Enhancing Inclusivity in Higher Education: *The Case of TEMI Semi-Autonomous Robot for Special Needs Students in Technical Courses*

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Abstract: **The COVID-19 pandemic has accelerated the exploration of innovative teaching approaches in higher education. In this context, semi-autonomous robotic assistants have emerged as a potential solution to bridge the gap between physical and virtual classrooms. This research project aims to investigate the applicability of utilizing TEMI, a semi-autonomous robot, to enable special needs students to participate in technical courses in higher education. The study explores the impact of TEMI's telepresence capabilities on the learning experience of both the special needs student and their peers, but it also evaluates the broader utility of semi-autonomous robotic assistants in teaching technical subjects in higher education. The disruptions caused by the pandemic, including widespread school closures and limitations in physical classroom interactions, have underscored the importance of innovative teaching approaches. This research seeks to bridge the gap between innovative teaching approaches and the potential of robot-assisted instruction for all students. By examining the role and effectiveness of these robotic assistants in both special needs education and mainstream technical courses, the research aims to study how these devices can be employed for the purposes of enhancing the learning experience for students and improving overall educational outcomes. The findings of this research will provide insights and recommendations for integrating robotic assistants into teaching practices, with a focus on inclusivity and innovation. Ultimately, this research seeks to optimize the educational environment in higher education settings, particularly in technological universities.**

Keywords — telepresence robots, semi-autonomous robots, robotic assistants, higher education, technical courses, special needs students, remote participation, smart classroom, innovation in education, inclusivity

I. INTRODUCTION

The COVID-19 pandemic has had a tremendous impact on higher education, revealing the vulnerabilities and limitations of traditional teaching methods [1]. In particular, technical courses require hands-on learning experiences and practical demonstrations, provisioning of continuous feedback and students' performance monitoring, which are challenging to replicate in remote education settings [2]. The sudden transition to remote learning during the pandemic highlighted the need for innovative approaches that can effectively bridge the gap between physical and virtual classrooms [3]–[5].

Furthermore, the pandemic has emphasized the importance of remote participation and the ability to adapt to rapidly changing circumstances. Educational institutions must be prepared to handle similar situations in the future, ensuring the continuity of education without compromising the quality of instruction [3], [4]. Therefore, there is an urgent need to explore alternative solutions that can enhance the learning experience in higher education for technical courses and provide students with opportunities for engagement and practical learning, regardless of their physical location [6].

While the COVID-19 pandemic accentuated the greater need for innovative teaching methods, it also brought to the forefront the unique challenges faced by students with special needs – challenges that could be addressed with advanced remote learning advances [7], [8]. It has been a struggle to accommodate fully the learning needs of students with special needs, even when using the pre-COVID era traditional teaching methods. Recently, telepresence robots (TPRs) have been suggested as an innovative approach to enhance inclusivity in technical education, as TPRs can provide a physical body for students (or teachers) who otherwise could not be present in the classroom [9]. This approach allows special needs students to participate actively in practical activities and engage with their peers in real-time.

In this challenging context, our research project addresses the broader issues faced in higher education, and examines a specific case that highlights the potential of TPR-based semi-autonomous robotic assistants.

First, the study investigates the applicability of utilizing TEMI, a semi-autonomous TPR, to enable special needs students to participate in technical courses in higher education. The research explores how semi-autonomous robotic assistants can act as facilitators, assisting instructors in delivering course material, providing real-time demonstrations, and helping to monitor laboratory work. This case study was conducted at IT College, Tallinn University of Technology, where a special needs student with a walking disability faced challenges attending the practical part of the Fundamentals of Networking course. To address this issue, the student utilized TEMI, a semi-autonomous TPR, for telepresence purposes to actively participate in the class. This unique case offers valuable insights into the potential of robotic assistants to enhance inclusivity in higher education and bridge the gap between traditional and remote education, ensuring that all students have equal opportunities for learning.

Next, this research evaluates the broader utility of semi-autonomous robotic assistants in teaching technical subjects in higher education. The integration of robotic assistants into higher education has the potential to significantly enhance the learning experience by providing students with a more interactive and immersive environment [10], [11]. By leveraging telepresence and semi-autonomous capabilities, robotic assistants can offer students an enriched educational experience, irrespective of their physical presence in the classroom [12], [13].

II. CASE DESCRIPTION: TEMI ROBOT IN THE FUNDAMENTALS OF NETWORKING COURSE

The data collection for this case study took place over the course of the spring semester of 2023, spanning over 16 weeks. Multiple methods were employed to gather comprehensive insights, primarily relying on interviews, observations, and questionnaires.

Interviews: In-depth interviews were conducted with students who participated in the Fundamentals of Networking Course and interacted with the TEMI robot. These interviews aimed to capture the students' perspectives, experiences, and perceptions regarding the robot's impact on their learning.

Observations: Extensive observations were made during class sessions where the TEMI robot was utilized. These observations focused on both the special needs student using the robot and the reactions and interactions of their peers and the lecturer.

Questionnaires: Questionnaires were administered to gather structured feedback from students regarding their experiences with the TEMI robot. These questionnaires helped in quantifying the overall impact and sentiment of the students toward the robot-assisted learning environment.

Data Processing: the collected data was processed by the lecturer of the Fundamentals of Networking Course, who was also the primary researcher of this study. Qualitative content analysis was employed to extract meaningful insights from the interviews and observations. This approach allowed for the identification of key themes, patterns, and noteworthy observations related to the integration of the TEMI robot into the course.

This approach, utilizing interviews, observations, and questionnaires, enabled a holistic examination of the impact of the TEMI robot in the Fundamentals of Networking Course and ensured that the study's findings were grounded in both qualitative and quantitative evidence.

Non-written informed consent was asked from all the students (n=150) who witnessed the study (i.e., students who took part in the Fundamentals of Networking Course). The data was collected only from the primary participant (the student who used the TEMI robot to participate the course) and from these students (n=50) who agreed to give their feedback. The data was anonymized and all identifying information was removed. No specific health-related or other sensitive information was asked or recorded.

A. *Background of the Fundamentals of Networking Course*

The study used the Fundamentals of Networking Course at IT College of Tallinn Technical University as the learning context for the study’s participant (one student of special needs).

The Fundamentals of Networking course at IT College, Tallinn Technical University, is a 6 ECTS course that is offered in both the fall and spring semesters each year. The course spans a duration of 16 weeks and is designed to provide students with a comprehensive understanding of computer networks.

Course Components:

1. **Theoretical Part:** The course includes a theoretical component that covers fundamental concepts in the field of computer networks. This theoretical part of the course can be accessed remotely, allowing students to engage with the course material online.
2. **Practical Part:** In addition to the theoretical component, the Fundamentals of Networking course features a practical aspect that is essential for building practical skills in networking. This hands-on component requires physical presence in the laboratory to gain hands-on experience in configuring, operating, and troubleshooting computer networks.

Course Objectives:

The primary objectives of the Fundamentals of Networking course are as follows:

- Provide students with a foundational understanding of computer networks.
- Empower students with the theoretical knowledge required to comprehend networking concepts.
- Develop practical skills necessary to build, operate, and troubleshoot small local area networks (LANs) using switches and routers.

B. Aspects of using TEMI by the Special Needs Student:

One student with a walking disability encountered significant challenges in attending the practical sessions of the course. The obstacles primarily stemmed from the physical demands of the practical sessions, which included activities such as setting up and configuring network equipment in the laboratory. These physical activities were difficult for the student due to their mobility impairment, hindering their ability to participate fully in the hands-on aspects of the course.

The utilization of the TEMI robot was introduced as a potential solution to address these obstacles and enable the special needs student to actively participate in the practical sessions, thus enhancing inclusivity in the Fundamentals of Networking course. This case study explores the impact of using the TEMI robot in this specific context and its implications for both the special needs student and the overall learning environment. The student with a walking disability, who participated in the Fundamentals of Networking course through the TEMI robot, employed a simulator software on their personal computer (PC) to actively engage in the practical components of the course. This simulator software allowed the student to replicate real-world networking scenarios, configure network equipment virtually, and apply practical skills in a digital environment.

Key Aspects of the student's approach:

1) Simulator Software: The student utilized specialized networking simulator software that emulated the operation of networking devices such as switches and routers. This software provided a virtual lab environment where the student could practice and experiment with network configurations without the need for physical hardware.
2) Practical Skill Development: Through the simulator software, the student could gain hands-on experience in configuring and troubleshooting computer networks. They were able to simulate network setups, create virtual LANs, and implement routing protocols, all within the virtual lab environment.
3) Real-time Interaction: The TEMI robot facilitated real-time interaction between the remote student and the physical classroom. The student used the robot's telepresence capabilities to join the class virtually, communicate with their peers and the lecturer, and share their screen to showcase their work within the simulator software.
4) Enhanced Inclusivity: This approach not only enabled the special needs student to actively participate in the practical aspects of the course but also contributed to an inclusive learning environment. The use of simulator software and the TEMI robot ensured that the student's contributions were valued and integrated into the classroom experience.

The combination of simulator software and the TEMI robot allowed the student to overcome the physical limitations posed by their walking disability and actively engage in the course's practical activities. This innovative solution highlights the potential of technology to enhance inclusivity and bridge the gap between physical and virtual learning environments in higher education.

C. *Use of TEMI Robot*

To facilitate the remote participation of the student with a walking disability in the Fundamentals of Networking course, a TEMI robot with specific capabilities was employed. The robot was selected for its telepresence capabilities, allowing the student to actively engage in practical sessions despite their physical limitations. The TEMI robot was equipped with a range of features and functionalities:

1) Battery Life and Docking Station: The TEMI robot came with a rechargeable battery, as shown in Fig. 1. It could operate for extended periods before requiring recharging. A docking station was provided to facilitate easy recharging between sessions.
2) Mobility and Navigation: The robot was designed to navigate within the learning environment. It had the ability to move autonomously on the floor, which required that the floor space be kept clear of obstacles and cables. The robot also had the capability to detect obstacles on the floor and would adjust its path to avoid them.
3) Communication and Interaction: To ensure real-time communication and interaction, the TEMI robot featured a camera, microphone, and speakers, as shown in Fig. 2. These components allowed the student to see, hear, and communicate with the instructor and peers during the practical sessions. It was crucial for enabling effective remote participation.
4) Mapping Function: The TEMI robot was equipped with a mapping function that played a crucial role in enhancing the student's remote participation. This feature allowed the robot to create a map of its surroundings, enabling it to understand its location within the learning environment. As a result, the student using the robot had access to information about the current location or room setup.
5) Language Capabilities: The TEMI robot had the capability to understand and communicate in both English and Estonian, accommodating the language preferences of the student and other participants.

Fig. 1. TEMI robot docked on a charging station.

Fig. 2. Temi robot front view and user interface.

From the student's perspective, a pre-training session was conducted before the start of the course. During this training, the student physically attended the lab room at the university. This training served multiple purposes:

- Familiarization: The student became acquainted with the lab environment, infrastructure, and the presence of the TEMI robot.

- Instructions: Detailed instructions on how to operate the TEMI robot were provided step by step. The training ensured that the student was comfortable and confident in using the robot for remote participation.

Throughout the semester, the process involved the lecturer reserving the TEMI robot and sharing the reservation link with the student. The student would then join the session remotely through the robotic body, as shown in Fig. 3. Importantly, the student had the ability to move the robot around, take part in group work, and present their work through the robot's camera and screen.

The TEMI robot's autonomy, including its battery life, obstacle avoidance, and ability to follow a person on the floor, significantly contributed to the student's seamless participation in the course. This innovative approach not only addressed the student's specific needs but also enhanced their engagement and inclusion in the learning process.

Fig. 3. Telepresence student in Fundamentals of Networking class

III. IMPACT AND IMPLICATIONS

The utilization of the TEMI robot in the Fundamentals of Networking course had several notable impacts and implications on both the special needs student and the broader learning environment.

A. *Interactive Learning Experience*

The use of TEMI robot by the study participants in order to attend the Fundamentals of Networking course created an interactive and inclusive learning environment for both the special needs student and their peers. The robot allowed the student to move around the lab (Participant: "I felt like I was the robot and I could go to where the action was"), engage in discussions and ask questions (Participant: "I could actively participate in discussions and ask questions just like I was physically there"), and participate in group activities as if they were physically present (Participant: "Being able to join group activities and collaborate with my peers made me feel fully integrated into the class"). It also provided the instructor with the means to offer real-time demonstrations and support to the remote student (Instructor: "I could demonstrate networking concepts and provide immediate assistance to the remote student, which was a game-changer for their learning experience").

B. *Enhanced Inclusivity*

The use of TEMI in the Fundamentals of Networking course significantly enhanced inclusivity by allowing the special needs student to actively participate in practical sessions. For example, the student could actively engage in hands-on networking tasks such as configuring routers and switches remotely, thus overcoming physical limitations. This inclusivity extended to classroom discussions and group activities where the student could interact seamlessly with their peers, regardless of their physical presence. Furthermore, it created a more equitable learning environment where all students, regardless of their physical abilities, had equal opportunities to engage with the course content. The characteristics of this inclusive learning environment included increased participation, reduced physical barriers, and a sense of belonging for all students.

C. *Improved Learning Experience*

The interactive nature of the robot-assisted learning experience not only benefited the special needs student but also enriched the overall learning experience for all students in the class. For instance, the introduction of the TEMI robot sparked curiosity and engagement among peers, who actively collaborated with the robot in group activities. The robot's ability to facilitate real-time demonstrations and remote participation encouraged active learning and critical thinking among students. This pedagogical shift fostered a collaborative and inclusive atmosphere, where students felt empowered to explore complex networking concepts, troubleshoot issues collectively, and learn from each other's experiences.

Such a dynamic and interactive learning environment enhanced overall learning outcomes.

D. *Pedagogical Considerations*

The case of TEMI integration highlights the importance of considering pedagogical strategies for accommodating special needs students in technical courses. It underscores those innovative technologies, such as telepresence robots, can effectively address the challenges of remote participation and create a more inclusive educational environment [14]. This experience prompts educators to rethink their teaching methodologies and leverage technology to bridge physical and virtual learning spaces. Pedagogical considerations should include designing content that caters to diverse learning styles and abilities, implementing interactive tools, and fostering collaboration among students through technology [15], [16]. The TEMI robot case serves as a model for the successful integration of innovative solutions in technical education, ultimately benefiting both special needs students and the entire student body [17].

CONCLUSION

The integration of TEMI, a semi-autonomous robot, into the Fundamentals of Networking course at IT College exemplifies how technology can enhance inclusivity in higher education, particularly for special needs students. The case study demonstrates the potential of robotic assistants to bridge the gap between physical and virtual classrooms, providing an interactive and engaging learning experience for all students.

This research aligns with the findings of other scholars who have recognized the transformative power of technology in education. As evidenced by previous studies [18], [19], the inclusion of innovative tools like robotic assistants not only promotes accessibility for students with disabilities but also enriches the educational experience for everyone.

This research offers valuable insights into the applicability of robotic assistants in higher education, emphasizing the importance of considering special needs students in pedagogical planning. It highlights the need for institutions and educators to adapt and harness emerging technologies to create inclusive learning environments that cater to students with diverse needs and abilities.

As technology continues to evolve, it opens new possibilities for creating inclusive learning environments that benefit students with diverse needs and abilities [20]. This case study stands as a testament to the ever-expanding frontier of technology-enabled education and the pivotal role it plays in fostering equitable access and enriched learning experiences for all.

FUTURE STUDY

The successful use of TEMI in this case study suggests the need for further exploration of robotic assistants in higher education. Future research could investigate the broader applicability of such technology across various technical courses and institutions. Additionally, the development of guidelines and best practices for integrating robotic assistants to enhance inclusivity should be considered to support educators in their efforts to create more accessible learning environments.

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