Make 21st Century Education: The Importance of Teaching Programming in Schools

Shorena Abesadze and David Nozadze
The University of Georgia, Tbilisi, Georgia
Email: {shabesadze, davit.nozadze}@gmail.com

***Abstract*—During recent years, there are huge discussions regarding 21st century education; Experts, scientists, educational specialists offer different ideas, results, and conclusions about how to improve educational processes in schools and how to develop students' 21st century skills; one of the important steps that have been taken in this direction is to introduce programming (coding) from the first grade as an independent subject in schools. The goal of this paper is to find out why it is important to teach programming in school. The main questions about this issue are: what are the reasons to teach programming? What are the main problems in the teaching process? How to teach programming? Answers to these questions are not always connected with each other and the teachers, who really create education in the classroom, need much more precise and complete information to what to teach and how to teach. Because of these issues, we decided to research this field and share our own experience, which we believe is successful in our school: we teach programming through the project-based learning method. Using this method, it is possible to develop 21st century skills and teach the basics of computer science from elementary school. In this paper we will discuss about secondary school students; by the end of the project, the 10th grade students have solved one of the problems of the school community - they have created educational games on the topic of ecology; games were created by the request of elementary school teachers; this year the games are successfully used in learning process.**

***Index Terms*—school education, computational thinking, problem-solving, project based learning, programming**

I. Introduction

The 21st century is unbelievable without technology. In the last 30 years, technology has significantly changed how we work, live and learn. Gen Z (people born from 1995 to 2010 - our students) are digital natives: from early years they use internet, social networks, mobile systems to communicate, play, read, write etc. [1]. They use technologies everywhere: in school, in the street, in the gym, at home, etc. We do not mean only laptops and desktop computers or Smartphones, but we mean that computers can also be found in home electronics, automobiles, airplanes, security systems, elevators, robots and many other devices [2]. It is true that we do not teach students about these devices (in my country) because it is the topic of Computer Science and unfortunately this subject is not introduced in the schools, but students know that all digital devices are controlled by the specially created programs.

Children are born eager to learn [3]. Curious by nature, students want to know how to manage digital devices, that means they want to "look in" programs and change them or create the new ones. If we consider the simplest case, our students always ask us to teach them to create the games, in other words to teach them programming. Creating computer games requires more than only programming: at least manage with graphics and hardware essentials. Interested and dedicated students can somehow cope with the final issues but deal with programming independently is very difficult for them [4]. This is natural because programming is considered as one of the main challenging and directions of computer science.

On the other hand, we all know that programming is one of the fastest growing professions in the world. "According to the U.S. BUREAU of Labor statistics, by 2020, there will be 1.4 million computer-science related jobs available with only 400,000 computer science graduates to fill those roles" [5]. Very fascinating statistics for the future profession!

Obviously, to introduce programming in schools is important, but because of only two reasons we described above or there are some other goals that make programming compulsory and necessary to teach from primary classes.

We decided to investigate this topic and our research question is: What are the best practices for developing 21st century skills and at the same time increasing the motivation for studying computer science?

II. Literature Review

Franklin D. Roosevelt once said: "we cannot always build a future for our youth, but we can always build our youth for the future." Provide students with a high-quality education mean to help them connect learning with real-life and equip them with the necessary skills that prepare them for success.

A. 4 C's of 21st Century Skills

Nowadays the need for teaching students to provide outstanding education and equip them with the capability to cope with the technologically developed 21st century has become a very important issue. Students should try to

Manuscript received March 9, 2020; revised July 1, 2020.

doi: 10.18178/ijlt.6.3.158-163

become developers of knowledge rather than consumers. It is becoming increasingly clear that only theoretical knowledge is not enough to prepare students for the 21st century. Employers often express disappointments about the newly hired graduates that they don't have the skills to complete their duties in the workplace. Why? Because graduates equipped with only theoretical knowledge are not able to succeed. That means they don't have the skills to create something new, to be innovators and not only users [6].

Researchers say that the 4Cs (Creativity and innovation, Critical thinking and problem solving, Communication, and Collaboration) are the requirements in creating "globally competitive learners" [7]. Therefore, educational policymakers must create the system by the above needs in the current education landscape.

The education system of the last century was constructed for the economy and society which does not exist anymore. In the society that existed 50 years ago, it was enough to teach students the "Three Rs" (reading, writing, and arithmetic). In technology developed society the "Three Rs" aren't enough and especially it will not be enough after 10-15 years when today's students finish the school [8]. If we want our students to compete in this global society, we need also to develop their "Four Cs" [9]. How? Many educators have come to realize that they must engage in more problem and project-based learning if they want to embed the "Four Cs" into their classroom practices [10].

B. Reasons to Teach Programming

What is programming? Definition from Khan Academy says: "Programming is the process of creating a set of instructions that tell a computer how to perform a task" [11]. Some programmers describe the programming as the process of encoding an algorithm into a notation that can be executed by a computer [12]. These definitions are pretty general, but if we ask: "how to create a set of instructions that will be understandable for the machine?" or "what an algorithm is and how to create it?" answering these questions will help us to understand the essence of programming. Programming is really a complicated skill and to learn and strengthen you in this field is quite difficult.

Developing a program involves various steps to complete like any problem-solving task. There are at least five main steps to develop in the programming process: defining and analyzing the problem, planning the solution, coding the program, testing and evaluating the program. These steps are described as slightly different in different resources, but the main idea is that writing a program is quite a sophisticated process. As a result, learning programming is not easy [13].

Years ago, everyone thought that programming should be learned only by special talented people with a strong analytical and logical mind; but now it's introduced as an important ability for 21st century learners and is becoming a key component of many curriculums, even in primary schools [14]. So, what's the benefit of teaching kids to code? Can it be assumed that during the process of programming the learner improves all the skills listed in 4C? Let's start with the simplest advantage, which is obvious and does not require a lot of evidence: basic coding courses in schools provide students with the experience to create their own websites. Students like to create webs using HTML and CSS (that is easy for them), but they want much more - use JavaScript to add automation, animations and interactivity to the web [15].

A second advantage will probably be problem-solving and independent decision-making skills. Coding encourages students to gain new skills that can help them solve various real-life problems. Students develop the ability to overcome difficulties, not to give up and reach the goal. For example, in the coding process, while testing the program students can get incorrect results and they will not be able to move forward; but they can go back and try again. This approach to test the program again and again till the time to succeed will be extremely helpful for them and they would achieve success in their future life [16].

It is said that coding is a universal language. We know that learning a new language improves students' communication and logical thinking skills, also verbal and written skills. Learning a new language helps students to understand the world around them better. Learn coding makes the same. Every character, we can type on the keyboard, has a special representation with 0's and 1's. These 0's and 1's give the ideas to students to understand how technology work and operate. The best way for our students to understand how the technology communicate with us is to teach them coding. When students learn to code it is a similar process of learning a new language. It does not matter where you are in the world; if the students know any programing language, they would be able to communicate with other people, and that is great [17] and [18].

Coding improves creativity: by experimenting, kids learn and strengthen their brains. Even when they make a mistake in coding they learn. Creativity is part of the learning process because when they try to solve a problem, they use imagination, knowledge, background and experience to find a solution. When they learn a language, they use it to express themselves. The same thing happens when learning to code. Coding allows kids not only be consumers of digital media and technology but to create it. Instead of simply playing different games or using applications, they can imagine how they are creating their games or websites the way they want, and they'll have the opportunity to implement their wishes and ideas [19].

The traditional belief has always been widespread in the community that kids interested in coding should have strong math skills. However, according to many researchers, it appears that the opposite idea might also be true: coding can help students improve math skills and make learning math more engaging and fun [20]. Understand abstract math concepts can be a challenge to many kids; Teachers and technology specialists can use programming to help children visualize abstract math concepts.

Let's discuss one example that coding helps kids learn math and vise verse math is used to create a program:

Once, I placed 10 sheets on the table with 10 different numbers on the hidden side and asked my students to find the maximum (largest) number. They quickly turned over the sheets and gave me the answer even faster. Then I asked them to validate the correctness of their answer. This was a little difficult for them. Their answer was approximately like this: we looked at all the numbers together and realized which was the largest. Then I asked them to imagine that they had 1000 instead of 10 numbers. Would they be able to solve the task in the same way? After thinking, they described the way we call an algorithm "to find maximum in an array". Then they wrote the program, and as the students told me, they understand what an abstract concept - find the maximum value means in a "very clear and tangible way". This is only one example, how to improve math skills; Lots of examples can be given on how to use Scratch in elementary school to investigate the properties of geometric figures and much more.

Coding improves students planning skills: students who learn to code understand how to plan and organize thoughts. To create a program, first they need to create an algorithm, which is a sequence of clearly formulated commands that must be precisely and completely performed to reach the solution [21].

Coding to improve logic and insistence: reading and writing algorithms is a great activity. Let's take any well-known algorithm, for example, find prime numbers and try to solve it on your own. If you make mistakes, you can search in the internet the already written program, read, think and understand and then try again to write by yourself. Reading algorithms is a great skill as well; Coding also requires insistence, because no matter how smart you are or what kind of experience you have, any program, written by you will almost never work the first time you try it and you will need to test it and improve the solution [15].

Coding improves collaboration: really most programming projects are developed by a group of programmers because the problem can be broken down in sub-problems and they can be completed concurrently, the overall project can be completed in a short period of time. Also, the development of a complex project requires many different skills. By allowing each part to be programmed by a professional in that field, the quality of the final product will be significantly higher than assign one person to do all the work alone. If a group of students is creating an educational game, one may work on the game content, the second may be the head coder, and the third may be the visual artist to create a design of the game; or students can write different modules of the game separately and then combine in one program. During the project development, students must work together that brings them new skills and valuable experiences [16].

Coding improves communication: when kids learn coding, they improve communication skills in different ways. In the classroom, coding is a collaborative activity and students can share their individual ideas. Also, if students create an educational game, they need to communicate with different users: teachers or other students (players), to find out what they like or dislike: what colors or designs they want to have in game and a lot of different requirements. Understanding the requirements of users is even more important than the coding because otherwise, nobody will use your program. Be able to communicate with the users, including asking good questions and making decisions is very important. Above all, students learn to communicate with computers. As we discussed, coding teaches students how to break down complex problems into parts and represents them in a way that computers can understand. This relationship obviously helps the learners to develop communication skills [19].

C. Main Problems in the Teaching Process

In many studies we can found descriptions of the problems that arise in the process of teaching programming; Programming has been introduced as the new subject in many schools; in some schools, programming is taught as a module of technology subjects. In all cases this has brought challenges for the teachers as well as for students. Teaching a new subject means teacher should be equipped with perfect subject knowledge and appropriate methodologies for delivering new knowledge, skills and attitudes to students. Even though many schools recognize how computer programming is engaging, interesting, motivating and fun for students, the teaching process still has different challenges for the whole school community [22] and [23].

Challenges for teachers are the following: lack of subject knowledge, learning resources, professional development trainings, assessment system, teaching methodologies. Challenges for students are the following: lack of confidence, struggle with problem-solving, less practice, lack of proper guidance, etc. [23]-[25].

Programming, that is the most difficult part of Computer Science, needs more recognition: computer science is the newest field of study. It's so new that most people think that it's only a university subject and there is no need to teach it in school. Such views and opinions need to change. It's necessary to bring not only modern technology in the classroom but to introduce technology education as well.

Parents and the community need more awareness: nowadays only teachers, programmers and science specialists say that computer science education should be a top priority in the school. How can we push schools to introduce the programming in the education process, if they don't understand the importance of Computer Science education?

To recognize the importance of teaching programming in school, parents and the community should take more responsibility, be more aware of current processes and technology advances and help the school. Schools need more resources: books, digital resources, and teachers support materials, lesson plans, curriculums, online platforms etc. before many good programming teachers will be available in schools. Then they start to create teaching resources and share with collages [26].

III. How to Teach – Our Experience

How to teach programming, this new and quite rigorous subject, is very difficult to answer. Experts, scientists, teachers, programmers offer different websites, programming languages and tools to teach coding and much more. Until more or less complete syllabus, teaching resources, methodologies, books and supporting materials are created taking into account students' age and background knowledge, before teachers have perfect professional development, they try their best to solve problems: share their experiences, help each other and use available resources to teach this difficult subject to students [21].

In our school we teach programming in all grades as a mandatory module on Coding and Robotics lessons. In all grades we use PBL (project-based learning) method depending on the age and level of preparation of the students; each module includes from 10 to 36 lessons according to grade. In this paper we want to describe a learning project that was implemented in grade 10 and explain how students enhanced 4C skills along with academic knowledge during the project development (project duration 36 lessons).

Project Description: The project was implemented by 10th grade students. They had to research whether it is possible to improve the quality of teaching and learning using computer-based educational games in primary classes; the main questions were: what are the factors that help increase students' motivation? What kind of games are there for elementary school students around the world, how do teachers use these games, etc.?

On the first stage of the project, the students found out that educational games really increase students' interest and the involvement in the lesson in elementary classes. Then they started researching what type of games might be used in the classroom to increase motivation, that is, what game elements should be included in the game. In the next step, the students needed to learn the game design and elements. They communicated with the elementary school teachers to select the problematic topics for their game.

The next step was to write the game code (program) using Java OOP. Students needed to learn not only the programming language but also the main algorithms. The teacher's role was the most important here: help students learn the basics of algorithms and introduction in OOP. Finally, students created computer-based educational games for elementary school students. The presentation of the project was followed by the actual use of games in the elementary classroom. The kids liked the games and gave their evaluations: they expressed satisfaction and mentioned about improvements. Finally, the programs were corrected and completed.

"HealthMan" is one of the best games created by the student during the project development (Fig. 1); the game topic is Healthy Lifestyle; the game style is the well-known "Hangman". The idea of the educational purpose of the game is that the player (1st grade student) must guess the word in English according to the picture. After guessing the word, a player collects coins; the number of coins obtained by the player depends on how well he/she guesses the word.

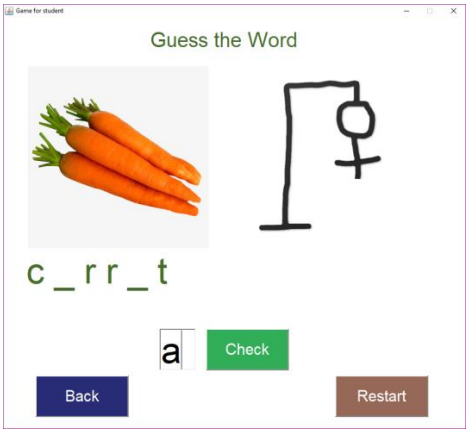

Figure 1. Guess the word.

The number of coins goes to the player's balance and the player can buy stickers (four different stickers) in an online shop (Fig. 2); in the Shop window on the right side we can see stickers purchased by the player. According to teacher's requirement student (author of the program) can easily input new words in the program. Each word in the game is represented by a colorful picture. Today, teachers are using this game in our school to teach English.

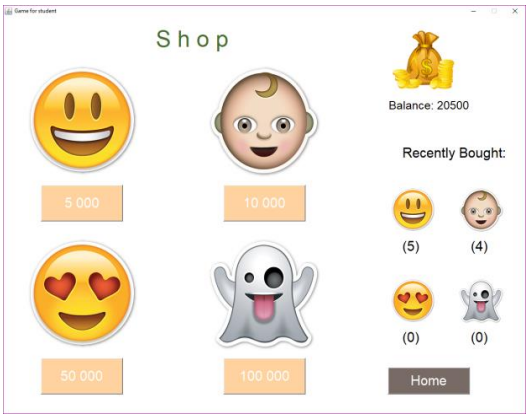

Figure 2. Online shop.

Qualitative research method was used by us to obtain data about the problem solution and answer not only question - "what" students and teachers think about learning and teaching programing and 21 century skills but also "why" they think so.

We decided to use a combination of two of the classic research tools: project participant observation - we observed grade 10 students during project development process; how they learned to solve real-life problems by creating games using java OOP and in-depth interviews with programming teachers and some students to collect, analyze and evaluate data on student's behavior, motivation, engagement and achievements.

Problem solving: 10th graders have created educational computer games for elementary school students the same that everyone can play in the internet, but according to teachers' (users) requirements. About 70% of students created the final product - a game

(prototypes for desktop app). About 30% of them are original, functional and can be used in education process. In interview these 30% of students mentioned that they already had little experience in programming. This year 10th grade students are doing the same project, but they already have programing experience. Thus, we believe more students will be able to create interesting games.

Development of 21st century skills: 10th graders had to research information, analyze and evaluate, communicate with primary school teachers to select educational topics for game content, collaborate with each other and teachers to learn and understand basics of programming, develop creative thinking as the game had to be designed in its own way.

Finally, the students not only started to learn the programming language and the basics of algorithms (loops, 2D arrays, search and sort algorithms etc.), but also went through the whole Software Development Cycle: problem analysis, design, development and implementation, testing, and evaluation.

IV. Conclusion

Over the last decade, a huge amount of energy has been spent by many countries to create new policies around 21st century education. However, if 21st century education will be changed for improving the lives of students, teachers must have the support they need to do this work in the classrooms every day. Teaching critical thinking and problem solving, communication and collaboration, creativity and innovation are not unexpected requirements for educators. In fact, they are the foundation for creating the best education and most teachers aspire to teach in a manner that helps students to develop 21st century skills.

According to studies teaching programming at school is necessary and important; using the PBL teachers can make this process interesting, fun, and attractive for students; every child love games. They will be more interested if they can create the game. The result is amazing: during the project development 10th graders learn programming and develop 21st-century skills, while elementary school students have new games and can play and learn at the same time. Learn to program through game creation is an interesting and innovative method to use in practice. It is obvious students' interest and involvement in the learning process will increase. At the same time, project-based learning provides students with all the skills that are so significant today.

In addition, by learning the basics of programming, students will be more interested in learning how to program robots, learn about artificial intelligence, and engage in other interesting projects.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Problem research, literature review was conducted by Shorena Abesadze. David Nozadze took an active part in the implementation of the project with focus group (grade 10 students) by helping students generating game ideas, creating the design, writing code for the application; at the end of project he helped students to provide lessons with their applications in elementary school classes. Data was analyzed together by both authors. Shorena Abesadze wrote the paper. Both authors had approved the final version.

References

[1] S. Gaidhani, L. Arora, and B. K. Sharma, "Understanding the attitude of generation Z towards workplace," *International Journal of Management, Technology And Engineering*, vol. 9, no. I, pp. 2804, January 2019.

[2] S. H. VanderLeest, J. Nyhoff, and N. Zylstra, Being Fluent & Faithful in a Digital World, Grand Rapids: Computer Science Department of Calvin University, 2004.

[3] C. L'Ecuyer, "The wonder approach to learning," *Frontiers in Human Neuroscience*, vol. 8, pp. 764, October 2014.

[4] D. Callele, E. Neufeld, and K. Schneider, "Emotional requirements in video games," presented at 14th IEEE International Requirements Engineering Conference (RE'06), Minneapolis/St. Paul, MN, USA, 11-15 Sept. 2006.

[5] T. Kalil and F. Jahanian, "Computer Science is for Everyone!," The White House, 11 December 2013. [Online]. Available: https://obamawhitehouse.archives.gov/blog/2013/12/11/computer-science-everyone

[6] M. Bialik, C. Fadel, B. Trilling, and P. Nilsson, Skills for the 21st Century: What Should Students Learn?, Boston, Massachusetts: Center for Curriculum Redesign, 2015.

[7] I. M. Zain, B. Muniandy, and W. Hashim, "The integration of 21st-Century learning framework in the ASIE instructional design model," *Psychology Research*, vol. 6, no. 7, pp. 415-425, July 2016.

[8] H. A. Alismail and D. P. McGuire, "21st century standards and curriculum: Current research and practice," *Journal of Education and Practice*, vol. 6, no. 6, pp. 150-154, 2015.

[9] National Education Association (NEA), Preparing 21st Century Students for a Global Society, Washington, DC: National Education Association (NEA), 2019.

[10] S. Lamb, Q. Maire, and E. Doecke, "Key Skills for the 21st century: An evidence-based review," Centre for International Research on Education, New South Wales, 2017.

[11] Khan Academy. Computer programming. Khan Academy. (2019). [Online]. Available: ttps://www.khanacademy.org/computing/

[12] B. Miller and D. Ranum, Problem Solving with Algorithms and Data Structures, Auckland: The University of Auckland, School of Computer Science, 2013.

[13] Y. T. W. Tiky, "Software development life cycle," The Hong Kong University of Sciene and Technology, Hong Kong, 2016.

[14] L. Sterling, "Coding in the curriculum: Fad or foundational?" in *Proc. Research Conference*, 2016, pp. 79-83.

[15] D. Storte and M. Webb, "Coding, programming and the changing curriculum for computing in schools," UNESCO/IFIP TC3 Meeting at OCCE, Linz, Austria, 2019.

[16] S. Nelson. (March 2018). 5 Reasons why Coding is Important for Young Minds. Learning Resources Ltd. [Online]. Available: http://blog.learningresources.com/5reasonskidscoding/

[17] U. Kaplancali and Z. Demirkol, "Teaching coding to children: A methodology for kids 5+," *International Journal of Elementary Education*, vol. 6, no. 4, pp. 32-37, 2017.

[18] O. Mironova, I. Amitan, and J. Vilipõld, "Programming basics for beginners. experience of the institute of informatics at Tallinn University of Technology," *International Journal of Engineering Pedagogy (iJEP)*, vol. 7, no. 4, pp. 7-18, 2017.

[19] Ryan. (September 2019). Coding for kids: Reasons kids should get started, and how they can find success. iD Tech. [Online]. Available: https://www.idtech.com/blog/5-reasons-your-child-should-learn-to-code

[20] A. Gomes, E. Bigotte, L. Carmo, and A. J. Mendes, "Mathematics and programming problem solving," presented at 3rd E-Learning Conference, Portugal, September 7-8, 2006.

[21] M. Saeli, J. Perrenet, W. M. Jochems, and B. Zwaneveld, "Teaching programming in secondary school: A pedagogical content knowledge perspective," *Informatics in Education*, vol. 10, no. 1, pp. 73-88, April 2011.
[22] M. Mladenovic, D. Krpan, and S. Mladenovic, "Learning programming from scratch," presented at International Conference on New Horizons in Education 2017, Berlin, Germany, 2017.
[23] M. Rahmat, S. Shahrani, R. Latih, N. F. M. Yatim, N. F. A. Zainal, and R. A. Rahman, "Major problems in basic programming that influence student performance," *UKM Teaching and Learning Congress 2011*, vol. 59, pp. 287-296, 2011.
[24] K. A.-M. Sarpong, J. K. Arthur, and P. Y. Owusu, "Causes of failure of students in computer programming courses: The teacher – learner perspective," *International Journal of Computer Applications*, vol. 77, no. 12, pp. 27-32, 2013.
[25] J. Gal-Ezer and C. Stephenson, "Computer science teacher preparation is critical," *ACM Inroads*, vol. 1, no. 1, pp. 61-66, 2010.
[26] Walden University. There's more technology in the classroom than ever before, but there's still a lot of room for improvement. Walden University. (2019). [Online]. Available: https://www.waldenu.edu/programs/education/resource/top-challenges-facing-k-12-computer-science-education

Shorena Abesadze is a PhD candidate at The University of Georgia. Her research field is in programming and Intelligent Learning and Teaching Systems. Currently she works at the international school as an IB DP Computer Science and AP Computer Science teacher in Georgia, Tbilisi.

David Nozadze is a PhD candidate at The University of Georgia; His research fields are in STEM Education, Project Based Learning and Engineering Education. Currently he works at the international school as a Robotics teacher, at the Georgia's Innovation and Technology Agency as a Robotics teacher and at the Ministry of Education, Science, Culture and Sport of Georgia as an IT Trainer in Georgia, Tbilisi.