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TRINE: TELEPRESENCE ROBOTS IN EDUCATION

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Abstract

The shift to the virtual world through activities such as gaming, e-sports, streaming and time spent on social networks continues. Next to the leisure sector, current developments around COVID-19 caused a massive increase in the use of online educational resources in 2020/2021. However, not all of the schools and universities in the EU were well prepared for this "digital only" scenario: based on the e-learning ranking by the Center for European Policy Studies, Austria is on the 10th place, Germany on the 27th place with regards to the logistical and didactical preparedness for distance learning.

In the digital education of the future there is the vision of seamless virtual and physical access for every home and between each home and the school, as well as its inhabitants such as educators, students and parents. Among the increasing number of available teleteaching tools, the use of telepresence robots (TR) has particular potential. TR can compensate the lack of mobility of students for various reasons (i.e. distant residency, bad weather conditions, disabilities or illness, force majeure conditions such as epidemics) and enables them to study in a social environment, where they can take an active part in the class on a peer-to-peer basis. The technology also enables distant educators from remote areas or other countries to be present in class. Compared to common teleteaching methods such as video conferencing solutions, the advantages lie in the possibility to actively control the robots and thus also to occupy the physical space. Telepresence robots thus not only enhance the feeling of social presence, but also enable interactions with the environment that are otherwise impossible. The use of telepresence robots in education as an innovative practice in a digital era inherits positive effects on inclusion, it fosters 21st century skills such as collaboration and communication and finally it reduces the environmental impact of educational routines.

This paper is thus concerned with the use of telepresence robots in educational institutions at the upper secondary and higher education levels, such as in classrooms and other (e-)learning settings. A better understanding of TR will be gained through a use case in terms of a hybrid course start for students at Danube University Krems. A mix of quantitative (online-questionnaire) and qualitative methods (virtual focus group) will be used to evaluate the risks and challenges as well as the opportunities of using telepresence technologies in hybrid learning settings by questioning the participating students. It is envisioned that our findings will support the adoption of digital technologies and resources for hybrid learning settings next to raising awareness of the importance of media literacy and social competences in the context of distance education.

Keywords: Distance Education, Telepresence Robots, Virtual Mobility, Media Literacy

1 INTRODUCTION

The continuing spread of the COVID19 virus shows, that adequate preparation for telepresence scenarios such as teleteaching is elementary for teaching in a structured manner in secondary education without negative effects on teaching quality, be it 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 the technology itself is ready, only early innovators such as Menntaskólinn á Tröllaskaga in Iceland already use TR in secondary education. At the same time there is also a clear lack of proper guidelines of how this technology can be used sensibly and effectively in the educational sector. While many professional tasks can be shifted away from the workplace rather easily, social aspects gain particular significance in the context of

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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.

1.1 Telepresence robots in education

Virtual mobility offers the opportunity to reduce physical traffic through the use of digital technology and services - which in turn reduces the burden on the environment [1] as well as on personal health & wellbeing through less emissions, less infrastructure costs, less travel time [2]. With the TRinE project, we want to show which application scenarios for telepresence robots already exist and where their chances and risks lie. After the diagnosis and treatment of a serious disease or illness, a return to "normal" life is often only possible after a long time. This return is made more difficult by problems at school, as the illness inevitably requires a break from school, often lasting for months. According to figures from the Norwegian company 'No Isolation' more than 780.000 children are currently affected in the UK [3]. Telepresence robots give ill or otherwise disabled students the opportunity to visit their school and to attend classes [4]. When applying distance education methods social competences and media literacy are of particular importance [5]. By learning and using digital tools such as telepresence robots, TRinE helps teachers and students to acquire communication and collaboration skills next to a technology-oriented attitude, which will play an important role in the future world of work due to increasing digitization.

Current application scenarios for TR mainly lie in settings such as home care [6] or industrial manufacturing [7]. There are only very few projects that address the use of telepresence robots in schools. TRinE closes this gap and analyses the needs, motivations and limitations from different actors in the educational sector. The project findings will be available as an interactive guidebook (TRinE toolkit), which is intended to serve teachers, students and other actors within the educational sector as primary resource in terms of the usage of telepresence robots in education.

2 METHODOLOGY

A mix of qualitative (literature review, technology review, expert interviews, focus groups) and quantitative methods (online surveys) will be applied by the consortium in order to postulate a technology acceptance model on TR, which in contrast to current literature adaptations, will focus on the feasibility and suitability of adopting TR within education. The goal is to assess the scientific impact on the use and deployment of the proposed innovative technology in pre-defined educational contexts, based on the different use cases identified for the project (inclusion of distance students, intercultural exchange and language learning). The transferability of the results will extend the technology acceptance model proposed and utilized in the project, towards a general adoption of teleteaching technologies for teaching and learning.

The results reported in this paper rely on two focus groups with students, educators and managers at Karlsruhe Institute of Technology with less experience with TR as well as on the content analysis of two central aspects of the literature analysis next to a technology review of existing telepresence robot models.

2.1 Research Objectives

The main objective of TRinE is to enable educational institutions, teachers and students in secondary education to draw on the potential of ‘on site’ learning via the use of telepresence robots (TR). The key goals are:

3 enabling decision-makers 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;
4 providing educational institutions, teachers and students with viable strategies to use TR solutions in a meaningful and effective way as part of their educational efforts; and
5 to make the relevant information on the use of TR accessible to as many educational institutions as possible, while promoting exchange about and raising awareness of the opportunities, challenges and limitations of telepresence technologies.

Wernbacher, T., Pfeiffer, A., Häfner, P., Buchar, A., Denk, N., König, N., DeRaffaele, C., Attard, A., Economides, A.A., & M. Perifanou (2022). TRinE: Telepresence robots in education. In: ***Proceedings of the 16th annual International Technology, Education and Development Conference (INTED) 2022*,** pp. 6514-6522, 7-8 March, IATED. DOI: 10.21125/inted.2022.1653

These objectives will be achieved by firstly providing comprehensive data and information for decision makers (TRinE Decision Support Materials); secondly by developing practice-oriented strategies for the use of TR in the educational context (TRinE Framework); and thirdly by developing an online toolkit where these materials are made accessible and can be discussed, evaluated and supplemented by users' own materials (TRinE Toolkit). For a successful implementation of the project, an international collaboration is crucial. This way the project can include a wide range of expertises, perspectives and best practices with Menntaskólinn á Tröllaskaga and Háskólinn á Akureyri as leading educational entities already using TR in education.

2.2 Research Questions

The empirical phase of TRInE is centered around the following research questions:

6 *What different TR technologies currently exist on the market?*

Overview of different TR technologies, including their respective practical potentials, costs, ease of implementation, ease of use and ease of adaptation for individual educational situations (based on technology review): telepresence robot is only a general term for a growing number of different solutions. Decision makers require an overview of these different solutions, not only regarding available features, costs of purchase and maintenance or required operating skills but also in regard to the requirements that institutions must meet (e.g. in technical or spatial terms) in order to be able to use these solutions sensibly and efficiently.

7 *Under what conditions are TR currently applied?*

Information on the legal / policy situation in different European countries (based on policy review): If the already difficult merging of personal interactions with Internet-based technologies is to be applied to the particularly sensitive area of education, then keeping an eye on (local) legal requirements is of crucial importance for decision makers and users alike. Especially since TR is a technology not yet widely used, the legal basis is not uniform throughout Europe, and is often derived from policies that can only be applied indirectly to TR, making a locally differentiated overview essential for informed and responsible decision making.

8 *How are telepresence robots currently used?*

Selected use cases highlighting practical applications of TR in the educational context (based on school/university review): TR as a technology can be applied in numerous ways in specific educational context, and the potential of TR will only take form when theory is put into practice. Especially since examples of TR in education are still rare, learning from some of these early adopting institutions' experiences can be of particular value for decision makers. School/university reviews can provide use cases that not only provide insight into the challenges of using TR in daily practice, they can also make the need to adapt ready-made solutions for the specific educational context tangible.

9 *What benefits, challenges and limitations of TR can be identified?*

Tangible personas showing the possible benefits, limitations and challenges of TR for various actors within the educational sector (based on SWOT analysis): The benefits of TR do not only emerge from the technology itself, but from its ability to meet the demands of the individual engaged in the educational process. Before deciding on the use of TR, it is important to understand how TR can affect these actors (especially teachers, students and parents). At the same time, it is necessary to develop a sense for the acceptance of or resistance to this new technology, as the effectiveness of TR is not only dependent on its general potential, but also on how well it is accepted by those involved, before and during the application.

Wernbacher, T., Pfeiffer, A., Häfner, P., Buchar, A., Denk, N., König, N., DeRaffaele, C., Attard, A., Economides, A.A., & M. Perifanou (2022). TRinE: Telepresence robots in education. In: ***Proceedings of the 16th annual International Technology, Education and Development Conference (INTED) 2022***, pp. 6514-6522, 7-8 March, IATED. DOI: 10.21125/inted.2022.1653

2.3 Research Methods

Literature Review

The literature review relied on desktop research and content analysis as qualitative methods. It consists 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 finally 3) the enablers and opportunities that facilitate take up of these strategies. In total 70 papers were reviewed and rated.

Technology Review

The technology review was conducted in parallel with the literature review, which identified the initial models. Other models on the market were searched out from the internet for further investigation. The first step was to analyse which models are still current and which companies still develop, produce and support them. To accomplish this task, we conducted interviews with manufacturers and dealers, and made test drives with most of the TR devices.

Focus Group & Case Study

We decided to use the focus group discussion as a qualitative method, to achieve an insight into the benefits and challenges of TR perceived by experienced and inexperienced users. Two groups were formed each consisting of six to eight participants. The first group contained a range of university students between 20 and 27 years old, while the second group was composed of people in second management and teachers in higher education, whose age varied between 28 and 50 years. Both groups have been asked questions depending on their level of familiarity with TR. These questions varied from general former experience with TR to the participants' thoughts on TR's strengths, weaknesses and their idea of improving the usage and technology of TR. The acquisition of the statements has been enabled through live sessions, where about 25 questions have been answered.

Next to the focus group conducted at Karlsruhe Institute of Technology we also did a case study at Danube University Krems for offering a personal evaluation of using telepresence robots for a hybrid class.

3 RESULTS

3.1 Focus Group

When talking about TR the participants mainly referred to the use of TR in higher education.

The discussion of the focus groups showed that participants find TR beneficial when wanting to take part in an educational environment even though they are forced to stay at home due to health or weather conditions. TR would also make it possible to avoid short-dated and distant traveling. They agree that the use of TR feels more personal and intuitive than using other kinds of recent telecommunication tools (e.g. Zoom or MS Teams) due to the movement possibilities and the feeling of physical presence of TR. They see the potential usage of TR in laboratory assignments, general practical courses and exam situations. Generally, both groups perceive a person using a TR as more integrated and physically present than compared to other forms of telecommunication.

The participants also named concerns when they think about maneuvering TR in teaching facilities. They doubt that the recent infrastructure in educational buildings are adequate for the use of TR. For instance, aisles and corridors might be too narrow, doors couldn't be opened by the TR manually, stairs could not be used and distances on e.g. a campus site (from one building to another) could not be overcome. Additionally, Wi-Fi signals may not be area-wide distributed, so disconnects could be a major problem. There is also the concern people could damage or even vandalize the TR. Another point mentioned was the lack of hands and therefore the lack of gestures like e.g. pointing. The missing of this important communication tool makes it hard to integrate the TR into natural interaction. Therefore, people interacting with the TR, like teachers and students, struggle to integrate it as a real person.

Wernbacher, T., Pfeiffer, A., Häfner, P., Buchar, A., Denk, N., König, N., DeRaffaele, C., Attard, A., Economides, A.A., & M. Perifanou (2022). TRinE: Telepresence robots in education. In: ***Proceedings of the 16th annual International Technology, Education and Development Conference (INTED) 2022***, pp. 6514-6522, 7-8 March, IATED. DOI: 10.21125/inted.2022.1653

Furthermore, the participants are mostly concerned by two ideas: First, is the cyber security and in particular the data privacy of the TR. They see a problem by never knowing when a TR's audio is turned on, is it recording, photographing or which persons are present on the other side of the TR without being seen (e.g. parent or sibling). It might be hard to control these cases, especially because not all issues could be solved with the help of technology.
The second concern relates to the technology adoption process. The participants find a major obstacle in fulfilling the necessary legal requirements to enable a use of TR. Data protection ordinances, operation agreements and no liability-clauses may have to be met in advance down to the smallest detail and therefore require a great deal of bureaucracy and time.

Participants also talked about the potential of the TR if technical changes would be made. A better immersion on the user's side should be possible through improvements like collision detection, 3D sound and a pointing mechanism like a laser pointer. To partly solve the problem of recording sensitive data there was an idea to use RFID-chips to regulate the robot's access to certain rooms. Additionally, a face recognition system could back the protection of privacy. Moreover, the infrastructure of teaching facilities should be enhanced to fit the needs of a TR that should automatically also fit the needs of disabled persons.

All in one, the participants have mixed feelings when asked about the meaningfulness of using TR. They agree that telepresence robots make sense in exceptional circumstances and that their usage should be further explored. However, most of them do not currently see a need to use them on their campus (from students perspective) and their own teaching activities (educators perspective).

3.2 Case Study

In October 2021, a pilot project took place at Danube University Krems on how the telepresence robot, controlled by the lecturer, can be used in a hybrid learning setting. The lecturer participated in the classroom via the "Ohmni Robot" [12]. He had to speak to the audience via a microphone and was recorded by several cameras of the online lecturing system which then streamed the lecture live via Zoom. The lecturer himself was in his home office workplace and had the TR software running on one PC and the Zoom classroom on the other PC. The slides were presented via Zoom and displayed in the classroom on the TV infrastructure. The aim was to assess from this self-experience whether the technical setting appeared to make sense, how much time and effort it took to operate it and how the lecturer felt about teaching in this setting. Another aim was to find out how the lecturer was perceived by the students during the breaks.

From a technical perspective, everything worked fine. This is certainly due to the stable internet connection both on campus and in the lecturer's home office, and the new e-lecturing solution at the Krems campus. The Ohmni software also worked flawlessly and did not cause any interruptions. There were only some problems with feedback in the beginning, but these could be solved with the right settings on all units and a little more distance from the TR to the microphone.

In the self-assessment of the lecturer, there was initially a good feeling of being present and the lecturer also sensed a certain curiosity on the part of the students in the room. But it was extremely exhausting in terms of concentration and attention. You had to keep an eye on both the people in the room and the people in the zoom via the TR. You had to control the PowerPoint separately and you couldn't make any mistakes in order not to disturb the flow and the attention of the students. It was another puzzle in the game as if the lecturer had only been teaching in the Zoom and connected to the classroom via TV. Or he could have been in the classroom with the Zoom guests and commented on a laptop at the table in front of him. From the lecturer's point of view, this solution is not an everyday scenario of teaching but rather an option for emergencies. If he cannot attend due to illness or adverse weather conditions or a missed flight. He calls this a Plan B solution, or in other words an emergency solution. There was hardly any interaction during the breaks. And if there was, it was not profound. Compared to on-site teaching, as well as only via Zoom using break-out rooms, the lecturer felt unable to respond to the individual needs of the students. In summary, it was a very exciting experience that should be given more attention from a research and development perspective, but at least for the presenter in this setting, not yet a solution for permanent use, but an acceptable plan B.

Wernbacher, T., Pfeiffer, A., Häfner, P., Buchar, A., Denk, N., König, N., DeRaffaele, C., Attard, A., Economides, A.A., & M. Perifanou (2022). TRinE: Telepresence robots in education. In: ***Proceedings of the 16th annual International Technology, Education and Development Conference (INTED) 2022***, pp. 6514-6522, 7-8 March, IATED. DOI: 10.21125/inted.2022.1653

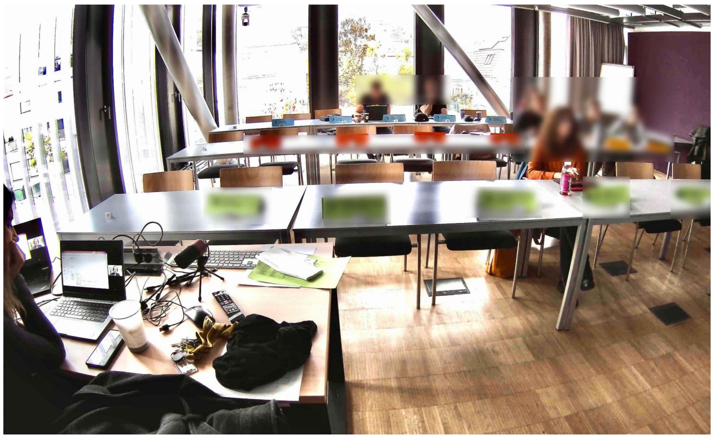

Figure 1. Screenshot from the Ohmni TR Perspective

Figure 2. Photo taken by the lecturer Natalie Denk during a break

3.3 Literature Review

Relying on the method of a content analysis two categories were analysed in course of the literature review process: the benefits as well as the challenges in relation to the use of telepresence robots in education. The figures 3 and 4 below visualise the results based on percental values.

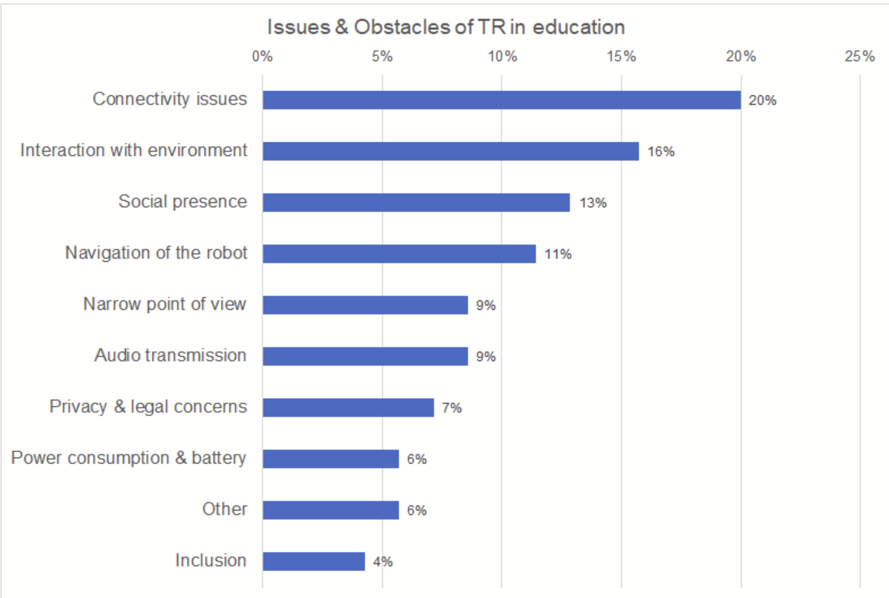

Figure 3. Issues & Obstacles of TR in education

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The biggest challenges when it comes to the application of telepresence robots in an educational context are connectivity issues (Wi-Fi) followed by limits when it comes to the interaction with the environment as well as to social presence of users. This limitation is mainly caused due to missing mechanical arms and technical obstacles such as bad audio transmission. The navigation of the TR is reported as difficult and the field of view as narrow. Users furthermore reported the following issues:

> "*Network delays and no mechanical arms to express body language in current telepresence robot may influence the communication.*"

> *"Privacy and safety concerns for children and their families, particularly for marginalized communities, breaks in the audio transmission, it is hard to see the full scope of the classroom and learning environment."*

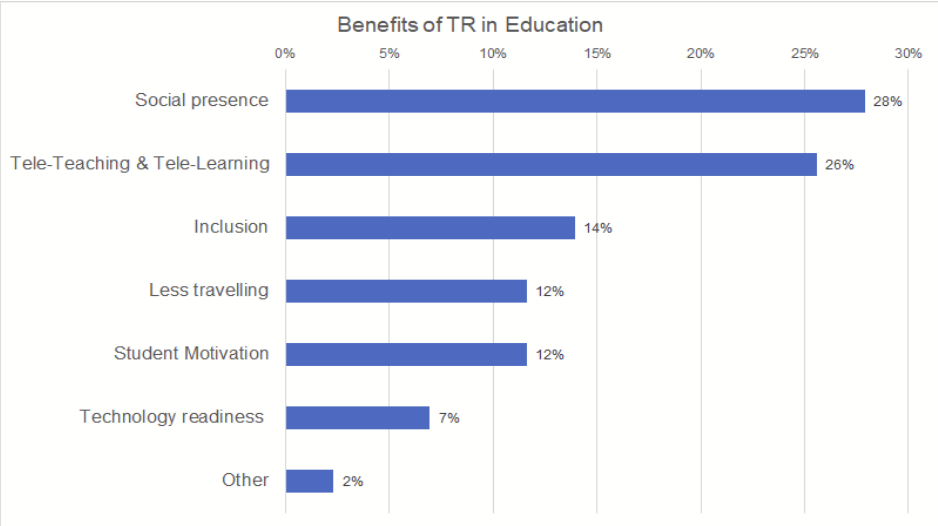

Figure 4. Benefits of TR in education

The benefits of using TR are enhanced social presence followed by the opportunity for tele-teaching and tele-learning from almost any place. The technology is well suited to let remote users participate in class and reduces the amount of travelling needed. The following two citations out of the literature analysis formulate some of the benefits that are seen by the users of TR:

> *"The extent to which the positive attitude towards telepresence robots continued to increase in the course of the seminars is remarkable. The strong effects from the longitudinal analysis make it clear that even a relatively short experience with telepresence robots in university teaching can reduce possible reservations about this technology and contribute to a high level of acceptance of the technology."*

> *"TR have the potential to give remote children more direct access to learning and interacting with peers in the K-12 classroom, thereby expanding access to social learning environments and potentially improving cognitive and social outcomes for absent children."*

3.4 Technology Review

The technology review resulted in a comparison document with technical specifications describing numerous features and subfeatures (see table 1 for some of them). Furthermore, with the help of the producers and researchers from the literature review, we defined what are the most relevant features from an educational perspective. The goal is to provide a guide for selecting a telepresence device for specific educational needs and budgets. The most relevant features for the use of telepresence robots in educational settings are the connectivity, quality of the audio-video communication, the ease of use or the intuitiveness of driving [8,9]. In addition, weight, height, and stability are very important characteristics for safety. In contrast, battery life and time for battery charging are not very relevant. Prices for telepresence robot models vary from 1500 to 10.000 Euros. The following TR were evaluated:

Wernbacher, T., Pfeiffer, A., Häfner, P., Buchar, A., Denk, N., König, N., DeRaffaele, C., Attard, A., Economides, A.A., & M. Perifanou (2022). TRinE: Telepresence robots in education. In: ***Proceedings of the 16th annual International Technology, Education and Development Conference (INTED) 2022***, pp. 6514-6522, 7-8 March, IATED. DOI: 10.21125/inted.2022.1653

Table 1. Technology Review

Model	GoBe	Double 3	Ohmni Robot	BotEyes-Pad ++	PadBot P2	UBBO Expert
Weight	45 kg	6.8 kg	9 kg	13.4 kg	6.5kg	21 kg
Height	1.7m	1.2 to 1.52m	1.42 m	1.42m	1,10 m	1,60 m
Connectivity	Wifi, 5G LTE	WiFi	WiFi	WiFi	WiFi, 4G LTE	Wifi, 4G/5G LTE
Encryption	WebRTC 128-bit AES	WebRTC 128-bit AES	WebRTC 256-bit AES	WebRTC 128-bit AES	n/a	WebRTC 128-bit AES
Front camera	2 x 13MP, 180°, 4K	1 x 13MP, 180°, 4K	1 x 13MP, 140°, 4K	1 x 8MP, 4K	1 x 5MP n/a	1 x 8MP, 100°, 4K
2nd / floor camera	Full HD, 160°	13MP, 4K	Full HD	13MP	5MP	2MP, 120° HD
Screen size	21.5"	9.7"	10.1"	11"	10"	13.3"
Display resolution	1280×720	1280×720	1280×800	2560x1600	1280×720	1280×720
Head tilt/pan	no	pan and tilt of camera	tilt (130°)	tilt (+160°/ -180°)	tilt (30°)	tilt (+/- 45°), pan (+/-90°)
Speakers	4 x 4W	8W full range	10W full range	quad-speaker on tablet	2 x track woofers	2 x 15W (84dB)
Microphones	4 x omni-directional	6x beam-forming	6mm omni-directional	embedded in tablet	n/a	2 x omni-directional
Battery life	8 hours	4 hours	6-8 hours	10 hours	10 hours	8 hours
Recharge time	2-3 hours	2 hours	5-6 hours	10 hours	6 hours	4 hours
Price	€€€	€€	€	€	€	€€

Figure 5. Telepresence Robot Models, from left to right: GoBe [10], Double 3 [11], Ohmni Robot [12], BotEyesPad++(Samsung Galaxy S7)[13], PadBot P2 [14], UBBO Expert [15]

Wernbacher, T., Pfeiffer, A., Häfner, P., Buchar, A., Denk, N., König, N., DeRaffaele, C., Attard, A., Economides, A.A., & M. Perifanou (2022). TRinE: Telepresence robots in education. In: ***Proceedings of the 16th annual International Technology, Education and Development Conference (INTED) 2022***, pp. 6514-6522, 7-8 March, IATED. DOI: 10.21125/inted.2022.1653

4 CONCLUSIONS

Our project on the use of TR in educational settings provides current, accurate and relevant key data and background information that can serve as a decision basis for educational institutions or educational systems (i.e. decision makers on the verge of deciding for or against acquiring TR solutions for educational use in schools). These materials will cover the state-of-knowledge on telepresence robots in education, a review of different TR technologies, information on the legal / policy situation, practical applications of TR in education as well as possible benefits and limitations of TR for different actors in the educational sector. Our empirical studies show that TR is accepted in some contexts, while some challenges persist which leads to the perception of this technology as a backup solution.

Through the TRinE project we propose an interactive toolkit (https://trine-platform.com/) that will serve as a primary resource for educators, students and other actors within the educational sector in terms of the use of telepresence robots in education. One of the main aims of the project is to create awareness about the opportunities as well as challenges correlated with using TR within an educational context. The use of TR in educational settings is addressed from various angles. In this way new innovative didactical methods on TRinE can be developed that foster collaboration and engagement and bring distance education to a new level.

ACKNOWLEDGEMENTS

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