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Michele Moro
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Educational Robotics in the Context of the Maker Movement

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Preface

The volume “Educational Robotics in the Context of the Maker Movement” includes papers presented at the International Conference “Educational Robotics in the Makers Era-EDUROBOTICS 2018” held on October 11, 2018, in Rome. The conference was organized by the *Dipartimento di Ingegneria Informatica, Automatica e Gestionale “Antonio Ruberti”*, University “*La Sapienza”* of Rome (Italy, http://www.dis.uniroma1.it/en), EDUMOTIVA (Greece, www.edumotiva.eu), the *Dipartimento di Ingegneria dell’Informazione*, University of Padua (Italy, http://www.dei.unipd.it/en). The conference was the 2018 edition of a sequence of scientific international meetings of researchers working in the Educational Robotics (ER) field, starting from the 1st International Workshop entitled “Teaching Robotics and Teaching With Robotics-TRTWR” organized in Venice in the context of the TERECoP project (www.terecop.eu), followed by other TRTWR workshops (Darmstadt 2010, Riva Del Garda 2012, Padua 2014), and then generating the first edition of the “Educational Robotics in the Makers Era” conference held in Athens in 2016. Publications from those workshops have included open online proceedings, two special issues in the journals: Themes in Science and Technology Education, 2013 and Robotics and Autonomous Systems Journal, 2016, and the book “Educational Robotics in the Makers Era” (Springer 2017).

This book explores more deeply the connection between educational robotics and the maker movement which is currently inspiring new innovative ways to exploit technologies as educational “vehicles” for new ways of learning in and out of school, with a special focus on block-based programming environments, Do-It-Yourself electronics, 3D modelling and printing, the use of intelligent distributed systems, the IoT technology, gamification, and more. So empowered, Educational Robotics (in a broader sense) is proving a more and more fruitful field of development and experimentation both in formal and informal education settings, involving a continuously growing community of researchers and educators with interest in this field across EU and beyond. Starting from pedagogical premises that are the lessons learnt from constructivism, constructionism and social constructivism (Piaget, Papert, Vygotsky), current advances in Educational Robotics focus on the development of STEAM (Science, Technology, Engineering, Arts and

Math) education and the 21st-century skills: creativity, critical thinking, team working, and problem solving.

"Learning by doing" and "Learning by making" are the "mantras" around which the Maker Movement and its inspiring principles are successfully developed. Low-cost materials, free software, and a low access threshold are the pre-conditions to democratize access to new opportunities for learning through the 21st-century digital making technologies. The production of meaningful artefacts, where the "robotic" component can be more or less relevant, is an up-to-date interpretation of those "powerful objects to think with" that Papert considered crucial means for an effective and long-lasting education. The 2018 EDUROBOTICS conference was a valuable occasion to deepen these aspects with scientific contributions that deal with new proposals and innovative experimentations in this field.

The book includes 14 chapters plus six short papers coming from twelve different EU countries, the USA, and Israel.

The content of the book is organized into five sections

First section: Educational Robotics and the Maker Movement
Second section: Pedagogy behind Educational Robotics
Third section: Programming, Games, and Social Robots
Fourth section: Technologies for Educational Robotics
Fifth section: Short Papers Reporting Good Practices or Work in Progress (Presented in the Conference as Posters)

We thank the conference participants, academics, researchers, and educators from all the levels of education (primary, secondary, and tertiary), and the young researchers, PhD and postgraduate students, for their active participation and great contribution to the success of the conference and for authoring this book. Special thanks go to our Programme Committee members who have reviewed the papers and provided important help to authors to improve their manuscripts.

Finally, this book is dedicated to the memory of Edith Ackermann, the brilliant Swiss-American psychologist, collaborator of Seymour Papert at MIT and pioneer in studying the influence of technology on children's learning, who passed away at the end of 2016.

March 2019

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Designing a Makerspace for Children – Let's Do It

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Abstract. When makerspaces are designed for children, special motivation and reasoning needs to be made. Within this article, we describe a case study: A temporary four-day open makerspace for about 40 children per day. Motivation, considerations and the development process as well as the actual realization are described and discussed. We comment on how such a space for children and adolescents should be arranged for future studies. As described, considerations in terms of participation, peer tutoring and gender mainstreaming influence the design of the space, the methods used, as well as the general setting.

Keywords: Maker education · Maker Days · Maker movement · Children · Education

1 Introduction

Makerspaces, fablabs and hackerspaces are typically designed with adults in mind. Special offers are made for children occasionally, but adults are usually seen as the target group and considered to be the main users. In recent years, making activities for children have gained more interest. Seen as an activity with "creative and technological impacts, learning by making is an important component of problem-solving and relating educational content to the real world" [1]. Making is supported by its own learning theory: Seymour Papert proposed "constructionism" or "learning-by-making" [2] where learners would use tools to make things to construct knowledge. Papert, who died in July 2016, left his marks in several popular maker tools for children such as Logo, Lego Mindstorms, Scratch and the MaKeyMaKey and, additionally, in books such as "Invent to Learn: Making, Tinkering, and Engineering the Classroom" by Martinez & Stager (2013).

Although interest in making with children has increased, makerspaces for children are not common in the whole world. In the USA, makerspaces for kids exist in various learning environments: in-school, after-school, home-based and museum-based. [3] The MENTOR program aims to have more than one-thousand makerspaces installed in high schools [4]. In Europe, makerspaces with children as a single or main target group are less common and less studied.

Within this contribution, a case study of special makerspaces for children is described and discussed. The temporary, four-day long open workshop for about 40

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children per day, called “Maker Days for Kids”, was probably the first event in a German speaking country with an open approach and more than 130 visitors.

2 Methodology

To get an idea of how a proper maker space setting for more than 40 children and adolescents, aged 10 to 14, should be organized, including tools, activities, rules and design, we did a literature study. We looked at evaluations that were described in existing publications [5]. We combined these results with our own motivation and as responsible initiators and managers of the “Maker Days” project, we wrote proposals for financial support. In this paper, we will describe the motivation behind the project as well as the different stages of development that lead to our final setting and concept.

During the Maker Days, we used printed workshop cards to document how many workshops were offered and to monitor which participants attended which workshops. Every participant got an ID, that was used for all further documentation.

In this paper, we will present the results of the case study and reflect on the planning and realization of the Maker Days to provide the lessons learned for future events with a similar goal and target group.

3 A Temporary Workshop: The Maker Days for Kids

Considerations, steps of development, preparations and results of a four-day long maker space designed for children between 10 and 14 years old are discussed. The event “Maker Days for Kids” was created by Sandra Schön and supported by Martin Ebner.

3.1 Motivation

The event called “Maker Days for Kids” took place in April 2015 in a town in Southern Germany. In creating this makerspace, Sandra’s idea was not only driven by the desire to provide an innovative workshop on the creative usage of new and innovative digital tools. Taking her background as a researcher into account, her goal was to investigate how such a setting could be organized and to answer the following question: Does this setting attract children of both sexes and from families of less fortunate social backgrounds?

3.2 Early Considerations

The first time we got in touch with the maker movement was in a German speaking open online course called “mlab14: Kinderzimmer Production 1”. The aim of the course was to show children how to use technologies for learning purposes and creative work. Two girls, with whom we had worked together in former projects, also contributed to this course with a presentation about two projects in which they were involved. They talked about video production with tablets (and how they brought the mayor to Paris with the help of the green screen technology) and described how they produced a stop-motion film about monsters that appeared in the city's center.

Another part of the course was about the "Maker Movement" and we were absolutely stunned. Everything that was mentioned there was exactly what our work with children was already about: Doing something creative with the help of new technologies, even this did not include 3D printing or laser cutting at that time.

As researchers, the next step was to collect materials and literature and to write some posts on a German speaking weblog about media education and maker education. Together with Swapna Kumar, we also published a longer scientific contribution in the European e-learning papers [1].

While discussing the idea of a bigger making event with children and adolescents in an open setting, a friend suggested a possible call for projects. While waiting for a decision, we had already started a weblog for the project and announced that we would try to organize the event called "Maker Days for Kids" in autumn 2013 and asked for sponsors and additional co-operations. When we received the rejection for the project funding, we openly shared the decision with a post in our personal weblog as well as in the newly created project's weblog.

The reaction to these blog-posts was fantastic: A potential sponsor, the HIT-Stiftung, called (there was no contact before). They wanted to learn more about the idea and asked for the minimum amount of money needed to run the makerspace.

With the help of this funding, which easily covered all costs for material and rent but didn't cover the effort involved (especially the countless hours in preparation) the first step was done.

The next step was to find a proper location – the local youth center was very interested and agreed, that the event could be held there. Martin, who also works as an educator in educational technologies, organized part of his team from Graz University of Technology and some students to support the event. Seen as a unique learning event, they were all excited to be part of it. Sandra also asked her boss for support and other partners were found as well.

Nevertheless, the development of the makerspace, the design of the setting as well as the planning and preparation of training events, had still to be done.

3.3 Initial Design Considerations

As researchers, we perused examples and descriptions [3, 4, 6] in the first stage of the development process. Nevertheless, we could not find helpful descriptions for an open setting, where children could come and go without registering or applying beforehand. Announced as a requirement for funding the project, one of our main sponsors, the HIT-Kinder-Stiftung, made it clear that the Maker Days should address children from less fortunate social-economic backgrounds.

Additionally, it was hard to decide on the tools we should use and, on the projects/activities we should provide. Finally, we had to develop a setting and an evaluation design which allowed the documentation of the activities within the makerspace.

As a first step, we wrote down six principles that we wanted to follow within the design and realization stages: We wanted (a) to realize an open and low-threshold offer

(b) to foster participation of children, (c) to support idea and innovation development, (d) a (self-organized) competence development concerning new media and ICT (e) to design a gender sensitive setting (gender mainstreaming) and (f) to select tools and software that children could continue to use after the four days.

The development of the makerspace was the most important and longest part of the project. All in all, it took us six months. Finally, we shared and discussed our ideas with a group of experts (called Maker Days experts' committee), teenagers (peer tutors) and we organized a two-day long introduction meeting for all peoples involved. There we openly discussed minor issues and applied smaller changes. Additionally, the project consisted of a rising number of organizations collaboratively working together, e.g. the local youth center, two research institutions, the regional young researcher center (in German "Schülerforschungszentrum"), as well as companies and individuals who provided materials and/or support.

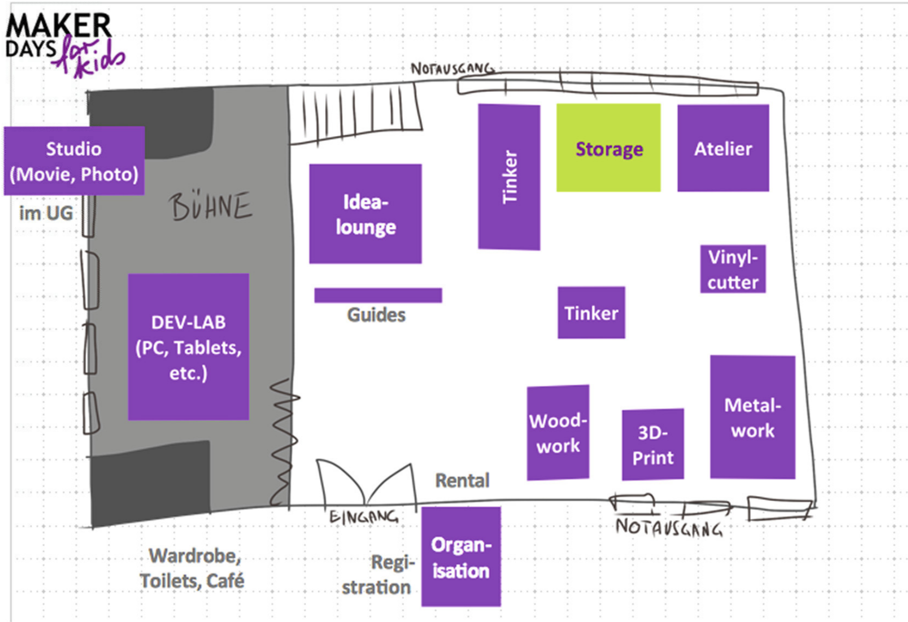

Fig. 1. Room drawing of the Makerspace, where the "Maker Days for Kids" took place

3.4 Designing the Makerspace Location

Although we were developing an open setting, the organization and preparation was complex (see Fig. 1).

Design Evolvement. From the beginning, the local youth center made the main hall available for our project, including the use of the toilets and the main kitchen and some additional space like the room under the stage.

Three peer tutors, Sandra and another tutor visited the location. First considerations were:

- Where are plugs? Especially: Where is more than one plug and is it possible to connect multiple sockets?
- Where should we install the router ("Freifunk", free Wi-Fi) so that we can easily connect to the main router in the youth center's office?

This technology-driven approach led to the conclusion that all the equipment that needs a lot of electricity should be placed on the stage. At the first moment, this sounded a little bit weird because we only considered the main hall as a location for the Maker Days.

During this first visit, Sandra realized that the whole hall had to be made more attractive and engaging, with separated spaces for certain activities etc.

The next design questions were:

- What are low-cost possibilities to mark certain spaces? (for example buntings, big sign posts, tables, shelves if available, fabrics)
- What furniture and equipment do we need? (How many tables and chairs? Where should we place them? How many computers?)
- What do we have? (e.g. the youth center has a sofa)

Building upon the parallel ideas on equipment and activities (for example 3D printing, making videos, using colors, wood work and need of simple wood tools) a sketch of the room was done. This sketch did not differ a lot from the room drawing in Fig. 1.

Especially the concept of the "idea lounge" as heart of the maker space made it necessary to develop a setting which is interesting for children and teenagers. Besides the existing sofa, we therefore bought several beanbags.

As far as possible, all decorating as well as functional furniture and equipment was bought or painted in the project's colors (light green and violet).

Decisions about the room and its equipment were also discussed in the preparation sessions with the peer tutors, which also helped in painting posters, signs, etc.

Looking back, one of the main learnings was that it was useful to start with the main technical challenges as this produced an unusual but smart solution with the "developers' space" on the stage. We should have thought about the possibility that a lot of stuff, especially paintings, need a place to dry, that it would have been useful to have a sink in the room for cleaning hands and that children need "save places" for their products as we experienced that someone missed a 3D printed object or a LED construction.

Room Plan and Tools. The Maker Days for Kids was offered in the Youth center of a small city (less than 20.000 inhabitants) in southern Germany, near the Austrian border. The big hall of the center with approximately 300 m^2, the stage, a little accompanied room and the cellar under the stage were used. Additionally, the participants had access to the kitchen (for example to prepare their lunches) and additional rooms.

The big hall was completely re-organized as different areas. Therefore, tables, shelves, posters with the area's name and decorative stuff as buntings were used to organize the areas.

At the registration desk, everyone had to check-in. There, the participants could also ask for support in organizational issues and for help if something got lost or if they needed special tools. At the center of the main hall, there was an information desk displaying the daily events (e.g. visits of the press, the daily challenge) and the mini-workshops. Everybody was invited to offer or participate in these mini-workshops. They usually lasted no longer than 20 min and were intended as a first introduction for the use of tools, software or techniques. The big table also acted as meeting point for the Maker Days tour for newcomers (and sometimes adults, especially parents), that were guided by tutors and peer tutors.

The other spaces in the hall included: (a) a space for woodwork with a set of basic tools, (b) two 3D printers, (c) a place for electronic tinkering ("metal work"), including work with LED and a storage place for material (with no direct access by the participants), (d) a table with the vinyl cutter and the ironing press, (e) the atelier with a sewing machine, sewing stuff and tools and a big basket of used clothes, (f) a huge supply bank, freely available to each participant, including paper, canvas, colors, cutters, glue, (g) two big tables for tinkering of all kinds (one especially for dirty work), (h) the "idea lounge", a comfortable space with a couch, bean bags, books and white boards (i) the "dev lab", situated on the stage with about 9 laptops and 3 tablets, the Lego Mindstorms robots and a drone. Under the stage, there was a helpful additional room: The darkened room was used for the light painting technique and video production.

3.5 Designing the Makerspace Activities

Design Evolvement. Besides Sandra and Martin, the peer tutors were also involved in discussing which activities would be interesting and how they can be arranged so that newcomers would easily become active users of the makerspace.

The design questions were:

- What activities are interesting?
- How could users get easily involved with the makerspace's different sections as well as activities? (we developed the idea to start with a guided tour for every new beginner and a "waiting space" where the new participants were encouraged to start tinkering with their badge and a small paper journal for notes)
- What are our rules? How would we like to work? (Therefore, we adapted the maker manifesto [7]).
- How can we prevent the usage of very expensive materials or limited tools? (Some materials were limited. Participants had to ask for some materials and tools at the registration desk. Only one 3D-print was possible every second day, for example.)

Building upon the idea of creating an e-portfolio for every participant, Sandra also came up with the idea of badges. Every badge was attached to a lanyard and contained the participant's ID. These ID's were also used to tag photos and posts within the weblog, so that everyone had the possibility to share his/her own e-portfolio (The ID was also mentioned in their certificate).

The development of the design was very tricky as we did not find any good examples of similar open makerspaces for children.

Invitation. Conceptualized as an open setting, the participants did not have to register for the event and participation was for free, of course. Concerning gender issues, we developed posters and materials, which did not highlight technological issues such as programming, 3D-printing or video production. From the literature study and our own experience, we knew that this kind of announcement usually attracts more boys than girls. We decided to keep it as inclusive as possible by just announcing "creative production within an open workshop".

The Maker Days' Principles. Together with some children, we provided some "Maker Days Principles" that we printed out several times and introduced to every newcomer. The principles are a variation of the Maker Manifesto by Hatch (2013) [7]: "1. Be creative! Make it different; try it! 2. Be curious! What are the others doing? 3. Copy! Good ideas are meant for copying. 4. Share! Share your ideas, materials and tools! 5. Work sustainably! Use garbage, avoid waste! 6. Ask for help! Look for support! Ask! 7. Fail! It does not hurt. 8. Tidy up! (A stupid principle has to be there, too) 9. Have fun! And now start!" Another important rule was not mentioned in the list of principles but was put above the entrance: "No adults allowed!" One exception was the special "adult's tour", run by peers or adults, where adults were asked to stay with the tour guide.

The Maker Days' Offers. Designed as a participative event, the main focus was on the participants' ability to self-organize their activities in the maker space according to their interests (see Fig. 2). In general, participants could use all materials and tools (if available). Free WiFi, special printed-out learning materials (e.g. for the programming language Scratch) as well as books were available for inspiration and tutorials. Within the DevLab, continued support from tutors was available. For the vinyl cutter and the 3D-printer, there were regular time slots for printing (more or less organized by the tutors). Photos of the final results or projects were done at the registration desk and were included in the project's weblog.

Besides this, every newcomer got a guided tour through the whole makerspace, including an introduction about the organization of the day and the Maker Days' Principles.

Every day we did a "daily challenge". This was a special task, announced and moderated by the tutors. On the first day, the name of the event "Maker Days" was formed with cardboard letters and the participant's task was to design these letters. Later, the cardboard letters were used as piano keys together with the MaKeyMaKey kit. The challenge for the second day was to make a film about the Maker Days. On the third day it was a "Maker Days Game" and on the fourth day, participants were asked to help with the preparation for the final public presentation.

Mini-workshops were offered almost over the whole day, excluding the "challenge time" and the last half hour, which was reserved for tidying up. 120 mini-workshops were offered by (peer) tutors and more than 90 of these workshops actually took place.

Finally, every day ended with a common tidy-up-session and a presentation of the projects in the (overcrowded) idea lounge where the participants shared their experiences and results with the other participants and tutors. Opening at 10.30, the hall was closed at 16.30 every day.

Fig. 2. A part of the makerspace, looking from the "DevLab" into the idea lounge (left in front) and several spaces for material storage, tools and work (behind it).

Being a Participant in the Maker Days. From the perspective of a participant, the journey started at the registration desk, where some sheets of papers had to be filled out by the parents. Afterwards, newcomers got the materials to tinker their name badges and a small paper notebook. They were asked to wait for a peer tutor, who would do the guided tour. The waiting or tinkering time normally took some minutes. The peer tutors typically started the tour, when there were 3–5 newcomers. During the tour, the tutors explained every part of the space, including the rules, the possibility to eat, the location of the restrooms etc. Newcomers were also asked to start with one of the mini-workshops, which were announced at a designated pinboard, or with the daily challenge (always at 11.00 am without any parallel workshops). The most frequently asked question was whether it was all right to take stuff such as cutter knives and paint self-dependent without asking anyone. At the computer lab and the 3D-printer desk, tutors were available all the time to support participants and to invite potentially interested children.

As described in the next section, the children usually stayed for several hours and came back for another day (if not the next day).

4 Results and Reflections

4.1 Children's Participation and Activities

Usually, it is a complex task to document activities within an open setting in a big room and with such a huge number of people involved. Some developments and considerations made it easier to observe the main activities. First of all, we collected some general information about the children at the registration desk (e.g. age, sex, school, home town). Then, every participant got a name badge with an ID. The first number indicated the day of the visit. This was helpful to identify newcomers or peer tutors, which, for example, started with "0". The next two digits were the numbers they got at the registration. All three digits together resulted in a unique number and the ID was used for registration, the documentation of the mini-workshops as well as the name of a file (e.g. for printing or cutting at the machines). The ID was also used to keep track when limited materials such as the set of lenses for the virtual reality cardboard goggles were used. When participants borrowed special tools, we also recorded their ID. Of course, all comings and goings were recognized at the registration desk. Last, but not least, the photos of the projects in the weblog were tagged with the IDs of all participants involved. This way, everybody got an individualized but anonymous online portfolio.

This structure made it easier to document and monitor at least parts of the participants' activities, at least in the organized mini-workshops. The data was collected and analyzed (see Table 1).

In general, 61 children participated in the Maker Days, 10 more in the general projects, and 8 were actively involved as peer tutors on each of the four days. At least 8 adults (researchers, experts, teachers and teacher training students) served as tutors over the four days. All in all, 124 "daily visits" were counted (as several children came for more than one day). For example, a special 3D printing expert or an urban gardening expert joined for a single day.

Table 1. Activities of the participants (without peer tutors) in mean or in percent (N = 61)

Activities of participants	In figures
Percentage of children who participated in the Maker days only one day	39%
Percentage of children who participated in the Maker days for 2 days	25%
Percentage of children who participated in the Maker days for 3 days	13%
Percentage of children who participated in the Maker days for 4 days	23%
Number of visited mini workshops (average)	5,3
Percentage of children who participated in a mini workshop	90%
Percentage of children who constructed 3D models (for 3D printing)	39%
Percentage of children who used sheets for the vinyl cutter	43%
Percentage of children who borrowed the 3D doodler (others could have used it, too)	7%
Percentage of children who took lenses for the virtual reality cardboard goggles	11%

Of course, one of our main interests was to see how many children had participated. On the first day, 28 children took part, and our maximum limit of 40 was nearly reached on day 2 and 3 (39). On day 4, the Maker Days attracted 28 kids and teenagers.

The majority of visitors came for the opening and stayed until the end of the day. 15 children who had come on day 1 came again on day 2 – which is an impressive ratio of 86%.

The analysis also gives some insights into the activities. All participated in the guided tour and 90% of the children took part in at least one mini-workshop. On average, each participant took part in more than five mini-workshops. More than a third of all participants printed at least one 3D model and cut a shape of vinyl film with the vinyl cutter. The number of children who borrowed the 3D doodler was smaller (7%). 11% of the children used the lenses for their own VR cardboard goggles.

With the help of the registration data, additional results are available. Because we asked for the school, we can analyze the data for different types of schools. In general, this project attracted a surprisingly large number of students who came from disadvantaged schools (40%). 28% of all participants were from advantaged schools. The other participants attended an elementary school. If we assume that the choice of school provides information about the socio-economic status of the families, we potentially achieved our goals concerning the socially disadvantaged. The deeper analysis does not show significant differences between the analyzed activities regarding the three types of schools.

Additionally, we also tried to attract as many girls as possible, as they are usually not attracted by technical projects in large numbers. Therefore, the ratio of 44% of female participants is really satisfying. Looking at the difference between boys and girls we only identified one or two statistically significant differences: Only 21% of the girls but 53% of the boys developed at least one 3D model ($p < 0{,}01$). Only girls (14%) borrowed the 3D doodler ($p < 0{,}05$). We did not recognize other significant differences, also in other areas (for example on how the participants got into contact with the Maker Days, see [5]).

Looking back at the considerations and principles we are very satisfied with the results we have achieved during the Maker Days. It seems that we succeeded in designing a low-threshold offer and attracting nearly as many girls as boys, which was also true for our peer tutors. On the other hand, we saw only limited initiatives from the other children. Only one external (non-peer tutor) male participant offered a workshop on day four, for example. We think that this would have improved if the event lasted longer.

4.2 Programming Languages and Educational Robots

For coding activities, the visual programming language Scratch and the mobile app Pocket Code were used. Pocket Code is a free mobile app, which was developed within the non-profit Catrobat project at the Graz University of Technology. The aim of the app and the Catrobat project is to raise interest in coding and STEAM-related subjects and to acquire coding skills in an entertaining and engaging way. The app acts as a development environment for programs that can be created directly on the smartphone or tablet with access to all built-in sensors. The values of the inclination sensor, for