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Limits and Benefits of Using Telepresence Robots for Educational Purposes

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Abstract. The continuing spread of the COVID19 virus shows that adequate preparation for telepresence scenarios such as teleteaching is elementary for structured teaching in secondary education. There should be no negative impact on teaching quality, either in times of general crisis or simply as a measure to ensure institutional stability and individual flexibility in an increasingly digital world. State-of-the-art telepresence approaches include the possibility to use telerobotic systems or telepresence robots (TR). These systems are configured with an immersive interface such that users feel present in a remote environment, projecting their presence through the remote robot. While many professional tasks can be shifted away from the workplace rather easily, social aspects gain particular significance in the context of learning and education. By enabling physical and spatial interaction far beyond the possibilities of mere video conferencing, the high degree of social presence provided by TR can assist better learning experiences. TR can compensate for the lack of mobility or restricted travel options of students, educators or staff. TR can foster language learning and intercultural exchange, and TR can prepare students for the workspaces of tomorrow.

Keywords: Telepresence robots, distant education, virtual mobility, technology enhanced learning

1 Introduction

Our paper addresses the use of Telepresence Robots (TR) in educational institutions at upper secondary and higher education levels, such as in classrooms and other (e-)learning settings. TR are mobile remote-controlled devices that represent the remote user via video and audio. We deal with the question of how the educational sector can benefit from this technology, what challenges we face, and what projects and research already exist in this area. On the project platform, we collect our findings and make them accessible to educational institutions, parents, students, researchers and any stakeholder interested in TR technology.

The main objective of our project is to enable educational institutions, teachers and students in secondary education to draw on the potential of 'on site' learning via the use of TR. We aim to achieve this by:

- Providing current, accurate and relevant key data & background information that can serve as a decision basis for educational institutions or educational systems (targeted towards decision-makers on the verge of deciding for or against acquiring TR solutions for educational use in schools);
- Developing a framework that can be followed by potential TR users to provide them with a validated approach of employing TR within their education institution;
- Promoting the technology to increase virtual presence, social learning and inclusion in classrooms and university classes (hybrid learning and teaching modes);
- Investigating user-friendly and efficient ways of introducing TR in educational settings;
- Providing guidelines to decision-makers and enablers on how they can benefit from using TPR in education, to allow them to make informed decisions about whether and which TR solutions should be procured at a specific educational institution or even for an entire educational system.

2 Method

The systematic literature review relied on desktop research and qualitative content analysis. It consisted of a review of the scientific literature and the current effective practices with TR in education. We examined:

1. the strategies employed to integrate telepresence technologies in the instructional everyday activities,
2. the barriers and challenges that inhibit or restrict the wider use and adoption of these strategies, and
3. the enablers and opportunities that facilitate the take-up of these strategies.

In total, 70 peer-reviewed papers were reviewed, classified and rated.

Table 1. Distribution of Publishers of all reviewed papers

Publisher	Count	Percentage
IEEE	7	10.0%
ACM	9	12.86%
Springer	3	2.86%
Other	52	74.29%

The technology review was conducted in parallel with the literature review, which identified the initial TR models. Other models on the market were identified in the course of desktop research activities for further investigation into the technical specifications. The first step was to analyse which models are still on the market and which companies still develop, produce and support them. To accomplish this task, we conducted interviews with manufacturers and resellers and made test drives with most of the evaluated six TR devices.

3 Results

3.1 Literature Review

The upcoming sections present key findings on educational subjects, educational scenarios, use cases as well as benefit and obstacles. The authors give an in-depth review and collectively provide a solid understanding of the integration strategies that facilitate the use of TR in educational institutes. Furthermore, the challenges that prevent the adoption of telepresence robots on larger scale are presented, as well as the factors that stimulate the adoption of telepresence robots in educational entities.

The introduction of telepresence robots in education is not a trivial task. The first issue to consider is to select and buy the right TR. Then, teachers, students, parents, school administration and technical staff should agree and be appropriately prepared for the integration of TR in the teaching practice [1]. There are varieties of ways that TR can be used in different educational subjects, at different educational levels, and in different educational scenarios.

Educational Subjects

- Business communication [2];
- Engineering [3];
- Informatics [1, 4-6];
- Laboratory [7, 8];
- Language [1, 9 -17];
- Mathematics [1, 9, 18, 19];
- Psychological support [20];
- Public administration [21];

- Science education [22, 23];
- Special education [20, 24];
- Teacher education [25].

Educational Scenarios

1. A remote educator teaches a class of N students using a TR located in the class: In this scenario, the remote teacher delivers the lesson controlling a TR that is located in front of students [2]. In another case, the remote teacher teaches the students and simultaneously controls the robot, moves and turns it to any students, makes eye contact with the students, responds to students, and controls the teaching slides [6]. Similarly, a remote teacher teaches mathematics to a student via a TR [19] whilst a native language teacher asks questions to a child via a TR after showing teaching material on TV [10].

2. A remote expert advises a class of N students and a teacher using a TR located in the class: In this scenario, the remote expert advises a single student or a class using a telepresence robot. Remote experts observe and evaluate classrooms in pre-kindergarten and elementary schools, review teaching, determine teaching quality [9]. In addition, remote consultants support students with disabilities using TR [20]. In another case, interaction designers acted as students and controlled a robot in a middle school classroom [22]. Remote surgeons use a TR to teach anatomy classes, where students perform surgery [26]. Finally, a native language speaker (expert) communicated with a class of Korean students and their teachers using a TR [16].

3. A remote student participates in a class of N students and a teacher uses a TR located in the class: This scenario is the most popular. Most related studies consider a remote student who participates in a class using a TR [1, 3, 4, 18, 21, 22, 27-32].

4. A remote student interacts with a local teacher using a TR: In this scenario, a remote student controls a TR and interacts with a teacher. For example, a remote language learner communicates with a native speaker using a TR [11-13]. The remote students achieve virtual access to an authentic environment in the target language and interact with native speakers in this environment in real-time. The physical environment around the TR, such as the trees, flowers, and sculptures encountered in the garden tour, allowed conversational topics to emerge naturally, as learners moved along the route. Initially, they introduce themselves and discuss various subjects. Then, the student reflects and reports what he/she learnt.

5. A remote student collaborates with a local student using a TR: In this scenario, two students collaborate to discuss a topic, solve a problem, develop a project, or anything else. During this collaboration, the remote student can increase social relatedness by controlling the TR to make certain gestures (e.g., head tilting, nodding, smiling, raising eyebrows) or movements [23].

6. A remote class communicates with a teacher using a TR located in the teacher's location: In this scenario, the TR is at the location of the teacher while the whole class of students is at a remote location (e.g., an isolated island).

7. A remote class communicates with an expert using a TR located in the expert's location: In this scenario, the TR is at the location of the expert while the whole class of students is at a remote location.

8. A remote class communicates with a local class using a TR located in the local class: In this scenario, two classes at a distance (e.g., in different countries) communicate and collaborate. For example, despite the language difference that existed between both sides, the children were capable of communicating through the TR [17]. However, teachers must be trained in the use of TR and feel confident in using the TR in education [32].

Use Cases

In the following, we would like to address the different use cases (17) that were identified in the literature review:

Table 2. Identified Use Cases

Nr.	Identified Use Cases	Number of Papers
1	Absence from school/university due to illness/disability; Attendance of kids with chronic/long-term illness and/or disabilities (6); Attendance of temporary homebound kids in school (mostly due to the Covid-19 pandemic) (4)	10
2	Concept and lab setting	9
3	Learning a foreign language – connecting with native speakers via TR	9
4	Meta studies / Literature reviews – cases not able to be classified in any other of the identified categories, as the scope of the papers are generally on TR	9
5	Use cases in schools not targeting a specific group of pupils	7
6	Different research settings involving education at universities	6
7	Value of teaching / understanding the content / effect of TR	5

8	Building low-cost TR	3
9	Shared Learning experiences and workshops	3
10	Difference between TR and Social Robots	2
11	Children with ASD (autism spectrum disorder)	1
12	Students that are afraid of visiting school / university (and helping them to do so in the future)	1
13	TR vs normal video conference tools	1
14	Elderly person care	
15	Industry use cases (walk around in a plant/factory)	1
16	Teachers with special skills (like STEM) teaching at different schools through a TR	1
17	Attending a conference as a speaker, personal experience	1
	Total papers:	70

Benefits and Obstacles

The benefits of using TR are enhanced social presence [3, 10, 21-24, 33-37] followed by the opportunity for teleteaching and telelearning [17, 21-23, 25, 26, 34, 36-39] from almost any place. The technology is well suited to let remote users participate in class and reduces the amount of travelling needed [10, 24, 35, 36].

The biggest challenges when it comes to the application of telepresence robots in an educational context are connectivity issues/Wi-Fi [1, 3, 8, 13, 17, 20, 26-28, 31, 32, 36]. They are followed by limits when it comes to the interaction with the environment [6, 11, 12, 19, 22, 30, 35, 40, 41] as well as the social presence of users [3, 22, 24, 30, 35, 38, 40, 41]. This limitation is mainly caused due to missing mechanical arms [11] and technical obstacles such as bad audio transmission [4, 22, 30, 31, 35]. The navigation of the TR is reported as difficult [4, 10, 11, 17, 19, 22, 38, 42] and the field of view as narrow [4, 8, 10, 19, 35].

3.2 Technology Review

A telepresence robot is a device that transports a person virtually to another location. It makes a person's presence felt even though the person might not be physically present. The robot has a screen and body-like structure onto which the user streams their video and controls the robot's movement remotely. The significant advantage is that it provides accessibility with the feeling of being physically present. Anyone can join a meeting virtually but joining that meeting virtually through a human-like structure makes the user feel physically present. They can control the robot's movement and interact with various people as they go around a place (e.g., an office) like they would if they were physically in that place. Being equipped with displays, speakers, microphones, cameras, and various other features (depending on the multiple robots in the market), telepresence robots are a revolutionary concept in the field of virtual interaction [42]. They are a sense of extension of the user's presence.

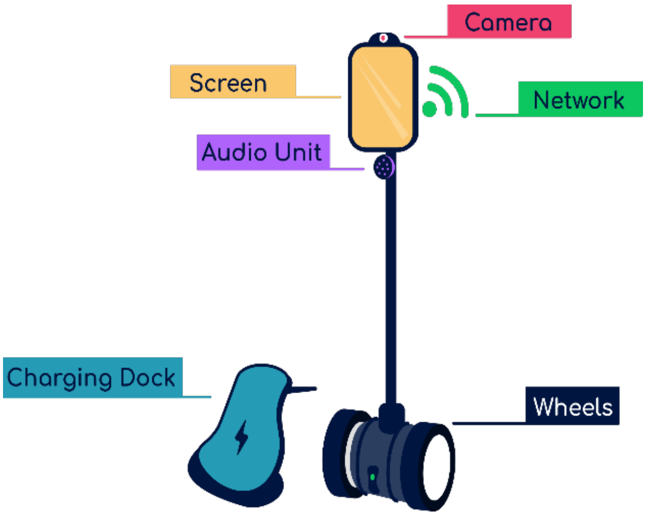

Fig. 1. Schematic View of a Telepresence Robot

Error! Reference source not found. depicts the main hardware components of the telepresence robot system. Starting with the movable, motorized base, which is connected with a telescope tube to the main display. For the audio-video communication on the TR operator side, the display is used to represent his or her head and speakers are provided to transmit his or her voice. Microphones capture the sound and voices of the remote environment, and cameras (usually a system of two or more cameras) transmit the video stream to the TR operator and help him or her navigate through the remote space. The energy for the system is provided by a battery, which can be charged with a special charging dock. One of the most important hardware components of a TR system is the network adapters, which can provide Wi-Fi or LTE (4G or even 5G) connection for the transmission of the data. The connection to the devices is usually web-based, which means that users only need a web browser to operate a telepresence robot. The communication protocols use a high level of encryption (mostly WebRTC 128 or 256-bit encrypted with DTLS-SRTP) and are secure. A list of hardware and software components is shown in Fig. 2. Main Hardware and Software Components of a

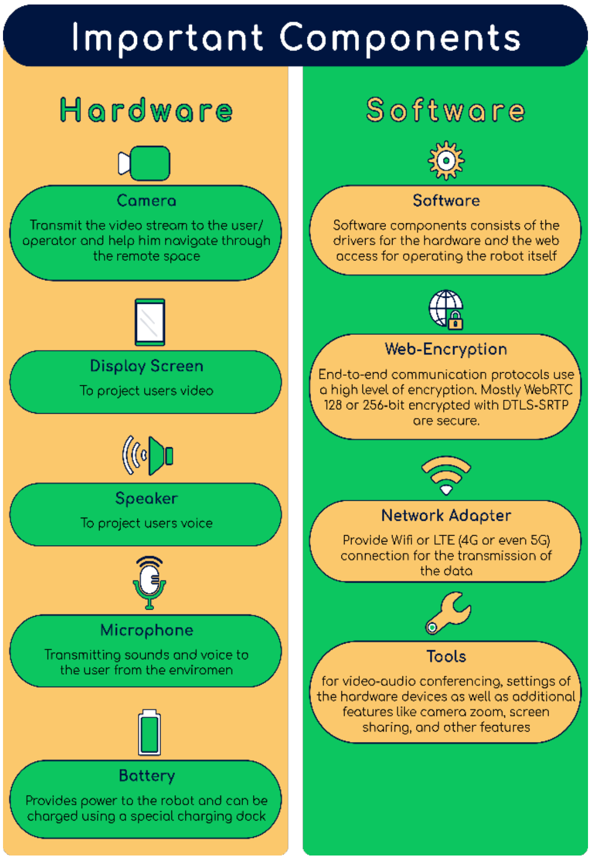

Fig. 2. Main Hardware and Software Components of a TR

Self-built Models

The self-made TR or prototypes from the literature review are mostly developed on Raspberry Pi systems, which are used to acquire data from sensors and stream the same data to the servers. The TR prototypes build by researchers use open-source components and freeware component tools. Many of them are easy to mount and flexible due to cost-effectiveness [42]. The studies in the papers show that students feel motivated to study and actively participate in the class lessons [10]. The self-made systems have certain challenges they are facing, such as lack of connection due to poor infrastructure. Time lag issues in the audio due to the poor Wi-Fi connection were observed in some low-cost TR systems [11, 43].

Commercial Models

The most prominent used telepresence robots are the following: BEAM, Beam +, Double 2, Ohmni and Kubi. The BEAM and Beam + technologies (today known as GoBe robots) provide much better flexibility and height compared to other robotic systems. The challenges faced by all the telepresence technologies were mostly the loss of connection due to lack of connectivity or poor internet infrastructure.

4 Conclusion

We reviewed the scientific literature and the current effective practices with TR in educational settings. The strategies for integrating TR into the daily classroom routine were investigated, along with the barriers and challenges that inhibit or restrict the wider use and adoption of these strategies. The enablers and opportunities that facilitate the take-up of these strategies to enhance educators' digital competence, as well as confidence in the use of TR for teaching and learning, were examined. We also analyzed which TR technologies and models have been used in the literature so far.

The efforts noted in this paper will pave the way for the work, which is ramping up on the development of a didactic framework for the use of telepresence robots in educational contexts. This framework will combine a set of contemporary teaching and learning methods (i.e, project-based learning, inquiry-based learning, problem-solving approaches, collaborative teaching and game-based learning) to be implemented in educational practice. Our study contains current, accurate and relevant key data & background information on the general conditions, benefits & limitations of using TR in education, and is broad enough to cover all aspects relevant to decision-makers regarding possible uses of TR for specific educational institutions (or educational systems).

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