HUMANOID ASSISTANT ROBOTS IN TEACHING & LEARNING
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Abstract
This paper describes the first results of the German federal ministry of education and research (BMBF) financed projects H.E.A.R.T. and RoboPraX at the Philipps-University Marburg, Germany. The projects study didactic possibilities of social robots in teaching at school and university level. The overall research goal of the projects is to develop guidelines which enable educational institutions to use the developments in digitization and robotics to their advantage. The project team develops applications and assesses their implementation in teaching. Furthermore, robots are used as teaching tools and as teaching assistants. The exploratory research uses a realistic setting (i.e. different courses on linguistics, school workshops etc.) for their implementation tests and evaluates students’ responses to this new teaching tool through observation and qualitative questionnaires.

The paper focuses on didactic possibilities, speech related issues and advantages. The applications that have been developed so far will be presented as well as the in-class experience (including technical difficulties and implemented advancements), results from the student responses and outlook to further development plans.

Keywords: robots, digitization, didactics, Inverted Classroom Model, programing.

1 INTRODUCTION
For humans as social beings, utilizing social connections within the learning process can be beneficial [1, 2, 3, 4]. One option for enhancement presents itself through dialogic or social learning. When researching robotic implementations in teaching, every researcher in the field of didactics will be confronted with questions about the added value of using robots in teaching compared to other, less expensive and less complex digital devices such as tablets. The answer can be subsumed under one word: anthropomorphism. Humans have a tendency of building relationships and even do so with objects such as robots [5, 6, 7]. This tendency positively effects the usage of robots irrespectively of their outer shape, as long as they display humanlike behavior and actions. Such patterns and lines of reaction will then be interpreted within the frame of interpersonal behavior, additionally supported by humans’ tendency towards anthropomorphism [5, 6]. The humanoid shape of the robots strengthens and exhilarates the effect, leading to learners anthropomorphizing the object robot within just a short period of time, even attributing a personality to it [8, 9].

Several humanoid robots of the type Pepper and NAO are employed within the projects H.E.A.R.T. and RoboPraX and are only distinguishable through name tags and armbands of differing colors; in cases when project members confused the names of the robot used for a specific implementation in class, students repeatedly insisted on correcting this mistake and indicated the correct name of the respective robot [9]. This forming of relationships can be used constructively for the process of learning and, in consequence, for successful learning outcomes. Teaching and learning scenarios in seminars could, therefore, employ social learning situations supported by robots. The robot models used in the projects, Pepper and Nao, are social robots and as such specifically designed for Human-Robot-Interaction (HRI). They are intended for realistic imitation of human behavior and communication patterns [4, 5, 7, 9, 10]. The robots occupy several social roles within the teaching and learning process and have to be programed according to each situation and role respectively.

In the following, the projects will be described including the didactic approaches used and the applied teaching model, their respective goals and intended learning outcomes. Furthermore, the results of the first evaluations along with the methodology used will be presented alongside an outlook as to what still lies ahead.

2 TEACHING MODEL AND ROBOT ROLES
This chapter briefly describes the used teaching model as well as the differing roles our robots take on during the teaching and learning process.
2.1 The Inverted Classroom Model

The teaching model used in all our courses, seminars and workshops is the Inverted Classroom Model (ICM). In the ICM, content delivery takes place in an online scenario prior to in-class sessions (i.e. via an e-learning platform, videos multimedia elements etc. – see Fig. 1, part 1). Students attend in-class sessions prepared, which is assured through formative testing methods (see Fig. 1, part 1a, mastery learning) and practice the skills, which were acquired in self-study, during the sessions supported and guided by the class instructor (see Fig. 1, part 2, deep learning). In class, the students work in differing social settings (e.g. individually or collaboratively in groups) depending on the tasks and applied didactic method.

2.2 Robots as Tools

The use of robots in courses as tools can take on various shapes in the teaching and learning process. The application of robots in classes is often based on Papert's learning theory constructionism [11] and uses collaborative, project-based settings [12]. The robot function as tool differs slightly in both of the projects presented here. While in Project H.E.A.R.T. robots are used as learning devices comparable to tablets, computers and other educational gadgets with a clear support function (tool type 1), robots in the project RoboPraX are the subject of the learning process with programing, algorithmic thinking and robotics etc. being the topic of the Robotikum-workshops (tool type 2). In the following, both forms will be further described.

An example for a tool type 1 application that has already been tested in a linguistic seminar of the English Department at the University of Marburg is the use of robots as a form of a specialized field-related glossary. Students working collaboratively in small teams received the task of defining linguistic key terms in the style of “Twitter”-posts, using adequate scientific sources. The definitions were quality assured through the lecturer and entered into the robot’s database (model NAO). For the subsequent sessions, the robot served as glossary-like information source for the defined linguistic key terms, as the robot was available during the in-class sessions and could be questioned accordingly whenever a student needed reliable information.

In an increasingly digitized (work) environment it is of great importance that learners are exposed to and confronted with robotics and programing developments from their early youth on to prepare them for and enable them to be a productive part of the digital future. To achieve this goal, within recent years, there has been a growing variety of applications on offer for children and teenagers working on programing abilities with computers and robots such as Lego Mindstorms, Calliope mini, Raspberry Pi and so forth. The robot workshop Robotikum, which is part of our project RoboPrax, uses NAO-robots to help high school students make their first steps into the world of programing. This example of robots as tool type 2 will be further explained in chapter 3.3.

2.3 Robots as Assistants

Robots can additionally fulfill a support or assistant function for the lecturer, not only in a seminar environment but also outside the classroom. While in traditional teaching settings, such as lectures, the use of robots only makes little sense as a robot cannot present content as vividly as a human or adapt the content immediately to its audience and, most importantly, listening to it is highly tiring, in the ICM more use cases can be determined [13]. During the “knowledge deepening” in-class meetings the robot can take over the role as quiz moderator creating new opportunities and freedom for the teacher as well as providing a clear class structure. Due to the online content and learner data available from the online

Figure 1. The Inverted Classroom Model
platform in the ICM, the robot can also function as FAQ for the courses and give out personalized feedback on the students’ online performance. Both of these use cases will be described in more detail in chapter 3.2.1. Besides being a technical novelty, robots offer an entertaining factor and peak the audience’s interest [14]. This raises the memorability of the lesson and give it a type of brand value while impacting the progress in learning positively.

If interested in using a robot as assistant in traditional teaching scenarios, one of the few reasonable as well as meaningful application areas is the integration of a live-voting system into the robot. This does not offer many advantages for the students, but rather for the teacher, who has just one technical device to set up compared to several [13]. Furthermore, a relatively simple use that works in every teaching scenario regardless of ICM or traditional teaching is to use the robot for introduction rounds during the first in-class session at the beginning of a new semester. Starting a seminar this way leads to a more relaxed atmosphere and prepares students for further implementation of robotic support during the course of the semester [9].

3 THE PROJECTS – H.E.A.R.T. & ROBOPRAX

Both projects, H.E.A.R.T. (Humanoid Emotional Assistant Robots in Teaching) as well as RoboPraX, are funded by the German federal ministry of education and research (BMBF) to investigate the future implementation of humanoid robots in teaching and learning. Whereas the three-year project H.E.A.R.T. was completed in March 2019, RoboPraX just started around that time and is to be carried out within the next three years (until February 2022). In the following, the deployed robot models will be explained briefly as well as in greater detail both projects presenting evaluations where available. The evaluations used in or planned for our projects are mainly qualitative in nature. Several formats are applied, among them are qualitative questionnaires, (expert) interviews, observational studies (some of them participatory) as well as “before-after” comparisons (usually in the form of free-text tasks). As the project RoboPraX has just started, only a pilot study has yet been conducted while the other evaluations are still in the planning stage.

3.1 Our Robots – Pepper and NAO

The humanoid robot NAO was designed between 2005 and 2007 by the French robotics company Aldebaran – acquired by SoftBank in 2013 —, while in spring 2008 the first production version was released. NAO has a height of 58cm, weighs approximately 5kg and possesses 25 degrees of freedom. Due to his complete humanoid form – head, upper body, and legs – it can walk, fall and stand up similarly to a human. In comparison, the robot model Pepper was introduced in 2016 by the Japanese company SoftBank, at that point already the parent company of Aldebaran, and differs especially in height, the integration of a tablet as well as body shape. Pepper measures 120cm, weighs roughly 30kg and only the upper body reflects a humanoid form. The lower body consists of merely one leg with 3 rollers below for locomotion meaning Pepper rather rolls than walks. Hence this robot has fewer degrees of freedom, 17 in number. Additionally, Pepper uses sonars and lasers for orientation and navigation [15].

In matters of software the two robot models barely differ especially comparing the newer versions of NAO to Pepper. This is due to the same manufacturer. For both robot models, the following features are available: several language packages, locomotion, navigation, object and face recognition, emotions, sensors (head, arm, and lower body), use of the internet, incorporation of other media like sounds and predefined autonomous abilities in regards to speech and movements. Moreover, applications for the two models (Pepper up to version 2.9) can be developed either in block programming using the manufacturer software Choregraphe or in one of the programing languages of Python or Java. The newest version of Pepper (2.9) is programmed exclusively in Android and Java [15].

Whereas project H.E.A.R.T. deployed three Pepper and four NAO robots, RoboPraX only makes use of the NAOs.
3.2 Project H.E.A.R.T.

Project H.E.A.R.T. aimed to explore the topic of "robots in everyday life" using qualitative methods to generate research questions and hypotheses, which can then be examined empirically using qualitative methods on a larger population. Within the scope of the project, different areas and tasks within the University of Marburg were to be identified and investigated in which a coexistence of humans and humanoid robots might be beneficial, because a concrete added value for man and machine could be expected. These included:

- Support for teachers and students
- Advice on routine questions and problems, but also on issues that cannot be solved with simple FAQ systems (for example promoting teaching and learning processes)
- Information services for visitors and users of university facilities
- Advertising the university internally and externally

The initial assumption here was that humanoid robots, in contrast to simple FAQ systems, have three special strengths that they can contribute productively in their interaction with humans:

- The ability to have embodied multimodal dialogues with people in their familiar environment by combining language, eye contact, gestures, facial expressions, posture, and movement
- The ability to deal intelligently with humans and one's own emotions
- The ability to build relationships with people using the first two skills

The central aim of project H.E.A.R.T. thus was to evaluate the possibilities and limits of using a humanoid robot in the discussed areas by developing applications as well as investigating them scientifically and documenting them in order to make recommendations for the future and similar robots used in universities or other institutions. [13]

3.2.1 Applications

In the course of the project several robot applications were developed which ranged from rather simple apps as a glossary or a round of introduction moderated by the robot to highly complex apps using data from the Virtual Linguistic Campus (VLC) which includes linguistic content as well as learner data. The Quizmaster and the Student Advisor App are to mention here, they will be explained more thoroughly in the following. For these classroom applications, the robot model Pepper was used.

The goal of the Quizmaster App is to check the student's competences and prepare students - completely controlled by the robot - for potential exam questions using a quiz. This app can be used either in a one-on-one setting or in a one-to-many situation. In the latter, the robot presents questions one after the other with a set timeframe, and afterwards reveals the corresponding solutions as well as the explanations. Hence, the teacher gains the freedom to help students during this simulated exam situation and receives support with regard to time management and lesson structure. When used in a one-on-one situation, the robot asks a question which the student needs to answer directly within the given time. In real-time, the answer is evaluated and feedback is given including whether the answer was correct as well as the solution and an explanation. In the future, this version of the application could
be used for placements tests, oral exams or for students who simply want to do some exercises. For such an application to be feasible, several prerequisites need to be fulfilled. First of all, a database consisting of the contents for the quiz - question, solution, explanation - is required. Here, the distinction between the displayed and the spoken question is essential. In many cases, the displayed text differs from what the robot is supposed to say. Secondly, several quiz types – suitable for the robot – need to be developed as some types do not make sense with a robot (e.g. an essay task). Thirdly, especially for bigger groups, it is important to enable screen-sharing, displaying the image from the robot tablet via a projector on a larger screen for everyone to see clearly.

The Student Advisor App is intended to provide students with feedback on their performance concerning the online content of the courses they attend on the VLC. By accessing this e-learning platform, the robot can give general information about the courses, provide individually tailored feedback, advise students on their learning performance and then send the minutes to the respective student by e-mail. The added value is two folded. On the one hand, students have a second contact person and receive personalized feedback in real-time, for which a teacher would need to gather information beforehand and could not deliver a feedback immediately due to lacking the robot’s computing abilities and instant access to online data. On the other hand, it serves as a work relief for teachers as general questions which are repeated frequently, such as about the final exam date or next office hours, can be delegated to the robotic assistant. To enable the robot to provide personalized feedback several prerequisites need to be met. Most importantly, a database with learner data needs to be set up, which obviously goes along with an online learning platform. Giving personalized feedback is only feasible if the robot can identify the user unambiguously. As the hard- and software of the robot does not manage to do so using face recognition, a unique QR-Code is generated for each student in the profile of the e-learning platform to serve as identifier for individual students which can be recognized by the robot. Moreover, the robot’s performance-based dialog structure leads to personalized dialogs containing semantic variants of statements to appear more human-like and less monotonous.

3.2.2 Evaluations

After two smaller pilot studies and adaptations of the Quizmaster App in November 2017, a bigger experiment (n=52) with an improved application was conducted in the first semester course "Introduction
to Linguistics” in December 2017. The table below shows that while more than the majority of students still think of the robot as scary, 75% also regards the robot use as entertaining which can support the learning process substantially [14, 16]. A little less than half of the students would like to have another interaction with the robot and roughly 30% are neutral, which, for the most part, goes along with the distribution of students rating the interaction as useful.

Figure 4. Feedback on the Quizmaster App (n=52)

The questionnaire did not only ask about the likes and dislikes of the robot use in the classroom, but also tried to shed light on necessary application improvements from students’ point of view. Unfortunately, the highest rated statement “speech” cannot really be modified by the research team as improvements need to be implemented by the robot manufacturer or in the speech synthesis software (Nuance). However, the desired improvements in the categories “abilities” and “solution” could be addressed. The latter was integrated by making the robot utter the solutions as well as explaining why an answer is the correct one. The category “abilities” was further developed by completely automating the application, meaning, the teacher presses the “Start Quiz” button and the robot carries out the quiz without further human involvement. Additionally, the one-on-one version of the app as well as a greater variety of question types enhance the abilities of the robot in this application.

Figure 5. Desired improvements for the Quizmaster App

In addition to the Quizmaster App, the Student Advisor App underwent a pilot study (n=13, 26.11.2018 – 30.11.2018) with observations and interviews conducted with first and third semester students in the innovative robot office hours. Due to the relatively small group, only preliminary feedback and some desired improvements could be identified. Regarding the communication, users initially preferred the tablet input, which, to some extent, had to do with inexperience with humanoid robots as well as their verbal abilities. After a short hint that verbal input is also possible, conversations between robot and students increased - at first, with a little hesitation, later however, more fluently. Even though, students rated the interactions as not too helpful because they were able to gather the same information by themselves and only received little new information, their reactions towards the robot feedback on their online performance demonstrated an emotional bonding. A positive feedback arose a positive reaction, while a negative one led to embarrassed laughter and a guilty conscience, which was attested by the students in the interview afterwards. The conclusion of this first evaluation is that the robot’s feedback is not rich enough in content, however, students’ interest in this application is present and leaves room for improved versions as well as similar future applications.
3.2.3 Outlook

As project H.E.A.R.T. is finished by now, the research finding of the pilot studies for the Student Advisor App should be verified on a larger scale making use of more learner data which would improve the dialogues and conveyed information. This could convince students of the usefulness of such an application as they had an initial interest, however, found the amount of the information too poor. Additionally, in a side project, the Quizmaster App is supposed to be replaced by the so-called Classroom Packages which are to be developed in cooperation with the Centre for Learning Enhancement and Research (CLEAR) of the Chinese University of Hong Kong. The goal is to increase the meaningfulness of the in-class robot use by delegating more tasks onto the robot. A Classroom Package is supposed to comprise of a live-voting system, similar functions to the Quizmaster App and a class moderator in one app what enables the robot to administrate a class for a specific amount of time while the teacher has the freedom to support students where necessary. A prototype structure of this app is as following: First the robot summarizes the intended learning outcomes (ILO) of the lesson, then asks a competence question with a given time frame and solves the question afterwards, next it presents a task for the students to carry out, followed by a control question to ensure the quality of the students’ research. The number of questions, tasks and timeframes can be set individually. During this Classroom Package the robot acts autonomously, leaving the teacher with a lot of freedom. The application content is entered through a web-based interface which should not add up to a higher workload than preparing a presentation or similar in-class content. Furthermore, another future feature is to make the robot move around from time to time in this application attesting it even more human-like features as lecturers usually do not stand still for the entirety of a lesson.

3.3 RoboPraX

The advancing development and spread of digitization in the world of work requires in many ways a rethinking in the field of basic education and training. The responsible protagonists often bluntly underpin this need for change with the demand “informatics as mandatory part of school education”. However, so far, the necessary concepts and required content to realize this demand are still missing. A digital transformation not only requires teaching and learning with media, but also learning through media, ultimately creating new media literacy and new approaches to solving problems. In addition, new teaching and learning concepts must be embedded in holistic change processes of the education system. The project RoboPraX aims at addressing these challenges in their entirety and creating a new qualification framework that enables media learning through dedicated tools as well as media, identifying structural factors that support or counteract process implementation and transferability. Humanoid robots and the utilities available for their development serve as a practical basis for this new path. With RoboPraX, in multi-day trainings (Robotikum – see chapter 3.3.1) which are tailored to their respective target groups, pupils, trainees and teachers in all phases of teacher training will be introduced to the problem-solving strategies needed for creating and strengthening their ability of algorithmic thinking as well as developing robot applications. To introduce the topic, the Massive Open Online Course (MOOC) “RoboBase” will be provided, which, as a side effect, also promotes self-directed learning as part of RoboPraX through the use of an ICM. Through careful cyclical evaluation (“RoboEval”) and subsequent adjustments (“RoboFit”), a digital curriculum is developed as an integral part of teacher and school education. [17]

3.3.1 Robotikum

In cooperation with the City of Marburg, the project team has established the Robotikum: a robot internship, or workshop if you want, for students at high school level during which they have the opportunity to work with robots of the type NAO for three days, thereby experiencing artificial intelligence first hand. They develop dialogues, program movements and work with image recognition and emotions. All these applications can be tested using the actual robots during the Robotikum. The ILO is not only to familiarize students with robots and deepen their understanding, but also to initiate and strengthen algorithmic thinking abilities which are of utmost importance in today’s digitized world and will gain further significance in the coming years [18]. To participate in this workshop, students do not need any prior knowledge of programming or robotics. The user software Choregraphe allows even newcomers in this field to take their first steps in robot programming as no knowledge of any specific programming language is needed. The focus of this workshop is rather on facilitating an understanding of logical propositions and sequencing, system-dependent processes and algorithmic procedures. Students develop a better understanding of structural dependencies of process flows and receive a first glance into the field of (speech) logic, for instance condition dependencies and repetitions (loops) as well as
scripting of dialogues. Furthermore, they learn the still necessary use of a controlled language (CL) while working with robots.

Figure 6. Impressions from a Robotikum

3.3.2 Speech related Aspects of Human-Robot-Interaction (HRI)

The communicational problems, described here, suggest, at least for now, the development and implementation of a Controlled Language (CL) as used in many technical domains [19]. Such a language is already in use, partly defined through the basic software of the robots and the predefined commands for initiation of preinstalled applications. Open Source developers usually adopt this characteristic language style, as it is natural in such types of situations: coding-languages are devised using similar command structures so that the continuation within the realm of spoken language commands appears as a natural advancement of such coding.

Coding languages are designed for efficiency and clarity of command, which presents further advantages for HRI as orders or tasks including all subsequently required actions can be initialized time efficiently and accurately. Usage of a CL, therefore, reduces the error rate for interactions with and the service of robots significantly, which is most likely another reason for the presumably subconscious use of a Controlled Language. The presumption that the usage is subconscious is observation-based: the numerous progressions of applications (often but not exclusively in research projects) follow the same characteristic language style, irrespective of the actual profession and vocational-academic socialization of the developers. This is additionally, of course, supported through the development software (e.g. Choregraphe) and the development language (e.g. Python or JAVA).

Despite all mentioned advantages, the progression towards a more natural human-like communication style continues to serve as goal for any advancement [20, 21] and Controlled Languages can only be a transitional solution until expectations and reality of HRI overlap. The ongoing question here is, whether and, if yes, how our human language and our handling of artificial intelligence (AI) change. Do humans adapt their language use and their routines further to machines or do machines have to be refined until they can adapt to humans flexibly [22]?

Research findings concerning possible applications in the financial field (e.g. banks) show that shyness of customers when supposed to interact with robot is still a major issue. Customers prefer other input modes, if available, over spoken interaction with the robot. This suggests that people are not yet used to verbal interaction with technical devices, not even humanoid ones. Additionally, the humanoid shape and ability to converse as well as polished company marketing videos and Hollywood movies have led to false expectations. People believe robots to be able to converse freely with them. If the robot is of more child-like exterior, they assume a child-like speech pattern and apply subsequent behavior. A consequence is quite often breakdowns in communication due to impatience (i.e. not letting the robot finish its sentences, even reacting somewhat aggressive). Issues with code-switching or mixed-language input (i.e. lexical German-English combinations) could also be observed as well as problems due to background noise, loud environments, dialects and too fast speech. Furthermore, technical aspects of communication such as a different position of input and output devices compared to placement on a human body (i.e. output device (speakers) located at position of human ears, input
device positioned at the center of the robots’ forehead) can cause additional communication issues or even breakdowns. [23]

The recent and past technical developments and our handling of them (as described above) suggest the assumption that future structures will settle somewhere between the two opposite poles mentioned before.

### 3.3.3 Evaluations & Outlook

In addition to a six-month start-up phase and a 6-month implementation phase, the project consists of two project phases of 12 months each. In the start-up phase, the actual digital state of the participants will be surveyed using pilot study-groups in order to develop and adapt target group specific concepts for the Robotikum and the upstream MOOC “RoboBase”. In the first phase of the project, pilot tests will be carried out within the Robotikum in accordance with the strategy for digital education of the German Standing Conference of Education Ministers (KMK) and the digital competencies defined there. In addition, interviews with the management of the stakeholder institutions (in education, politics and economy) will be prepared, carried out during the subsequent project phases and evaluated. The first project phase consists of eight cycles of four weeks each. Each cycle builds on the evaluation of the previous cycle. With eight cycles, four target groups (teachers, students, mixed or gender-specific groups, trainee teachers) can be studied two-times.

The second project phase also consists of eight cycles. However, in this project phase, the target groups are slightly changed. After the evaluation of gender-differentiated target groups, subject-specific questions will be added (e.g. dialogue and communication in the linguistic subjects, or special aspects of object recognition in the STEM subjects). After a final evaluation, the findings will be put together so that the learning modules of RoboPraX can be used in regular lessons. For this purpose, implementation proposals will be made, which should be available by the end of the project as carefully evaluated recommendations, innovative didactic concepts and supporting learning scenarios for a curricular integration digitally and analogously (in book form) to enable the stakeholders to handle the requirements of digitization and to meet the challenges of the future digital work environment.

So far, only a qualitative pilot studies has been conducted: a “before-after” comparison (n=7). The aim of this “before-after” comparison was to determine the learning progress of the Robotikum participants. As described above, one of the indented learning outcomes of this workshop is the development and strengthening of algorithmic thinking abilities. To make changes in students’ thought processes visible, two free-text tasks were used, one before starting the Robotikum and one after finishing it. Students had to describe, for instance, the process of opening a door or of picking up a glass from a table and drink. The text analysis of the differences in the process descriptions suggests a change in the thought process of the participants. While the “before”-description were based on human-human-interaction (HHI), and, therefore, contained scarce process details (e.g. “use door knob, open door, go through”), the “after”-descriptions were, in all instances, much more detailed, describing the process with reference to the involved body parts and their movement requirements including several additional in between-steps (e.g. “move hand forward, open hand, move hand to glass until it reaches glass, close hand around glass, lift arm, bend elbow, move hand backwards to the mouth, tilt hand and open mouth, drink”).

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