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When Kids are Challenged to Solve Real Problems – Case Study on Transforming Learning with Interpersonal Presence and Digital Technologies.

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Abstract. Whereas the world around us changes radically, innovations in the school system tend to be extremely slow. In the era of digitalization this is particularly unfortunate, since kids urgently need to acquire skills that teachers were not prepared to teach. This situation calls for new models of education. This case study is about implementing one such model, namely applying the Stanford Design Thinking Method to let pupils design elements of their life like schoolbags, classrooms and robots, and implement prototypes using technologies such as Minecraft, Micro:bit, and Lego Education. In the innovative educational intervention "MadeByKids", the DaVinci Lab, an external organization, worked with pupils (at grade K2 to K6, in sum about 450 children), in a series of three workshops at 17 Austrian schools. We researched the workshops via a case study on essential features of the intervention and by quantitative and qualitative pre-test and post-test questionnaires of pupils. Results show that pupils learn meaningfully regarding programming as well as social competences and most of them enjoy this kind of active learning. Results also indicate clearly that - even though the intervention is centered at children - their teachers need to be intensively included, otherwise a remarkable share of them may experience a loss of control over their class and remain skeptical. Besides discussing the results of the survey, the authors address the challenge of sustainability and share important learnings from the project.

Keywords: Digital Competence, Teamwork, Coding, Making, Kids, Stanford Design Thinking, Challenge, School, Minecraft, Micro:Bit, Lego Education, Stop Motian, Scratch

1 Introduction

One of the agreed upon strategies of the European Union [1] and world-wide [2] is the early promotion of digital- competencies and computational thinking, both from a technological and interpersonal point of view. This is because the European Union, and indeed our world, needs people who can communicate and collaborate virtually and face-to-face, do not shy away from using Information and Communication Technology (ICT), and are flexible to adopt new technologies.

Two (out of four) key recommendations made by Informatics Europe and the ACM Europe Working Group on Informatics Education (2013) [3] are closely related to the content and aim of this work. These recommendations call for education in digital literacy from an early age, and an early start with developing creative solutions involving teachers and experts.

> *Recommendation 1*
> All students should benefit from education in digital literacy, starting from an early age and mastering the basic concepts by age 12. Digital literacy education should emphasize not only skills but also the principles and practices of using them effectively and ethically.
> *Recommendation 3*
> A large-scale teacher training program should urgently be started. To bootstrap the process in the short term, creative solutions should be developed involving school teachers paired with experts from academia and industry. [3]

The transformative interventions described in this paper are targeted at addressing the two recommendations cited above and, furthermore, at mediating computational thinking [4], a core informatics concept covering finding and using abstractions, breaking problems down into smaller pieces, logically organizing pieces, algorithmic thinking, coding, and analyzing possible solutions. Facilitating computational thinking at appropriate ages has frequently been called for [3], [5], [6], [7].

In this context, our work is aimed to promote computational thinking at an early age where boys and girls don't shy away from technology and can build trust in their capacities to use technology skillfully and to accomplish something they aspire to and perceive as valuable, like a smart schoolbag or a classroom that is designed according to their imagination. More concretely, the intervention underlying the research described in this paper aims to:

- Let pupils solve real problems and get in touch with real issues that matter to them directly and use technology as a means, not as an ultimate goal. Technology is supposed to serve the humanity and not vice versa requiring humanity to adapt to technology.
- Provide incentives for hands on experience with programming and making for kids.
- Develop listening, communication, collaboration, and presentation skills "on the job".
- Experience how the Stanford Design Thinking Method works with kids and digital devices.
- Provide some counterbalance to the overload of transmitting passive, intellectual information in schools by letting kids work with their hands, heads, and whole bodies [8] while creating new ideas and objects of their immediate environments.

The unique contribution of our work is to combine the learning of computational thinking and digital literacy with active, student centered learning [8], [9], problem solving, and interpersonal skills training by using and adapting the creative framework of the Stanford Design Thinking Method [10] described in the second chapter. Even though Spikol and Milrad [11] use a different approach with having children co-design outdoor games, they aim to promote an analogous bundle of multi-dimensional learning experiences and arrive at similar findings compared to our research.

In particular, our paper deals with describing and researching an innovative educational intervention ("MadeByKinds"[1]) at 17 Austrian schools (with pupils at grade K2 to K6). The innovation's essence is that the DaVinci Lab[2], an external organization, worked with pupils in a series of three workshops to have kids solve real challenges (like designing the classroom of the future or a school-bag4.0) by applying Stanford Design Thinking and digital technologies such as Minecraft[3], Micro:bit[4], Lego Education[5], and Stop Motion. We researched the workshops amongst others by (quantitative and qualitative), pre-test and post-test questionnaires of pupils. In essence, this paper addresses three areas of educational transformations:

- transformations of pedagogical models/practices from traditional categories to solving challenges with the help of digital technologies;
- transformations of learner and teacher roles, from teacher as expert and information provider to teacher as facilitator and moderator of challenge-guided, collaborative problem solving;
- transformations of learning spaces and media from quite static arrangements such as sitting behind desks and listening to the teacher to more dynamic arrangements like interacting in a circle, forming teams and using desks to co-create products, using tablets for getting instructions how to build a robot and for visual programming, testing vehicle-like robots on the floor, presenting in front of a green screen, etc.

Hence, this work will be of interest to educational and research staff, educational and academic delegates of ICT companies, educational policy makers, teacher candidates and teacher trainers in academic and continuing education settings.

Survey results, outcomes of handling challenges, and our experience in the workshops unanimously show that pupils tend to learn meaningfully regarding digital competences, programming and, importantly, social capacities. Moreover, the vast majority of them enjoy this kind of active, vivid learning. An interesting insight we gained from the project is that teachers need to be intensively included, otherwise some of them might experience a loss of control of their class and remain skeptical.

Related Work. Even though an increasing number of authors report on digital competence, computational thinking and coding education in school-children [12], research on using digital technologies to solve concrete challenges in Europe's K2-K6 education is still sparse. One notable example is the work by Weigend [5], who tested the capabilities of kids at the elementary-school level (K1 – K4) to follow algorithmic instructions. He conducted a survey among 126 K3 and K4 graders (67 girls, 58 boys,

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1 https://sites.google.com/madebykids.at/start
2 http://www.davincilab.at/
3 https://minecraft.net/de-de/
4 http://microbit.org/de/
5 https://education.lego.com/en-us

one without response) and found that the majority of them had already been confronted with following algorithmic instructions for activities. Moreover, they had no problems in correctly executing simple algorithms.

In the field of design thinking in the school-classroom [13], [14], Carroll et al. [15] investigated the use of this method with pupils who were asked to identify, describe, and re-design systems in the context of their school experience. In essence, they found that creating a classroom design project that integrated content learning and design thinking was a challenging process. While design thinking provided much appreciated opportunities for students to engage themselves actively and express their voices, students made just tenuous connections between subject specific content learning and design thinking. Thus, the authors imply that teachers need to see and appreciate the value of the design thinking process and that the design curriculum needs the strategic integration of educational standards, principles of design, and content. Our case study corroborates this finding and leads on to illustrate, how the acquisition of digital competencies can succeed when integrated with the application of design thinking. This is currently particularly relevant in Austria, since a new law calls for the provision of a mandatory curriculum on basic digital competence for each K5 – K8 classroom.

In a different field, namely humanistic pedagogy, the American psychologist Carl Rogers [8], [16] had suggested transforming the teacher role to become a facilitator of significant learning. By significant learning Rogers meant "learning which is more than an accumulation of facts. It is learning which makes a difference – in the individual's behavior, in the course of action he chooses in the future, in his attitudes and in his personality. It is a pervasive learning which is not just an accretion of knowledge, but which interpenetrates with every portion of his experience." [17] He observed that significant learning occurred more readily in situations that students perceived as problems. From this he implied that for significant learning to happen, "we permit the student, at any level, to be in real contact with relevant problems of his existence, so that he perceives problems and issues which he wishes to resolve." [18] Yet, Rogers was aware that this implication ran sharply contrary to the trends in his time and culture. He challenged the educational system by posing the evocative question: "Could we possibly permit students to come in contact with real issues?" [19] In our view, this is a crucial question and challenges the educational system even nowadays. Still, in a time of the open-movement[6] [20] and citizen science[7] [21] the attitude seems to have changed to some degree. Nevertheless the authors perceive the current Austrian school system to be still quite rigid, in particular at levels upward from K5 (secondary level), with being far more teaching-centered than learner-centered [8], [22], [23], [24], [25].

Structure. The paper is structured as follows. In the following chapter, we describe the objectives and essence of the educational intervention. Chapter three presents the research method which is a case study with an embedded survey of about pupils' attitudes and learning. In Chapter four, the findings are presented to be subsequently

[6] https://www.openmovement.org/
[7] http://www.citizen-science.at/

discussed in Chapter five. Chapter six concludes the paper and points to issues for further research.

2 The Educational Intervention #MadeByKids

The #MadeByKids project was driven by the following overall objectives. It aimed to:

- Bridge real life problems/challenges of industry partners (e.g Microsoft currently developing and testing different types of "future classroom") with innovative power of kids – benefiting for both – disruptive innovation source for industry with an innovative project based learning for pupils;
- Evoke interest and even enthusiasm for technology and research in kids, in particular girls, at an early age; this is deemed important from social and economic reasons;
- Allow youngsters to have concrete hands-on experience with digital technology and to apply new knowledge immediately by solving pre-defined concrete challenges;
- Remove girls' and boys' barriers and fears of technology and awakening their excitement and joy through a playful "maker" approach to concrete challenges, following the motto: "I made it myself!"
- Provide positive role models for girls by engaging women with a strong affinity to technology and computers to work with children during workshops.

Aspired learning outcomes on the side of each child included:

- Solving a particular challenge associated with a child's life context in a small team and describe aspects of the experience;
- Getting a first-person experience of computational thinking and coding in a team and being able to describe it;
- Being able to present the team's achievement/product in front of a camera
- Being able to give helpful feedback and to receive feedback;
- Getting evidence on one's - i.e. both boys' and girls' - ability to resolve a challenge (appropriate for children) requiring computational thinking in a creative way.

Aspired learning outcomes on the side of the facilitating and researching team included:

- Gaining experience of the project- and workshop design
- Gathering experience in working with kids and their teachers
- Learning about various effects of the intervention on kids
- Learning about performing research with and about children.

In brief, the project aimed to bring about learning on multiple levels. We were curious and enthusiastic about the project and its possible contribution to transforming education by using digital technologies and facilitating significant, whole-person learning by solving challenges in teams.

Design Decisions. In the following we describe our rationale behind selecting the schools, the challenges, and the digital technologies for the intervention. Even though all the cooperating schools of the University of Vienna and the University College of Teacher Education were addressed via an email to the school directors, no responses were obtained. Thereupon the DaVinci Lab contacted schools directly. They were selected to represent the overall heterogeneous Viennese population – schools in top locations as well schools in districts with a high percentage of immigrants (in one class only 2 kids out of 25 were able to speak German properly). The sample of 17 schools contained primary and secondary schools such as to investigate the difference in the acceptance of the educational innovation and its effects on different age groups. Overall, the number of pupils reached was 450, the demographic data of those who filled out the questionnaires are displayed in Figure 2 below.

Five challenges were selected with the goal of touching the kids' live:

- Future classroom (place to learn) – concrete case in order to understand learning needs
- Schoolbag 4.0 – very concrete product design – the most closest to the Stanford design thinking process
- Robots at school
- My children's-room at home (portraying similarities/differences in the needs at school)
- The world in which I am adult (innovation and creation potential of the young generation)

The workshop design loosely followed the Stanford Design Thinking Method for Kids [26] is a generic process for problem solving that is briefly sketched below. The intention behind this choice was to deliver an inspirational new "teaching" (better learning) method which does not require expensive technological equipment. In a nutshell, design thinking guides the process of tackling a complex problem by following five steps:

1. Empathizing: Understanding the human needs involved
2. Defining: Re-framing and defining the problem in human-centric ways
3. Ideating: Creating many ideas in ideation sessions
4. Prototyping: Adopting a hands-on approach in prototyping
5. Testing: Developing a prototype/solution to the problem.

While the Stanford Design Thinking Method was used as a guide for designing the three half-day (about 3 hours each) workshops, it needed to be adapted to fit the idea of having just three workshops with kids. For example, instead of creating personas in the first step, children themselves were designers as well as users and thus "only" had to empathize with their and their colleagues' ideas and needs.

Importantly, steps four and five were supported by the application of digital tools. Presentation challenges were scheduled at the definition, ideation, and prototyping stages to train pupils' presentation skills on the one hand and to allow for video-documentation of results in the other hand. The test phase was the only phase strongly deviating from the original design thinking process (except for the LEGO robots) and was reduced to presenting the solution and obtaining questions and feedback. There was no time left to adopt the product/solution any more (no loop in the process). For a sample scenario illustrating our adaptation of the five phases of the Stanford Design Thinking process see Section 4.2.

Finally, after participation in the workshops, children should be rewarded for their achievements and the public was to be informed. Hence, a jury of the project was formed to consist of project sponsors and supporters who were present while the project was being presented and discussed with all parties responsible for teacher training in the area of digital competencies in Austria. The closing took place in the Vienna City Hall at the important event of the Digital City Vienna (Organisation of local government and ICT companies) in order to ensure the biggest possible media reach.

3 Research Approach

3.1 Research Questions and Case Study Framework

The overarching question of interest that underlies the research can be put as follows:

How can computational thinking and both digital- *and* interpersonal competences be effectively promoted in schools with traditional structures?

Narrowing the questions down to this particular study we formulated the following two overall research questions: What effects did the workshop series designed by adapting the Stanford Design Thinking Method for Kids have on the children's attitudes, skills, and knowledge in the area of interpersonal competences and computational thinking?

What insights did the facilitating team gain in terms of further development of such workshops and the transformation's sustainability for the (Austrian) school system and beyond?

In order to address the research questions, a single case study design [27] as overall research framework was chosen for several reasons. This research method most comprehensively satisfied the need for a descriptive field research. As behavior should not be manipulated for the sake of research and there was little evidence from literature for this educational intervention, investigating real-life phenomena helped to understand the observed socio-technical innovation. Moreover, the role of the investigators (the DaVinci Lab team and research partners) in the case study research was important not only to enable systematic observation and reflection, but also to interpret the data coming from multiple sources.

In order to provide focus in the case description, we selected some key-issues of interest. These are reflected in the following focal research sub-questions that are going to take priority over the multiple other issues that we encountered while studying the case:

- How often did children use digital devices at home as compared with school?

- How did pupils perceive the digitally enhanced design thinking workshops and what did they learn?
- Did the workshops have an influence on children's attitudes towards coding and did they even influence their attitudes towards school?
- Would children like to participate again in a similar offering?
- What were the learnings of the whole team regarding the facilitation of the educational innovation and which significant experiences and insights did they take with them?

These research questions will guide the case study so that the exploration of the case undertaken in section four focuses on these questions.

3.2 Methods Used Within the Case Study Framework

The following methods were integrated into the overall case study framework:

Data Collection from Children via a Pre-Test Post-Test Survey Design. The basic idea behind the pre-test post-test survey design was to find out about the children's attitudes, feelings, and knowledge in connection with the intervention before and after the workshops. For this purpose, we constructed a pre-test and a post-test questionnaire. We asked the teachers to ask kids to fill out the pre-test questionnaire before the beginning of any workshop, and the post-questionnaire after the last workshop. The exact time when the questionnaires were to be filled out was not specified precisely such as to leave teachers and children some flexibility to find an appropriate time slot. Furthermore, the pre-test and post-test questionnaires for children were tested beforehand on two children who did not participate in the workshops. The questionnaires were adapted based on children's (and their teachers') feedback.

The pre-test questionnaire for children consists of 15 closed-ended questions, e.g. "Do you use internet at home?", including questions on demographic data and 9 open-ended questions, e.g. "What do you wish for the workshop?" and, in total 24 questions. For the teachers' pre-test questionnaire, we used 5 closed-ended questions, e.g. "Is there a PC room in your school?", including questions on demographic data and 7 open-ended questions, e.g. "What are you expecting of the workshop?" and demographic data. The post-test questionnaire for kids consists of a mix of 25 short open- and closed-ended questions, 15 of which are the same as the ones used in the pre-test questionnaire and 11 of which were added, for example "Name 3 things you will remember from the workshops!" The full questionnaires (in German or translated into English) can be obtained by emailing the authors.

Quantitative Analysis of Survey with Children. For the closed-ended questions we used descriptive statistics, since no hypotheses were tested and we wanted to simply describe what the data showed. For the open-ended questions, content analysis was used. Notably, children's (n = 322 pre-test and n = 318 post-test) responses tended to come in the form of single words or verb-noun pairs (e.g. building robots),, making the unit of analysis – a single verb or a verb-noun phrase - easy to establish..

Qualitative Content Analysis of Pre-Test and Post-Test Questionnaires for Children. For harmonizing the collected data, qualitative content analysis was used [28]. The responses to each open-ended question were codified separately in 6 steps, with one feedback loop for examining consistence (see Fig. 1).

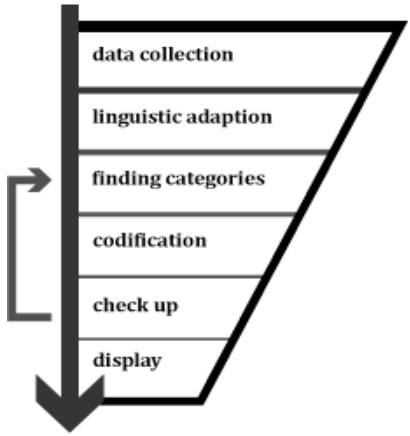

Fig. 1: Qualitative content analysis of post-test questionnaire for children.

i. Data collection
   At first the data was collected and displayed in an excel worksheet.
ii. Linguistic adaption
   For getting overview and find first ideas for categories the answers were harmonized about spelling and grammar. E.g. upper case and lower case, same verb different time or person
iii. Finding categories
   Same meanings were collected and summed to one category. E.g. coding robots and building robots are collected in coding/building robots, … To increase reliability, a second researcher checked the categories. After two iterations of a dialoging process, consensus was reached on the categories and the visualization of the results.
iv. Codification
   The answers were coded in the worksheet.
v. Check up
   After reaching the end of the answers the coding was checked and abstracted.
vi. Display
   The data was displayed in a bar chart sorted by frequencies. Only the top X (X varies from question to question) occurrences of a category were displayed.

To meet the paper's length limitations, the researchers also agreed upon a selection of question-response items to be included to best illustrate the children's perspective under given constraints and give responses to our focal research questions.

4 Results and Findings

In order to allow readers to get an impression of the field, the following we first briefly describe the demographic data and continue with sketching a sample scenario of a workshop. Thereupon, the results of selected question of the pre-test post-test study are described.

4.1 Demographic Data

Out of about 450 children participating in the workshops, 322 (pre-test, see also Fig. 2) and 318 (post-test) pupils took part in the survey, 55% of them were male 45% female, 58% were visiting a primary school grade K2 or K3, and 42% a secondary school grade K5 or K6.

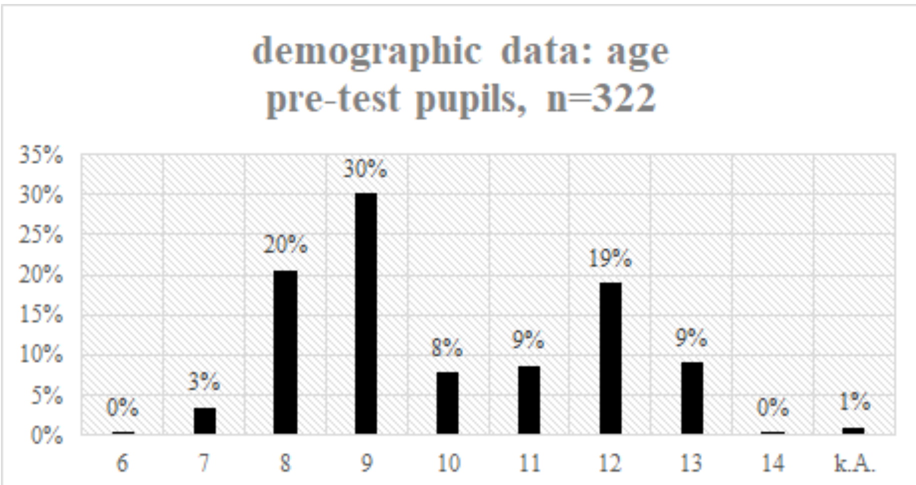

Fig. 2: demographic data: age distribution pre-test pupils, n=322.

4.2 Sample Workshop-Scenario and Outcomes

As a sample-scenario of applying the adapted Stanford Design Thinking Method for Kids let is trace the process-instance of designing the "Schoolbag 4.0" – a high-commodity product in pupils everyday life.

First Workshop: Empathizing, Defining, Ideating and Initial Prototyping. In the first workshop, the phase of empathizing was simplified such that pupils explored their own needs and imagination, rather than investigating into the needs and wants of different stakeholders. In this phase and the follow-up phase of defining needs, problems, and wishes, we were intrigued by the great capability of children to define very concrete problems and propose easy to imagine innovative solutions. The problems ranged from very concrete e.g. pain in the back (therefore no books but only digital ones, or pillows for the neck) up to very inspirational: In order not to have to carry my bag, it can autonomously follow me and eventually even serve as a means of transportation! Finally the class defined a common problem: “I do not want someone else to open my back” and defined a solution they could implement with the help of the Micro:bit – schoolbag alarm. At the end of this workshop kids produced a first material prototype. In teams of four pupils they crafted schoolbags out of cartoon. For an illustration of pupils collecting their ideas on post-its during the first workshop see Fig. 3., The presentation of the material-prototype is depicted in Fig. 4.

Second Workshop: Digital Prototype of Schoolbag Alarm and its Testing. In the second workshop kids worked on a solution to protect their schoolbag from being opened by others. As a first step, they learned the functionalities of Micro:bit and how to code with it (see also Fig. 5). In order to build quite complex code to program the schoolbag alarm, a “secret agent” game “crack the code” had been developed by the DaVinci Lab such that kids were guided through more and more difficult code sequences step by step. In order to make the process more engaging, pupils were divided into 4kid teams – as soon as a team knew the answer to the coding-challenge, they pressed a button of a buzzer and presented their solution in front of the class. If the solution was correct, the team received a sticker. Finally, most 4kid teams were able to code the alarm and test if it worked. Its working served as immediate feedback on the functionality of the digital component of the schoolbag 4.0. In this playful way, kids worked hard at acquiring basic computational thinking and programming skills.

During the project a small test has been made – one class went through the workshop as described above and was able to solve all challenges within the given time, mostly arriving at the right answers. Another class was lead through a more teacher centric approach – a DaVinci Lab trainer presented the right solution over the beamer. That class arrived at only 50% of the code sequences. The interesting thing was that the first class was a primary school class whereas the second one was a secondary school class with an informatics profile! We conjecture that more research is needed to find out about the suitability and effectiveness of various didactic approaches when applying the design thinking method in class (see also Carroll et al, 2010)

Third Workshop: Presenting and Responding to Questions and Feedback. In the last workshop, kids presented their schoolbags in front of the camera and a green screen. The interested audience asked questions, often about how some feature would work, thus resembling users’ feedback on the product and its presentation. This phase can be seen as gathering feedback on the innovative product and thus would be subsumed under the 5th phase (testing) of the design thinking process. At the same time, the third workshop served to train presentation competences of kids and their capacity to give and receive feedback. It is important to mention that this “soft skills” part caused the biggest problem to pupils. Our overall observation was that most kids tend not to have problems obtaining digital competencies including coding, but they do have serious difficulties presenting their products/results in a structured and engaging way. Also, resolving conflicts in teams tended to pose tough challenges on pupils, regardless of their age group.

Fig. 3: Snapshot of the ideating phase in teams (left frame)
Fig. 4: Illustration showing the presentation of material-prototypes in teams (right frame)

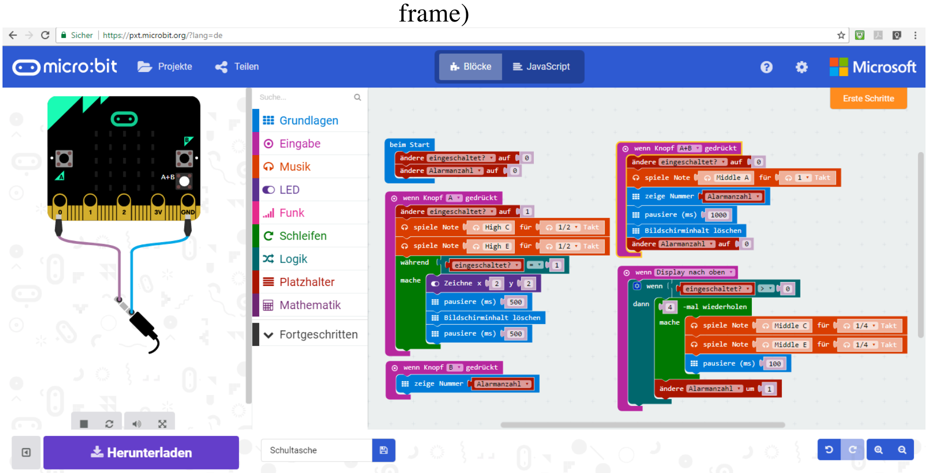

Fig. 5: Screen showing visual programming with Micro:bit

4.3 Description of Survey Results

While the survey addressed a multitude of aspects, below, we focus on responding to the research subquestions given in Section 3.

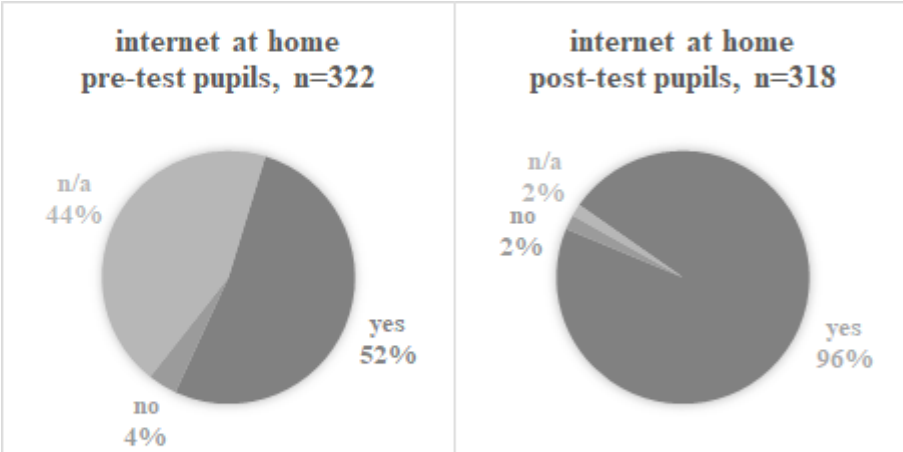

Fig. 6: internet at home, pre-test (n=322, left-hand side of the Fig.) and post-test (n=318) pupils

Figure 6 shows the result of the question "Do you use internet at home?" In the pre-test it is apparent that most children responded with yes (52%, 168) and almost every second child gave no answer (n/a: 44%, 127). The smallest group answered "no" (4%, 12). The post-test shows a totally different picture. Here, almost every child (96%, 307) responded with "yes" (giving an increase of about 44 percent points). Also, the n/a section dropped by 42 percent points to just 2% and the "no" section by dropped by 2 percent points to 2 percent. Trying to interpret the big change, we assume that kids got interested and asked their parents if they had an internet connection at home to find out that in fact they did have one.

Figure 7 depicts the results of the frequency of using a digital device (computer/smartphone/tablet) at home or at school per week. We can see that a digital device is used most frequently "daily" at home (44%, 137) and "1-2" times at school (47%, 149). We can also see that the second frequent group is a few times at home (22%, 70) and "1-2" times at school (12%, 35). Thus, using a digital device daily seems pretty normal for almost every second child at home, but not at school, there a digital device is used a lot less frequently (e.g. 1-2 times for every second child). While it is apparent that the usage of digital devices is much more prevalent at home than at school, it must be taken into account that the survey (for brevity) did not distinguish between different kinds of devices. So, using a mobile phone at home would not be distinguished from using a computer for maths.

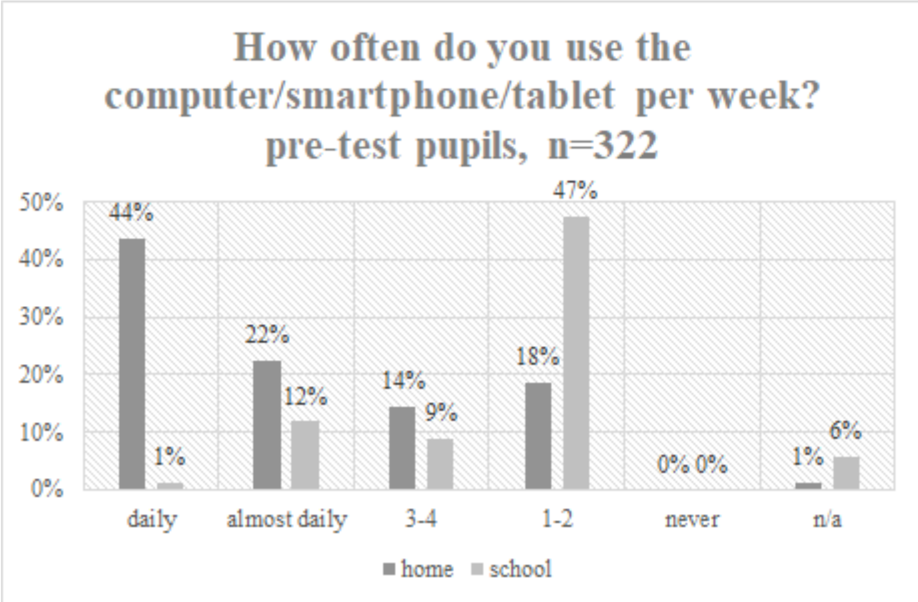

Fig. 7: How often do you use the computer/smartphone/tablet in a week? Pre-test pupils (n=322)

Figures 8 and 9 show the pupils' attitude towards coding before and after the workshops. From the six word pairs interesting versus boring, funny versus serious, simple versus difficult, modern versus old-fashioned, and known versus unknown, the biggest relative difference (a rise by 15 percent points from 21 percent to 36 percent) was found in the adjective "known." Interestingly, the next largest difference concerned the adjective "simple," whose ratings rose by 14 percent from 16 to 30 percent, followed by "cool," rising by 10 percent points from 46 to 56 percent. On the side of the "negative" or unpleasant adjectives, the largest dropping concerned the adjective "unknown" that dropped by 7 percent points from 15 to 8 percent, followed by "difficult" that dropped by 4 percent points from 15 to 11 percent. All other droppings were by two or less percent points. In the class of "no answer," the largest dropping (by 12 percent pints) concerned the word-pair simple versus difficult, followed by dropping by 8 percent points at the word-pair known-unknown.

These results let us speculate that it was easier to inspire or enthuse children with prior positive attitudes towards coding than those who did not already have an idea or positive preconception of coding.

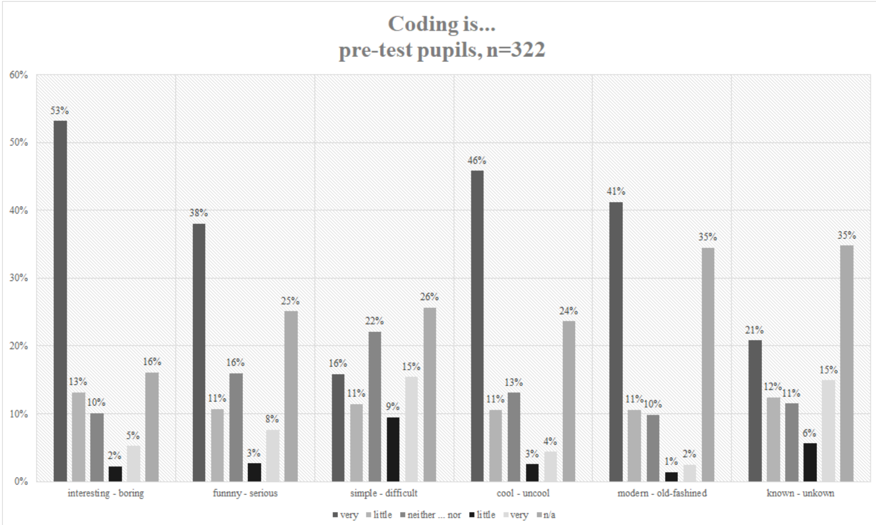

Fig. 8: Coding is... pre-test pupils, n=322

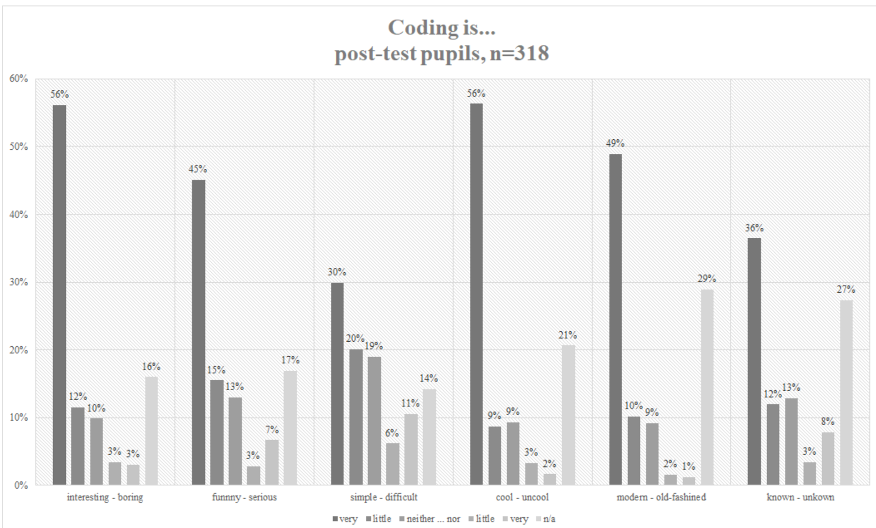

Fig 9: Coding is... post-test pupils, n=318

Figure 10 shows the distribution of answers to questions regarding the pupils' workshop experience as such. It is apparent that the vast majority of children would participate again, choose the same trainer and think that their friends should participate as well. Nevertheless, some children (18 percent) would not participate and do not think (17 percent) that their friends should participate. The reasons for depreciative or dismissing attitude are manifold, as we learned throughout the project. For example, some pupils were not allowed by their parents to be filmed and apparently felt excluded at such exciting activities. Other children, e.g. refugees had difficulty with their command of German, yet other pupils were frustrated by technological faults when their computers or robots did not work, etc. etc. All these instances are of utmost importance and need to be considered both pedagogically and technologically in follow up projects!

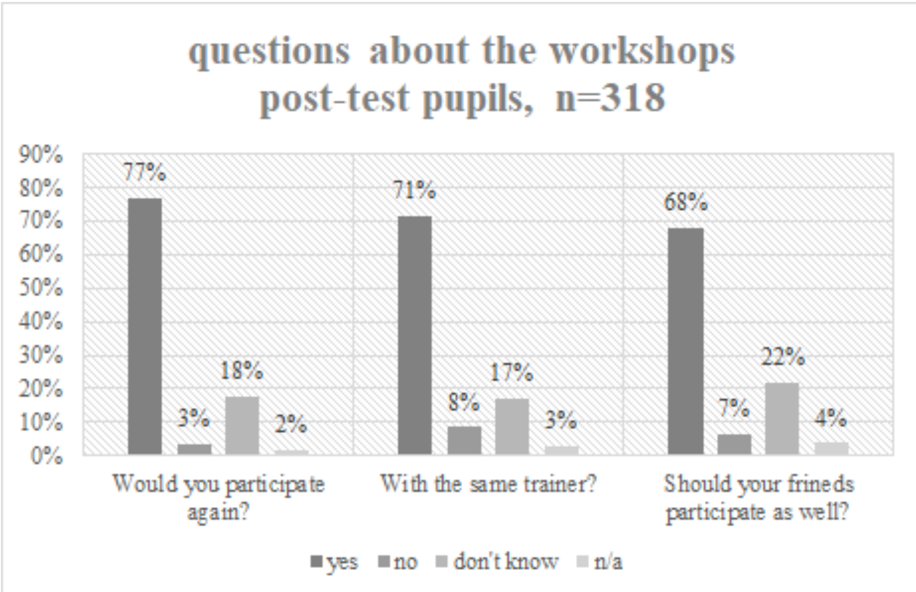

Fig. 10: Questions about the workshops, post-test pupils, n=318

Figure 11 lists the answers of what pupils liked about the workshop by the frequency of mentioning of a word or concept. Due to very different answer (other mentions amounted to 14%) just the top 12 are displayed in the Figure. Many liked Minecraft (81 mentions, 31%), coding (53, 20%), and working with “robots” (46; 18%), the “robots” category subsuming the mentions of coding robots, building robots, or controlling them. Exemplary items in the “other mentions” category were “Micro:bit”, “taking pictures” or “nothing” with the amount of 2% or 1%, respectively. Interestingly, items such as using the “tablet” or "working in teams” (both about 3%) made it to the top 12 favorites.

To perceive also the other side, we investigated what children didn’t like. Most frequently kids didn’t respond to the question at all (143, 82%). The second frequent group were divers other mentions (62, 35%) with low frequencies. The next frequent category concerned the aspect that there was too little time (25, 14%), followed by problems with the devices (connection to bluetooth, problems with the computer, …). Some children didn’t like the teamwork (20, 11%) and mentioned problems with group members or dispute, others didn’t like long explanation (16, 9%), presenting

(10, 6%), the introduction (7, 4%), flooding (7, 4%), coding (6, 3%) or tinkering (5, 3%).

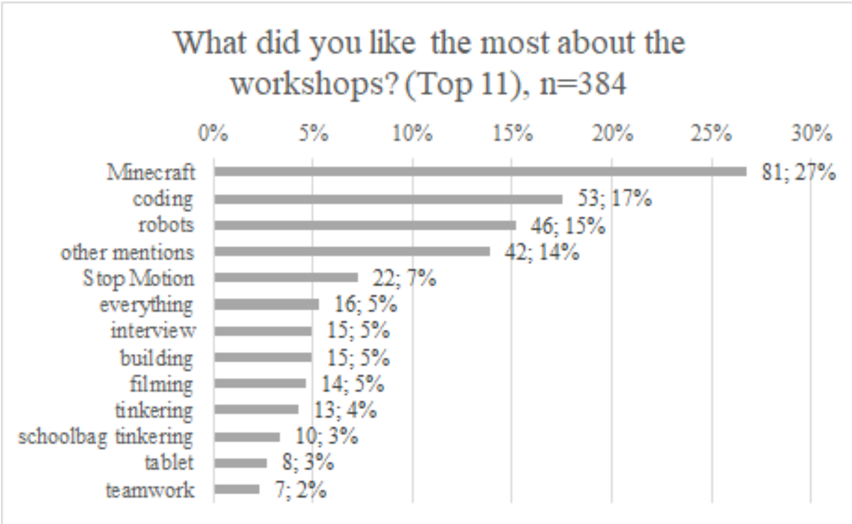

Fig. 11: What did you like the most about the workshops? (Top 11), n=342

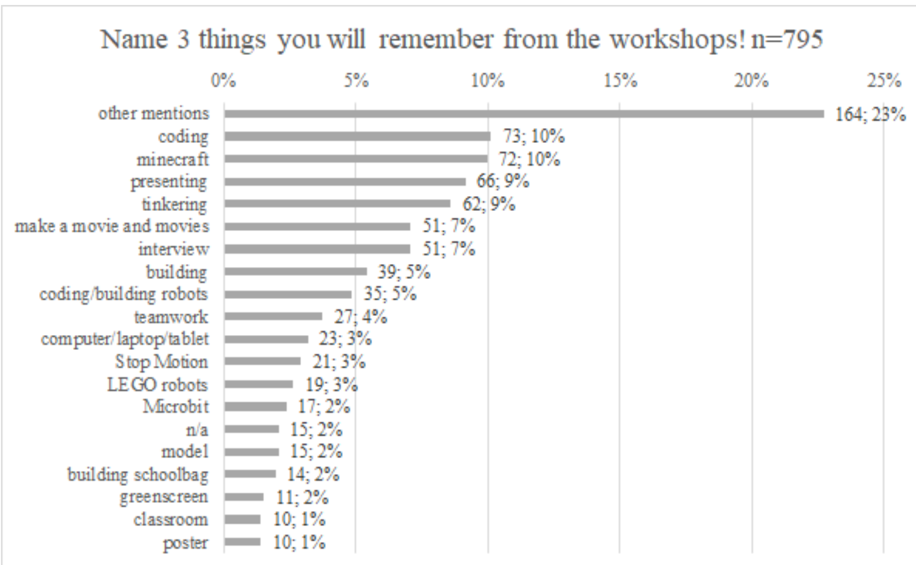

Fig. 12: Name 3 things you will remember from the workshops! Top 16, n=795

The question on what pupils remember form the workshops (see Figure 12 depicting the top 16 categories) elicited even more versatile responses that the question on what they liked (Figure 8). Here it is worth mentioning individual items which did not fit into any category were the majority. These answers were subsumed in the category "other mentions" making up about a quarter of all mentions (23%). The biggest isolated cluster was coding (73 mentions, 10%) followed closely by Minecraft (72; 10%). Intriguingly, the activity and soft skill of presenting (66, 9%) followed by tinkering (62, 9%) as two larger clusters. Also, making a movie or watching movies (51, 7%) or the interviews (51, 7%) were mentioned frequently. Teamwork is remembered 27 times (4%). classroom Giving no answer or not know what I remembered is summarized in the category "n/a" with a share of 15, amounting to 2% and pointing to the observation that even though astonishingly many things were remembered, a non-zero amount of pupils may have felt over-challenged or not included sufficiently, giving rise to further thought on how to handle this phenomenon in future workshops.

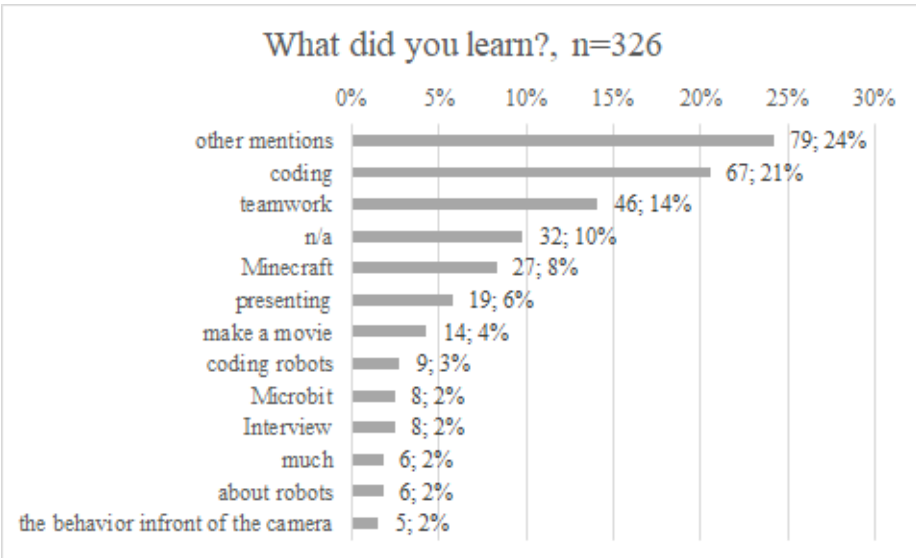

Fig. 13: What did you learn? Top 10, n=326

Figure 13 shows what pupils tend to distinguish as a learning from the workshops. Again, individual mentions, which didn't fit into a category were the majority (79, 24%). 21% of the pupils identified coding as a learning, followed by teamwork (46, 14%). 10% didn't reflect anything as a learning or didn't respond (category n/a). Again, Minecraft was a frequent learning, also "presenting," "making a movie," and "coding robots" as most frequent specific category of "coding," directly followed by working with Micro:bit, and giving an interview. Also, 2% of the kids simply said that they learned "much", with about the same frequency as "something about robots" and "the behavior in front of the camera". Interestingly – and consistent with the intervention's objectives - soft skills like teamwork and presenting were perceived to be learned about equally intensively as coding skills via Minecraft, Micro:bit, and (LEGO) robots!

5 Discussion

5.1 Interpretation and Implications of the Findings

A distinguishing feature of the intervention researched in this paper is the use of the Stanford Design Thinking Method to guide a series of educational workshops targeted at kids solving real challenges in teams while building and presenting prototypes and applying various digital technologies. This setting closely approximates the demands on life-skills needed in contemporary times in terms of required "soft-skills" like working in teams and presenting as well as "hard-skills" like designing prototypes and coding. We as researchers appreciate the fact that children were able to remember and reflect upon the whole variety of aspects, pointing to the probability that the learning had a "whole-person" [8] quality and did not just connect to pupils' intellect. In this context, the "making" aspect nicely complemented the sphere of ways to learn and included the pupils' hands and bodies, building concrete prototypes prior to coding aspects of these prototypes, such as an alarm system of a schoolbag 4.0 or a program that would let a LEGO™ robot drive to a specified spot and return back again.

Notably, the experience of meaningful whole-person learning tended to be appreciated by children who responded that they remembered the coding. Minecraft, presenting, tinkering, movie-making, interviewing, building, teamwork, etc. experience, illustrating a wide variety of "things" they had kept in their minds. Thus, digital competencies became integrated with other essential 21st century skills that were seamlessly promoted in the workshops by being lived or modeled by the facilitators and orchestrated by adapting the Stanford Design Thinking Method.

Regarding digital technologies, the one that was mentioned most often was Minecraft. This may be due to different factors such as the number of children who had the opportunity to use Minecraft, the fact that it was already known to some kids, the expression of "controlling robots" (or similar) used to denote the experience with LEGO Education, the fact that two of the five challenges (proposing a children's room and a classroom) used Minecraft, etc. In brief, we want to say that the frequency percentages need to be interpreted with care and can't simply be used to imply the children's preference for one or the other of the technologies used.

An interesting tendency was observed when comparing children's attitudes towards coding before and after the workshops: They tended to perceive coding as more simple and less difficult after the workshops. For example, while 16% of the pupils considered coding to be very simple before the workshops, the percentage rose to 30% (compare Fig 9). At first sight, this appears to be a desirable outcome pointing in the direction of kids in young age already having an affinity to programming such that they could imagine starting a career or studies in this sector [29]. Also, research indicates that the positive attitude can be transferred to „real programming languages“ [30]. Yet, it might happen that the imagination of coding to be very simple can cause disillusion once pupils are confronted with coding in textual programming languages that isn't that simple any more. Therefore, a transfer from visual coding with blocks (e.g. in Scratch) to „real coding“ should be initiated in a safe environment and proceed gradually to allow the positive effect of „coding is simple“ to be retained [30].

Another intriguing finding was that while children's attitudes towards coding tended to be (positively) influenced by the intervention, children's attitudes towards school as such did not change observably when comparing the pre-test and post-test ratings. From this we conjecture that a series of three workshops, conducted by external facilitators, did not suffice to change children's attitude towards school as such.

Even though the vast majority of children liked the workshops and would recommend them to friends, an important question we pose is: How could the results be further improved? One strand of responses points to the direction of better including all pupils, even those who experience problems due to whatever reason. For this, more time and/or more facilitators would be needed. Alternatively, or in addition, the teachers could be integrated more tightly into the whole process from workshop design to implementation such that they could better support their pupils during the workshops. Also, ideas for improvement will be derived from analyzing the interactions as captured in the observation sheets, video documentation, and focus group protocols that complement the research reported in this paper. Furthermore, a second paper is being prepared to analyze teachers' expectation and reactions to the educational innovation.

Another strand of responses concerns technology, namely making it and its installation at schools more reliable! Technological problems (computers not starting properly, etc.) could have easily been avoided with more reliable and a better available digital infrastructure in schools. And for the unavoidable case of technological faults, workarounds need to be planned such that alternatives are readily available if technology happens not to serve the human beings as expected. All in all, the intervention provided us with rich and versatile learning and we are grateful to all who made this experience possible!

Overall, the project was a unique experience to understand, in depth, the chances and barriers for the transformation process at the school system. An essential strategic insight was that there is a need to invest the same amount of time used for innovative workshops with kids for preparatory- and reflection meetings with the involved teachers in order to ensure engagement, understanding of what is happening and why (what is being intended) as well as to reflect on what had happened, especially regarding the teacher-pupil and pupil-pupil interaction. Without this time investment, there is a serious risk that teachers will be overcome by fear and will block any transformational process.

An astounding finding concerned the extreme innovation power of kids who were able to define problems and possible solutions similar to problems and solutions discussed by top industry experts (e.g leaving extra Terre in the future; different transportation means). Intriguingly, however, for the young generation the collaboration, communication and presentation poses by far a tougher challenge than intellectual understanding or the capability to code.

A finding that made us sad was that starting with age 11+ kids tend to be strongly losing on innovation power and the gender gap in finding interest for STEM topics is growing.

An interesting side aspect was the observation that there is no need for the high tech “future classroom” to change learning formats. Even with simple investment (greenscreen; few tablets/laptops and a beamer) it *is* possible to implement mobile learning zones within the classroom, fully changing the dynamics and the class atmosphere. But the Key Success Factor of the transformation is still the teacher – his/her engagement and attitude.

5.2 Limitations of the Study

Our research is subject to a number of limitations. They are mostly grounded in the fact that performing the educational intervention in the field had precedence over collecting research data. First, it needs to be acknowledged that the participating schools were not chosen randomly, but selected based on the criterion to reach a representative sample and on participants’ networks and direct inquiries to school directors that were known to members of the research team. We made a query to address schools that had cooperated with the University of Vienna, however did not receive any response within the quite short time frame we had at our disposition. Nevertheless, the astounding regularities we observed can serve as valuable orientation and estimate on what can and cannot be achieved with similar interventions at the elementary and K5 – K6 levels.

Another limitation concerns the comparison of the kids’ responses to questionnaires between classes. This is because we didn’t prescribe a standard procedure on when exactly to let kids fill out the questionnaire and how much help to provide if kids didn’t quite understand some questions. Here it needs to be mentioned that some children didn’t have a full command of the German language due to their migration or flight background. In short, the modes of filling out questionnaires differed from teacher to teacher, ranging from not giving any hints at all to going through the questions collectively in a step-wise fashion.

Finally, we want to share that individual workshop activities, in part, had to be improvised due to real-life constraints such as changes in the time-table, non-availability of tablets, missing overhead projector, broken internet connection, etc.

Fortunately, such hindrances were kept to a minimum due to careful preparation, communication and personal flexibility of the facilitators.
Another limitation is the fact that the teachers' view is not discussed in this paper. This is due to the limited length allowed for this article and will be overcome by composing an upcoming paper focused on researching the teachers' perspective.

6 Conclusions and Further Work

Summarizing, results show that pupils learn meaningfully regarding programming as well as social- and "making"- competences, and most of them enjoy this kind of active learning. Results also indicate clearly that - even though the intervention is centered at children - their teachers need to be intensively included to allow them to "co-own" the experience to a large degree such as to assimilate it into their educational aspirations. One powerful lesson learned was that if this did not happen to a sufficiently large degree, some teachers would experience a loss of control over their class and remain skeptical.

We experienced that interventions of the kind as described in this article have the potential to provide invaluable experiential learning [8], [9] on a myriad of dimensions. Insights on the basis of such experience need to be exploited to guide next steps in more sustainably innovating the educational system - not only in the direction of the use of digital technologies but also in leading schools to promoting life-skills most urgently needed by all of us to solve the real challenges we are confronted with day by day. In this context, a very positive lesson learned was the following: The Stanford Design Thinking Method - as adapted for the purpose of promoting both design thinking *and* computational thinking - combined with the digital tools we used, proved highly valuable and sufficiently flexible to support the aspired learning outcomes of our project (see Section 2).

Further work concerns the evaluation of further facets of the workshop experience such as capturing and discussing the teachers' view, analyzing the videos and observation sheets in detail, and designing potential improvements of the workshops. We are also in the process of comparing our experience and findings with those of others, e.g. [1], [6], [11], [15] and analyzing the contribution of the intervention for the purpose of sustainably innovating the educational system to meet the digital as well as broader educational challenges of contemporary society and economy. After all, teachers - their attitudes, competencies, and engagement - will play a primary role in educational transformation, with all the ramifying impact.

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