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„To boldly go, where no one has gone before!“ A transdisciplinary journey to technology education for everybody

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1 ABSTRACT

Our work is based on the idea that technology literacy contributes to a self-determined life as responsible citizens in a technologically constituted society [1]. For more than ten years, founded on an inquiry based learning approach [2], we have developed, tested, and improved the “vehicle theory” [3], particularly to implement technology education more widely in Austrian secondary schools.

Since 2008 hundreds of pupils – who were originally not very interested in technology – took part in our interdisciplinary, gender-sensitive technology education projects. In these projects, youth’s interests (e.g. music, fashion) have been used as vehicles to introduce science and technology knowledge and skills [4].

The results have been very promising; pupils reported about being more interested in technology, technological abilities have increased [5].

However, the critical point in all these interdisciplinary school projects has been a lack of sustainability: Too often only one school class or cohort benefited from the project, while science and technology teaching for future classes stayed the same. That was the starting point for the transdisciplinary technology education project “Kids4Wearables”, which does not only bring together various disciplines (e.g. fashion, coding, physics) but a diverse set of experts (teachers, academics, companies) to increase lasting multiplying effects in schools.

The paper presents the approach of transdisciplinary technology education by means of Star Trek analogies with the hope to be read and shared widely.

2 Introduction: The journey begins

„To boldly go, where no one has gone before“, is a well-known quote from the spaceship Enterprise’s captain Jean-Luc Picard, whose very words prelude every episode of the TV series “Star Trek: The Next Generation”. Of course this pop-cultural reference is a catchy title, which should raise a certain interest in its readers, and it seems overly exaggerated when talking about an educational project. However, the second part of this paper’s title refers to transdisciplinarity, which is indeed a rather uncommon approach in technology education. Furthermore, what we will present in this paper is a very ambitious journey of a transdisciplinary group of travellers indeed: teachers from five different primary and secondary schools, computer scientists, physicists, social and education scientists, an artist, and an industrial enterprise. And where are they headed? They are all motivated to enable kids to experience science and technology education in a meaningful and empowering way. But to stay within our journey metaphor: the captain of this spaceship wants to go even further than teaching kids technology. She wants to develop didactical concepts for teachers outside classical technology education with her transdisciplinary crew, so that someday technology literacy is for everyone.

2.1 Joining the journey: why technology education for everybody?

On entering the project, our ‘spaceship’, we were to think about what technology education means for the journey ahead and what it means in the greater context of the project’s predecessors. Our approach to technology education relates to our understanding of technology as co-construction to society. Thus we cannot think about technology in general, and technology education in particular, without thinking about its social and environmental implications. This means that, to us, technology education is not only teaching theory and practice of technological applications. It is also about the social, ecological, economic and ethical questions related to these applications. Considering these questions makes us responsible citizens in a technologically constituted society [6; 1]. Thus, we do not have to be engineers or understand all the technologies surrounding us to their core. It is technology literacy in a sense that enables us to codetermine the way technologies shape society and vice versa. Actual examples may be the way social media as technologies of communication shape the way we interact and spread/receive information – with grave consequences for free speech and democracy as such. Another current discussion that moves people across Europe is the implementation of 5G technology and the hopes and fears that go along with it.

Technology literacy, as we understand it, acknowledges that technologies are actors [7] that have impact on society; often autonomous from the purpose they were developed for. As a consequence, there is an empowering moment inherent in technology, which is key to our approach to technology literacy. We want and need to foster a perspective on technology that underlines its usefulness, that one 'can make something with it', rather than the image of being committed to the way technologies, as agents of power, control and dominate our everyday lives. According to our approach, technologies should facilitate and empower. Thus, successful technology education enhances technology literacy for responsible citizens to enable recognition of the role of technologies in society and the power relations inscribed, and to enable decision making in handling technologies accordingly.

Considering the agency of technology [8] and the technologically constituted society we live in [6], we all should ask ourselves: How are technologies designed? What are the norms inscribed and supported by technologies, and who are the people participating in their development? What kind of idea of the human being forms the basis of technologies that shape society? What kinds of technologies get funded, which ones do not? And finally: How can we use the agency of technologies to enhance participation in democracy – how is the development of technologies itself a process of democratisation?

These rather abstract questions boil down to the fundamental question of accessibility of technologies – not only in the sense of availability and affordability but also in regard to the possibility to appropriate, adapt, 'hack' technologies for individual needs. What kind of knowledge is required to access, handle and modify technologies? How accessible is the knowledge behind technologies [9]?

2.2 How to get kids on the journey: vehicle based technology education

Even though technologies shape our everyday lives, many people do not feel self-efficient in handling technologies. This subjectively felt distance to technologies makes it hard to get people interested in participating in technology development processes. We therefor need a 'vehicle' to get them on board of our 'spaceship'. With our pilot project "Engineer Your Sound!" we tested music as such a vehicle. We approached sixth form pupils with special focus on music and used their interest and expertise in music to teach them music related technology skills. And it worked. Not only did it increase the pupils' interest in science and technology, but they also developed technology skills and their self-efficacy was strengthened [3]. One of the five pupils' projects was the development of an 'air piano' based on the principle of gesture mapping using Nintendo® Wii technology.[1] With

[1] By attaching infrared reflecting material to a finger moving in front of an infrared camera (the remote of a Wii console) MIDI commands triggered corresponding notes in the sound of a piano.

the help of a technological coach, three female pupils could realise their vision of making beautiful piano music in the main square of their hometown – without having an actual piano there. Their vision was so strong, and their expertise and interest in music so deep, that they learned about infrared technology and coding along their way [10].

Key to our idea of vehicle based technology education is interdisciplinarity – not only in the sense of bringing natural sciences and technologies together (as it is sometimes the case in academia when talking about interdisciplinarity). It is a strongly holistic approach that helps young learners to find out that seemingly non-technological topics and activities they follow in their spare time are actually emerging from a technological context (such as music or TV series; see table 1).

Table 1. Overview of completed vehicle based technology education projects

Title (period)	Target group	Participants	Vehicle	Outcomes
Engineer Your Sound![2] (2008-2009)	sixth form	20 female and 8 male learners between 17 and 19 years	music	1. realisation of five music-technology projects 2. raised interest in and understanding of technology 3. gender-reflexive didactical concepts for technology education
PictureIT[3] (2009-2010)	sixth form	68 learners between 15 and 18 years	photography	1. gender-, technology- and photography-knowledge and skills transfer between groups of pupils 2. openly accessible database with gender-sensitive pictures of people using technology
TransFAIR-mation[4] (2013-2014)	secondary school level	24 female and 30 male learners between 12 and 16 years	TV series	1. remix videos of 'un-fair' episodes of TV series 2. building up media-technological skills 3. reflection knowledge about legal, social and ethical aspects of technology
useITsmartly[5] (2013-2016)	sixth form	331 learners between 16 and 20 years	fashion, DIY, photo-graphy, video making, music, video games, theatre	1. different vehicles served successfully as entry points for science and technology education 2. all participants became 'green IT peers' (incl. technological skills and reflection knowledge especially about environmental aspects of IT) 3. green IT knowledge shared with ca. 39,000 other persons

[2] The project Engineer Your Sound! was funded by the Sparkling Science programme of the Austrian science ministry; IFZ was managing the project (details: www.ifz.at).

[3] The project PictureIT was funded by the Sparkling Science programme of the Austrian science ministry; IFZ was managing the project (details: www.ifz.at).

[4] The project transFAIRmation was funded by 'Zukunftsfonds' of the Styrian government; IFZ was managing the project (details: www.ifz.at).

[5] The project useITsmartly was funded within the Intelligent Energy Europe programme by the European Commission; University of Wuppertal was managing the project, IFZ was the scientific coordinator and in charge of the evaluation (details: www.ifz.at).

So far, with this vehicle approach we reached more than 450 young learners who might not have acquired technological skills and knowledge without our projects. But the success of our projects is not merely based on using youth interests as entry point for science and technology teaching. We always follow our own framework of gender- and diversity-reflexive education [1, 3; 4]. Furthermore, we foster a transdisciplinary culture with our approach. Transdisciplinarity is a principle of so called ‘Mode 2’ research which integrates not only different disciplines and goes beyond the academic arena, but also forms new sites of knowledge production aside traditional academic hierarchies [11]. By including teachers and learners as research partners and not merely ‘research objects’, educational research becomes much more relevant for all participating actors. Research is tackling problems which are of interest for learners and teachers. By using their real life experience and immediate feedback, gained knowledge is much more robust and valid.

With our research projects (described in table 1, page 5) we focused on getting young learners on board, and indeed we found that vehicles work with learners in technology education. However, we observed a lack of sustainability of our didactical concepts when it comes to classroom teaching after our projects ended. This is why in our new project, we decided to step up with the transdisciplinary expedition and get teachers earlier on board, as jointly responsible and proactive crew members, from the very beginning of the journey. And now we are asking:

Will we – together with this new crew – discover a passage to a new galaxy of technology education for everybody?

3 Starting a new adventure with Kids4wearables

In the following, we are presenting our case study, the currently running transdisciplinary project – our spaceship – “Kids4Wearables”. Here, pupils learn to produce their own intelligent fashion, and we are testing whether such a transdisciplinary project, which includes teachers from the beginning, can help make inclusive technology education permanent in Austrian schools.

Can we – with this project – boldly go, where no one has gone before?

3.1 The spaceship, its mission and its crew

Kids4Wearables is a project funded by an Austrian technology research programme[6] which is to foster collaboration between research, schools, and industry. One of the main objectives of the programme is to get pupils to experience research and innovation in order to encourage respective career choices. One challenge that had to be met with in the call was that it requires the collaboration with at least five schools (primary and secondary level). In contrast to our former projects this meant not only that we would not be able to take part in classroom activities ourselves but it also meant that we could finally tackle our sustainability problem by training teachers as multipliers, supported by our project partners from research, industry and arts. As another consequence of involving such diverse schools, we would have to develop didactical concepts that suite the conditions of every single school. We pinned our hopes on this constellation that vehicle based technology education would finally be implemented in a more sustainable way and that this kind of technology education would go on after the project.

[6] The project is financed by the 6th call of “Talente regional” programme of the Austrian Research Promotion Agency (FFG). Both authors have developed the concept of the project, which ran from 2017 to 2019, together. Birgit Hofstätter was the coordinator of the project, Anita Thaler was in charge of its evaluation (in her team Michaela Jahrbacher helped with the empirical research).

The youth interest we connect technology to in Kids4Wearables is fashion, and the technological field to be entered is wearable technologies. Spoken in our metaphor, we use the shuttlecraft "fashion" to bring pupils at the age of six to fifteen years on board of our spaceship Kids4Wearables. For the crew we recruited teachers from five schools from the rural Salzkammergut region (Upper Austria), computer scientists, physicists, social and education scientists, an artist, and an industrial enterprise.[7]

The objectives of the Kids4Wearables crew are

1. to enhance the interest of young people in research, technology and innovation,
2. to actively involve them in a process of research and innovation,
3. to develop a didactical concept for the cooperation of education, industry and research,
4. to particularly focus on involving girls and children from immigrant families.

Our approach of vehicle based technology education caters to all these objectives as it seeks to be meaningful to young people regardless of gender and ethnic/cultural background – the vehicle has to be chosen from everyday life experience of the learners. It therefore is inclusive, trans- and interdisciplinary, and it is open to include actors from outside the classroom.

However, as said before, the captain of this spaceship has an additional vision. She wants to create a sustainable framework for an inclusive technology education for everybody. With the vehicle approach we know how to successfully get learners of various age groups and across genders interested in technology as well as in acquiring respective competencies.

Thus, now it is time get teachers actively involved in producing didactical concepts and convince them to practice inclusive technology education in their classrooms also in future. So the question now is:

Have we really managed to get all members of the crew on board of our Kids4Wearables spaceship?

3.2 The Captain's log book: collecting data

Kids4Wearables is evaluated with quantitative and qualitative instruments before and after the project in order to measure the impact concerning the previously mentioned objectives: enhance the pupils' interest in technology, actively involve them in a research process, develop didactical concepts, and specifically involve girls and children from immigrant families.

Additionally, the accompanying evaluation produces feedback for the involved actors already during the process based on pedagogical ethnography. With participatory observation, interviews, analyses of documents and learning materials, and reflection meetings with teachers and the project coordinator, the process of teaching and learning is accompanied continuously. The major advantage of pedagogical ethnography is that its results are not limited to verbally and consciously accessible information or by social desirability [12].

[7] The schools are VS Traunkirchen, NMS Altmünster, VS & NMS Gmunden-Stadt, and Rubenshof. We were joined by the Institute for Pervasive Computing and the Department Soft Matter Physics (SoMaP) from Johannes Kepler Universität Linz (JKU), supported by Cool Lab, a newly installed innovative lab for digital education and computational thinking at JKU. As partners from industry we were able to win one of the biggest companies in the region, Lenzing AG, which produces cellulose fibers, and artist Gertraude Stüger, who experiments with space and fabric.

In the following chapter, we draw on preliminary results from the ongoing ethnographical research and interview data, and we explain why we might need another shuttlecraft (this time a ‘vehicle’ for teachers) to really bring the whole crew on board of our spaceship.

4 Being on the journey: challenges along the expedition

4.1 The expedition of Kids4Wearables

Vehicle based technology education, like inquiry-based learning[8] [2], is process oriented. This caters to the needs and resources of the crew rather than to an external goal that may inhibit creativity and a culture of error where it would be safe to experiment with ideas: The journey is the reward. This approach was key to the overall project. We roughly pre-structured the process in four phases which overlapped and allowed the crew to stay flexible according to the needs and resources of the teachers and learners. The first phase was for the teachers to get acquainted with the idea of vehicle based technology education and to develop a didactical concept that caters to their respective learners’ needs. The second phase took place in class, activating fashion as the vehicle for kids between six and fifteen years. The third phase introduced technologies making fashion accessories into wearable technologies. The fourth phase is explicitly dedicated to knowledge transfer and reflection. This is what we learned through our process evaluation so far:

In the first phase we tried to bring the teachers of the participating schools together. While getting to know each other they might want to exchange experience – particularly since we were gifted with a mix of schools that follow ‘conventional’ pedagogical approaches and reformist pedagogy. The first crucial learning was that teachers from ‘conventional’ school systems seemed reluctant to engage in this exchange and rather wanted to move within their comfort zone. Interestingly, the didactical concepts developed along this line. Teachers from ‘conventional’ schools lead their pupils to create the same product (mostly creatively ornamented bags and backpacks with LEDs) while the reformist schools encouraged the pupils to imagine themselves as inventors without any pressure on creating a working prototype.

In the phase of thinking about the didactical approach we found out that not all teachers were aware that they would have to implement the concept themselves. In the beginning we asked them about their relationship with fashion and technology. Some of the teachers clearly stated that they were either not interested in fashion or in technology and that their competencies in these fields were accordingly restricted. Together with project partners we organised workshops for teachers where they could try themselves in e.g. sewing electric circuits in T-shirts or coding a microcontroller with a light sensor and LEDs. In this process we discovered: Teachers, too, need vehicles to the topics they feel distant from (for the physics teacher fashion might be as distant as coding might be for the English teacher).

The second phase was to activate fashion as topic of interest for the learners. An artist opened this process with a workshop where paper was used as fabric, and the pupils tried to put it on as clothes. In some schools, whole classes took part in these project activities, in others the pupils themselves decided whether to participate in the

[8] However our vehicle approach goes a step further than inquiry-based learning as it starts with topics which are of interest and importance for the involved learners and where they have expertise and competencies.

activities or not. This aspect showed how important it is to use 'gender-neutral'[9] topics as entry points for our technology education: With our vehicle approach (using gender-reflexive and inclusive didactics) we could manage to attract an almost gender-balanced group of pupils:

Table 2. Learners participating in Kids4Wearables

	Total number of learners	female	male[10]
Total	129	60	69

Thereby, in total, 129 pupils learned about the challenges of bringing material to the human body. After that, an engineer offered a multi-sensual workshop on how hard wood is processed to become soft cellulose fibres. The pupils learned from her about the various fibres our clothes are made of and the technologies used to make them. The teachers then were free to add activities strengthening the vehicle before technologies leading to wearables were introduced in the third phase.

The most crucial part of the project was to weave in technologies like electronics and coding into the classroom activities. As already mentioned, the didactical concepts followed different approaches according to the resources of the respective schools. We observed two types of concepts: introducing a basic technology[11] and developing ideas from that ("technology-to-idea-approach") or thinking about something that would be useful in clothes and trying to find technologies[12] that would help realise this idea ("idea-to-technology-approach"). The latter bears the risk of bringing the learners to dead ends with their prototypes, but two schools took this risk as part of the learning process.

The fourth phase is dedicated to knowledge transfer. As we write this paper, April 2019, we are in the process of organising a research festival where the pupils will present what they have created throughout the project. However, it is not the specific prototypes at the heart of the festival – even though they may be most important to the learners and teachers. It is the journey they have mastered so far, the skills they have been introduced to, the ideas that were not realised because they probably were too complex, to futuristic. At the event, the pupils will act as coaches to other pupils visiting the festival. They will e.g. show them how to code microcontrollers with light sensors and LEDs and tell about other technologies they have learned to know throughout the project.

[9] We are aware that 'gender-neutrality' is not real in our current binary system, and also that fashion has a 'female connotation' in our culture. However, as technology and engineering are fields with a higher rate of male students and employees in Europe, we tend to use either interest fields which are open to all genders (like TV series) or have a tendency to be considered 'more female'.

[10] We offered gender diverse categories for our data collection, too, but these have not been made use of.

[11] Our project partner from the Institute for pervasive computing of the university of Linz introduced LilyPad Arduino technology to the teachers, and the group decided to use it for the workshops with the pupils. Students of Cool Lab in cooperation with the institute first trained the teachers and then pupils in coding Arduino software.

[12] Our partners from the department soft matter physics of the university of Linz helped pupils with this approach as they tried to realise the prototypes and acted as coaches in school workshops.

4.2 The sustainable recruitment of the spaceship crew

The participatory observations of workshops, interviews with teachers and interviews with school development and teacher professionalism experts[13] indicated that many of the teachers are not used to transdisciplinary settings. The Austrian (conventional) school system is built on the notion that there is one person in a classroom who knows (almost) everything and can do it all alone. This leads to a culture where mistakes are avoided at all costs, and this means that teachers tend to stick to well established methods and plans and may be reluctant to experiment a lot. When a project like Kids4Wearables wants to integrate teachers as part of an action research team who work on new didactical concepts together, starting from scratch, it leads to insecurities. Indeed, many teachers reported about being very confused and insecure in the beginning of Kids4Wearables as they did not know what was expected from them and whether they could master those challenges. When we did a workshop on creating e-textiles with the teachers, it became finally obvious that teachers, too, need some sort of vehicle to join the journey, and we found hope that they, at some point, might possibly launch on their own spaceships without us on board.

5 The continuing mission: technology education for everybody

The approach of vehicle based technology learning shows that many topics from everyday lives of learners can be used for technology education. Almost any subject in school can serve as a starting point for accessing technological fields. However, Kids4Wearables showed us that for changing classroom teaching it takes a shift towards transdisciplinary approaches where teachers are involved from the beginning and that all actors need to be on par with each other. Our research indicates there are crucial parameters to be considered (graph 1) – individual and organisational factors as well as framework conditions – when it comes to classroom innovations like the vehicle approach.

[13] We conducted two expert interviews with researchers from the area of school development and teacher professionalism to discuss our preliminary findings of Kids4Wearables and reflect deduced hypotheses (used in graph 1).

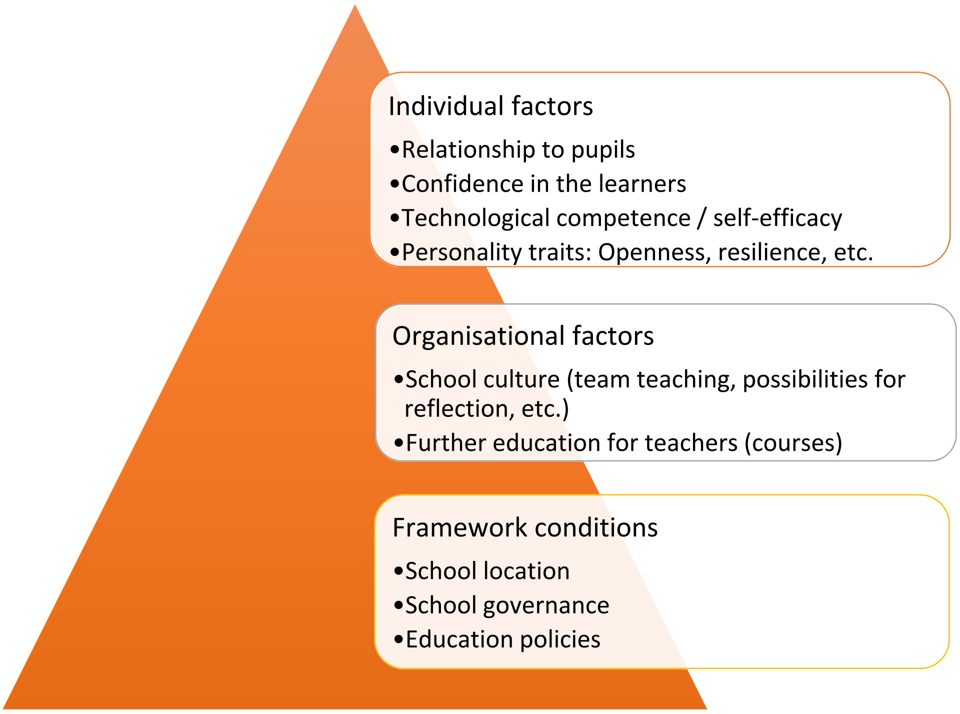

Fig. 1. Parameters of implementing classroom innovation

The didactical approaches used in a classroom reflect the relationship teachers have with their pupils, the degree of confidence they have in their pupils, their own technological self-efficacy, and, of course, their individual personality traits. But it takes more than individual teachers to sustainably implement technology education for everybody. The schools participating in Kids4Wearables presented us with invaluable insights in their respective culture and taught us that it is factors such as practicing team teaching, possibilities of reflection, support from the school management and valuing the participation in further education for teachers, that foster the systemic implementation of classroom innovation in school. Finally, conditions like school location and education policies can hinder or enhance the success of implementing interdisciplinary technology education for everybody.

To sum up, our two key lessons of Kids4Wearables in regard to sustainably implementing technology education for everybody are:

1. Not only do we need vehicles for learners that take them into fields of technology: We also need vehicles for teachers (particularly from non-STEM subjects) to get them on board.

2. It is not enough to focus on teachers and learners when including them in a transdisciplinary process such as Kids4Wearables: We have to consider the culture of the respective organisations and teams.

The data we collected alongside our journey with our fabulous crew of Kids4Wearables was that there is hope for the transdisciplinary utopia of technology education for everybody in classroom teaching: In our projects we have sought to empower learners and now we wanted to do the same with teachers. However, we cannot fix the system by solely focussing on the teachers. Schools should be given more resources to invite external professionals from various disciplines and practices in order for learners to experience a range of role models and have access to first-hand information from potential future occupational fields. Why should teachers know everything when there is the saying: “It takes a village to raise a child.” Our utopia towards the end of Kids4Wearables reflects the hope that teachers might one day assemble their own transdisciplinary crews and start out for new adventures towards a technology education for everybody.

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