Using Robotics to Foster Creativity in Early Gifted Education

Tomislav Jagust[1,2(✉)], Jasna Cvetkovic-Lay[2], Ana Sovic Krzic[1,2], and Damir Sersic[1]

[1] Faculty of Electrical Engineering and Computing, University of Zagreb, Unska 3, 10000 Zagreb, Croatia
{tomislav.jagust, ana.sovic.krzic, damir.sersic}@fer.hr
[2] Center for Gifted Child Development "Bistric", Nikole Pavića 5, 10000 Zagreb, Croatia
nadarenost@gmail.com

Abstract. This paper presents our experiences from workshops with gifted primary school students (grades 2–4) especially in programming with robotics sets (Lego Mindstorms EV3) and other technology. As a part of extracurricular enriched program at the Center for Gifted Child Development in Zagreb, Croatia, we organized a number of robotics and ICT workshops. Main goal of these workshops was to introduce gifted primary school students to computer programming and robotics, teach them some basic programming and mechanics skills, and develop their algorithmic thinking, problem solving and creativity. However, trough lessons, students showed unexpected productive giftedness in specific domains of creativity, with children experimenting with different ideas and designs, discussing inventions or alternative approaches to the given problems, or expressing their visual arts or music talents trough robots and programming tasks.

Keywords: Gifted education · Productive giftedness · Creativity · Digital natives · Skills in ICT · Robotics · Lego mindstorms

1 Introduction

Today's generations of children and youth were born and grew up surrounded with the technology. Motivated by flexibility and resourcefulness of ICT around them, they show very high levels of creativity and interactivity. The common term used to describe children and youth who have interacted with digital technology from an early age is "Digital Natives" [1], "n-gen" [2], or "Millennial Generation" [3]. Some authors ([1, 4]) suggest that for these students, a different learning environment and procedures should be created, to accommodate to their specific way of living (e.g. multitasking, nonlinear information processing, shorter attention span, communication over social media and text messages, etc.).

Advanced technology is very strong media and educational tools, capable to explain and visualize complicated abstract concepts, help students in developing their competencies, and at the same time keeping every student on the challenging upper

W. Lepuschitz et al. (eds.), *Robotics in Education*, Advances in Intelligent Systems and Computing 630, DOI 10.1007/978-3-319-62875-2_11

limit of her own capabilities. It is also the useful tool to make giftedness productive in domain specific skills and abilities connected with ICT and robotics.

This makes computers and technology particularly suitable for gifted children, since their capabilities, specific interests and motivation are on a higher level than their peers. Well-tailored computer applications enable a free, playful and fearless approach to learning and thinking, often in a very creative and imaginative environment. This too, makes them a great educational tool for gifted children who often stand out of their surroundings because of their creativity and personal traits.

It is a common prejudice that gifted children do not need additional support for developing domain specific abilities and creativity. For that reason, many gifted children are in danger of becoming the so-called "unguided missiles" [5]. Key focuses of ICT and robotics workshops at the Center for Gifted Child Development is early identification and educational support of young creative talents but also professional mentoring aiming to make creativity and giftedness productive. The role of mentoring involves coaching, expertise, guidance, instruction, knowledge, or skill-building in domain-specific area of creativity in ICT.

Working in small groups, we strive to utilize creative skills of our young talented digital natives with the educational objectives in the fields of robotics and ICT, at the same time directing their development on legal and ethical path, and for the common good. Through the lessons, LEGO Mindstorms EV3 sets were used predominantly, but sometimes different sets or tools were utilized as well, e.g. LittleBits, LEGO WeDo, Arduino, Drones etc.

2 Theoretical Background/State of the Art

Creative thinking skills are one of the most important skills of the future, especially if they are combined with gifted and talented children [6]. Giftedness includes the above average abilities and task commitment as well as the evidence of creativity (products) [7]. Walberg and Paik find out that productive giftedness is not only potential but also achievement and accomplishment [8]. In robotics workshops, children are actively engaged, they collaborate and contribute on meaningful outcomes-products. And that is the best way of learning [9]. Taucei, Stoltz and Gabardo's study focused on one gifted student and his interactive relationships with teachers in regular school as well as special education for gifted. He has difficulty in making friends with students, but he expresses himself mathematically in a creative manner [10]. In an open-ended project, Samuel combined usage of robotic kits (LEGO Mindstorms NXT) with mathematical simulation environment GeoGebra. Presented method noted especially good results with autistic students [11]. Lykke, Coto, Mora, Vandel and Jantzen compared three learning designs in programming teaching lessons: a problem based learning, a combination of problem-based learning with LEGO Mindstorms and a control group. The results show that robots can be an effective educational tool, but to achieve that goal, the project tasks and theoretical background must be well-defined and prepared [12]. In [13] robotics activities for K-12 students and teachers are presented. The activities are based on 5-Step Active Learning Cycle model: concepts, models, application, problems and design. In our previous papers [14, 15], we showed how to use LEGO Mindstorms robots to teach

children some of the basic science concepts, e.g. friction or "Why do we move faster on the ice than on the asphalt?", ultrasonic sensors or "How do bats see?" etc.

3 Participants

The participants in this study are members of Croatian NGO - Center for Gifted Child Development – Bistrić (en. "Smartie")[1]. The Center offers different extracurricular enriched programs organized in a form of workshops throughout a school year (Mathematics, Logic, Informatics, Programming and Robotics), as well as parent counseling and in-service teacher trainings for educational professionals. All of the participating students were, before attending our workshops, professionally identified as intellectually gifted, at least two mental years above average some of them even more. The authors organize and conduct robotics and programming workshops, usually monthly or bimonthly, with a group of 4–6 professionally identified gifted students, lasting 90 min each. Roughly 15 students, aged 8 to 10 years participated in our workshops in the last two years. Typically, students work in pairs, cooperating or collaborating on a solution to the given task.

4 Lessons Design

Most of the lessons are organized as a "learning by doing" or "learning through experiment" activities. At the beginning of the lesson, students receive a worksheet which serves as a guide throughout the workshop. Worksheet usually contains several examples and exercises and a short explanation of important concepts. Although it is not necessary for students to follow the worksheet "step by step", they can always refer to it if they get stuck in any point during the lesson. For most of the lessons, a simple and easily expandable LEGO rover robot – Riley rover is used [16]. It can be assembled rather quickly, which is useful in more complicated lessons or lessons that have more emphasize on programming than on robot design.

Lessons are organized to gradually introduce more complex tasks, but also to showcase different science fields or problems that can be solved using robots or programming and foster creativity. The lessons are divided into several small tasks, giving students a sense of progress, and essentially gamifying the learning experience. For example, the introductory lesson, instead of explaining different "driving" modes of LEGO motors, ask students to compare them, write test results in a provided table, and draw conclusions on their own. All lessons are open-ended. Students need to use their creativity and communicate ideas with colleagues to find possible solutions. Gradually, different concepts from mathematics and other fields are introduced and incorporated in lessons.

In previous work we argued that first graders, and especially gifted students, can understand and even master some of the university-level programming concepts [17]. During the "programming workshops" students were introduced to loops, conditional

[1] http://www.bistric.info/index.php/home.

Fig. 1. Left: A young gifted student programs "Rock-Paper-Scissors" game for robot. Right: What is a robot? Example of gifted child's drawing product.

statements, variables, etc. They created a number of simple games (like "Guess the number?" or "Rock-Paper-Scissors") and played them against robots (Fig. 1 left).

Many lessons were focused on support of creativity process with productive outcomes, such as: students built a robot that created different drawings or played songs that they composed. Sometimes, before they built the robot, students were given a task to imagine and explain what "a robot" means to them (Fig. 1 right).

The third group of lessons was intended for practice of acquired specific knowledge. For that purpose, the FIRST LEGO League 2017[2] (FLL) field materials, models and mission problems were used. Applying acquired knowledge, students had to upgrade and program their robot to autonomously carry out different missions. Through these lessons children practiced teamwork, collaboration and cooperation skills, problem solving and trial and error approach. Although the FLL is intended for ages 9 to 16, even younger gifted children successfully solve some of the challenges.

5 Results and Student Reception Discussion

During the workshops, the following observations were made:

Gifted students are creatively productive - In a number of occasions, students' solutions to the given tasks were different than the solutions we prepared. Their divergent and out-of-box creative thinking allowed them to imagine many possible (or impossible) ways to solve a common problem, e.g. build a robot that can move faster than its motors. The brainstorming sessions sometimes went in the unfeasible direction, at these occasions the pros and cons of the proposed solution were discussed and the workshop was reverted on the intended path. Another way of expressing creative productivity was through various creative products (drawings, constructions, composing and recording music, etc.), resulting in different robot designs (Fig. 1). Many students expressed other talents: composing music for robots or simply decorating robot with different visual add-ons.

[2] http://www.firstlegoleague.org/.

Gifted students are focused and task oriented "speed learners" - As a part of our outreach activities through the ŠUZA Program[3] at the University of Zagreb Faculty of Electrical Engineering and Computing, we organized a number of similar workshops with "regular" students of all ages. Typically, gifted students are much faster than regular students in adoption and application of acquired specific knowledge and skills, and need less time to solve given problems. Also, they can relatively easily understand complicated mathematical and physical laws. For that reason, lessons for gifted should be more content-rich and accompanied with at least several mental challenges and various possible problem solutions. Same approach in the "regular" student environment could have a negative effect on the workshop, with students giving up from task, or constantly asking for guidance from teacher.

Gifted students are more motivated and independent learners - If they encounter difficulties during the task, gifted students tend not to give up easily, but instead try until they come out with an answer, or ask for help. Further, in some cases, students didn't want to "go home" until they solved all of the problems in a worksheet. On the other hand, if the task was not challenging enough, gifted children would give up and take another task.

Gifted students like to collaborate, if they share the same specific interests and domain specific skills - They usually like working in pairs with other students, by splitting the task in two or working together on every detail of the problem. Since usually both students have their own idea how to solve a given problem, they learn how to debate with arguments. In "regular" student population, an "alpha" pair member is elected easier. The best teamwork results with gifted students were achieved when teams were able to meaningfully split the task into two loosely connected parts.

6 Conclusion

In this paper we presented our experience in special educational support to domain specific abilities – talents of creatively productive gifted students through ICT and robotic workshops. We have selected tools which inspire our creatively productive gifted to create independent projects and other various creative outcomes, which would otherwise be impossible to achieve without the use of ICT skills. Robots, especially LEGO Mindstorms, have proven to be an excellent learning medium, due to their attractiveness, ease-of-use, and almost unlimited creative building and combining possibilities. During the workshops, different observations and students' reactions were noticed, and discussed in more detail in this paper. Creatively productively gifted students are fast and independent learners, think divergently and are motivated solve demanding tasks. The main duty of a mentor is to enhance the independence and the creativity of a gifted child, in relation to child's skills and capabilities. Tasks should be complex, challenging and open-ended, further boosting already high level of creativity and resulting with various outcomes (products). Teamwork can additionally improve the quality of learning.

[3] http://suza.fer.hr/.

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