Teaching Physical Computing in Family Workshops

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Family workshops in which children together with a parent learn basic physical computing concepts and programming have proven very successful in popularizing computing in Santa Catarina/Brazil. During the hands-on workshops, participants learn step-by-step how to "give life" to an interactive superhero robot through a simple, low-cost, platform-independent, reliable, and stable strategy integrating a microcontroller, a few hardware parts and block-based visual programming languages. The results of several of these family workshops in Santa Catarina indicate that the workshops enable the learning of basic computing concepts (specifically programming) besides providing additional benefits through the involvement of the families.

Teaching computing to kids either at their school or as part of extra-curricular activities, such as summer camps, after school clubs, or workshops has become a trend in education [20]. However, it's not only the children who need to be considered. Parents, family, and community members play significant roles in the lives of children and their involvement in education is important for several reasons [11]. Parents and families have the most direct and lasting impact on children's learning and education [5]. When parents are informed, and convinced of the importance of computing education, their motivation, assistance, and investment (e.g., in books or computers) can help their children to achieve more, exhibit more positive attitudes and behavior, and increase attendance and engagement [2,3,6]. Thus, involving parents in computing education is even more important as they probably have little computing knowledge themselves [1]. In this context, children from low-income families may be disadvantaged for several reasons. With less involved parents, they often experience fewer of the academic benefits than children coming from higher income homes and, thus, may be more at risk for lower academic achievement [17]. Often, their parents do not appreciate the opportunity of computing education for the careers of their children and/or even for themselves. Sometimes parents even dissuade their children from pursuing a computing career in favor of entering the labor market as unskilled workers to start contributing to the family income immediately. This undesirable situation contributes to an increased mismatch between an unskilled workforce and labor market needs for very skilled computing professionals as highlighted by several studies [9,10].

Therefore, computing programs for kids should also reach out to families to build the kind of relationships that inform and engage them as active partners in their interest and learning about computing [7]. Yet, for parents to develop supportive roles, they must gain first-hand competence in computing for themselves and with their children [12]. However, so far, most initiatives focus on the children only by teaching computing either within the classroom or in a more informal way as summer camps or after school clubs. Very few programs take into consideration the education of children and parents together. To support families, we need to design learning experiences where families can engage in joint activities to learn computing [8,19]. As part of our initiative *Computação na Escola* [4], we projected family workshops to teach physical computing to children and parents (or other adult family members) in which children and adults learn together through pair programming.

RUNNING FAMILY WORKSHOPS

We run physical computing family workshops either as part of school programs or independently as part of our initiative *Computação na Escola* [4]. The workshops are aimed at children (10-14 years) accompanied by a parent (or any kind of adult family member or friend). During the 3 1/2-hours workshop each child, together with a parent as a pair, learn how to program

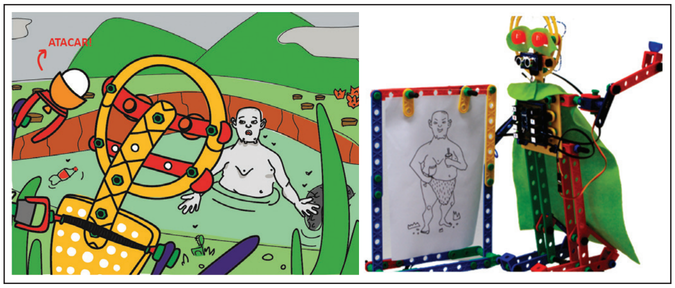

Figure 1: Interactive "superhero" robot

an interactive robot. Within the context of a story on an otter (native animal of our region) that needs to educate an ogre to stop polluting his lake, workshop participants are asked to help the otter to accomplish his mission. Therefore, they "give life" to a superhero robot, creating him to fire lasers with his eyes, to throw mud balls against a picture of an ogre, and, once sensing the presence of the ogre, making a sound to draw its attention.

We created a simple, low-cost, platform-independent, reliable, and stable strategy integrating a microcontroller and block-based visual programming languages. The robot is automated by an Arduino Nano microcontroller and a few hardware parts, such as a servo motor, an ultrasound sensor and two LEDs (with an approximate cost of less than US$45.00).

To facilitate programming, we use a block-based programming language, either Scratch 2 [14] or Snap! [18] (depending on the available IT infrastructure). To enable a quick learning experience and avoid having kids to hassle with jumper wires, breadboards, and command line-based microcontroller drivers, we developed a set of tools:

- **Scratchduino [16]:** a Scratch/Snap! to Arduino communication server. It is an easy to use, multiplatform GUI-based program that acts as a bidirectional protocol translator, providing interoperability between the Scratch/Snap! Extension Protocol and the traditional Firmata microcontroller protocol. Scratchduino is an extension of the s2a_fm command line Scratch to Firmata protocol translator originally developed by Yorinks [13]. To avoid the usage of a Unix-like command line application, we developed Scratchduino with a simplified GUI, supporting its usage in an intuitive, flexible and easy way.
- **Scratchboard [15]:** a low-cost and easy to use Arduino Nano break-out board that allows to build physical devices rapidly using telephone cable jacks and helps to visualize the structure and logic of the connections. The Scratchboard was developed as a printed circuit board with a DIP socket for the Arduino Nano, and eight 4P4C modular jacks, where the automation devices can be connected, as shown in Figure 2. These can be analog and digital devices, ranging from actuators and sensors to simple handmade analog devices.

We also provided a Portuguese localization for the Scratch and Snap! Arduino Blocks and the Brazilian Portuguese localization for the Snap! programming language to enable their application in Brazil.

During the 3 1/2-hours workshop, participants learn step-by-step how to program the "superhero" robot. This involves learning to use simple commands as well as events, conditionals, loops, and functions. They also learn how to use operators and interface commands to read sensors and pass over outputs. Basic computing concepts—such as an understanding of algorithmic problem-solving (problem statement, implementation, and testing cycle), collaboration in form of pair programming as well as the understanding that a computer program is a set of step-by-step instructions to be undertaken—are taught implicitly.

The workshops are divided into three parts. In the beginning, we rapidly present the programming environment, teaching the participants how to move an actor. Then, the participants learn how to program the robot. We designed the workshops with an exclusive focus on active learning. Right from the beginning, the instructor starts explaining step-by-step how to program the robot presenting only a minimum of theoretical knowledge, for example on angles to control the movement of the robot's arm. Immediately after the explanation of each step, the kid/parent pairs program and test their robot, if necessary, with help from the assistants. An online tutorial also supports this part of the workshop. In the end, they are free to explore how to modify/enhance the robot.

As of this writing, we have run five family workshops in the state of Santa Catarina /Brazil. In total, 75 families participated, with children ranging from six to thirteen years. A parent ac-

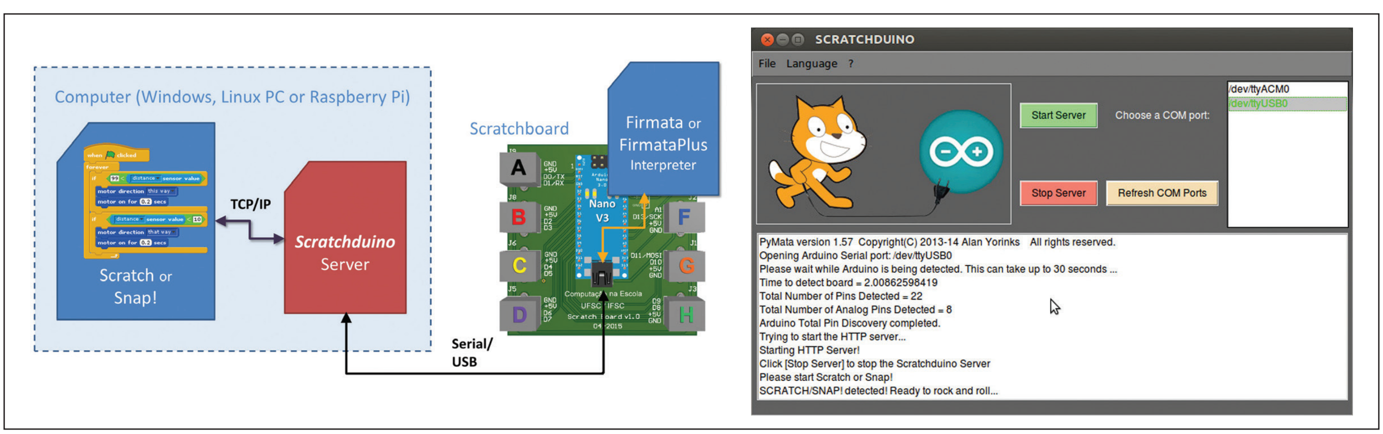

Figure 2: Scratchduino/Scratchboard operating schema and Scratchduino GUI

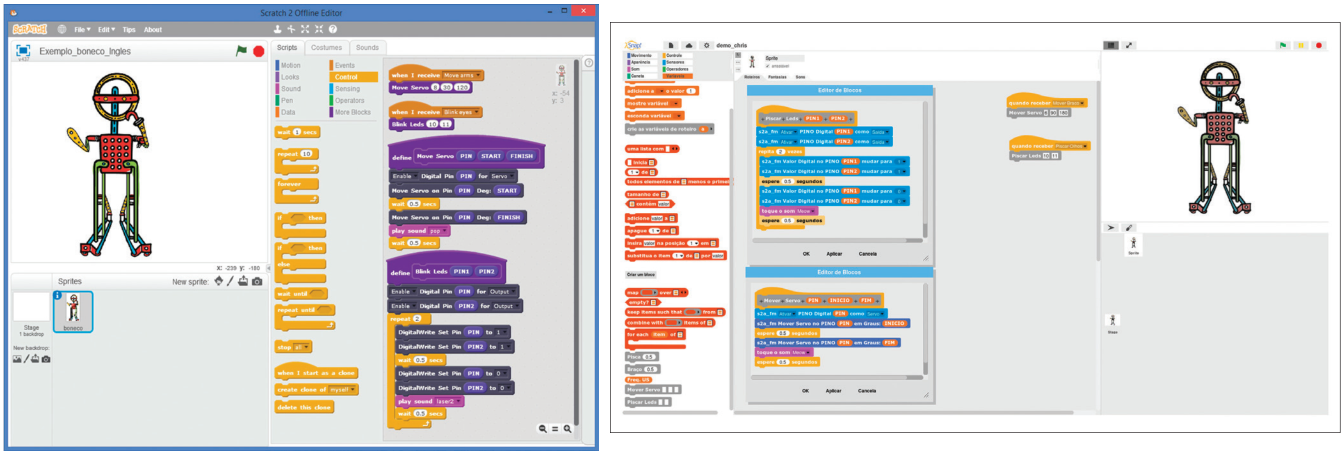

Figure 3: Command blocks used by Scratchduino and example of a program for moving the robot's arm (left: in Scratch, right: in Snap!)

companied each child—although in a few instances a grandparent or uncle/aunt (Figure 4) served as the 'parent' participant. The workshops were offered for free funded by the Google Rise Award and governmental funding (CNPq).

LESSONS LEARNED

All workshops have been very successful and we experienced a much larger demand than expected. The children like the workshop a lot, expressing this in their comments: "Very cool and lot of fun;" "I loved the workshop;" and "Incredible—it's magic," emphasizing especially that they appreciated learning how to make a robot move. In the same way, parents also demonstrated their contentment, praising especially the didactic, dynamic, and active format of the workshop in which programming concepts are taught in a creative and attractive way for the children. This positive evaluation has also been confirmed by post-class surveys in which the workshop was highly rated: on a scale of 1 (poor) to 4 (excellent), the participant's average ratings were 4 (median) for the workshop in general. Most of the children also considered the workshop easy and fun. The parents also expressed very positive feedback indicating that they very much liked participating in the workshop.

During the workshops, participants actively take part and can follow the instructions. And, although not measuring any kind of experimental data on the learning impact, we observed that each participating pair successfully programmed their robot. At the end of the workshop most participants also think that they can make computer programs and want to learn more about programming.

The children express their enjoyment—especially when seeing the robot working (e.g., lighting up its eyes)—satisfaction and self-esteem and show their surprise that they achieved something they thought of to be very complex. This again has

Figure 4: Scenes from the physical computing family workshops

also been expressed by their comments on what they liked most about the workshop (e.g., "when the robot throws the balls against the ogre" and "make the robot move"). Parents as well as the children enjoy programming the "superhero" robot and we observed that they immerse themselves into the story. One child, for example, had his mother film him re-telling the story while running the robot he programmed.

Furthermore, by gaining first-hand computing competencies themselves and with their children, parents are also motivated to assume a supportive role. A first step for them to encourage their children to pursue computing activities is that they themselves understand that computing is something their children can master as well as to recognize their child's interest in this area. At the end of the workshop, parents pointed out that it helped them to demystify computing and that they recognize the importance of computing education as well as the interest of their child: "I was very happy to see that my daughter was interested and liked the workshop;" "Finding out that it is very easy to program a robot, when I imagined that it was a very difficult thing only few people are able to achieve, and how children interacted and were interested."

Parents also cited as a strength the possibility of having this experience together with their child creating valuable parent-child activity time ("the chance to work/play with my son" and "the explanations with practical examples and to see the motion sensor working with all actions programmed. And we learned together!"). We also observed further benefits of the family-based design of the workshops. Parents and children collaborated naturally as pair programmers. Typically, the child assumed control by assembling hardware parts and programming, while the parent sat by his/her side observing and reviewing. Several times we observed a reversion of the traditional roles between parents and children, with the children leading and explaining the activities to their parents. However, as the children often rushed into the activities aiming at making it work, they did not necessarily take the time to understand the concepts. Parents on the other hand often adopted a more systematic approach and guided their child when something was not working as expected by carefully repeating the steps to identify the mistake. We also observed that the way the workshop is designed, with constant support by teaching assistants, makes children and parents feel comfortable in asking for help, whenever necessary. Thus, the workshops yield benefits by contributing to the children's education through parental involvement, but also by reaching a different group—the adults—and, thus, providing computing education to a larger share of the community.

At the end of each workshop, most participants (parents and kids) were eager to continue at home and/or through other workshops. Due to the success, we plan to continue these workshops as well as our game and app development workshops not only as self-contained events but also as a part of school programs. To broaden access to these workshops, we are also starting to develop teacher courses. Furthermore, we are developing additional activities via online tutorials to enable participants to continue at home afterwards. ❖

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