Human-Robot Co-Teaching in Online University Course during Covid-19

A.M. Velentza, I. Lefkos, and N. Fachantidis

School of Educational & Social Policy, University of Macedonia, Thessaloniki, Greece

Laboratory of Informatics and Robotics Applications in Education and Society (LIRES), University of Macedonia, Greece

Abstract:

Online lectures are extensively used in the academic area. Especially due to the Covid-19 lockdown restriction measures, the educational institutions were forced to conduct online classes. Consequently, it is important to determine how these classes can become more enjoyable while at the same time delivering the academic objectives to the students and how academic tutors can optimally interact with students. This paper specifically looks at the performance of social robots in place of university co-tutors, in the field of engineering, measuring the students' enjoyment and understanding of the basic principles of the lecture's content. Inspired by previous educational studies which have evidenced beneficial effects for both students and tutors after taught/conducting lectures with two collaborative tutors, the goal of this research is a) to test the students' evaluation of two collaborative human tutors in comparison with one individual human when teaching academic lectures during online lectures, and b) to investigate the effect of a social robot co-tutor after comparing students understanding and level of enjoyment after attending a lecture given by human-human or human-robot co-tutors. The lectures took place via an online educational platform during an actual university course. Results indicated that students evaluated higher the co-tutor lectures in comparison with the individual tutor lectures, while they equally enjoyed and gained knowledge from both human-human and human-robot cotutored lectures.

SECTION I.

Introduction

The Covid-19 pandemic found us unexpectedly and forced us to change our habits. The educational field was affected too and people in academia had to find new solutions on how to deliver their classes. Thankfully, technological research was already mature regarding the online classes, offering a variety of software and hardware solutions [1]. At the same time, a wide discussion about the educational challenges and issues was ongoing [2]. The research about the use of social robots in physical classrooms was also in progress, revealing interesting and promising results.

The most common educational roles performed by social robots were the students' or teachers' assistants or independent tutors [3]. Social robots performing as tutors were able to achieve similar teaching skills to humans, especially for restricted tasks, increasing at the same time students' cognitive outcomes [4]. The humanoid robot NAO successfully performed as a university professor in a physical classroom (f2f)

[5], lecturing about engineering principles, increasing the students' enjoyment level and in some cases their learning outcome in comparison with a human professor [6], [7]. The interaction of students with a robot seems to enhance their computational thinking and support them to understand robotics and computer science principles [8]. Moreover, The robot has been similarly successful in performing the tutor role in online education settings [9].

The role of robot teaching assistants mainly focuses on delivering new educational material [10]. Human and robot coteachers are simultaneously present in the classroom and they both interact with the students [10]. Social robots as teaching assistants are able to assist and advise students by supporting the classroom, management and reacting to emerging problems [11].

The current study stems from the observation that many university tutors started to co-teach their online courses driven by both intrinsic motivations, i.e., to feel less alone, and extrinsic motivations, i.e., to make the course more interesting and interactive for the students. Co-teaching was already applied in various face-to-face courses before the pandemic. The definition of Co-teaching is having more than one tutor or teacher, simultaneously deliver a lesson or activity in a single classroom with one student's group. Many researchers have studied the advantages and limitations of co-teaching in f2f and online education, as will be further discussed during the related work section that follows. Additionally, we aim to investigate the role of a social robot as a co-teacher in online lessons.

The paper is divided into five sections, starting with the related work, describing the latest evidence from the research in co-teaching in two subsequent co-sections, one for real and one for virtual classroom environments. In the 'Present Study' section that follows, we define the goals, context, and hypotheses of the current study. Next, we present the Experimental studies in two separate sections, 1) Students' attitudes regarding one or two human collaborative university tutors for online courses, 2) Two Collaborative university tutors: Human-Robot or Human-Human Collaboration. Both sections are followed by the subsections regarding each study's participants, design and procedure, data analysis, and results. Especially in the case of the second experiment, we thoroughly explain the interaction guidelines between collaborators, by also giving a script example from the beginning of the lecture. The final section is focused on discussion, conclusions, and future plans.

SECTION II.

Related Work

A. Physical classroom Co-teaching

Waters and Burcroff [12] observed ten years of co-teaching process, focusing on the professors' and students' needs and the effectiveness of the taught strategies and theories during the teaching. During the first co-teaching attempts, both students and tutors were stressed about the procedure. The tutors adapted by refining the goals, and supporting each other, while they tried different teaching styles to help students decrease their stress levels [12]. Co-teaching exposes students to tutors with different expertise and background, combines their strengths and knowledge, and model positive working relationships [13], and effective collaboration [14]. Co-teachers with

different academic status or social identities promotes diversity [15]. However, to optimize students' learning outcomes, it is vital to apply the appropriate curriculum and co-teaching models to highlight the strengths of both tutors and set an environment that nurtures critical thinking and self-reflection to support the multidimensional approach to tutors' knowledge [16]. The literature review of Nevin et al. [17] concluded that university and K-12 tutors who co-teach, learn from each other, adopt collaborative teaching strategies, and reduce the culture of isolation in the university institutions, while we still need valid instruments to measure the outcome in both tutors and students' performance [17].

Moreover, Sebald et al. [18] suggest the co-teaching, especially for pre-service teachers' education since based on their experimental findings it increased their confidence, enhanced their experience with the use of technology, and supported the teaching duration and differentiated techniques [18]. Vazquez-Montilla et al. [19] suggested four criteria to fulfill for a fruitful university co-teaching, a) shared planning, b) teaching effectiveness, c) team interactions, and d) teaching satisfaction. Keefe et al. [20], support the idea that for a successful co-teaching procedure, tutors should know themselves, their colleagues/ collaborators, their students, and the scientific area, to avoid criticism and embrace the team effort. Additional co-teaching strategies suggested by Kluth and Straut [21], using ice-breaking techniques to introduce co-tutor, implementation of bot parallel and 'one teach/ one assist' teaching methods, and station teaching, dividing the lesson content into separate categories.

Finally, co-teaching in physical classrooms has been proposed for better inclusion of students with disability in typical education classes with the collaboration of typical and special needs educators [22].

B. Virtual classroom Co-teaching

Co-teaching was used during the Covid-19 pandemic to tackle the challenges of instructing in socially distanced and remote settings. Many researchers proposed virtual co-teaching methods by adapting the face-to-face methods based on the virtual classroom needs. Chizhik & Brandon [23] proposed co-teaching between a mentor and an assistant teacher by using the Zoom video-based conference tool. They recommended the collaboration of teachers in the same virtual environment (main room) in a)one-teach/one-observe, while the main teacher teaches, the observer observe the students' behavior (being distracted, leaving the session), b) one-Teach/One-Assist, the co-teachers manage responsibilities, when the teacher teaches, the assistant monitor students in the platform i.e. notice when students raise their hand, actually or via the "blue" hand Zoom feature or assist them with technical details and c) team-teaching, where both teachers equally teach and support students, distributing responsibilities. Additionally, they recommended the use of the breakout rooms (BR) in a) Station teaching, where teachers split the class by using BR and teaching simultaneously, b) Parallel teaching, where students are split in BR, co-teacher covers the same information while mentor teacher changing BR to support or answer questions. c) Supplementary Teaching, where a teacher can move a student to BR to explain further and avoid stigmatized from peers [23]. Similar strategies also proposed by Svobodová [24] in the technical report of Technology Agency of the Czech Republic (TACR, TL03000133) project, and also by [25] Weiss & Rodgers [25] who suggested that in order to maximize the learning time, co-teachers should

provide structured instructions about the taught lesson, and make the general curriculum assessable with the differentiation of teachers' role -mentor or assistant- and with the aid of breakout rooms [25].

Despite the fact that remote classrooms during the pandemic lack of feedback from the students, however, Gares et al. [26] noticed that students were highly motivated, and they needed adapted strategies in order to express their motivation during online classes. Students, during collaborative e-learning lectures, manage to develop the required skills and the teamwork was enhanced [27]. Moreover, faculty co-led discussions encouraged students to get engaged into virtual class conversations, by seeing the tutors exchanging ideas and asking and replying questions of one another [28]. Technology solutions have also been used from co-teachers, especially for small groups of students, to enhance engagement and build flexible communication channels [29].

Arroyo et al. [30] proposed the use of educational robots to support children during online classes, expecting to increase their attention and awareness about the lecture by utilizing social behaviour cues and monitoring tutors' voice. Finally, Abendschein et al. [31] examined the role of a social robot cotutor via short pre-recorded lectures. Results shown that students rated as more credible and appealing the scheme of a human-led, robot teaching assistant in comparison with other schemes presenting the robot performing in more dominant positions.

SECTION III.

Present Study

In this study, we investigate the use of the social robot Nao in a virtual university classroom performing as a co-tutor comparing a) the self-report attitudes of university students regarding the tutor position of a human-tutor vs two human cotutors and b) a human vs. a social robot co-tutor. Measuring students' attitudes, enjoyment level and basic understanding of the lecture's content. The subject of the lecture focused on basic engineering principles, and more specifically about Cryptography. Although there have been conducted studies supporting the use of social robots in online classes for children's education [30] and also others who gave students the chance to evaluate tutor-assistive robot online classes through pre-recorded video lectures [31], however, to the best of our knowledge there are no previous studies evaluating the use of a social robot co-tutor in a real university classroom during the established lecture hours.

First, we conducted an extent survey to find out if the students evaluate more positively their experience with one or with two collaborative human tutors and thus if they prefer to have a course with the corresponding number of tutors during the online lectures. Secondly, we designed an experimental study based on the survey's outcome, by utilizing an online university lecture conducted by two collaborative human tutors and by two collaborative tutors, one human and one social robot. At this context we evaluated the student's enjoyment from the lecture, comparing the different co-tutor combination (human-human or human-robot) and also the students' understanding of the basic principles of the taught subject.

A. Hypothesis

H1. University students in online classrooms during Covid-19 restrictions will prefer to be taught by two collaborative human tutors instead of one. This hypothesis stems from bibliographic reports supporting that co-teaching in physical environments reduce the academic culture of isolation [17] and enhance learning, since collaborative tutors combine their strengths and knowledge [13]. Moreover, in virtual environments studies have shown that co-teaching enhance students' motivation [26], and teamwork while developing all required skills [27].

H2. Students will enjoy more having an online course with two collaborative tutors, a human and a robot, instead of two humans. This hypothesis is based on evidences on physical university classrooms, when students enjoy more to get taught by one robot-tutor in comparison with one human-tutor [6], [7]. However, due to the multiple differences between those studies and the current study, i.e., environment (physical vs virtual) and number of tutors (one vs collaborative), we still need to investigate how students evaluate both co-tutored lectures. Since in the academic procedure enjoyment is equally important with gain knowledge [32] we will consider it a success if students evaluate equally high the lectures.

H3. In the third hypothesis, we plan to investigate the effect of the co-tutors (human and robot) in the students' understanding of the basic principles of the lecture's content. There are evidences that co-teaching with a robot co-tutor increase students' attention and awareness about the lecture [30], others that support the idea that humans and social robots can perform similar tutoring skills [4], while other who suggest that during the first time that students are taught by an individual robot-tutor, they gain less knowledge in comparison with an individual human-tutor because of the surprise effect [6].

SECTION IV.

Experimental Studies-One Or Two Human Collaborative University Tutors For Online Courses?

A. Participants

The total number of participants was 208, 180 Women, 22 Men and 6 who preferred not to mention, distributed in all academic semesters in the School of Educational and Social Policy. All students were taught at least two courses with collaborative tutors during the winter semester.

B. Design and Procedure

The online survey was shared to the students via the official department website. They were able to fill it only once, after registering to the academic platform only with the use of their academic e-mail. After submitting their answers, the researchers were not able to correlate the e-mail address with the answer sheet.

The questions were based on two questionnaires, designed to evaluate 'Teacher's competence in university environment' [33] and 'Collaboration Effectiveness' [34].

There we 23 Liker Scale questions evaluated from 1 (strongly disagree)-5 (strongly agree). Each participant had to answer each question following the same Likert scale, evaluating their variation of their agreement with the statement for having a lecture with one tutor and having a lecture with collaborative tutors. For Example, 'Presents the content of the lecture following a clear and logical framework', evaluate for one tutor and evaluate for two collaborative tutors, as shown in Fig 1. In the instructions, we firstly explained the concept of having two collaborative tutors. The questions translate from English to the course's taught language and also adapted to the students' culture and context of the research based on experts' evaluation.

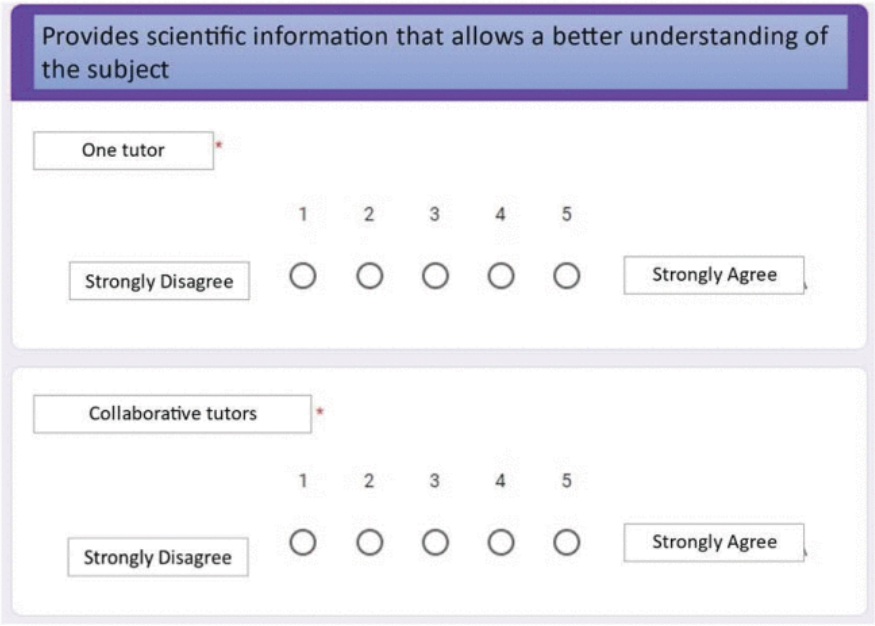

Fig.1: Example of the online survey design

C. Data Analysis

We separated the data in two categories, a) one tutor, b) collaborative tutors, and we calculated the Mean Value *(MV)* and Standard Deviation *(SD)* for each participant's answers per category. The maximum score per student can be 115, while the minimum 23. Then we performed the Kolmogorov-Smirnov parametric test and since the data were parametric, we applied a t-test between the two categories to find out which condition is more positively evaluated from the students. Moreover, we applied the Cohen's d effect size measurement appropriate for data with the same sample size.

D. Results

The Cohen's d test proved that the size of the sample is large and thus we can extract reliable conclusions. The students' attitudes regarding the two collaborative tutors' lectures (*MV*=97.4, *SD*=11.7) are statistically significantly more positive in comparison with the one-tutor lectures (*MV*=77.29, *SD*=14.41), as indicated by the performed t-test at t(208)=-15.58,p=<.001,d=20.12.

SECTION V.

Experimental Studies-Two Collaborative University Tutors: Human-Robot Or Human-Human Collaboration?

A. Participants

The total number of participants was 105, N= 47 in the Human-Human condition (HH) and N=58 in the Human-Robot condition (HR), 10 Men, 86 Women, and 6 who preferred not to state. All students were in the first year of studies, except for two. They were all attending the mandatory course "Basic Principles of Information and Communication Technologies" for the first time, which was taught via the zoom platform. The study took place in December 2020.

B. Design

We used a between-participants experimental design. The lecture was conducted via the zoom platform, which was regularly used for all the university virtual lectures during Covid-19. The main tutor was the same in both conditions, who is a professor of the same and similar courses for more than 20 years. The co-tutor in the HH condition was the ordinary coteacher for the course, teaching or co-teaching similar subjects for the last three years, while in the HR was the Aldebaran Nao V3.3. All tutors (human and robot) followed the same script. The robot's lines were written and saved by the choreographer, while the answers to the students' questions were given via the Wizard of Oz procedure. Moreover, tutors stood in the middle of the camera frame, as shown in Fig.2, depicting the standing position of the co-tutor, and Fig.3, depicting the representation of the Zoom platform. The lecture lasted for 30 minutes, and the topic was Cryptography, basic principles, and applications.

a) Interaction Guidelines.

Based on the bibliography about the effective characteristics of co-teaching, we separated four disciplines, that the interaction between the tutors in both HH and HR should follow. There is the indirect interaction with the students (through the tutor-tutor) and the direct interaction (tutorstudents).

a) Tutor Conversation-Dialog.

The main tutor starts a conversation with the co-tutor. Both tutors ask each other questions. They both should be able to a) reply to each other, b) solve questions, and d) decide together.

b) Subject Presentation.

Major: When presenting a topic, the main tutor teaches about specific aspects of it, while the co-tutor teaches about other aspects to have a clear categorization of what they are teaching [35], [36].

Supplement: The main tutor teaches about one aspect of the topic, and the co-tutor extends to the same aspect. For example, each tutor gives information based on their scientific expertise -from an educational perspective and from an engineering perspective.

c) Social Frame.

The social frame is referring to the vibe or mood to enlighten. In that context, we embedded the element of humour in the educational context [37], [38] and reward tutors to students. Providing feedback and verbal reward enhance learning during online classes since after receiving it, academic students feel more motivated. [39]

Organizational comments, i.e., comments for those who were late to the lecture: Main tutor: 'please do not be late when entering the zoom', co-tutor: 'if you are entering the zoom late, you will lose the beginning of the lecture which is very important for your understanding'

d) Interaction with Students.

Another important aspect is the direct interaction of the tutors with the students. The interaction should be two ways round, from tutor to students and vice versa.

Tutors-Students: Both tutors should be able to respond to the students' needs through all communication channels, i.e., chat, direct conversation, etc.

Students-Tutors: Students should be able to address both tutors in all the communication channels.

b) Script Example From the Beginning of the Lecture:

Main-Teacher (MT): As you already know, we are approaching the end of the semester, and we are heading directly to the final exams.

Co-Teacher (CT): Before the end, we would like to discuss some topics that we find important to fully understand the course.

MT: The current lesson will be taught in collaboration with my colleague who will give us his point of view about the topic, and additional information and he will be also available similarly with me to answer your questions, directly or through the chat.

CT: Thank you for the introduction, I think we can move forward to sum up the basic principles of the course.

MT: (addressing colleague -human or robot-with name) you are right, this is a very good idea. Do you want to start telling us which do you think are the most important and I follow by adding more?

CT: Yes, of course! The main purpose of the course is the understanding of basic principles of computer operation from both hardware and software perspectives. The contents of the course are the following seven.

C. Procedure

The students followed the standard log-in procedures using their academic credentials to get connected. They were not previously informed about the use of a robot during the lecture. Moreover, the first group was tough with HH to avoid expectation biases [40], while the second with HR. After the end of the lecture, both the tutors thanked the students for their presence and asked them to fill in the enjoyment and understanding questionnaires, which were attached in link form in the chat before leaving the zoom session. The students were informed that the answers were anonymous, and the purpose was to help tutors evaluate their performance together with the students' level of understanding of the course. They were also informed that the data will be used only for academic and research purposes.

The student's level of enjoyment was evaluated with the use of the same Likert scale questionnaire, originally used in [36], which has been given by the authors to evaluate students' impression after physical university classroom lectures taught by the Nao robot [6]. Moreover, to access the students' understanding of the basic concept of the course, we asked them to fill in an online quiz.

Fig.2: Classroom set up in the human (left) and robot condition (right)

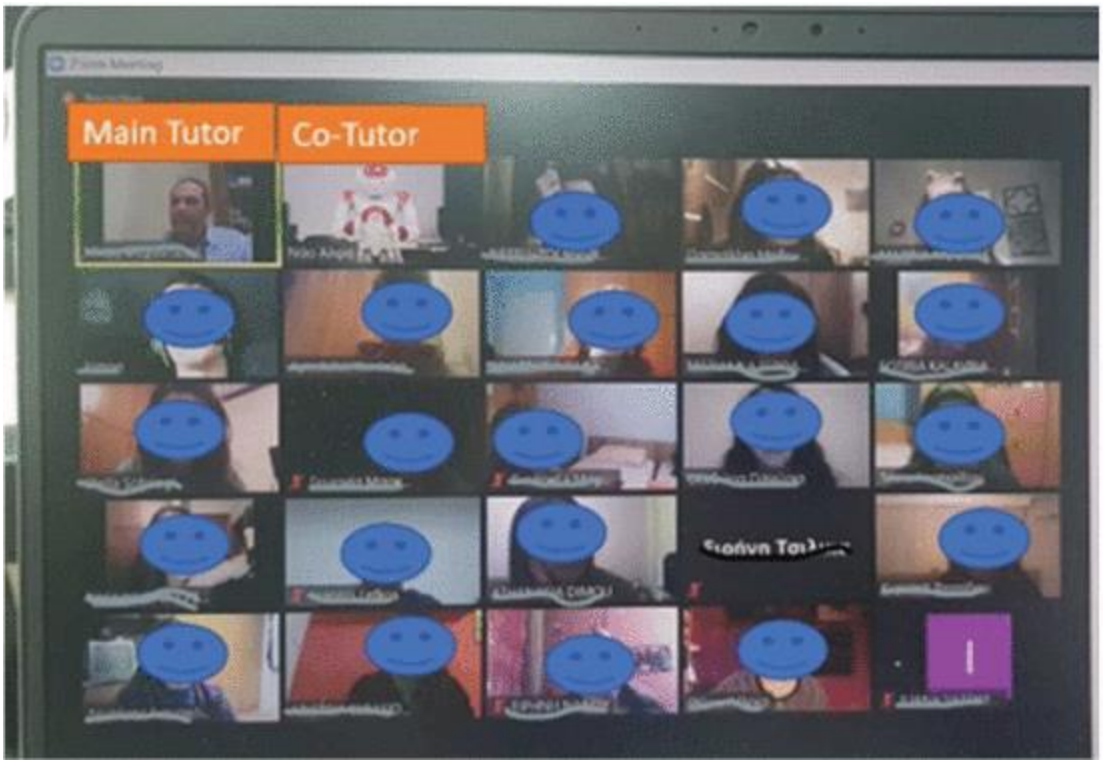

Fig.3: Virtual environment during the course (robot condition)

D. Data Analysis

In order to analyze the data of the enjoyment level questionnaire, we followed the data analysis process from the original research [36]. More specifically, we calculated a single number of each of the 35 Likert scale items by summing the response of all students for this item, and then we considered this sum as the interval data, by calculating the Mean Value (MV) and Standard Deviation (SD) for each condition. Finally, after performing the Kolmogorov-Smirnov parametric test, we applied a t-test between participants to find any significant differences between the students' level of enjoyment from lecture with human vs robot co-tutor. Moreover, we applied the Hedges' g effect size measurement appropriate for conditions with different sample sizes.

E. RESULTS

The Hedges' g = (150 - 146.59) /0.585 = 5.824, revealed a medium sample size effect, sufficient condition for reliable analysis. Regarding the students' enjoyment level, they had similar reactions after having a lecture with HH (MV=146.59, SD=21.77) and HR (MV=150, SD=22), as indicated by t(47)=-0.79, p=.431, d=3.41. Moreover, students in both conditions managed to understand the basic principles of the lecture.

SECTION VI.

Discussion and Conclusion

The present study focused on the interaction between university students and co-tutors during online lectures. We were interested mainly in how a robot co-tutor can improve the students' enjoyment level during Covid-19 and generally online lectures. The lectures were about basic principles of Cryptography. The students had one lecture held by two collaborative tutors, one human, who stayed the same in both

conditions and a) a robot co-tutor and b) a human co-tutor, and we evaluated the level of enjoyment they experienced during the courses and their understanding of the basic concepts of the lecture's content. The study was initially motivated by the effectiveness of robot-tutors in physical classrooms, and more importantly by the online survey outcomes conducted by the authors about the students' preference regarding having one or two collaborative human tutors during the virtual lectures.

The first outcome is that university students evaluated statistically significantly more positively the lectures taught by two collaborative human tutors in comparison to one tutor, based on their data retrieved from the online survey. Those findings are in line with the extensive research findings regarding the beneficial effect of co-tutoring in the education field. Especially during periods of extensive loneliness and isolation such as the Covid-19 quarantine, co-teaching seems to be refreshing for students. However, that evidence can be extended generally to online lectures.

Moreover, university students had equally high scores when evaluating a co-tutored lecture taught by human-human and human-robot, revealing once again the beneficial effect of cotutoring. The co-tutoring lecture in the current study was carefully designed based on the previous bibliography from the field of education and psychology. Both co-tutors had separate roles, interacted equally with the students, delivered new content, and presented different perspectives on the subject. Additionally, both co-tutor pairs managed to deliver the basic knowledge from the course to the students, supporting that humans and robots can be efficient co-teacher, especially when teaching a fully organized lecture, designed for co-tutoring [16].

Generally, the results demonstrate that social robots can serve as co-tutors teaching engineering subjects to university students similarly to a human co-teacher.

As for future work, we encourage educators and researchers to incorporate social robots as co-teachers in online lectures and more importantly to use different features of the robots, from personality traits to different storytelling and movements style [9], to software features such as voice recorder, and keeping notes. We are currently pursuing the same direction by also evaluating different robot characteristics and also planning to extend the research evidence to real classroom environments.

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