task 2. The median of teachers' responses in the robot setup for task 2 is 14.7% more negative than that of the tele setup. These subjective responses demonstrate that the teleoperated robotic system does not always bring desirable improvements in DL.

V. Discussion

A. Claim 1: The involvement of PI in DL allows users to convey and receive information more effectively and efficiently in terms of objective completion time and behaviors observation.

In a traditional teleconference setup, teachers only have the ability to deliver information through "implicit



(a) (b)

Fig. 5 (a) shows students' responses to our subjective questionnaire while (b) shows those of the teachers. Refer to Table II for their corresponding p-values. These p-values indicate that they are not significantly different.

communication". This form of communication refers to conveying information indirectly and therefore, interpretation is needed for students' understanding. For instance, one of the participants described the following when he played the role as a teacher, "Put a Pasture card in the middle tile located among the three consecutive ones on your left (see Fig. 3)." To place the card in the right spot, the student had to first look to his left, then find the three consecutive tiles and finally locate the middle one among them. The success of this kind of attempt depends on two conditions. First, the teacher needs to formulate an understandable and unambiguous description to tell the student what s/he is supposed to achieve. Second, the student needs to mentally interpret the descriptive instruction to derive the spatial information. The combination of these two requirements makes it hard for effective and efficient communication to take place.

In contrast, "explicit communication" is made possible in the robot setup. Teachers now can operate the robot and use the laser pointer to point to the desired location in the map with a simple instruction, "Put a Pasture card here." It is called "explicit communication" because the spatial information is conveyed explicitly with the pointing gesture. Information that used to describe now only needs one single pointing gesture. The teacher does not need to worry about how to express herself/himself, and their chances of making mistakes while explaining are greatly reduced. Simultaneously, the student does not need to process verbal information for accurate understanding. Hence, conveying and receiving information are greatly facilitated with the incorporation of pointing gesture in the robot setup by pointing, and simply saying "this", "that", or "here", "there".

Statistically, our experimental results also show that the pointing gesture has led to more efficient completions for task 1. The total time spent to complete task 1 in the robot setup is apparently shorter compared to the tele setup as analyzed in the previous section. Both the number of clarifications and the number of mistakes in the robot setup are significantly lower than those in the tele setup. Thus, it proves that PI, especially the pointing gesture, indeed enables users to convey and receive information more effectively and efficiently.

TABLE II. P-VALUE OF EACH PAIR OF CORRESPONDING DISTRIBUTION IN FIG. 5

Rated by Students

Positive Questions		**Negative Questions**	
Task 1	Task 2	Task 1	Task 2
0.3169[a]	0.7955	0.3379	0.6157

Rated by Teachers

Positive Questions		**Negative Questions**	
Task 1	Task 2	Task 1	Task 2
0.1905	0.5292	0.1707	0.8283

Note: that the first value is the p-value between students' responses to task 1 positive subjective questions in the two setups is 0.3169 and so on.

B. Claim 2: The involvement of PI in DL makes users feel easier to teach and learn in terms of subjective surveys.

It is evident that PI makes teaching and learning procedure easier in task 1 because PI allows the task to be completed with less mental demand. In a video call, users view the other participant as if they are standing face-to-face. Due to this opposite view, describing spatial information becomes mentally challenging since the definition of left and right is now ambiguous. To illustrate, the teacher's right-hand side is, confusingly, the student's left-hand side. In contrast to the tele setup, the robot setup is impervious to the counter-intuitive camera angle because of the additional ability to directly point at a specific location. As a consequence, teachers do not need to worry about translating directional vocabularies into the appropriate ones for the students sitting at the opposite side. As for students, it is less likely that they get confused about teachers' instructions. The whole procedure is thus easier. Experimentally, in the responses to a question asking about the level of mental demand of task completion, both teachers and students give less negative scores to the robot setup ($\mu_{teacher} = -2.4$, $\mu_{student} = -1.4$) in task 1 than they do in the tele setup ($\mu_{teacher} = 2.8$, $\mu_{student} = 2.3$). Their ratings show that they believe using the teleoperated robot requires less mental demand in task 1. The robot setup requires a similar degree of mental demand but a far greater amount of physical demand from teachers in task 2. The robot setup received more negative subjective scores ($\mu = 2.9$) from teachers compared to the tele setup ($\mu = 1.95$) in response to a question investigating their opinions on physical demand of task completion. This shows that teachers felt more physical demand to use the robotic system. On the one hand, this result is not surprising because the robot setup aims to encourage more PI. It naturally follows that physical demand increases as teachers have more PI with students. Their more negative ratings demonstrate that teachers actively attempted to perform more physical gestures.

Students generally gave similar ratings to the two setups in task 2 regarding mental and physical demand, showing that they do not think the introduction of the robot generates a significant influence. Potentially, this is because the involvement of more PI eliminates the possibility for the

TABLE III. TASK 2 AVERAGE QUIZ SCORES

1st Half of Participants		**2nd Half of Participants**	
First Setup (robot)	3.0/5.0	First Setup (tele)	4.0/5.0
Second Setup (tele)	4.1/5.0	Second Setup (robot)	4.2/5.0

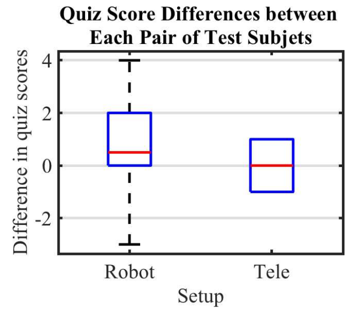


Fig. 6 The left box plot shows the score differences between each pair of participants in the robot setup in task 2 (min = -3, 25th percentile = 0, median = 0.5, 75th percentile = 2, max = 4). The right one shows the quiz score differences in the tele setup (min = -1, 25th percentile = -1, median = 0, 75th percentile = 1, max = 1). The p-value is 0.4128.

students to see teachers' facial expression in a tele setup. Evidence shows that facial expression is an essential element in students' learning experience [25]. Hence, adding a device like an iPad to display the teacher's face in the system will highly heighten students' preference towards the robot setup. The modified design would consist of both the display of facial expression and the availability PI. In summary, the involvement of PI in DL makes the process easier to a limited extent. Participants feel the procedure is easier when PI is introduced coupled with students' hands-on activities, but PI is not yet proven to be influential in a lecture-style memorization task.

C. Claim 3: PI in DL enhances students' learning outcomes.

Students' learning outcomes are evaluated by two criteria: 1) the effectiveness of understanding the given information and 2) their retention rates. We have shown that 1) is true through claim 1. Next, we will consider if PI increases students' retention rates. The students' quiz scores in task 2 do not suggest retention rates will improve even though PI like pointing is involved. Similarly, subjective data in Figure 5 also challenge this claim. A closer examination of the quiz scores obtained by students in task 2 suggests that the robot setup would potentially outperform the tele setup. Table III shows the average quiz scores in task 2 obtained by two groups of participants in each setup. The first half of participants started the experiment with the robot setup and then the tele setup, whereas the second half did the experiment in the reverse order.

We first compare the two average scores in the tele setup. The second half of participants had no prior experience in task 2 when they were in the tele setup and got an average score of 4.0 out of 5. In comparison, the first half of participants had already done the same task twice in the robot setup when it was their turn to use the tele setup. The first half possessed more prior knowledge and were familiar with the task rules. Despite the possession of prior knowledge, nonetheless, the first half received an average score of 4.1, which is very close to that of the second half in the same setup. This similarity indicates that participants' performance is quite stable in the tele setup. This trend is due to the fact that our participants are commonly used to a traditional DL environment. We then compare the participants' performance in the robot setup. When the first half of participants started the experiments in the robot setup without knowing a good strategy of using the robot to integrate descriptive information with spatial information, their average score (3 out of 5) is relatively low. In contrast, the second half of participants did a better job in the robot setup, obtaining an average score of 4.2 out of 5, after they attempted the task in the tele setup twice. This average score of 4.2 is the highest among all average values, and the improvement from 3.0 to 4.2 in the robot setup is relatively significant compared to the tiny increase in average scores in the tele setup. For the second half of the participants, their improved performance in the robot setup is not a result of students' increased familiarity with the quiz questions type. Since we provided all students with sample quiz questions before they each started task 2, the students had similar expectations about the questions they would need to answer and what they should pay attention to. Rather, teachers' performance played a key role in this case. Doing experiment in the tele setup first exposed teachers to the task rules, allowing them to familiarize with the task content. This order of experiment made it possible for teachers to develop teaching strategies that were more suitable for the novel robot setup. Their better teaching strategies, coupled with their enhanced familiarity with the task rules, allowed them to be more confident of using the robot setup, thus doing a better job integrating both spatial and descriptive information coherently. Students, thus, were able to receive more precise and fluent information which was far easier to memorize. Hence, the average quiz score in the robot setup obtained by the second half of the participants was the highest among all. This observation shows that using the robot setup have the potential to outperform the tele setup to enhance students' retention rates if teachers are familiar with what they are supposed to teach.

Fig. 6 shows another observation that suggests increased familiarity with the task and the robotic technologies can lead to improved performance. Since each pair of our volunteers switch their roles in the same setup and repeat the task one more time, we compute the difference between their quiz scores in task 2. The difference is computed by subtracting the second student's quiz score from the that of the first one. The larger standard deviation of the robot setup population (σ_{robot} = 1.90, σ_{tele} = 0.876) indicates that the robot setup is able to bring drastic changes in the second student's performance. Attempting the task once enables students to observe how the robot behaves during teaching, inspiring them to think about a strategy of how to make use of the robot appropriately when they switch their role to become teachers. Teaching students to complete the task similarly allows teachers to learn the type of information they will receive in the next round and become more prepared when they play the role of students. Therefore, the difference between the quiz scores obtained by the first and second student can be largely positive, showing that enhanced familiarity is a crucial factor affecting their performance. Students generally obtained higher quiz scores as the experiment proceeded, as indicated by the greater lower quartile values in the robot setup. Out of 10 pairs of participants, 8 pairs had the second student received higher or equally good quiz scores as the first student in task 2 in the robot setup. In light of the smaller standard deviation of the tele setup, it shows that participants' performance in the tele setup remains stable.

Based on the detailed analysis of participants' quiz scores above, it is conclusive that students' retention rates can be improved, or at least maintained, in the robot setup if participants are given opportunities to familiarize themselves with task rules and robotics technology.

VI. APPENDIX

Subjective Questions

Participants were asked to rate how far they agree with the following statements on a scale of 1 to 5, with 1 being "strongly disagree" and 5 being "strongly agree". Questions for teachers:

Positive Questions

- The communication is effective.
- I am satisfied with the task accomplishment.

Negative Questions

- It feels difficult to clearly express myself.
- I feel the student has difficulty in understanding me.
- I feel the student lost engagement/interest/attention during my lecture.
- I feel I need more effort to express myself compared to face-to-face communication.
- I feel the mental demand is high to accomplish the task.
- I feel the physical demand is high to accomplish the task.

Questions for students:

Positive Questions

- The communication is effective.
- I am satisfied with the task accomplishment.

Negative Questions

- It feels difficult to clearly understand the teacher.
- I feel the teacher has difficulty in expressing themself.
- I feel a loss of engagement/interest/attention to the lecture.
- I feel the mental demand is high to accomplish the task.
- I feel the physical demand is high to accomplish the task.
- I feel nervous because of the communication difficulty.

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REFERENCES

[1] S. Vicary, J. Copperman and A. Higgs, "Social work education through distance learning: the challenges and opportunities," Social Work Education, vol. 37, no. 6, pp. 685–690, 2018.

[2] B. Meyer, "Learning through telepresence with iPads: placing schools in local/global communities," Proceedings of the IADIS International Conference on e-Learning, pp. 11–18, 2015

[3] D. Miles, J. Mensinga and I. Zuchowski, "Harnessing opportunities to enhance the distance learning experience of MSW students: an appreciative inquiry process," Social Work Education, vol. 37, issue 6, pp. 705–717, 2018

[4] A. Rhema and I. Miliszewska, "Analysis of student attitudes towards e-learning: the case of engineering students in Libya," Issues in Informing Science and Information Technology, vol. 11, pp. 169–190, 2014.

[5] T. S. Ashwin and R. M. R. Guddeti, "Impact of inquiry interventions on students in elearning and classroom environments using affective computing framework," User Modeling and User-Adapted Interaction, 1-43, 2020

[6] A. C. Graesser, P. Chipman, B. C. Haynes and A. Olney, "AutoTutor: an intelligent tutoring system with mixed-initiative dialogue," IEEE Transactions on Education 48: 612-618, 2005.

[7] A.C.Graesser, "Conversations with AutoTutor Help Students Learn," International Journal of Artificial Intelligence in Education 26, 2015.

[8] A. Tlili, F. Essalmi, M. Jemni, M. Chang, and Kinshuk, "iMoodle: An Intelligent Moodle Based on Learning Analytics," Intelligent Tutoring Systems 2018, LNCS 10858, pp. 476–479, 2018.

[9] S. C. Herring, "Telepresence robots for academics." Proceedings of the American Society Information Science Technology, 2013

[10] R.M.deMoraes, L.S.Machado and R.K.Rangel, "Using robotic tele-embodiment to distance learning," The VII International Conference on Engineering and Technology Education, Santos, Sao Paulo, Brazil, 2002.

[11] A. Eckert, W. Geyer, and W. Effelsberg, "A distance learning system for higher education based on telecommunications and multimedia a compound organizational, pedagogical, and technical approach," World Conference on Educational Multimedia and Hypermedia and World Conference on Educational Telecommunications, Calgary, Canada, 1997.

[12] E. Cha, S. Chen and M. J. Matari´c, "Designing telepresence robots for K-12 education," 26th IEEE International Symposium on Robot and Human Interactive Communication, Lisbon, pp. 683–688, 2017.

[13] J. Weidlich and T. J. Bastiaens, "Technology matters – the impact of transactional distance on satisfaction in online distance learning," International Review of Research in Open and Distributed Learning, vol. 19, no. 3, pp. 222–242, 2018

[14] J.Baczyn´ski,M.Baczyn´ski,"Telerobotic technologies in e-learning," Information Systems in Management, vol. 2 (3) pp. 171–181, 2013.

[15] F. Tanaka and T. Takahashi, "Linking children by telerobotics: experimental field and the first target," Proceedings of the 6th International Conference on Human-robot Interaction, Lausanne, Switzerland, pp. 267–268, 2011

[16] S. Hutt, J. Hardey, R. Bixler, A. Stewart, E. Risko and S. K. D'Mello, "Gaze-based Detection of Mind Wandering during Lecture Viewing," Proceedings of the 10th International Conference on Educational Data Mining, 2017.

[17] A. Stewart, N. Bosch and S. K. D'Mello, "Generalizability of Face-Based Mind Wandering Detection Across TaskContexts," Proceedings of the 10th International Conferenceon Educational Data Mining, 2017.

[18] A. G. Picciano, "Beyond student perceptions: issues of interaction, presence, and performance in an online course," Journal of Asynchronous Learning Networks, vol. 6, issue 1, pp. 21–40, 2002.

[19] R.Mead,J.B.Weinberg,andM.J.Matari´c, "An ontology-based multimodal communication system for human-robot interaction in socially assistive domains," IEEE ICRA2010 Workshop on Multimodal Human-Robot Interfaces, 2010.

[20] M.S.L.Khan, and S.u.R´ehman,"Embodied head gesture and distance education," 6th International Conference on Applied Human Factors and Ergonomics (AHFE 2015) and the Affiliated Conferences, 2015

[21] E. Paulos and J. Canny, "Designing Personal Tele- embodiment," Proceedings of the 1998 IEEE International Conference on Robotics and Automation, Leuven, Belgium, pp. 3173–3178, 1998

[22] S. Yun, J. Shin, D. Kim, C. G. Kim, M. Kim, and M.–T. Choi, "Engkey: tele-education robot," International Conference on Social Robotics, pp. 142–152. Springer, 2011

[23] K. W. C. Shin and J. Han, "Children's perceptions of and interactions with a telepresence robot," 2016 11th ACM/IEEE International Conference on Human-Robot Interaction (HRI), Christchurch, New Zealand, pp. 521–522, 2016

[24] M. Timms, "Letting Artificial Intelligence in Education Out of the Box: Educational Cobots and Smart Classrooms," International Journal of Artificial Intelligence in Education, 26, 701-712, 2016.

[25] G. Gordon, S. Spaulding, J. KoryWestlund,J. Lee, L. Plummer, M. Martinez, M. Das and C. Breazeala, "Affective personalization of a social robot tutor for children's second language skills," Proceedings of the Thirtieth AAAI Conference on Artificial Intelligence, 2016.