Enhancing Stanford Design Thinking for Kids with Digital Technologies

A Participatory Action Research Approach to Challenge-Based Learning

Renate Motschnig
CSLEARN Educational Technologies
University of Vienna, Faculty of Computer Science
Vienna, Austria
renate.motschnig@univie.ac.at

Daniel Pfeiffer
CSLEARN Educational Technologies
University of Vienna, Faculty of Computer Science
Vienna, Austria

Anna Gawin
DaVinci Lab KG (Vienna)
Vienna, Austria

Peter Gawin
DaVinci Lab KG (Vienna)
Vienna, Austria

Michael Steiner
University College of Teacher Education (Vienna)
Vienna, Austria

Lisa Streli
DaVinci Lab KG (Vienna)
Vienna, Austria

***Abstract*—Can digital competencies be acquired by solving real problems? The educational intervention MadeByKids called an external educational provider to 17 schools to conduct a series of workshops, having pupils age 7 – 12 solve challenges such as designing the schoolbag 4.0 or the future classroom. The workshops were designed by adopting the Stanford Design Thinking Method for Kids (http://www.ideaco.org) and digital technologies with the goal to "teach" children computational thinking, collaborating in teams, resolving conflicts, presenting, giving/receiving feedback, etc. In this paper, we take a participatory action research (PAR) approach with the goal of exposing significant chunks of the incredibly rich experience. A content analysis of a qualitative survey among teachers and findings from a focus group reflect the teachers' view. The study indicates that the acquisition of digital competences needs to be backed by personal and social capacities that take time to mature. Furthermore, we learned that the children's teachers must be included consistently to ensure their cooperation and improve sustainability. Besides providing inspiration for teachers, implications for teacher education are derived and the national project is related to the findings from studies conducted abroad in order to contribute to constructive educational innovations crossing national boundaries.**

***Keywords*— 21st century competences; digital competences; design thinking; computational thinking; school; challenge; teacher education; sustainability**

I. Introduction

"Could we possibly permit students to come in contact with real issues?" [1] This question has challenged the educational system for more than half a century. We complement the question by asking: "Can 7 – 12 year-olds build digital prototypes of real issues?" While the response has been positive for the vast majority of children who participated in the MadeByKids project, this paper explores the teachers' view and what can be learned for providing engaging, timely, and sustainable education.

The essence of this work closely matches key recommendations of Informatics Europe and the ACM Europe Working Group on Informatics Education [2]. These recommendations call for developing creative solutions involving teachers and experts and demand encompassing education in digital literacy to start at an early age. For example, *Recommendation 1* says: "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."

Accordingly, the MadeByKids educational intervention underlying the research described in this paper was targeted, amongst others, at the following goals:

- Find out, what pupils learn and how they manage to work with digital tools, their hands, heads, and whole bodies when challenged and accompanied by skilled coaches to solve concrete tasks that matter to them.
- Investigate how teachers perceive the educational innovation and in how far they feel competent and willing to integrate their new experience and insight into their teaching.

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- Investigate in how far the adopted Stanford Design Thinking Method and digital technologies for prototype construction are appropriate to meet the learning outcomes specified for a series of three half-day workshops.
- Investigate in how far the chosen learning design for K2 – K6 pupils can be conducted at the respective schools.
- Analyze how various stakeholders react to the results of the intervention. Based on these insights, design the next iteration of a program that is aimed at promoting computational thinking hand-in-hand with personal and social competences needed to be developed to meet the challenges of our society and economy.

Related Work. Similar goals are followed by [3] who ask the question: “Can design education have a positive impact on primary school education beyond merely preparing designers?” After a detailed literature analysis, they conclude that “in addition to meeting traditional education demands, design thinking principles in children’s education, such as empathy, collaboration and facilitation, human-centeredness, and creativity by iterations of prototyping and testing, will [...] lead to higher engagement at school and greater success in life.” We conclude that projects like MadeByKids, aiming to gain concrete experience with promoting design thinking principles in children’s education [4], [5] are crucial since the research and experience gained are needed for a broader implementation of the promising pedagogical-technological innovation. At an academic level, [6] came to a similar conclusion for changing teaching and learning practices in engineering to stimulate more collaborative, inquiry-driven processes. Moreover, several case studies on how design thinking approaches can transform teachers, learners, and classrooms are thoughtfully described in [7], considering tensions as well as creative and collaborative potentials. The findings grossly resonate with those of our own previous case study in design thinking for kids [5] that emphasized the effects of the MadeByKids intervention on children’s learning, attitude towards coding, memories from and satisfaction with the workshops. While most kids were enthusiastic about the interactive learning experience, a few did not join in or were not allowed by their parents to appear on videos and, hence, felt excluded. This issue needs thoughtful, flexible solutions.

While design thinking and challenge-based learning appear to be educational innovations, their foundations are rooted in experiential learning [1], [8], [9] problem-based learning [10] and critical pedagogy [11]. As Cator [12] explains, the term “challenge-based learning” typically includes digital technologies to solve real issues and came up in the early 2000s.

Intriguingly as early as 1961, Rogers [1] characterized the importance of real challenges coupled with a facilitative learning climate: “The hypothesis upon which he [the teacher] would build is that students who are in real contact with life problems wish to learn, want to grow, seek to find out, hope to master, desire to create. He would see his function as that of developing [...] such a climate in his classroom, that these natural tendencies could come to their fruition.” An interesting issue that Rogers phrased more than half a century ago, namely the lack of trust in learners, still may be valid today and hinder progress [1]: “Another issue is whether we could permit knowledge to be organized in and by the individual, or whether it is to be organized *for* the individual. Here teachers and educators line up with parents and national leaders to insist that the pupil must be guided. He must be inducted into knowledge we have organized for him. He cannot be trusted to organize knowledge in functional terms for himself.”

The unique contribution of our work is the (trusting) workshop design including digital prototyping and the accompanying research design. The former targets combining the learning of computational thinking and digital literacy with maker-activities [13] and experiential learning of interpersonal competences [8] by using and adapting the creative framework of the Stanford Design Thinking Method [14], which will be described in the second chapter.

The **research design** reflects the complexity and the novel aspects of the educational intervention. The overall action research framework allows us to include the experience, perspectives and learning of all stakeholders and educational technologies providers. Moreover, the triangulation of various methods such as pre-test post-test surveys, focus groups, observations and video-analysis provides a rich picture of the intervention with its effects and, thus, enables rich learning for the second and wider cycle of educational interventions to follow the first action research cycle described in this paper.

Audience. Overall, this work will interest educational and research staff, action researchers, educational and academic representatives of ICT enterprises, learning technologists, educational policy makers, teacher trainees and teacher trainers in academic and continuing education settings. We hope to inspire some of these audiences to embark on the challenge of modernizing education in order to support kids to not only become more competent but also more motivated to learn and be happier in their school years and to learn in the most versatile ways to interact and solve relevant issues rather than remaining passive and primarily stuffing their heads with premade facts stemming from the adults’ frame of reference.

Results. Survey results, outcomes of handling challenges, and our experience in the workshops unanimously show that pupils tend to be surprisingly fast in learning to think computationally and even to code simple instructions. They let themselves be challenged to present their prototypes in front of a camera and give feedback to others. Importantly, the vast majority - if not all of them - enjoy this kind of active, vivid learning.

Stakeholders tending to be most wary, critical and suspicious are teachers, some of whom seem to feel threatened by the innovation. An intriguing insight we gained from the project was that while the majority of teachers and children highly welcome the fresh educational experience, care must be taken to carefully include teachers in all phases of the project. This would help to prevent or handle the phenomenon that some teachers experience and fear a loss of control in their class, remain skeptical, lack organizational rigor, dislike digital devices, and defend their safe, classical role as experts and keepers of control and order in class.

II. Pedagogical and Technological Aspects of the MadeByKids intervention

Aspired learning outcomes on the side of each child included:

- Solving real challenges from their life context in small teams by being guided through the problem solving process via (an adapted version of) the Stanford Design Thinking Method for Kids [15]
- Getting a first-person experience of computational thinking and coding in a small team
- Being able to present the team's achievement/product in front of a camera and conduct an interview
- Being able to give helpful feedback and to receive feedback;
- Getting evidence on one's - i.e. both boys' and girls' – creative ability to build and present a material as well as digital prototype to resolve a given challenge.

These learning outcomes call for the following three focal issues that are going to be described below:

- Learning scenarios providing challenges from the children's life context
- The adaptation of the Stanford Design Thinking Method for Kids
- The use of appropriate digital technologies to support computational thinking and digital prototype construction

Challenges. As described above, learning scenarios providing appropriate challenges – problems perceived as real in the kids' context - are known to have strong motivating and engaging effects. As Rogers [1] hypothesized: "students who are in real contact with life problems wish to learn, want to grow, seek to find out, hope to master, desire to create." Particular challenges tackled in the MadeByKids project were the design of a classroom of the future, a schoolbag 4.0, a future kidsroom, a scenario of the future world, and robots at school. Below we describe the general process that was followed to meet a challenge.

Adaptating the Stanford Design Thinking Method for Kids [15]. The workshops were designed by adapting **SDTMfK** as a generic process for problem solving. The intention behind this choice was to "revoke" the positive experience with SDTMfK from the US and UK and to deliver an inspirational new "teaching" - better learning – experience not requiring expensive technological equipment. In a nutshell, design thinking guides complex problem solving by following five steps [14]:

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 SDTMfK was used as a guide, it needed to be adapted to include digital technologies for prototyping and fit everything into a frame of exactly three half-days (about 3 hours each) workshops. The adaptation of SDTMfK and its mapping into three half-day workshops is described in Section four.

Educational technologies. We selected Micro:bit, LEGO Education, and Minecraft Education Edition on the basis of their provision of functionality appropriate to solving the challenges, their usability by kids, their availability, a short learning curve, and an accessible documentation.

III. Research Approach

A. Research questions

The central theme of the MadeByKids project can be put as follows: How can computational thinking, digital- and interpersonal competences be effectively promoted in schools (K2 – K6) with traditional structures?

Within this broad topic, a previous paper focused on various aspects of the children's learning and their perception of the workshops [5]. Here we just refer to the kids' learning and focus on the following questions: What was the rationale behind the design of the intervention and how were the workshops conducted? What effects did the series of three workshops have on

- Teachers' attitudes towards such workshops
- The teachers' own teaching practice and goals
- The facilitating team in terms of further development of such workshops and insight on sustainably promoting computational thinking and interpersonal competences in the (Austrian) school system?
- Various stakeholders from politics, education, and industry

B. Action Research as applied in the MadeByKids Intervention

Action Research has been gaining recognition for tracking the introduction of new media into innovative teaching and learning [16], [17]. Pioneering teachers/facilitators are likely to combine research with practice in acting as reflective practitioners in their own courses. This blend is known as Participatory Action Research (PAR) [18]. In this research, we take up Susman and Evered's [19] proposal that suggests that action research typically proceeds in cycles consisting of five phases: Diagnosing, action planning, action taking, evaluation, and specifying learning. Thus, we view the MadeByKids intervention as one PAR cycle into which we include complementary research methods for improving the evaluation of specific aspects of the intervention. For example, the teachers' view is investigated by a mixed qualitative and quantitative pre-test post-test survey design. This PAR extension allows us to deal more systematically with particular research questions, such as the effects of the workshops on the teachers' own teaching practice.

PAR as overall research framework was chosen for several reasons. It satisfies the need for a multi-perspective, participative and iterative approach. Since there was little evidence from literature for this educational intervention, investigating real-life activities and phenomena helped to deeply understand the intricacies and dynamics of the field and its stepwise transformation.

Moreover, presence in the field allowed for the use of a variety of sources such as existing tool training material from the industry, and data elicited through interviews, surveys, observations, videos, and a focus group. This blend supported integrating the DaVinciLab's practices with the actual childrens' and organizational demands in each classroom.

In order to provide focus in the PAR description, we selected the following key-issues that are given priority over multiple other issues that we encountered while studying the intervention:

- What did children do and accomplish in the workshops?
- What did teachers expect from the workshops and what role did they expect to play during the workshops?
- Were the teachers' expectations regarding the workshops fulfilled?
- How did teachers perceive the workshops and how did they characterize the role they actually played during the workshops?
- Would teachers use digital devices more (or less) often in class after the workshop experience?
- Would teachers and pupils recommend the workshops to others?
- What were the learnings of the whole team and stakeholders regarding the educational innovation and which significant insights did they take with them?

C. *Methods Used Within the Action Research Framework*

Data collection from survey with teachers. The basic idea behind the pre-test post-test survey design was to find out about teachers' attitudes and thoughts in connection with the intervention before and after the workshops. For this purpose, we constructed a pre-test and a post-test questionnaire for teachers. We asked them to fill out the pre-test questionnaire before the beginning of any workshop, and the post-test questionnaire after the last workshop, even though the exact time when the questionnaires were to be filled out was not specified exactly in order to leave teachers some flexibility.

The pre-test and post-test questionnaire for teachers had a mix of open- and closed-ended questions. The full questionnaires (in English or German) can be obtained from the authors.

Data analysis from survey with teachers. For the closed-ended questions we used descriptive statistics, since no hypotheses were tested and we wanted to simply describe the data. For the open-ended questions, qualitative content analysis was used [20]. To analyze the teachers' free-text responses for each question – these tended to amount to 0-4 sentences per response – one researcher read all responses, suggested categories, counted the number of occurrence of statements per category, and associated characteristic responses to each category. Thereafter, a second researcher checked the categories and counts per category and, in some cases, suggested to refine or revise the categories, producing his own associations. Then the two researchers compared their analysis results. They agreed upon a revised category system and statement assignments and counts per category after two iterations. They also agreed upon a selection of question-response items from the whole data set to be included in this paper to best characterize the teachers' perspective under given length limitations. The full set of findings can be obtained from the authors.

Focus groups with teachers. Two focus groups with teachers were organized. The first took place at the beginning of the project. In the spirit of a kick-off meeting, the goals were to share expectations regarding the project. As a result, teachers produced 'profile-sheets' of themselves. The second focus group took place in the friendly atmosphere of the DaVinciLab after all workshops were completed. It served as a means for reflection and feedback. After informal sharing, flip-charts with sticky notes on what teachers liked and did not like were produced and discussed with the facilitating team and the researchers, providing valuable feedback.

Video-analysis of workshops and their results. Facilitators documented parts of the workshops with photo and film in order to capture essential phases and preserve an impression of the atmosphere in each class for further reflection and analysis. Presentation challenges for children were scheduled at the definition, ideation, and prototyping stages to iteratively train pupils' presentation skills on the one hand and to allow for video-documentation of the results and effects on the other hand. In sum, more than 30+ movies of 8min plus were prepared. 10 hours plus of raw film material is available on the MadeByKids website (www.madebykids.at).

Observations. In several of the first, second, and third workshops, researchers from the University College of Teacher Education in Vienna and the University of Vienna, participated as facilitators and observers. We made notes and, later filled a structured form that was adapted from [21] by one of the researchers. The focus was on capturing the workshop setting along with the teacher-pupil interactions in order to allow for subsequent analysis [22]. On the whole, seven forms were filled out and their evaluation serves to spot essentials and improve follow up workshops.

IV. EXPERIENCES AND FINDINGS IN LIGHT OF THE FIVE PHASES OF THE ACTION RESEARCH CYCLE

A. *Diagnosing*

So far, the Austrian school system has foreseen computer science education as a compulsory subject only in grade K9. This is in discrepancy with the EU's recommendation to start education in digital literacy from early age and mastering the basic concepts by age 12 (K6) [2]. Furthermore, digital literacy education needs to include the principles and practices of using technology effectively and ethically, and to appeal to both boys and girls. Hence, the MadeByKids project was designed to investigate how education promoting computational thinking [23] and 21st century competences in an engaging way could be fit into the traditional Austrian school system.

B. Planning

Once the idea was born, energy levels were high to put the project into practice. Within three months (!), the industrial partners and 17 schools were found whose principals agreed to host three half day workshops at grades K2 – K6. All participating principals and teachers were invited to the project's kick-off workshop and focus group. The University of Vienna and the University College of Teacher Education Vienna agreed to research the MadeByKids intervention despite the very modest size of funding they could acquire in the short period. Personal learning and presence in the field were the major motivators to accompany and research the intervention and gain competences for a larger, sustainable follow-up project.

C. Action Taking

The Future Classroom Challenge as Sample Scenario. Children were asked to design their "Classroom of the Future". Small teams of children were formed to reflect on their current classroom situation and identify learning needs and ideas for improvement. Thereby, kids engaged in creative thinking processes and could refine their social-, team- and communication skills. In addition, they were challenged to engage in computational thinking and coding by working with digital technologies to create digital prototypes of their future learning environment. The challenge is analyzed in detail in [24].

The workshops. The learners - about 320 children from K2 to K6 from 17 schools, 55% boys, 45% girls - participated in three approximately three-hour workshops that were designed by adapting SDTMfK and employing digital technologies for designing and coding prototypes.

In the first workshop, teams of up to four children built models of their current learning environment, using wooden blocks. These models were then used to determine major qualities as well as areas for improvements and possible solutions, which were collected on sticky notes. Thus, learners considered what a classroom would have to offer in order to be most suitable for future learners. Afterwards, the teams were again asked to build a material model/prototype of the future place to learn, incorporating their improvements and future learning needs. In a final step, all material models were presented in front of the whole class.

The second workshop was dedicated to transforming the material model and the ideas from the sticky notes into a new digital three-dimensional prototype by using Minecraft Education Edition ™. Prior to coding, the teams of four were asked to quickly review their previous models such as to allow them to bring in more new ideas inspired form sharing with others. Furthermore, the teams roughly coordinated how they wanted to build the model together, because both teamwork and a strategic plan were necessary to finish their projects on time. After a brief introduction of Minecraft Education Edition, the team-members *collaborated intensively face-to-face and online* to implement their digital prototype of a future learning environment and to present their outcome.

In the third workshop the teams prepared presentations in form of interviews, which were then filmed in front of a green screen. All teams received feedback on their performance from their peers, the facilitators and sometimes the teacher. This led them to identify some crucial aspects of giving good presentations, which were tried to be put to practice when giving the final interviews in front of a green screen.

Adapting the Stanford Design Thinking Method. SDTMfK's five steps were approached in the workshops as follows.

1. Empathizing. Since children were both designers and users of the future classroom, they did not empathize with some external users but rather reflected upon their own needs and wants and empathized with their peers. This simplified variant of the empathizing phase happened in the first workshop and when building their digital prototype in the second workshop.

2. Defining. Using the sticky notes, the teams defined their areas of improvement, i.e. aspects of the learning environment that needed to be changed to better children's current and future needs.

3. Ideating. First, children sketched solutions to previously defined problems on sticky notes before implementing them into their initial, material prototypes. Second, they came up with further ideas while presenting and listening to others' presentations in the first workshop.

4. Prototyping. The children performed this step when they build the material prototype in the first workshop and the more elaborated, digital one in the second workshop.

5. Testing. Testing was reduced to the teams presenting and critiquing their solutions in class and, finally, presenting them to a more public audience (i.e. final video clip) with watching their test-videos before producing the final ones. For each presentation, feedback was provided by their classmates, the MadeByKids team, and sometimes the teacher. However, the children were not able to use the received feedback to adapt their prototypes due to the limited timeframe. Nevertheless, with the simplifications mentioned, all five phases of the Stanford Design Thinking Method were passed and to some degree even visited twice, once for producing the material prototype and once for creating the digital one.

Outcomes. From the numerous aspects that children had considered in their digital prototypes, we pick five to illustrate the creative solution space.

Every team included *sports activities* in their models, for example climbing walls, swimming pools, spring boards, football fields or trampolines. This suggests that the need of being active is considered an important part of children's life.

Being in *nature* and with *animals* seemed to be crucial as well. The children did not only place plants indoors and design outdoor spaces for their learning environments, some even wanted their schools to be surrounded by nature, e.g. on a mountain, in a large grass field or next to a lake. 15 out of 23 teams also wanted to learn with animals surrounding them.

Children welcomed the *availability of technologies* such as computers or tablets. Some pupils included robots in their vision of the future classroom. They were either used as a learning aid or even at times replaced the teacher.

Most pupils appreciated features that *personalize* their learning environment. They included poster boards, couches for relaxing, cozy reading corners, and the use of colors for creating a friendly atmosphere. Interestingly, all teams enlarged the space available, suggesting that classroom size was considered important.

Overall, the classroom space was hardly ever designed *just* for learning purposes. Every model had some features that were more focused on the aspects of students' lives such as sport activities, cinemas or areas for relaxing. Thus, children appear to have incorporated the modern notion of *functional zones* that industry is implementing in modern enterprises to better accommodate the need of multi-purpose office spaces. To sum up, the children valued personalized, technology-enhanced learning environments with comfortable furniture, surrounded by nature and facilities for sports and socializing. For an illustration of results visit www.madebykids.at.

D. Evaluation

The teachers' survey: demographic data. In total 16 out of 19 participating teachers submitted the pre-test – and 13 the post-test questionnaire. 19% of the participating teachers were male, 81% were female. One person was under 25 years of age, three were between 26-35, five between 36-45 and eight older than 45. The work experience varied a lot between teachers, ranging from two years to 35 years, with six teachers having taught less than 10 years, six teachers between 10 and 30 years and three teachers more than 30 years.

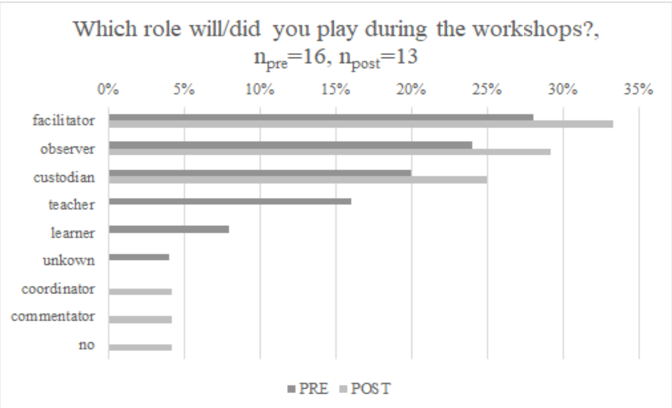

Fig. 1 Teacher-role-pre: Which role will/did you play during the workshops? n-pre=16, n-post=13

Teachers' role during workshops. In one of the first open-ended questions in the pre-test questionnaire, teachers were asked which role they intended to play in the workshop. The symmetrical question in the post-test questionnaire elicited responses to the questions which role a teacher actually played during the workshops. The categories formed from the responses are given in Figure 1. Interestingly, most teachers took on the role they had intended to play, whereby the majority of teachers wanted to play a more active role like being a facilitator (about 30%) or custodian (about 20%). About one quarter of the teachers preferred and actually played the less active role of being an observer. Intriguingly, just two teachers responded that they expected to learn something new themselves, amongst others. For example, one teacher wrote that s/he wanted "to learn and at the same time facilitate" during the workshops.

Positive features. The question "What did you like about the workshops?" gave rise to the following response categories and frequencies of statements falling into the respective category. Teachers liked:

- Materials: 4 out of 20 statements
- Structure and organization of the workshops: 3 out of 20 statements
- Promotion of creativity: 3 out of 20 statements
- 10 out of the 20 statements referred to features mentioned once or twice, such as naming one of the facilitators, frequent presentation, or phases of experimenting for pupils.

Some sample quotes were: "Well scheduled opportunity of including digital opportunities."; "The rich materials in the first workshop and the technical effort in the second and third workshop; the creativity of the children and the collaboration in the groups, the implementation via Minecraft."

Issues to be improved. Complementary, the question "What did not appeal to you regarding the workshops?" let us come up with the following response categories and associated statements-frequencies. Teachers did not like:

- Organizational issues: 5 out of 14 statements
- Concept, communicative and pedagogical issues: 5 out of 14 statements
- Too little time: 3 out of 14 statements
- Nothing: 1 out of 14 statements
- Four teachers left the response field blank

For example, a teacher shared: "That a synchronous start of all children with Minecraft did not work, that during the third workshop some children had problems presenting despite frequent practicing, and that a pupil didn't want to participate in the second and third workshop." Another teacher described his concern about too little time: "The time to implement the concept was too short; there was enough time during the first workshop, however time was missing in the third workshop. It should be planned differently such that children wouldn't need to sit quietly for such a long time."

These responses illustrate the prevalently constructive effort of teachers to provide helpful feedback for improving a grossly well-received workshop offering.

Impact on teachers' future teaching. In order to find out whether teachers might be inclined to change something in their own way of teaching, we asked the following two closed-ended questions:

i) Should pupils solve concrete challenges in teams more often? Here, seven teachers (54%) answered this with “yes”, one (8%) teacher with “no”, two (15%) were indifferent about this question and three (23%) gave no answer.

ii) Do you think you are going to use electronic devices (smartphone/tablet/computer) in category more or less often? Here four teachers responded with “more” and nine teachers with “the same amount as before” and no teacher answered that he/she would use them less. Intriguingly, a distinctly larger number of teachers (9 versus 4 out of 13) wanted kids to solve challenges in teams rather than increase their use of digital media in category. This leaves us with an open question as to the implication of these findings.

Were teachers’ expectations fulfilled? In sum, when being asked whether the workshops had met their expectations, most teachers (9 out of 13 who had returned the questionnaire) responded affirmatively. Two said “in part” and two said “no”. The two teachers whose expectations had not met did not provide any explanation. Teachers whose expectations were fulfilled wrote, for example: “I had expected three innovative, exciting workshops, this came true”. Another teacher shared: ”I liked it very much and anytime I would enroll in such a project again. Nevertheless, in my view three workshops do not suffice to cover such a complex topic.”

Interestingly, data indicates a parallel in the teachers’ and pupils’ perceptions regarding their responses to the question whether they would recommend participation in the workshop-series to friends or colleagues. In this regard, 68% of the youngsters would want their friends to participate in a similar project [5] and 8 out of 12 teachers would recommend the workshops to their colleagues.

Focus groups with teachers. While the opening focus group took place during the projects’ kick-off meeting and served to inform all stakeholders about the MadeByKids project, only the truly engaged teachers attended the closing focus group at the end of the schoolyear. Feedback on positive aspects, written on sticky notes and attached to a flipchart sheet, included: Fun while learning, team spirit, collaboration and presentation as well as innovative character (“new”) of the project.

Negative aspects pointed out included: Lack of time for exchange between project team and teacher before the sessions, not enough time for delivering the results, and fears/worries regarding the lack of sustainability of the project – without the digital tools used in the project (laptops, tablets, robots, micro:bits, etc) teachers can not duplicate the format. However, it has been stressed that particular aspects of the project, such as the focus on presentation, more teamwork, and the challenge-solving style of assignments can and will be replicated and, thus, sustained.

When asked if teachers could imagine using the technology in the classroom, the prevalent answer was: “Yes definitely, but it needs to be financed and, for the first 2-3 sessions, a coach who might help in difficult situations is needed.”

Observation, interaction and video analysis. This item denotes ongoing analyses. Results are being interpreted in the context of the method- and subject-triangulation of the whole study. The capture of observation and videos of kids’ emotions, classroom set up and concrete results enables further insight into the project’s impact and allows one to delve deeper into particular research questions in later stages of analysis. One important use of the video material was to provide it to various stakeholders and ask for their feedback; this is summarized below.

Stakeholders’ views. Political figures and educational experts were provided with the workshops’ videos and asked for feedback to be given to the participating children during the “Digital Days 2017” event. Some notable statements include the feedback of the representative of the Ministry of Education, who was moved by the kids’ motivation to work on the challenges and the multitude of solutions found. The CIO of the city of Vienna emphasized the children’s capability to empathize, detect the right problem and generate ideas. A professor from the Automation & Control Institute of the Vienna University of Technology stated that each child would have in him- or herself an innovator and she told the children to never let this inner innovator go away. Finally, a leading figure of the Vienna Business Agency noted that she liked to see how much fun the children had while working so hard and she expressed her hope that - due to the children’s enthusiasm - the world should improve with several exciting jobs available. All these statements of leading figures indicate the positive public notice of the MadeByKids project and express that the project achieved something extraordinarily valuable.

E. Specifying Learning

Observing the working process brought valuable insights. Below we summarize outstanding issues and refer readers to the detailed analysis given in [24]. In class, it soon became apparent that the teams felt at ease with using the digital tools such as Minecraft Education Edition™ or LEGO Education™. Children who were already familiar with using a computer and/or a tool had a slight advantage over the ones with no such experience. However, this did not significantly impact the quality of the prototypes. What affected the outcome more was the children’s ability to work as a team: Teams who discussed their activities and shared their workload produced more elaborated prototypes!

Consequently, the learners did *not seem to have problems acquiring digital competencies*, while a lack of teamwork skills might have affected the projects. A similar observation concerns pupils’ presentation skills. Even though presentations were used at various stages in the working process and students received rich input on how to present in an engaging way, most teams still struggled to do the final presentations. These observations “ring the bell” indicating that teamwork, communication, and presentation skills might require at least as much attention as digital ones in order to let children acquire the competences needed in the 21st century [11]! From all further findings, we list a few particularly relevant ones:

- Surprisingly (for teachers), kids who used to be passive in school were truly engaged, asked questions, and joined in.

- SDTM as design guideline, the challenges, and the digital prototyping proved highly appropriate. Our experience points to adapting some details in the workshop design.
- Everybody sitting in the circle on the floor while exploring something new and interacting had a highly positive effect on the atmosphere: It radiated trust, sparked ideas, and signaled inclusion. Providing physical and social space for encounters does make a significant difference!
- Taking time and caring for organizational issues, preparing teachers, making sure technology is available and works reliably must not be underestimated.
- Presence of researchers in the field sparks ideas and rich learning.
- Well-equipped classrooms with sufficient space definitely are an advantage, but any benefit from equipment hinges on how it is used and, hence, on the teachers' capacities.
- Workshop documentation, questionnaires, video material, and observation sheets proved to be very useful for illustration, promotion, and research. It is helpful to have them.

V. Discussion and Transition to the Second Action Reseach Cycle

A. Limitations of the study

Due to time constraints and the fact that the educational intervention per se took precedence over precise research, our study comes with a number of limitations. First, it needs to be noted that the percentage of school types was not balanced and the evaluation of questionnaires did not (yet) distinguish between grades (K2 – K6 were evaluated together) and school types. Also, schools were not selected randomly but based on the criterion of obtaining a representative sample. Based on participants' networks, inquiries to school principals helped to put together the sample in the short time we had. Second, some teachers/classes were severely challenged because the majority of pupils did not speak German well. In one school just two out on 25 pupils had a good command of German! Third, no precise protocol for filling out questionnaires was foreseen. They were distributed to teachers before the first and after the third workshop with the kind request to fill them out.

Despite these limitations, our research showed strong tendencies in the issues we researched and can, thus, provide valuable orientation in the field and for follow up projects.

B. Implications for the 2nd Action Research Cycle

Diagnosing. In line with the recommendation at the European level [2], Austria has introduced "basic digital competences" as mandatory subject at K5 - K8 level (with about 60 – 120 hours in sum). It spans eight competence areas to be taught separately or integrated into other subjects. Evidently, our experience during the MadeByKids project was eye-opening for designing offerings for facilitating "basic digital competences". At the same time, we realized that there was a severe lack of qualified teachers for this new subject as well as for promoting further 21st century skills such as problem solving, collaboration, creativity, communication, critical and appreciative thinking, and empathy [25]. Hence, respective offerings in teacher education as well as life-long learning are needed. Utilizing challenge-based learning and SDTM would be essential to let teachers experience this innovative, engaging style and motivate them to take the "risk" with their pupils.

Collaboration between the DaVinciLab, University of Vienna and University College of Teacher Education in Vienna will be crucial to join forces in this exciting pedagogical enterprise.

Action planning. MadeByKids threw some light on distinguished features that will orient future educational offerings. These include:

- More *self-directed learning* with more responsibilities for the learners and the group;
- Learning on the *social, personal, motoric and digital level* can go *hand in hand* and should take precedence over information transmission in lectures;
- *Challenge-based learning* is well apt to promote teamwork, empathizing, asking questions, specification, construction of material and digital prototypes, resolving conflicts, computational thinking, presenting, giving and receiving feedback, and powerful learning through correcting errors;
- *Multiple perspectives* on the problems and ideas become apparent, leading to more flexible and open mental models;
- Pupils take on *multiple roles*. Besides being designers, listeners, constructors, and presenters, they are peers, giving and receiving feedback on the work of others;
- *Learning* from "mistakes" or, more precisely, from personally feeling that some *aspects could be improved* tends to be a strong force in learning, if the communicative and error culture in the group acknowledges the impact of such learning.

We consider these features as sustainable building blocks resulting from the MadeByKids project. They will flow into our upcoming educational projects, regardless of their particular architecture. For instance, the next project is a youth hackathon, focusing on girls at K5-K8 grades, as we observed a strong gender gap starting at about K5. Learners will be asked to build an app or a game of their choice, visit high schools and meet female role models working in ICT companies.

VI. Conclusions

To summarize, participatory action research as overall research framework proved to be very helpful in reflecting upon the MadeByKids intervention from multiple perspectives. As authors, we hope that our rich experience with challenge-solving workshops following the Stanford Design Thinking Method for Kids provides inspiration and learning for like-minded educational innovators in schools, universities and enterprises. For sure, we need mindful innovators to directly pass on their skills, knowledge and practice to the new generation of teachers and/or pupils. We are happy to receive your feedback, questions or inquiries for collaboration.

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REFERENCES

[1] C. Rogers, "On Becoming a Person - A Psychotherapists View of Psychotherapy," Constable, London, 1961.

[2] Informatics Europe & ACM Europe Working Group on Informatics Education, "Informatics Education: Europe cannot afford to miss the boat," April 2013.

[3] L., A., Noel, T., L. Liub, "Using Design Thinking to Create a New Education Paradigm for Elementary Level Children for Higher Student Engagement and Success," in Design and Technology Education: An International Journal. (22)1, 2017,pp. 1-12.

[4] M. Carroll, S. Goldman, L. Britos, J. Koh, J., A. Royalty, and M. Hornstein, "Destination, imagination and the fires within: Design thinking in a middle school classroom," International Journal of Art & Design Education, 29(1), 2010, pp. 37-53.

[5] R. Motschnig, D. Pfeiffer, A. Gawin, P. Gawin, M. Steiner, "When Kids are Challenged to Solve Real Problems – Case Study on Transforming Learning with Interpersonal Presence and Digital Technologies," in Interaction Design and Architecture(s) Journal - IxD&A, N.34, 2017, pp. 88-111.

[6] S. McKilligan, N. Fila, D. Rover and M. Mina, "Design thinking as a catalyst for changing teaching and learning practices in engineering," in IEEE Frontiers in Education Conference (FIE), Indianapolis, IN, 2017, pp. 1-5. doi: 10.1109/FIE.2017.8190479.

[7] S. Goldman, and Z. Kabayadondo, Z., Eds. "Taking Design Thinking to School: How the Technology of Design Can Transform Teachers, Learners, and Classrooms,". New York, NY: Routledge, 2017.

[8] C. Rogers, "Freedom to Learn for the 80's," Charles E. Merrill Publishing Company A Bell&Howell Company, Columbus, Ohio, 1983.

[9] R. Motschnig and J., H., Cornelius-White "Experiential/Significant Learning (C. Rogers)," in Encyclopedia of the Sciences of Learning. Seel, M. Norbert, Eds. (4300 p.; 100 illus; in 7 volumes). Print (Book): ISBN 978-1-4419-1427-9, eReference: ISBN 978-1-4419-1428-6, 2012.

[10] C.E. Hmelo-Silver, "Problem-Based Learning: What and How Do Students Learn?" in Educational Psychology Review (2004) 16(3) 235 – 266. (https://doi.org/10.1023), 2004.

[11] M. Fullan and M. Langworthy, "Towards a New End: New Pedagogies for Deep Learning. Collaborative Impact." Seattle, Washington, USA. http://www.newpedagogies.nl/images/towards_a_new_end.pdf (accessed at 04/13/2018), 2013.

[12] S. Noonoo, "What's the Difference Between Project- and Challenge-Based Learning, Anyway?", EdSurge, https://www.edsurge.com/news/2017-12-27-what-s-the-difference-between-project-and-challenge-based-learning-anyway, (accessed at 03/28/2018), 2017.

[13] E. Rosenfeld Halverson and K., M. Sheridan, "The Maker Movement in Education," in Harvard Educational Review 84 (4), 2014, pp. 495–504. https://www.researchgate.net/profile/Erica_Halverson/publication/277928106_The_Maker_Movement_in_Education/links/5689dc6b08ae051f9af7899d.pdf (accessed at 04/13/2018).

[14] Stanford Design Thinking Process Guide, https://dschool-old.stanford.edu/sandbox/groups/designresources/wiki/36873/attachments/74b3d/ModeGuideBOOTCAMP2010L.pdf (accessed at 04/13/2018), 2018.

[15] Stanford Design Thinking Method for Kids, http://www.ideaco.org/2013/07/standfords-design-process-for-kids-teaching-big-picture-problem-solving/ (accessed at 04/13/2018), 2018.

[16] R. L. Baskerville, "Investigating Information Systems with Action Research," in Communications of the Association for Information *Systems*, vol. 2, available online: http://cais.isworld.org/articles/2-19/, 1999.

[17] R. Motschnig-Pitrik, "An Action Research-Based Framework for Assessing Blended Learning Scenarios," Proc. of ED-MEDIA 2004, Lugano, Switzerland, available online: http://www.gestalte.schule/, 2004.

[18] S. Ottosson, "Participation action research - A key to improved knowledge of management," Technovation, vol. 23, 2003, pp. 87-94.

[19] G.I. Susman, and R.D. Evered, "An assessment of the scientific merits of action research," in Administrative Science Quarterly, vol. 23, 1978, pp. 582-603.

[20] U. Flick, E. Kardorff, E., I. and Steinke, "Qualitative Forschung: Ein Handbuch," Volume 55628 of Rororo Rowohlts Enzyklopädie, Reinbek bei Hamburg, Originalausgabe, 11. Auflage, 2015.

[21] N. Grünberger, K. Himpsl-Gutermann, P. Szucsich, G. Brandhofer, E. Huditz, M. Steiner, Eds. "Schule neu denken und medial gestalten [Media design and thinking about school in a new way]," Vienna:Austria, Hülsbusch, W., 2017.

[22] P. Adler and P. Adler, "Observational Techniques," in Denzin, Norman K. & Yvonna S. Lincoln, Eds. Handbook of Qualitative Research. Sage: London, S. 377-392, 1998.

[23] J. M. Wing, "Computational thinking" Communications of the ACM, 49, 2006, pp. 33-35, doi:10.1145/1118178.1118215.

[24] L. Streli. "Austrian Education in 2017: Computational Thinking and the #MadebyKids Educational Intervention." Masters' Thesis, University of Vienna, Faculty of Computer Science. 2018, to appear..

[25] W. J. Chopik, E. O'Brien and S., H. Konrath, "Differences in Empathic Concern and Perspective Taking Across 63 Countries," Journal of Cross-Cultural Psychology, SAGE, 48(1), 2017, 23-38.