The Ecosystem of Computer Science Education in Bulgarian Primary School – State of the Art

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Abstract. Nowadays, many countries have started developing and implementing new curricula in the area of Computer Science (CS) as core or elective school subjects in different school levels. In Bulgaria a "Computer Modeling" course was introduced in 2016 for primary school in third and fourth grades (9–10-year-old). The new subject is directed towards basic concepts in Computer Science and programming in block-based environment.

This new school subject was (and partially continues to be) a challenge for all stakeholders in the educational area. Initially, it was a problem to provide enough prepared teachers and appropriate educational resources. Moreover, there are a lot of didactical problems such as the proper presentation of many abstract concepts in CS. In addition, the syllabi set relations to the mathematical concepts studied in the next grades such as negative numbers, coordinates, angles' metrics, random numbers.

In the paper the components of the ecosystem of CS education in Bulgarian primary schools are presented. The syllabi, teacher training issues, educational institutions efforts and overall challenges are discussed. A crucial component in the successful implementation of the subject - teachers' qualification, their experience, and competencies, is identified.

Keywords: Computer Science Education · Primary School · Challenges · Curricula · Educational Ecosystem · Bulgaria

1 Introduction

The digital transformation in the most sectors of society requires people with high levels of digital competence. The society needs not only people who are users of digital devices, nowadays we need people with strong algorithmic and computational thinking, people who will add value to the development of IT industry. Nowadays, many countries have started developing and implementing new curricula in the area of Computer Science (CS) as core or elective school subjects in different school levels [1–4].

The standards for computer science education, including primary school and even kindergarten level, have been developed in different countries e.g. United States (CSTA

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Standard) [5], United Kingdom (CAS - Computing at School), Australia, New Zealand, Israel [6], EU countries [7], Germany [8].

In Bulgaria, the CS area school subjects have different names, mainly according to topics included, i.e. "Informatics", "Information Technologies", and "Computer modeling". Traditionally, "Informatics" subject includes topics about algorithms and computer programming. Courses in "Information Technologies" are focused on the use of different technologies in daily life – word processing, spreadsheets, presentation, Internet services, hardware etc. Computer modeling was introduced in 2016 as new core subject for Bulgarian primary school students in 3rd and 4th grade (9–10-year-old) and teaching started in 2018/2019 school year. The new subject is directed towards basic concepts in computer science and programming in block-based environment.

The focus of the paper are the main components of the educational ecosystem in computer science education in Bulgarian primary schools and challenges rising in the process of implementation of computer science subject at the primary school level. Successful implementation of any course in schools, especially computer science subject, depends on the educational ecosystem.

The paper is organized in three chapters: Overview of computer science education in Bulgaria, Educational ecosystem in computer science education in primary schools and Challenges in teaching computer science in primary schools in Bulgaria.

2 Overview of Computer Science Education in Bulgaria

2.1 Educational System in Bulgaria

The school education in Bulgaria [9] is obligatory from the first grade (age of seven) till tenth grade (age of 16). Schools can be municipal, state, private, or religious. Also, the schools are specialized or non-specialized. According to the stage or level of education, non-specialized schools are:

- "primary (I to IV grade);
- main (I to VII grade);
- high schools (VIII to XII grade);
- united (I to X grade);
- secondary (I to XII grade)" [9].

2.2 History of Computer Science Education in Bulgaria

Teaching in Computer Science in Bulgaria started at the end of the 1960s years [10] and beginning of 1970s years as courses in Mathematical high schools. The CS area school subjects in Bulgaria have different names, mainly according to topics included, i.e. "Informatics", "Information Technologies", and "Computer Modeling". Traditionally, "Informatics" subject includes topics about algorithms and computer programming. Courses in "Information Technologies" are focused on the use of different technologies in daily life – word processing, spreadsheets, presentation, Internet services, hardware etc.

In the frame of the experimental curricula developed by the Problem Group of Education at Bulgarian Academy of Science from 1979 till 1992 some concepts of CS have

been included in the primary school and low secondary school courses – flow charts, coding, true-false, programming in Logo etc. [11, 12]. As a core subject CS concepts were introduced into high school curricula in 1986. Over the last thirty years, the school curricula have undergone significant changes. The subject of Computer Science has been moved around within the school curricula. In 2016 a new core subject "Computer Modelling" for students in third and fourth grade (9–10-year-old students) was included in the primary schools' syllabi. Teaching of the subject started in 2018/2019 school year. As of 2020 topics about computer programming are included in the new core subject "Computer Modelling and Information Technology" for the students in fifth – seventh grade. The extended timeline of CS education is presented in Table 1.

Nowadays the CS education in Bulgaria is conducted as core, elective and extracurricular courses at all educational levels, including special vocational education for professions related to information and communication technologies (ICT). Moreover, some innovative schools offer courses related to Artificial Intelligence, Robotics, Internet of things etc. A lot of private educational or IT companies offer different courses for students from 1st till 12th grades.

Table 1. Timeline of computer science education in Bulgarian schools

Period	Educational level	Description/Topics covered
End of the 1960s – till now	Math high schools	Traditionally: Algorithms, Programming. Nowadays: set of specialized courses in Computer Science
1979–1992	Experimental Primary and low secondary schools, 30 schools were involved	Basic concepts in Computer Science (primary schools) and Introduction to programming with Logo (low secondary schools) [9, 10]
1981–1986	High schools (Experimental education)	Programming with Logo or Basic
Since 1986/1987	High school	Core courses Programming with Logo or Basic in 10th and 11th grades.
1991–1994	High school	Removal of CS subject in vocational schools
1994/1995	High school	Six curricula for CS subject, depending on hardware and software equipment of the schools

(*continued*)

Table 1. (*continued*)

Period	Educational level	Description/Topics covered
2000/2001	High school	Two core subjects: Informatics in ninth grade and Information Technology – in ninth and tenth grade.
2003	Primary school	Elective course for primary schools – "Work with Computers and Information Technology". Content and software could be chosen by the teachers.
2006	Primary, low and upper secondary level	Core courses - Information Technology fifth - tenth grade, Informatics in ninth and/or tenth grade
2016	All school levels	New core subject – "Computer Modelling" in third and fourth grades (started in 2018/2019). Changes in syllabi for low and upper secondary school levels. New curricula for subjects Information technology and Informatics at high schools
2020/2021	Low secondary level	New Subject – "Computer Modelling and IT" in fifth - seventh grades, block-based and script-based programming – Python or JavaScript

3 Ecosystem in Computer Science Education in Primary School

3.1 Ecosystems in Education

The metaphor for educational ecosystem comes from the structure and organization of biological ecosystem. According to [13] "An ecosystem can be described as a community network of interactions between organisms and their environment." Transferring this definition to education, we could summarize that educational ecosystem describes the functionalities, activities, and interactions of all stakeholders in educational process with established educational environment. In [14] e-learning ecosystem is considered with three main components – human resources, technological infrastructure, and interactions between human resources and infrastructure aimed to achievement of learning outcomes. A lot of studies discuss the origin of the ecosystems in different areas. Hannele Niemi in [15] discusses relation among biological, human, business, health, educational ecosystems. The author pointed out that educational ecosystem "consists of a large

number of interconnected parts, both horizontally and vertically" [15] and argues that educational ecosystem is not stable and "needs human actors, and it is dependent upon conscious human behavior" [15].

3.2 Main Components of the Ecosystem in CS Education in Primary School Level

The ecosystem in CS education in primary school level could be outlined with five components (Fig. 1):

- **Main actors** in the educational process.
- **State policy**, including national regulation, curriculum, and national educational programs.
- **Providers** of teaching and learning activities. The provider could be public or private schools, IT companies, non-government organizations (NGO), private training companies (non-school).
- **Teachers training**, including institutions approved to provide in-service or pre-service teachers training.
- **Support** of students and teachers with appropriate educational content and hardware equipment.

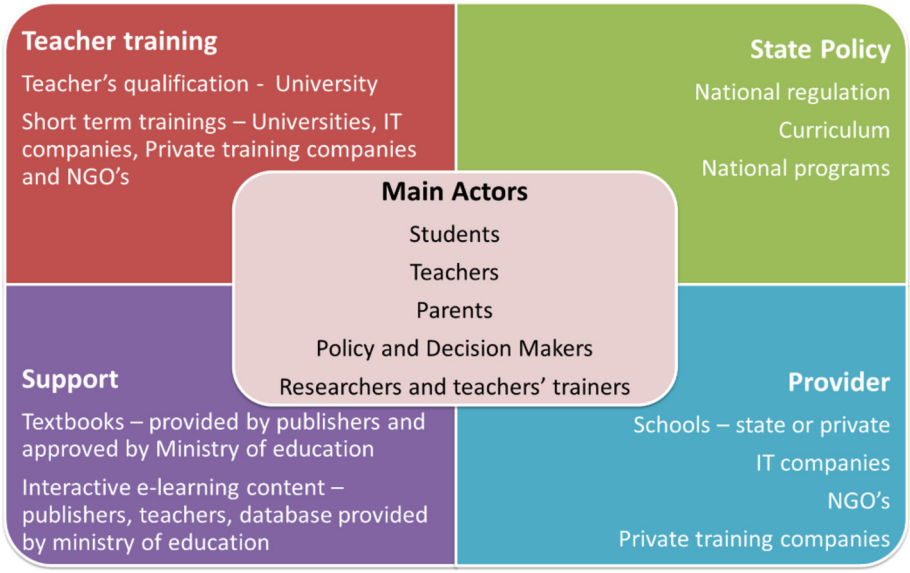

Fig. 1. Components of ecosystem in computer science education in primary schools

3.3 Main Actors

This group includes students, teachers, parents, policy and decision makers, researchers, and teachers' trainers. The main actors interact at different levels. In the center are students and teachers. Students in primary school have specific psychological and pedagogical characteristics and level of knowledge in mathematics and other school subjects. The abstract thinking for first - fourth grade students is still at a low level and that requires to use appropriate pedagogical techniques and methods. The teachers need special competencies in Computer Science and primary school education. In addition, the parents' support is very important too, considering some law requirements for using web-based learning environment, safety use of computer and internet etc. Policy and decision makers should provide adequate state educational policy. The researchers and teacher trainers give the teachers educational methods and skills needed to teach Computer Science topics in primary school.

3.4 State Policy

National Regulation. Regulations of the educational process are based on the state standards, syllabi for every grade, schedule of topics. The state standards outline competence and learning outcomes for every school level. The learning outcomes are decomposed in the syllabus for every core subject and every grade. The syllabi follow unified structure and contain learning outcomes, core topics, required distribution of hours for assessment and lessons, proposals for learning and teaching activities. The topics' schedule is developed by the teachers, but there are some requirements for its form.

In the case of elective and optional subjects, teachers must develop their own syllabi, that must be approved by regional educational authorities.

The government issues a national regulation about teachers' qualification in general and for particular subjects and educational levels. The requirements for teaching Computer Science subjects in primary schools outline that primary school educational level teachers or teachers in Computer Science subject could teach this subject in primary school.

Curriculum. The curriculum for primary school includes the core subject "Computer modeling" for third and fourth grades [16].

The accent of the syllabus of the subject "Computer Modeling" in third grade is directed towards acquiring competence for:

- Usage of digital devices and files;
- Developing animations in visual block programming environment using algorithms with loops;
- Safety and healthy usage of computers and digital devices. In the syllabus is mentioned that the creation of accounts in online environments must be under control of teacher and/or parent.

The content is outlined in four general domains: "Digital Devices", "Digital Identity", "Information", and "Algorithms". For the domain "Digital Devices" learning outcomes

outline that student should "Turns OFF and ON stationary or mobile digital devices; Knows basic components of digital devices; Knows health requirements for safety work with digital devices; Gives the right and precise commands to digital devices to conduct different tasks" [16]. The learning outcomes for the domain "Digital Identity" outline that a student should "create own avatar in learning content management system; make difference between digital and physical identification; know that he/she should not provide personal data during the communication and work in digital environment; know the main threats in a digital environment and applies rules to respond to them." [16]. About domains "Information" and "Algorithms", a student should "know that data in digital devices are stored in files and folders; know the working space and the visual environment; order blocks in linear sequence in visual environment; create storytelling according to given plot using blocks in visual environment; implement loop algorithm; create animated gift card; share projects in Internet." [16]. The main topics in the syllabus are "Digital Devices", "Digital Identity", "Constructing Sequential Actions", "Constructing Repetitive Actions (Loops)", "Visual Programming Environment", "Text and Sound in Visual Environment", and "Animations".

In fourth grade the accent is on acquiring competence for:

- Usage of digital devices and information;
- File management;
- Creating interactive projects (educational computer games) in visual block programming environment using branching algorithms and synchronizing activities of the characters;
- Safety and healthy usage of computers and digital devices.

The general domains are the same as in the third grade. The learning outcomes for the domain "Digital Devices" outline that students should "know functionalities of buttons of particular device; know basic components of digital devices and how to connect end-user devices, such as robots, to them; know ethical norms for working in digital environment; know of advantages and disadvantages of digital devices for the environment" [17]. For the domain "Digital Identity" a student "makes difference between digital and physical identification and does not provide personal data in digital environment; knows the main threats in a digital environment and knows how to obtain help if it is necessary" [17]. In the domain "Information" is outlined that the student "knows the ways of receiving information and forms of presenting; knows how to save information on a digital device; knows how to present information –in form of text, numbers, audio, graphics; compares units for information measurement; knows how information is processed in digital devices; understands that digital resources could not be free of charge for using, copying and distributing" [17]. The domain "Algorithms" outlines that a student "knows the particular visual environment and creates digital content in it; implements linear algorithms in visual environment and manages characters; experiments with characters in visual environment and sets basic properties, chooses the characters and their properties according to the particular plot; develops code using blocks for character management in game; Implements looping and branching algorithms; creates project with animations of more objects, sound and text; presents the project in real and virtual environment" [17].

The main topics in the syllabus are: "Information", "Digital Identity", "Branching Algorithms", "Working in Visual Programming Environment", "Programmable devices", and "Development of Educational Games".

National Programs. Every year, Bulgarian Ministry of Education provides several national programs related to the IT in education, including subjects in Computer Science. The schools develop project proposals and apply for funding. Some of these programs are:

- "ICT in Education". This program provides software and hardware equipment, internet access for the schools, e-learning environments etc.
- "Education for Tomorrow Day". The program supports extracurricular clubs in Computer Science; teacher training in ICT implementation in education or Computer Science subjects teaching; development of interactive educational content.
- "Innovative Schools". In this program schools can apply innovative teaching and learning approaches and increase the number of classes in different subjects.
- "Digital Backpack" (https://edu.mon.bg/). This new program provides digital learning content and other e-learning services for all school subjects at all educational levels. Teachers can create and share their own digital educational resources.

3.5 Providers of the Teaching and Learning Activities

The schools – state, municipality or private apply state syllabi in mandatory courses. In addition, they can include more hours per week for computer modelling or other CS topics in the school curricula. The schools have a possibility to include extracurricular courses in the frames of National programs – robotics, computer language or device programming etc. Also, schools could extend curricula with courses for preparing students for national contests in the Computer Science area. The syllabi for the additional courses are developed by the teachers and are approved by the regional or local educational authorities.

The private non-school organizations could use their own syllabi, and in general offer courses in block programming and robotics. Usually, parents must pay for the training. Some of these educational organizations also prepare students for national contests in the computer science area.

3.6 Support

Students and teachers in primary and lower secondary schools (first till seventh grade) are supported by free textbooks in printed and electronic format, approved by Bulgarian Ministry of Education. Currently six textbooks for third and six textbooks for fourth grade in Computer Modelling are approved and used in primary schools. These textbooks are supplemented by online content, disks with resources and working books.

Additionally, an interactive electronic content is provided by publishers of the approved textbooks – every publisher provides free and/or paid e-content, teachers can develop e-content and publish it in National e-library, supported by Ministry of Education.

Teachers and students could also use well-known online environments like https://code.org/, https://scratch.mit.edu/, https://bg.khanacademy.org/.

In addition, the publishers support teachers with teacher's books with methodological learning sheets for lessons. Also, the teachers established communities in social networks. Currently the Facebook group of Bulgarian teachers in Computer Modelling has more than 6300 members and the group of teachers in Computer Science - more than 10000 members.

In general, the hardware equipment in the schools passes the requirements for teaching the computer modeling topics, but may vary widely and teachers have to take into account the current state. In fact, some schools exceed the basic requirements and have modern computers, programmable devices, 3D tools for modelling etc., but at the same time some schools have computers that only pass the equipment requirements.

3.7 Teacher Training

Pre-service Teacher Training. Teacher training is provided by universities with accredited majors by the National Agency for Accreditation and Evaluation. Universities provide bachelor and master programs for majors "Teacher in mathematics and CS", "Teacher in CS", "ICT in Primary school", Primary school education (without focus on the ICT).

It is possible to obtain qualification to teach computer science subjects in one-year post diploma qualification for people who have graduated in teachers' majors in science school subjects or in the areas of engineering, economics, physics, chemistry.

Also graduates in primary school education bachelor's or master's degree programs could teach Computer Modelling in primary school.

In-Service Teacher Training. For the career development teachers must complete training courses with assigned credits (1 credit = 16 h training). These courses could be offered by universities with accredited majors related to the school subject, IT companies, publishers, private training companies, NGOs with programs for teacher's qualification approved by Bulgarian Ministry of Education. Also, the schools can organize internal trainings.

4 Challenges in Computer Science Education in Bulgarian Primary Schools

4.1 Lack of Well-Prepared Teachers

The involvement of the new core subject "Computer Modelling" in primary school raises a lot of challenges and problems. The first challenge was related to the teachers as a main drive of the ecosystem in computer modelling education.

The teachers in the primary school subject "Computer Modelling" must be qualified in the subject content and in wide spectrum of digital competencies. They need competencies about the psychological characteristics of the students in primary school

and knowledge about primary school curricula, working with parents, lifelong learning skills, diversity of pedagogical approaches suitable for primary school level.

At the beginning (2018/2019) "Computer Modelling" subject had to be taught only by primary school teachers with or without qualification in ICT. In fact, most of the teachers didn't have the necessary knowledge and skills in algorithms and programming and were unsure how to conduct their lessons. To change this, a short-term special courses for the content of the new subject were organized. Unfortunately, it became clear that the courses were not enough to provide adequate knowledge and skills for primary school teachers to teach programming concepts.

To solve the problem, in 2020 the Bulgarian Ministry of Education allowed the teachers in Computer Science area in fifth to 12^{th} grades to teach Computer Modelling in primary school.

The universities started master's degree programs for primary school teachers in the area of IT in primary school. Courses in programming in block-based environment were included in the bachelor's degree programs. Also, a lot of short-term in-service courses were provided both for primary school teachers and for CS teachers.

In addition, the publishers of the textbooks provide teachers' guides for implementation of the content with precise lesson plans.

4.2 Abstract Concepts and Terms that Require Mathematical Knowledge from Low Secondary Level

The syllabi include a set of basic abstract concepts, used in programming as information, data, algorithm, loops, branching algorithms, variable, broadcast, logical operators, and random number. In addition, some information society concepts as digital identity, copyrights, fake news etc. are included. The concepts should be introduced in an understandable manner for the students and at the same time precise descriptions of the concepts should be provided.

The syllabi set relations to the mathematical concepts studied in the next grades such as negative numbers, coordinates, angels' metrics, random numbers. Instead of the mathematical terms, the words and examples known to the primary school students should be used.

These challenges can be solved through the application of appropriate teaching methods and techniques [18] such as:

- Focus on the properties of the concepts, not only on definitions.
- Explaining concepts by examples.
- Usage of tales and everyday life examples and analogies.
- Usage of gamified and fun elements like puzzles, challenges, anecdotes, riddles etc.
- Usage of educational computer games, simulations, or video clips.
- Usage of electronic textbooks with interactive exercises.
- Usage of appropriate unplugged activities.
- Experimenting with ready (so called "baked") code and completing of "half baked" code.
- Problem solving.

5 Conclusion

To support the proper functioning of the ecosystem in computer science education in primary schools, a lot of efforts are made by all stakeholders. Schools are provided with hardware and software equipment which is sufficient to meet the minimal requirements. The teaching process is supported through syllabuses, methodological instructions and teaching materials. Students are provided with free textbooks and interactive learning resources.

As long-time lecturers in Computer Science teacher training courses and authors of school textbooks from third till tenth grade we identified many challenges in the ecosystem of computer science education in the school. Our observations show that the crucial component in the successful implementation of the subject "Computer Modeling" in the primary school level is the qualification of the teachers in the area of Computer Science, their competencies and teaching experience. Therefore, all stakeholders in this area must focus their efforts towards:

- Improvement of pre-service and in-service teacher trainings in two main streams. The primary school teachers must obtain competencies in Computer Science at least to be able to teach "Computer Modeling" subject. The Computer Science teachers must obtain competencies how to teach in primary school level.
- Providing appropriate methodological, teaching and learning resources for teachers and students.

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