Stem Education Reversed: Enhancing Science and Technology Awareness in Social Science and Humanities Students

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Abstract

A lack of science and technology awareness impairs students in the humanities and social sciences in their participation in social discourse about science and technology. However, students express the wish that innovative technology, science and interdependencies with society should be addressed as a topic in their university studies. Closing the gap between students expectations, societal needs and the reality of university education proves difficult, as addressing these topics in university courses in the humanities and social sciences is a complex challenge. A novel university teaching program based on empirical data has been designed and tested to address this issue.

Keywords: science and technology awareness, STEM subjects, interdisciplinary

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Crossing the Boundaries: Science, Technology, and Society

Monitoring the current science news, we are confronted with new, cutting-edge achievements of science and technology every day: 3D printing of the human heart, gene editing for blood disorders, spotting autism with the help of AI. These headlines are only a few examples of how innovative technology and science are rapidly changing the boundaries of medical possibilities.

The achievements of innovative technology have permeated society and in consequence the everyday lives of individuals. Technologies and scientific concepts that for centuries were regarded as science fiction—the enhancement of the human body with digital implants, the creation of artificial intelligence, or the colonization of our solar system—are on the verge of becoming reality. Yet the impending implementation of these technologies is not without societal consequences. Similar to the historical consequences of industrialization, we might be facing new and drastic dimensions of social change and inequality. In some fields, e.g. in health care, this is already obvious. While the privileged parts of the world's population are contemplating the application of nano robots for medical purposes, the socially deprived are dying of easily curable diseases (American Chemical Society, 2019). On the other hand, innovative technology and scientific progress are often discussed as a means to meet the challenge of growing social inequalities both in national and global contexts. This includes basic survival technologies that enable access to clean water as well as elaborate socio-technological constructs like public health-care or energy grids (Fraunhofer-Institut IAO, 2016).

In order to address the possible impacts of cutting-edge technology and scientific achievements on all aspects of life in the future, it is essential for students and academics from various disciplines to engage in shared activities that enhance not only interdisciplinary dialogue, but also the cooperative production of knowledge. In order

to make this possible, university education has to enable students to take part in the academic and societal discourse concerning technological and scientific developments. Students who are enrolled in teacher training courses should be especially prepared to take on this responsibility for the future citizens they will be educating. The children who are going to school today will be challenged to contribute their visions of justice and a life that is worth living to a highly technological society. They therefore need more than a one-dimensional perspective on technology and science if they are to be able to contribute in a meaningful way.

This paper will introduce the concept of science and technology awareness as a theoretical framework within which university education can play this important role. Empirical data from a quantitative pre-study will support the assumption that the average student enrolled in teacher training programs is not exceptionally well prepared to deal with societal, ethical or pedagogical issues created by technological and scientific development. The paper will then describe a way to address this issue by presenting an innovative interdisciplinary teaching concept that has been developed, implemented, and evaluated over four semesters with students enrolled in social work and teacher training programs at two different universities. The results suggest that students introduced to the concept not only become more interested in and aware of societal challenges connected to science and innovative technology. They also develop a better understanding of the multiple opportunities that technology offers regarding the enhancement of social justice and equality, e.g. for people with disabilities, as well as improving the quality of life by opening new perspectives for the humanities and social sciences.

Traditionally, technology has not been a major issue in the social sciences and humanities when teaching at university level. However, social processes caused or intensified by technology are becoming an central issue in the practical experience of teachers, as well as social workers, nursing staff, pastors, and other social or educational professions. In fact, most professions will be affected by those societal changes. We will be facing the consequences of a development that leaves certain groups of people in society deprived of familiar landmarks. Many of us will be facing this challenge unprepared. The following paper will illustrate how university education can make a contribution to this necessary preparation.

A Preliminary Study on Science and Technology Awareness

In order to test the authors' hypotheses on the science and technology awareness (STA) of students, a preliminary study was conducted among 100 students in teacher training programs in sociology and theology. Using a standardized questionnaire, the students were asked about their knowledge of certain technological concepts and specific technologies and institutions (only if they knew about them, not *what* they knew). They were also asked to assess their emotional evaluation of these concepts, institutions, and technologies and to offer their opinion on their future importance and their personal interest in learning more about these concepts and technologies in their courses. The specific items were selected because they had been in the news during the eight weeks preceding the survey. The preliminary study focused on students from the humanities and social sciences and did not include a control group from other academic domains. The study was meant to be explorative and the results were used to build sound

hypotheses for the principal study. In the next step of the project, the study was conducted among students in STEM subjects as well.

The authors intially assumed the following:

1. Students in the humanities and social sciences have a limited knowledge of technology and science topics.

2. Students in the humanities and social sciences have strong emotional reactions to specific technological and scientific concepts.

3. Students the in humanities and social sciences ethically evaluate technological and scientific concepts based on these emotional reactions rather than on domain knowledge or an assessment of their possible societal impact.

As the following summary will show, the results partly confirm the above hypotheses, but were, in some cases, surprising. As expected, a high percentage of the surveyed students had knowledge of some general technological concepts, specific technologies and institutions such as GPS (83%) or NASA (76%). But in some cases, the numbers were surprisingly low, e.g. the term „robotics," which was known to only 55% and ESA to merely 38% of the students. Quite a number of specific institutions and concepts were familiar to less then 10%, including Break Through Starshot, Human Enhancement, Hyperloop, Mars One, and SETI.

On the other hand, the students had very well-defined ideas about their emotional reactions. A strong positive connotation was found for roughly 70% of students concerning information technology, innovative transportation technology, and aerospace technology. As the survey did not collect data on the reasons for this, we can only speculate that the positive connotation might be due to the everyday presence and usage of these technologies (e.g. taking a plane to go on holiday or writing messages on

a digital device) and a lack of insight into topics such as military aspects of aerospace technology. In the forthcoming principal study, the reasons for these emotional connotations will have to be addressed. Similarly, the survey showed strongly negative connotations for certain technological concepts, notably nuclear energy, computer implants, brain-computer interfaces and robots in healthcare. This corresponds with the fact that students consider some technologies and concepts to be ethically questionable. Artificial intelligence (77%), robotics (76%), nuclear technology (74%) and brain-computer interfaces (70%) score the highest in this category. As already stated, there are currently no data on the specific reasons, but the question will be approached in the principal study.

One rather unexpected result was that roughly 40% of the surveyed students evaluated the general term „innovative technology“ either neutrally, negatively, or strongly negatively. If we interpret this as resentment or even fear of innovative technology in general and also consider the fact that the surveyed students will be future teachers and therefore in a position to influence a whole generation of students on their opinion on technological and scientific innovations, the need for transdisciplinary university courses and socially relevant research across the boundaries of academic domains becomes essential. This assumption is supported by another finding of the survey that was unexpected: even though both concepts had appeared in the news in the weeks preceeding the study, more than 45% of the surveyed students thought of asteroid mining as a science fiction topic. For the concept of Mars colonization the number was even higher with more than 60% of the students putting it down as pure science fiction (see Waltemathe, Hemminger 2019).

Summing up the results of the preliminary study, we see that the surveyed students from teacher training programs in sociology and theology already have some

knowledge about specific STEM topics. They are also interested in learning more about some of the concepts, institutions and technologies. The students evaluate STEM topics from an ethical perspective, even when they are unknown to them. They generally state that ethical and societal questions concerning STEM topics should be part of their university education.

However, specific concepts, institutions and technologies are unknown to the greater part of the students. For certain STEM topics, the students stated that they are not interested in learning more about them. Unfortunately, these last two areas are identical. Again, we can only speculate on the reasons for this. Hopefully, the lack of interest in the unknown topics is due to hesitation or fear of getting involved in a complex and challenging field of discussion and can therefore be addressed as part of their university education. Apart from the specific reasons, this attitude certainly seems to be part of the process that reproduces the gap between academic domains and should be further analyzed. But even while lacking profound answers to a number of relevant questions in this context, the preliminary data that we obtained triggered the development of a teaching and research project concerned with enhancing science and technology awareness (STA) in social science and humanities students.

Science and Technology Awareness (STA): A Theoretical Framework for a Research and Teaching Project

Both the terms „science literacy“ and „public understanding of science“ (PUS) have been subject to criticism for some time. There are at least two reasons for this. First, the terms seem to be incompatible with modern theories of learning, since they imply that people should acquire knowledge not as an active choice, but against their particular interests. Second, both models focus on deficiencies and the need to combat

ignorance and misunderstanding of the general public (Stocklmayr, Gilbert, 2002: 836). This somewhat arrogant perspective on the complexity of the relationship between public and science is targeted by the term science and technology awareness (STA) that the authors propose. In contrast to Stocklmayr and Gilbert (2002), who introduce a concept of „public awareness of science and technology," STA is conceived not as a process of constructing personal meaning from experiences (ibid.: 836), but rather as the opposite. Instead of starting with personal interests and experiences, STA, as the authors define it, is focussed on enhancing the awareness of the relevance of science and technology for societal questions on a macro level. Based on the understanding of the general interdependency of science, technology, and society, students can develop interest in specific topics and skills in acquiring the necessary knowledge. As a result, enhancing STA can build confidence in taking part in societal and academic discourse on science and technology issues and thus enable students to help shape the future they deem desirable both for themselves and for society as a whole.

In order to enhance STA among social science and humanities students, we designed a comprehensive project consisting of three major components. The first component is an empirical study on students. Ultimately, the study is planned as being representative for students in general, but currently the authors are focussing on gathering data on students enrolled in teacher training courses at German universities. The second component is a teaching module that has been developed and tested for four semesters already. According to the students' evaluation of the courses and based on the results of the study up to this date, the module is currently being revised and modified for future implementation.

A third component of the project will be an empirical study of interdisciplinary academic work. Based on the assumption that the boundaries between social sciences

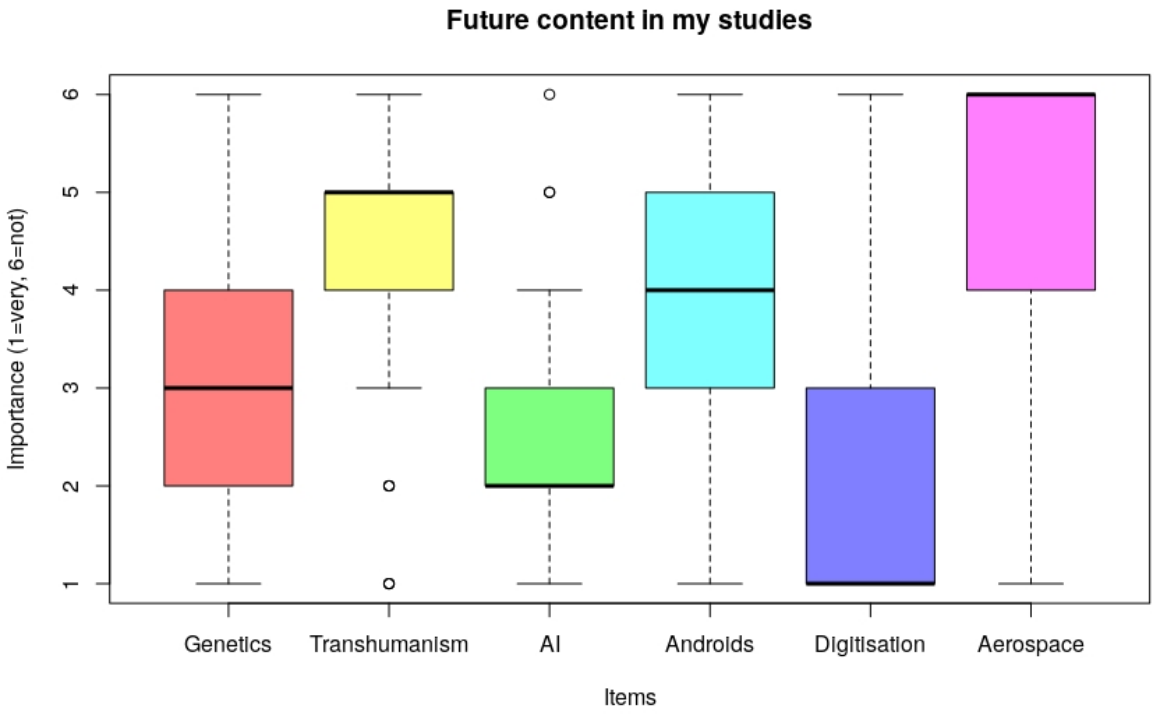
and humanities and STEM subjects are constantly re-produced in our educational system, the study is designed to give insights in the social practice of interdisciplinary academic works and the inherent challenges and possible incentives.

Empirical Study on Future Teachers: Selected Results

In the following, we present selected results from the empirical study of STA among students, focussing on teacher training courses. The study was designed as a quantitative questionnaire and conducted via an online tool, based on the results of the preliminary study mentioned above. Students were asked about their knowledge of technologies and institutions that had been mentioned in the news during the weeks preceding the study. Further questions focussed on the emotional connotations the students had considering certain keywords and on the assessment of their own competence in participating in academic or societal discourse on topics in science and technology. As the data collection is not yet finished, the numbers presented here are not completely representative, but can still give an insight as to the direction in which the final results might be pointing.

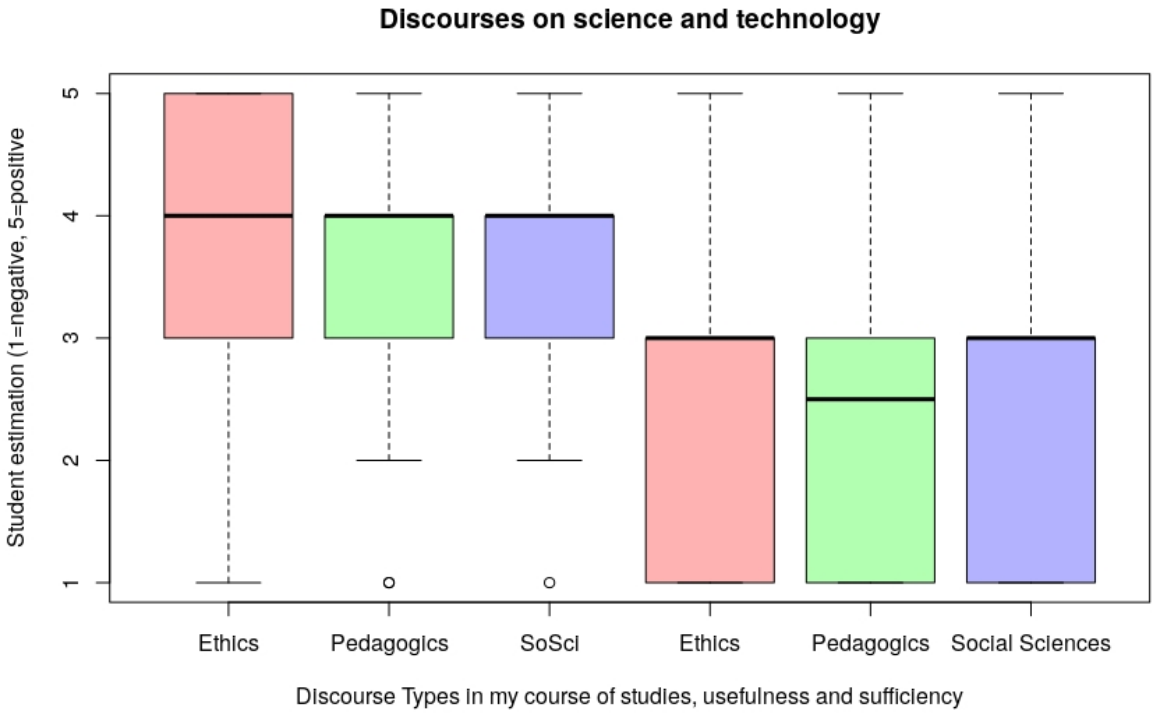
Asked about their wishes for technology and science content in their future studies in the humanities and social sciences, the students identified digitisation and artificial intelligence as the most desirable subjects, while transhumanism and aerospace engineering were the most undesirable subjects. Looking back at the results of the preliminary study, this finding also points out the clear distinction between subjects students want to learn about or not. Digitisation and artificial intelligence stem from the field of information technology, something that is being pushed into education by federal politics in Germany (BMBF 2016) at the moment. One could thus argue that—

once again—the students prefer to learn about something with which they are already somewhat familiar.

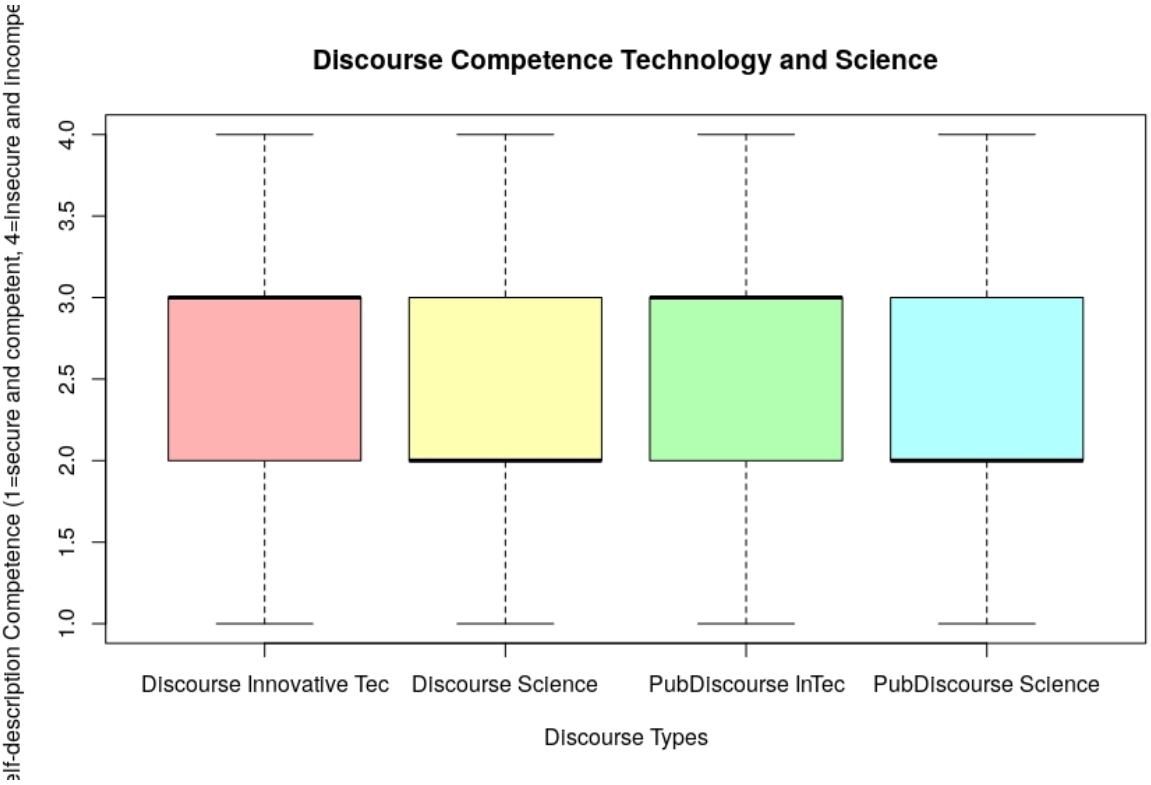


Students' wishes for future content in their respective syllabi.

The students were also asked about the usefulness of learning about the ethical, pedagogical, and social science aspects of the science and technology for their education as well as the current discussion about these topics in their courses. The following boxplot shows that while students think this discourse useful, they do not think they learn enough it. For them the pedagogical aspects seem lacking more that the ethical and social ones.



Looking at these results from the students' participation in societal discourse on science and technology is especially revealing. While they do profess to a certain level of comfort and competence in this domain, they also lack conviction in their ability to participate on a high level. Such competence and comfort, however, would be very useful for future teachers.



It is interesting to note that the students feel more competent in the discourse on science than they do in the discourse on technology.

Considering these results, especially the students‘ wishes for their university studies and their assessment of their competence in participating in the discourse on science and technology topics, the importance of implementing STA into the curriculum is evident to us.

The Teaching Module: Interdisciplinary Seminar Courses

In a teaching module that was developed initially for a cooperative project between students in Protestant theology, social work, and elementary pedagogy from two universities in Germany, several seminar courses were designed that brought the students together. After the first trial semester, other student groups (including international students from the Netherlands, Turkey and France) from diverse

disciplines (e.g. engineering, informatics, biology, arts, or physics) were involved in the courses as well. The seminar courses were integrated into the existing curriculum, making them part of the regular structure of the syllabus. These courses, as they have been taught in the past four semesters, share a number of basic principles outlined below; the specific topics and formats vary from example to example:

1. The basic general issue of the courses was science and technology and the interdependencies with society. However, every specific course focussed on different aspects of this issue.
2. The courses are strongly based on exploratory **students' projects** and include kind of final **presentation**.
3. Every course was in some way **interdisciplinary.**
4. Every course involved at least two **different universities**.
5. Parts of every course took place in **special environments**, such as a conference setting at another university, a summer school or a multi-day international workshop at a European research center.
6. The courses involved renowned **experts** from scientific and technological fields, e.g. robotics, astrophysics, informatics, but also visual arts, environmental studies and science education.
7. The pedagogical tool of the **thought experiment** was an essential part in the design of the courses.

Exemplary courses included among others (1) Innovative Science and Technology: Scenarios of a Future Society, (2) Digital Media and Memory Cultures, and (3) Technology in Pedagogical Contexts. Course (1) focussed strongly on possible impacts of innovative technologies and scientific findings (e.g. CRISPR gene scissors, AI, robotics) on societal issues like social inequalities, environmental issues, and the basic

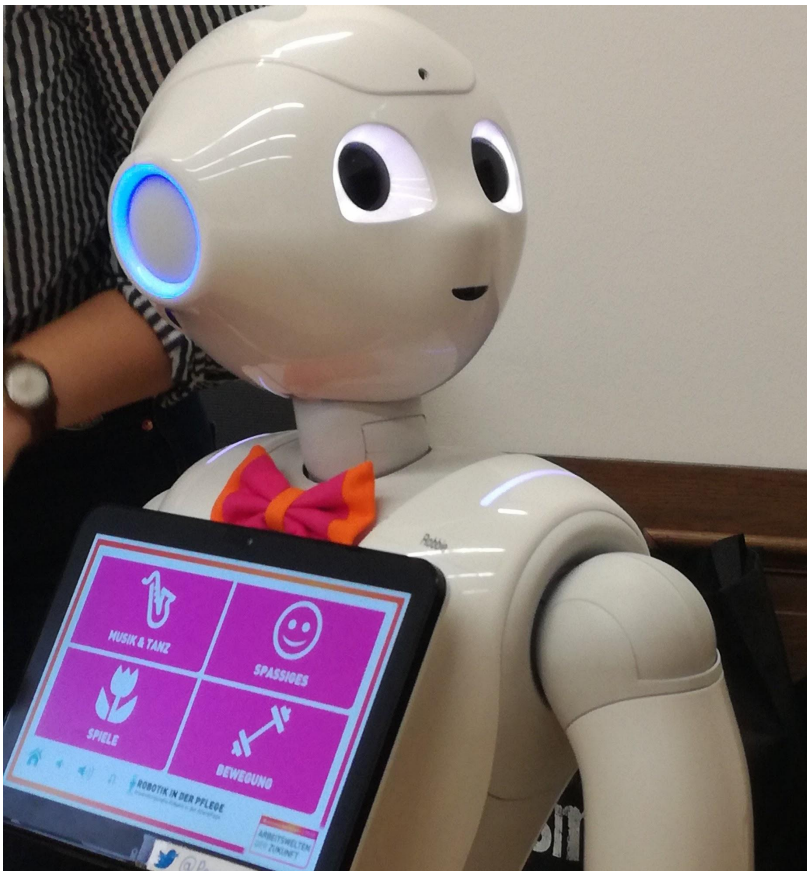
concept of being human. It involved lectures from interdisciplinary experts at VU Amsterdam and a workshop at ESTEC, an ESA technological centre in Noordwijk, the Netherlands. The students worked in international and interdisciplinary groups on different projects and presented their work before experts and students in the inspiring context of a place dedicated to space exploration.

Students simulating an extravehicular activity at ESTEC during course (1)

Course (2) centered on digital media and culture, especially memory culture. It included a week-end at the Protestant Academy in Hofgeismar, Germany, with students from five different universities participating. The program consisted of keynote lectures and workshops, e.g. on analogue and digital photography, selfie culture and „5 stars for Auschwitz on Tripadvisor," resulting in lively and controversial discussions on sensitive issues.

Bathroom repurposed as a makeshift darkroom to develop analogue pictures for course (2).

In course (3) seminar informatics students and students enrolled in pedagogical or social work studies designed projects for the humanoid robot Pepper in educational contexts, e.g. working with autistic children, pre-school science education, or as a support for young refugees. The scenarios will be put into practice and evaluated in a forthcoming course, but already during the designing stage, interdisciplinary cooperation appeared to be most valuable for the mutual understanding of different perspectives on the same technology. As a first explorative experiment, the humanoid robot Pepper assisted the university vicar in the opening service at the Protestant University of Applied Sciences in Bochum, triggering many fundamental questions, discussions, and quite a few smiles.



Pepper, Humanoid robot during course (3).

In summary, these three courses covered basic theoretical approaches combined with a broad range of scientific and technological innovations. The students got involved in creative work, using thought experiments in order to develop interest and understanding for the complex interdependencies between technological development and societal issues. Seeing experts at work, having discussions with other students and university teachers, and cooperating on joint projects helped the students to gain the confidence and skills required to take part in academic and societal discourses on science and technology topics. Instead of specialized skills and knowledge, the students acquired the necessary, basic understanding of what specialists are working on, what we might be facing in the future, and how technologies will change the society we live

in. They also learned how society can influence the development of technologies and science and who the stakeholders in this process are.

Future Prospects

By enhancing STA in social science and humanities students, the authors hope to support them in feeling responsible and willing to think about a future society and perhaps become stakeholders themselves in a democratic and analytical process of forming a technologically permeated society.

Apart from the anticipated benefits for the students, the university teachers who are involved also gained new and interdisciplinary perspectives on their fields and profited from the cooperation. The future focus will be on expanding the teaching project and develop a tool box applicable for any study subject. Enhancing STA could thus be not only feasible for the social sciences and humanities, but also for STEM subjects. After all, our approach is based on interdisciplinary cooperation and communication; this should hopefully involve university teachers and students from various disciplines, including the STEM subjects.

The existing boundary between STEM and social sciences and humanities is a rigid and persistent one. In many cases it even becomes manifest in the campus layout of universities. The ultimate objective is therefore to literally get people to walk from one side of the campus to the other in order to work together on those essentially important issues for our future society.

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