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Reprint of 'First exposure to Arduino through peer-coaching: Impact on students' attitudes towards programming'

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A B S T R A C T

In this paper we report the work that jeKnowledge (*Júnior Empresa da Faculdade de Ciências e Tecnologias da Universidade de Coimbra*), a student-led initiative, has done in the '*jeKnowledge academy*' courses to actively engage Portuguese high-school students in STEM education through hands-on projects based on the low-cost Arduino platform. F2F activities, based on a peer-assisted learning strategy, were complemented with tutorials and more advanced project suggestions in a blog. Pre and post surveys on students' attitudes towards programming and peer-coaching were administered to pre-university and first year college participants, finding an overall increase in the Likert scale for all the programming-related constructs under study (confidence, interest, gender, usefulness and professional) after the introductory course. As regards the peer-based learning approach, younger students seemed to be more eager to be taught in a less formal way than their older counterparts. The course resulted in high degrees of satisfaction for both the student tutors and their tutees.

1. Introduction

This paper reports details on an introductory Arduino course and the results of surveys administered to pre-university and first year students attending a school of science and engineering. It constitutes a first effort to understand Portuguese students' attitudes towards programming and to gain insight on what encourages/discourages them from pursuing degrees in computer science and related disciplines, in addition to evaluating their postures and beliefs about peer-based learning.

Building on the work developed by Hoegh and Moskal (2009) on validated assessment instruments to support the measurement of students' attitudinal changes as a result of interventions in computer science and information technology, a survey that could measure five constructs (confidence in their ability to learn computing skills, interest in computing, gender bias in the field, usefulness of learning computing and professional prospects) was administered to tutees. The survey was further expanded to include their views on the chosen peer assisted learning strategy (PALS).

Out of the five constructs, the gender related one is, in our view, particularly relevant: the lack of gender diversity in the computing field is problematic not only in terms of equity, but also for innovation, as noted by several entities (e.g., the National Center for Women & Information Technology (NCWIT), the Association of Computing Machinery (ACM-W), and the Anita Borg Institute (ABI)). In particular, they place emphasis on *the need for women to be a much greater part of the equation as the field moved into its next phase* (DuBow, Quinn, Townsend, Robinson, & Barr, 2016). Stereotypical attitudes towards women in computer-related activities go beyond the professional sphere, affecting even leisure activities such as gaming (Kaye & Pennington, 2016). Consequently, it is important for tutees to have female role-models as tutors, which is actually a common practice in jeKnowledge.

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jeKnowledge (*Júnior Empresa da Faculdade de Ciências e Tecnologias da Universidade de Coimbra*, http://jeknowledge.pt/) is a student-led initiative that started in 2008, aimed at offering students from the Science and Technology School at the University of Coimbra (Portugal) the possibility of applying the knowledge acquired in their higher education degrees to the global market, through different internal and external projects. This initiative not only works as a start-up incubator, but also organizes summer schools for 14 to 17 year-old high-school students and courses for freshmen in Science, Technology, Engineering and Mathematics (STEM) degrees at Universidade de Coimbra. These courses (*jeKnowledge academy*) are primarily aimed at actively engaging them in learning through hands-on projects, but introductory courses on programming (e.g., HTML, Arduino, Docker, ReactJS, RoR, etc.) are also taught to college students. In all cases, prior knowledge of programming is not a pre-requisite, only the desire to learn.

In order to expose the students to tools that will lead them to ideation, innovation, energy awareness and problem solving skills, which will enable them to become part of a very competitive workforce in the future, the ubiquitous embedded systems are an optimum platform (Benitti, 2012; Duncan & Bell, 2015; Merkouris & Chorianopoulos, 2015). Steve Jobs once said, "*Everybody in this country should learn how to program a computer, because it teaches how to think*". Many studies in programming, both in K-12 and higher education, have reported the positive outcomes of this exposure to a constructionism-based problem-solving learning environment, with authentic problem, information processing, scaffolding and reflection activities (Lye & Koh, 2014). Going one step forward, the European Union is currently funding projects, such as TACCLE3, aimed at sharing experiences and resources to introduce computational thinking in the educational agenda of its member states in an optimized and coordinated manner (García-Peñalvo, 2016; Rees, García-Peñalvo, Jormanainen, Tuul, & Reimann, 2016).

To teach a basic microcontroller is a challenging task, mostly at early stages (pre-university education). Some students may come with experience already on one or more particular microcontroller development platforms that they have used as hobbyists. On the other hand, the majority of students have not been exposed to any microcontroller platform at all. Moreover, there is a large number of alternatives available: CISC and RISC architectures; platforms that can be programmed very efficiently in assembly language and others using very high level languages; platforms that do not have any open source libraries to perform input/output interfaces and other ones that have a complete set of libraries; and platforms that hide all the microcontroller architecture and just focus on applications (Mondragon & Becker-Gomez, 2012).

The chosen platform should satisfy five basic criteria: (*i*) ease to program in assembly language and high level languages; (*ii*) ease to perform graphical system programming and configuration; (*iii*) possibility for students to apply it in project based learning (PBL); (*iv*) affordable for students to buy and experiment with; and (*v*) useable later in their degree program. Consequently, in this case of study, we opted for the open source Arduino prototyping platform, that has all of the above traits and that had been successfully used for other similar experiences. For instance, Junior et al. (2013) tested a low-cost educational robotics kit based on Arduino Uno platform with Secondary Education students, using a step-by-step approach and a block-structured environment, reporting substantial advantages over other alternatives based on standard and proprietary components. Assaf (2014) was also successful in introducing BotSpeak, a universal programming language for robotics, to K-12 students, selecting Arduino as one of the three preferred platforms (together with Raspberry Pi and LEGO Mindstorms). Arduino has been used in combination with Squeak e-toys to teach the object-oriented paradigm to middle school students, confirming positive results in both the cognitive domain and the definitional domain (Jang, Lee, & Kim, 2015). RoboParty, a three-day camp organized at Universidade do Minho in Guimarães (Portugal), chose a team-based approach to teach electronics, mechanical engineering and programming to school age children, while they participated in various cultural and sports activities. Once again, the *Bot'n Roll One A* robotics kit used was an Arduino based one, and an increased interest in engineering resulted amongst the participants (Eguchi, 2014). The same change in high school students' perceptions of computing was also achieved by using Arduino-based e-textiles and scaffolded challenges by Kafai et al. (2014); Kafai et al. (2013). They observed that creative freedom helped students feel a great deal of ownership in designing their projects.

At a university level, Rubio, Hierro, and Pablo (2013) showed improved results when Arduino was used in introductory programming courses for undergraduate students as compared to traditional classes. Likewise, Aldridge, Brandt, and Parikh (2016), by using a PBL strategy with an Arduino Uno board, had their undergraduate students experience the entire design process when building the autonomous educational robots by themselves. They concluded that this platform was the most suitable when there were budget constraints, and observed a remarkable success. With this being said, using Arduino in an introductory microcontroller-based programing course is not a novel idea anymore, but innovation in the present work comes from the chosen peer assisted learning strategy.

Arduino can provide an introduction to microcontrollers without dwelling much into the programming aspect of it or the architecture aspect of it. The implementation of *Processing* used in Arduino IDE would be a C/C++ 'dialect', which makes the transition easy for those who have just started learning C or any other language, and many graphical languages have been built around Arduino (e.g., Visuino, Ardublock, mBlock, miniblock, Snap4Arduino or Embrio, to name a few) that make it accessible even to non-programmers (Reas & Fry, 2014). At the same time, this inexpensive microcontroller might create enough curiosity as to what this beautiful thing is capable of. Moreover, adding peripherals is not difficult, as many modules are available that can simply be attached to the Arduino board like fitting two Lego blocks together. With a huge amount of online tutorials and a large user base to ask questions, it can become a great start for creating interactive objects or environments.

Thus, this student-led teaching/learning initiative, based on short and informal courses, and the chosen platform, particularly suited for developing the cognitive skills and problem solving processes included in computational thinking (Barr & Stephenson, 2011; Grover & Pea, 2013; Lessner, 2014), were regarded as an opportunity to evaluate students' attitudes towards computer science and related disciplines and student to student-based learning.

2. Materials and methods

2.1. Peer-coaching strategy

A peer-coaching approach was chosen since it has been shown through various studies that it has a number of benefits for both tutors and tutees: for the former, it results in the improvement on a range of soft skills, such as presentation and communication skills, and even in self-confidence (Smith, May, & Burke, 2007); while for the latter it enhances their academic performance and thinking skills, and influences their ability to apply abstract ideas (Capstick &