

Selected examples of cooperation between universities and schools in STEM education

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Abstract - “SUZA - from school to science and the academic community” is the official popularization program for science, technology, engineering and mathematics at University of Zagreb, Faculty of electrical engineering and computing. Volunteers in the program are professors, researchers and students from the Faculty. Although, the program is relatively new, it counts more than 20 activities during a school year. Activities are mostly specialized for K-8 or K-12 students or for their teachers and are hosted at the Faculty, or in their schools. In this paper, we present several approaches showing how we popularize computer science – depending on their age and their previous knowledge. For K-8 students we organize visits to our faculty research groups and laboratories. Further, SUZA participates in Computer Science Education Week - Hour of Code event. For K-12 students we host a student fair in electrical engineering and computing educational sector and several specific mini workshops for them to gain hands-on experience. At the same time, we educate their teachers how to use robots for education in the schools. In this paper we present teacher workshops “When science is boring, who is it boring to?” and “Autonomous robotic systems and their role in modern society”.

Index Terms - STEM, electrical engineering, computer science, teacher education.

INTRODUCTION

We live in a world that is strongly interconnected with the technology. Today's children are surrounded by technology and computers from the day they are born, and in order to function in the modern world, they must understand at least the basic principles of computer science (CS). Moreover, the world is changing rapidly. In 10 or 20 years, when today's children will become adults (e.g., workers, engineers, painters, scientists, decision makers), today's technology will be completely obsolete.

A difficult task is thus put in front of teachers, professors and other educators. They must prepare their students for a future that nobody for sure knows how will look like, and for jobs that do not even exist yet. Educators must ensure that their students acquire enough knowledge and experience to be able to cope with the challenges that they will encounter. It is logical to assume that almost all people in the future could benefit from CS or computing knowledge, and many of them will work in CS or related fields. Therefore, CS knowledge is not important only to students that intend to work in the field, but is also important to every child and every student. This is the reason why students should start learning the basics of CS and programming as early as possible, preferably in the elementary school, or even earlier.

Unfortunately, this is not the case today. As an example, in the US, CS or similar courses are behind the other academic disciplines [1]. Similarly, in Croatia, with tradition of a centralized and subject based curriculum, CS and information and communications technology (ICT) related knowledge can be obtained only by attending an elective subject "Information science" [2]. Most recently, Croatian Minister of Science, Education and Sports announced a plan to make information science a compulsory subject in the elementary school. At the moment, the only mandatory CS and ICT content in the elementary school is the one being taught as a part of a “Technical culture” [2].

According to the U.S. National Academy of Engineering and National Research Council, the Science, Technology, Engineering, and Mathematics (STEM) field is too wide and complex and no single educational institution can gain expertise in all of the STEM areas [3]. Therefore, for the successful education of students in the STEM field, it is necessary to combine the strength and knowledge of the various institutions. The academia and other high educational science institutions often have the knowledge and resources that some of the elementary and secondary schools lack of. That is the reason why high education institutions can, and should, cooperate with elementary and secondary schools in education of the future CS experts.

Some of the examples are given in [4][5][6]. Beside school-university collaboration, it is also very important to have school-university-industry cooperation [7][8][9]. Benefits for schools are: receiving resources from different companies, and exposing their students to scientists and engineers working on real-world applications. With good experience, students could choose STEM universities [7].

In our previous work [10] we discussed different approaches to teach the basic computer programming and math concepts to K-12 students. In this paper we present SUZA, a science popularization program of the University of Zagreb, Faculty of Electrical Engineering and Computing (FER). Our goal is to awaken an interest in STEM among children and youth, but also among their teachers and parents. Through its activities, SUZA tries to give K-12 students a basic education in the CS field in a way they could not receive in their schools (e.g., by organizing tours to our laboratories). Moreover, we encourage schools to set up new CS extracurricular courses, or offer their students additional CS education through some other activities (e.g., by taking a part of different CS events, like EU Code Week [11], Hour of Code [12], various competitions, festivals and science fairs).

The rest of this paper is organized as follows. In the Background section we give a brief overview of the elementary and secondary (K-12) school education in Croatia, along with the issues that the CS education in Croatia faces today. The next section describes our popularization program – SUZA, and activities carried out as a part of it. The last section covers some of the most important SUZA activities in more detail explaining different activities, created for elementary or secondary school students as well as for their teachers. Finally, we finish this paper by presenting our results and by sharing our final thoughts in the Conclusion section.

BACKGROUND

Croatian education system is organized in the following way: after kindergarten or preschool education, children start attending regular elementary school, usually at the age of 6 or 7. Elementary school education lasts for 8 years. For the first four years (age 7-10) students usually have one teacher for all or most of the subjects, and are taught Croatian and one foreign language, mathematics, science, music and visual arts, physical education and religious education. During the next four years, there is a different teacher for every subject, and also new subjects, like biology, history, geography, chemistry, physics, etc. Computer science or Informatics is an optional or elective course, and taught usually from K 5-8 grades [12]. The teaching units described by the Croatian education curriculum mostly include the basic computer usage, but also some simple programming [14]. The teachers can choose to teach programming either by using the language involving turtle graphics, or using a procedural language (e.g., Pascal, or more recently, Python).

Secondary school in Croatia is still optional. It lasts for three or four years, and depending on the type of school, can have computer science or informatics courses as obligatory or elective. Unfortunately, there are schools that still do not have any CS course in their curriculum. The CS topics highly depend on the type of school, from only basic computer usage to advanced programming courses in Natural Sciences and Mathematics Secondary Schools and technical / ICT – related secondary schools.

Since the Croatian educational system is organized in the aforementioned way, our work presented in this paper is focused on the K-8 or K 9-12 students and their teachers and the connection between their schools with FER.

SUZA PROGRAM

The program called “SUZA – from school to science and the academic community” (pronounced | ju:zə |) is the official popularization program of the University of Zagreb Faculty of Electrical Engineering and Computing. Our partners in this program are the Institute of Electrical and Electronics Engineers (IEEE) Croatia Section and the student organization eSTUDENT. The program is developed in cooperation and with the support of two Croatian agencies: the Education and Teacher Training Agency (AZOO) [15] and the Agency for Vocational Education and Training and Adult Education (ASOO) [16].

The aim of the program is to increase K-12 students’ and their school teachers’ interest in STEM fields by organizing different educational and popular science talks, presentations and workshops, organized tours and other events. The vision of SUZA program is to ensure the feasibility of the mutually entangled priorities of high science and industrial leadership defined by the Horizon 2020 program through ensuring quality learning outcomes and professional guidance for the top students [16].

Namely, as a part of SUZA program, K-12 school teachers in STEM fields are offered multiday educational workshops to equip them with presentation skills to present CS topics in such a way that is understandable, interesting and attractive to “ordinary” people, especially youth. In cooperation with AZOO and ASOO agencies, aforementioned workshops entered the calendar of professional teacher conferences and are now a part of the lifelong learning education and professional education offerings for K-12 school teachers in Croatia.

Alongside the educational events for K-12 school teachers in STEM fields, different science popularization events are also held at the FER, in cooperation with partner organizations and with direct partnering with K-12 schools. Those events include K-12 students’ and their school teachers’ visits to FER’s research groups and departments with demonstration of large scale experiments and other experiments which are impractical or dangerous to show in K-12 schools. Moreover, within SUZA program different science exhibitions and fairs are hosted at FER, as well as special educational workshops and other events that increase K-12 student interest in the STEM fields.

Finally, we were called to partner with Google as part of Google's ongoing commitment to increasing the number of women in CS. Their primary goal is to build an even stronger community of women in CS where they can connect, support one another and promote CS to women at the K-12, university and industry levels. Although our program is not strictly aimed at women in CS, our efforts were acknowledged by Google as we were invited to present results of our program at Google Anita Borg Scholarship Retreat in Zurich in July 2014 [18].

OUT-OF-SCHOOL STEM EDUCATION SETTINGS

Many jobs that today's K-12 students will have in 10 to 20 years have not been invented yet and moreover, the vast majority of careers in the 21st century will require an understanding of CS [1]. Additionally, since Croatian K-12 curriculum is jam-packed, as presumably also curriculums in other countries around the world, it is of a vital importance that in addition to the formal CS education, K-12 students also get out-of-school STEM education. The idea of SUZA program is to provide K-12 students with hands-on experience in CS adding thus immensely to their lifelong appreciation and understanding, even if they do not continue programming later on in their adult lives.

1. Level 1 & 2: Grades K-8

At the beginning of their education, K-8 students should be first introduced to the basic concepts in CS in order to understand that CS is an important part of their world. Later on, they should begin to use computation thinking as a problem solving tool. At this point, CS education could be embedded in some other curricular areas such as social science, arts, mathematics, biology, physics or chemistry.

Following the given concepts, within SUZA program we organize K-8 students' visits to our research groups and departments. FER has 12 different departments with every department having other things to offer for K-8 students. For example, at Department of Control and Computer Engineering K-8 students had the opportunity to see robotic mobile platforms, manipulators, quadcopters and humanoid-like robots. They also had the chance to play with and try some of the robots that were presented at the lab. Boys were thrilled since they got the opportunity to compete in robotic mobile platform racings (Figure 1), while girls were more fascinated with the humanoid-like robots against whom they played "tic-tac-toe" games (Figure 2).



FIGURE 1
BOYS COMPETING IN A ROBOT RACING

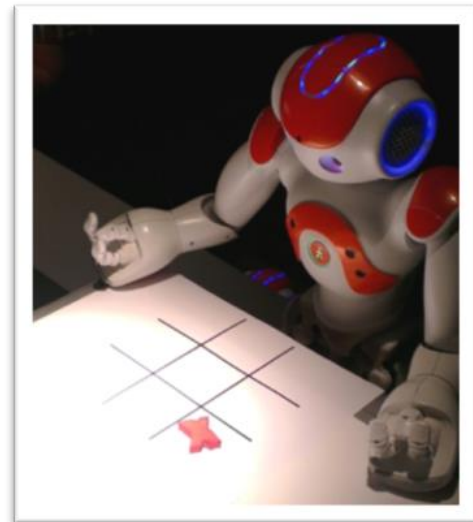


FIGURE 2
GIRLS PLAYING A "TIC-TAC-TOE" GAME AGAINST A ROBOT

Students were also offered the opportunity to play and learn how to code using concepts that were introduced in Hour of Code event [12]. Our first coding workshop was organized in December 2013 as a part of worldwide project "Computer Science Education Week", a project that promotes CS. The project goal is to achieve a greater accessibility and to encourage computing skills, especially logical thought, among the society. More than 100 attendees from ages 6 to 46 attended our first workshop where they got acquainted with coding while writing their first computer programs (Figure 3). Afterwards, we organized similar programming workshops only for K-8 students. Most of them were very excited because we "allowed them to play computer games" and were not aware that they are learning how to code. However, a few of them understood the concept of learning programming through a game and still loved it. At the end of every workshop, participants were awarded the certificates as a proof of their accomplishment (Figure 4).



FIGURE 3
EVERBODY MANAGED TO DO THEIR FIRST COMPUTING STEPS



FIGURE 4
K-8 STUDENTS BEING PROUD OF THEIR CERTIFICATES

II. Level 3: Grades 9-12

K 9-12 students should have a basic knowledge about: (i) CS in the modern world; (ii) CS concepts and practices and (iii) specific topics in CS. K 9-12 students should first learn how to appreciate the breadth of computing and its influence in almost every aspect of modern life and should be aware of social and ethical impacts of their choices when using computing technology, both in their work and personal lives. Then, they should also learn how to clearly understand the application of computational thinking for tackling the real-world problems and how to work collaboratively to solve various problems using modern collaboration tools. Finally, K 9-12 students should be involved in projects-based work focusing on a single facet of computing [1]. However, some Croatian schools are not adequately equipped and teachers are not satisfactory prepared for providing an appropriate knowledge to students. They thus need help that faculties (in our case FER) can provide.

Within SUZA program we organized several workshops where K 9-12 students were doing their own specific mini projects to gain some hands-on experience. As results of one of the workshops, K 9-12 students developed their first expert systems, constructed traffic light regulation systems (Figure 5), implemented computer vision algorithms for distinguishing between playing cards, and developed their games using the Unity game engine.



FIGURE 5
K 9-12 STUDENTS DESIGNING A TRAFFIC LIGHT SYSTEM

SUZA program also offers K 9-12 students opportunities to present projects that they are doing with their school teachers during a school year. The student fair in electrical engineering and computing educational sector was organized at FER two years in a row in cooperation with ASOO agency [16]. Every year more than 30 students and teams from almost 30 technical and vocational secondary schools in Croatia present their projects at FER. Figure 6 shows a K-10 student presenting his musical Tesla coil. In addition to the chance to present their work at FER in front of FER's professors and students, the best projects are awarded (Figure 7).



FIGURE 6
K-10 STUDENT PRESENTING A MUSICAL TESLA COIL



FIGURE 7
STUDENTS RECEIVING A PRICE FOR THEIR PROJECT

III. Educating K-12 school teachers

The challenge of improving CS education in K-12 schools is significant and requires attention and interventions from multiple institutions not only for out-of-school STEM education for K-12 students, but also for their teachers. Namely, K-12 school teachers who are willing, able, and empowered to deliver the CS curriculum are a core of improving STEM education for K-12 students in school settings. K-12 school teachers should be able to participate in a lifelong learning process where, except getting formal education, they should also have a chance to participate in appropriate teacher training programs, especially if the lectures are given by university professors in the field of electrical engineering and computing.

SUZA program offers K-12 school teachers opportunities to participate in different workshops and lectures with the goal of improving their abilities to teach CS concepts in a fun way. For example, we organized a mini workshop entitled “When science is boring, who is it boring to?” where teachers were taught how to use robots for education of their gifted students (Figure 8). Another example was a lecture “Autonomous robotic systems and their role in modern society” where it was shown how to apply different concepts from robotics in everyday school learning process (Figure 9).



FIGURE 8
WORKSHOP: HOW TO USE ROBOTS IN K-12 EDUCATION



FIGURE 9
LECTURE: AUTONOMOUS ROBOTIC SYSTEMS AND THEIR ROLE
IN MODERN SOCIETY

RESULTS

During the last two years we organized five K-8 school visits to our laboratories and research groups followed by programming workshops. The full statistic is as follows. We had more than 60 students visiting from elementary school “Kralj Tomislav”, more than 20 students from elementary school “Pavel Miskin”, more than 20 students from elementary school “Tin Ujevic”, more than 10 students from elementary school “Stenjevec” and finally more than 100 students participating in Hour of code workshop.

For K 9-12 students different activities (e.g., student fair and mini hands-on workshops) were organized. In total, we hosted more than 210 secondary students. We hosted more than 20 Swedish secondary school students, more than 90 students at Student fairs 2013&2014, more than 30 students visiting from Technical school „Ruder Boskovic”, more than 40 students participating in Scientific Saturday, and more than 10 students from Electrotechnical school.

Although in this paper we mostly presented activities that we carried on our own, in collaboration with other popularization groups, initiatives and organizations, we made impact on more than 540 not only students, but also other individuals interested in STEM field. Namely, we participated in Science Festival 2013 that had more than 200 visitors, Science Festival 2014 with more than 200 visitors and Innovation exhibit in Ivanic-Grad visited by more than 100 people. We also gave a couple of lectures at Summer School of Science in front of more than 40 students.

Finally, after each event that we organized, the participants’ feedback was collected. We rarely gave them specialized questioners, but rather gave them an opportunity to express their opinion in a nonstructural and for them, the most preferable way. In that sense, K-8 students were expressing their opinions through their paintings (see Figure 10), while K 9-12 students provided us with their feedback in form of a short written summary of their visit along with things that they liked or did not like. We took their feedbacks very serious and tried to improve our further activities based on the things that were listed as not so good. Our greatest achievement is when students are so happy and interested in things that we showed them that their last words are: “See you in ten years!”.



FIGURE 10
A K-8 STUDENT GIVING US HER FEEDBACK

CONCLUSION

Since different studies showed that job descriptions will significantly change in the following 10-20 years, different courses have to be offered to today's K-12 students in order to help them to cope with the changes. Not only students working in computer science (CS) related fields will benefit from a basic CS knowledge, but also students working in other domains (e.g., economics, medicine or politics). However, since curriculums are already jam-packed and there is not enough motivated K-12 school teachers, this matter requires an attention and intervention from multiple institutions, especially electrical engineering and computing faculties. In this paper we thus presented our program SUZA, that connect schools with university professors, scientist and researchers who live the CS. SUZA offers out-of-frame CS education for K-12 students and workshops that help motivate elementary and secondary school teachers to teach CS in a fun and interesting way.

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