DEV ELOPMENT OF ALGORITHMIC AND PROGRAMMING THINKING AT PRIMARY SCHOOL IN STATE EDUCATIONAL PROGRAMS

KATYETOVA Aliya, KZ

Abstract
Emerging countries have education program development that is outdated compared to advanced countries in terms of content, approaches, delivery, training, and use of technology. While Kazakhstan aims to raise its digital literacy to at least 80% by 2022, most of its grade school students have limited knowledge and exposure to information technology. In 2018, most of the professionals across Kazakhstan received digital literacy training from the government, yet this is insufficient to equip teachers with the knowledge and skills to properly educate young learners in computer science or programming. With limited experience in teaching computer science and the absence of teaching manuals that take into account Kazakhstan’s culture and learning styles, teachers may be unable to efficiently educate young learners. Indeed, information technology creates opportunities to enhance the educational and cognitive activities of young schoolchildren (6-10) but only if it can be properly utilized. The author believes that the same situation is true for the rest of the developing economies. Emerging economies need to have proper teacher training, facilities, and guidelines to successfully develop the algorithmic and programming thinking of children at primary school. The research aim is algorithmic and programming thinking development at primary school in state educational programs in selected countries (Kazakhstan, Hungary, Slovakia). In the field of the development of algorithmic and programmatic thinking in primary school, the author also means how programmable toys and robots are used to consider the methodology of teaching computer science. The author provides a literature review and a comparative study of state educational programs of Hungary, Slovakia, and Kazakhstan, particularly in primary school computer science with the purpose of the importance of the development of algorithmic and programming thinking in primary school in individual state curricula. The results will be used to help improvements in computer science programs for primary schoolchildren.

Keywords: algorithmic and programming thinking, computer science, programming, primary school, state educational program

Introduction

In state educational program as a binding document for the educational institution sets out the general goals of education and the key competencies to which education should be directed. Many countries are introducing computing as the main subject of the curriculum. Some have already done so; many others intend to do so. Obviously, the curricula details will differ in each country, but there is significant overlap – almost all currently available curricula include programming.

The rising use of a wide range of digital technologies in many aspects of modern human life has led to many changes in the childhood context, as they are mapped in the policies and curricula of the primary school sector. From an early age, children learn human languages, both for speaking and writing, natural languages, encompassing all matters related to the school sciences (physics, chemistry, biology, etc.), and humanity languages, involving social sciences and humanities. It is also necessary they learn digital languages, in which the competences to be successful in the digital era are included, using coding and algorithmic and programming thinking as the way to solve problems and acquire digital literacy.
The national curriculum of Kazakhstan, Hungary, and Slovakia acknowledges that digital technologies are relevant to students’ lives and play an important role in the process of knowledge construction, allowing young students to understand the world and express themselves in various modes.

The main research question for this topic study is: How does the development of algorithmic and programming thinking appear in the state educational programs? In addition to this main research question, four sub-questions were developed:

1. What are algorithmic and programming thinking and how do scientists and researchers understand this concept?
2. Why is the development of algorithmic and programming thinking added to the primary school's curriculum?
3. Why is it necessary to develop algorithmic and programming thinking for children from primary school?
4. What enhances the development of algorithmic and programming thinking of young students in primary school Informatics classrooms?

1 Review of the literature around algorithmic and programming thinking

In order to understand what is the development of algorithmic and programming thinking in this chapter, we will consider such definitions as algorithmic thinking, computational thinking, and programming (programmatic) thinking.

Algorithmic thinking is one of the basic concepts of computer science. According to Czakoova, algorithmic thinking is an artificial type of thinking because when students write a program, he or she has to find a solution for a machine (computer), not like in everyday life (Czakoova, 2020). Playing is a useful tool to learn algorithms and their principles in an effective way. Therefore, the pupils do not only watch the solution demonstrated by the teacher, but they are in an active role in learning by doing it themselves. At the same time, Tsvetkova (2021) believes “The early development of algorithmic thinking is based on computer algorithmic problems. There are many examples of such tasks, but the activity aspect of development is reflected in detail and clarity in problem tasks that stimulate the simplest approaches to modeling based on algorithms.” (see Tsvetkova, p. 113 for more examples). Algorithmic thinking is a way of getting to a solution through a clear definition of the steps needed. For instance, take a simple task of sorting 10 numbers. Firstly, we can take a look at them, then tell quickly about what the order should be and arrange the numbers correctly.

The author confirms that algorithmic thinking is thinking about how to systematically solve a problem. It is about clearly defining the problem; breaking the problem into simple parts; determining the solution for each part of the task; implementing the solution and increasing its effectiveness.

Programming thinking is probably the way of thinking, that is when you program, how you are supposed to think, and computer code and how it is interpreted, that is the difference to how human beings think. Programming thinking includes problem-solving and standard methods in programming. In accordance to Eckerdal, et al. “Learning is to understand some programming language and use it for writing program texts.” (Eckerdal, et al., 2005).

Programmatic thinking means how to think like a computer and translate a process into a specific set of instructions that a computer can understand. It also means understanding programming concepts like data, variables, functions, objects, etc.
Some scientists believe that computational thinking is the stage that comes before programming. This is the process of breaking down a problem into fairly simple steps that even a computer would understand. In the article “Robotics and computational thinking in primary school” the author emphasizes that computational thinking skills need to be developed from primary school and used in various learning fields. The skills include abstraction, generalization, decomposition, algorithmic thinking, and debugging (see Chalmers, 2018). Also, he stated that Professor S. Papert in the manuscript “Teaching children thinking, Programmed Learning and Educational Technology” is the first, who advanced computational thinking in schools, and claims that students can develop procedural thinking through programming.

Moreover, educational robotics and programmable toys are useful and innovative tools in Informatics classrooms for the development of algorithmic and programming thinking for primary schoolchildren. It positively affects computational thinking, problem-solving, and creativity too. And, in particular, games with these tools are used extensively for achieving the development of algorithmic and programming thinking. Game design is a popular way to teach programming to children who have little or no prior programming experience. For example, Gouws et al. (2013) use light-bot, an educational game whose objective is to program a small robot to light up all the blue blocks on a board. Authors apply their computational thinking system to evaluate skills and the levels at which these skills were practiced.

We can implement, evaluate, and model phenomena such as ICT competencies or digital competence in students. Currently, there are several tools and models that have been applied to children in primary schools (for example, Aesaert et al., 2015). Pupils’ competencies in the field of digital technologies are abilities related not only to the use of computers and the Internet but also to the corresponding mastery of algorithmic and programmatic thinking.

2 Comparative study

The author believes that informatics subject is a separate and important scientific field that occupies the same place in education as the school sciences of mathematics or physics. And there is the development of algorithmic and programming thinking plays an essential role in children’s development.

The given part of the paper aims to identify the most aspects of the implementation of the development of algorithmic and programming thinking at primary schools in state educational programs of three countries: Kazakhstan, Hungary, and Slovakia.

2.1 Kazakhstan

Studying the subject of computer science in Kazakhstan primary school solves the problem of propaedeutics of studying the basic course of computer science in primary school, creating the necessary basis for the effective organization of the educational process. Currently, the subject of computer science for primary school children is called digital literacy.

By Order of the Ministry of Education and Science of the Republic of Kazakhstan No. 182 dated May 5, 2020 "On Amendments and Additions to the Order of the Ministry of Education and Science of the Republic of Kazakhstan dated October 31, 2018 No. 604" (paragraph 14), the name of the subject "Information and Communication Technologies" in primary school was changed to "Digital Literacy".

28
In the 2021-2022 academic year, the subject "Digital Literacy" was introduced in the 1st grade from January 1, 2022 (Instructional and methodical letter “About the features of the educational process in the secondary education organizations in the Republic of Kazakhstan in the 2021–2022 academic year,” 2021). Also in the 2021-2022 academic year, the subject "Digital Literacy" is studied in the 3rd grade from 2021 September 1.

According to Table 1, there are representing a teaching load with the number of hours per year in the Instructional and Methodical Letter “About the features of the educational process in the secondary education organizations the Republic of Kazakhstan in the 2021–2022 academic year”.

Table 1 - Teaching load

<table>
<thead>
<tr>
<th>Grade</th>
<th>Subject</th>
<th>Hours/week</th>
<th>Hours/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Digital literacy</td>
<td>1</td>
<td>33</td>
</tr>
<tr>
<td>2</td>
<td>Digital literacy</td>
<td>1</td>
<td>34</td>
</tr>
<tr>
<td>3</td>
<td>Digital literacy</td>
<td>1</td>
<td>34</td>
</tr>
<tr>
<td>4</td>
<td>Information and Communication Technologies</td>
<td>1</td>
<td>34</td>
</tr>
</tbody>
</table>

When teaching the subject "Digital Literacy" in primary school, active forms and methods of teaching are used, taking into account the age characteristics of students.

The requirements for the content of education with a focus on learning outcomes and the requirements for the updated content of primary education are fixed in the State Mandatory Standard of Primary Education of the Republic of Kazakhstan (State Compulsory Standard of Primary Education, 2018).

The basic content of the subject "Digital Literacy" in the 1st grade is aimed at the formation of students' algorithmic thinking in a game programming environment, familiarity with the main components of a set of robotics, assembly, and control of a simple robot. The basic content of the subject for the 1st grade includes:
1. "Computer": rules of conduct in the computer science classroom;
2. "Working on the Internet": the reliability and usefulness of the information posted on the network, the risks of unwanted contacts on the network;
3. "Computational thinking": algorithms, performers of linear algorithms, the interface of the game programming environment (Scratch), creation, saving, and opening of the project in the game programming environment;
4. "Robotics": assembling the basic model of an educational robot, loading and launching a program for the robot, moving the robot at a given speed, for a given number of revolutions of the wheel, forward, backward, turning the robot at a given angle (90, 180 degrees).

Additionally, we will give an example of the basic content of the subject "Digital Literacy" for the 3rd grade:
1) "Computer": computer devices, keys for changing the character case, keyboard layout, cursor control. Software: hotkeys in application programs. Security: basic rules of personal safety when working on the Internet;
2) "Presentation and processing of information". Texts: typing rules, bulleted and numbered lists, text editing, font and paragraph formatting (font, color, alignment), cutting, copying, inserting
selected text into a document, inserting an image into the text, and adjusting the flow. Presentations: presentation designer, program menu, opening and saving presentations, placing text and images on a slide, transitions between slides, presentation design. Graphics: photo processing software (brightness, contrast, frames);

3) "Work on the Internet": information search: search for a fragment of text in a document. Information exchange: ways to exchange information online, use messengers to collaborate on a project;

4) "Computational thinking":
   - Algorithms: a cycle, a system of performer's commands when implementing a cyclic algorithm.
   - Programming: implementing a cyclic algorithm when creating a game in a game programming environment, developing a game according to a ready-made scenario, working with several scenes and characters in a game programming environment;

5) "Robotics": setting the speed and number of revolutions of the average motor, using a cycle to organize the movement of the robot.

Scratch is a very popular programming language for primary school students to learn coding and maths.

2.2 Hungary

Hungary has the NAT as a National Core Curriculum, the goal of which is to define the common requirements for general education. According to Abonyi-Toth, the new National Core Curriculum (NAT 2020) was introduced in the 2020-2021 academic year in grades 1, 5, and 9 in accordance with a phased system. The subject of informatics has been replaced by the subject of "Digital Culture", which has updated content and methodology. In the new subject, the topics of robotics, coding and algorithmics play an important role. In the new textbooks, students learn the basics of robotics, programming for modeling robot operations and other topics. Children will also learn how to develop self-created games and how to solve real-world problems using various learning robots (Abonyi-Toth A., 2021).

The timeframe set out in the Recommendation – as is included below in Table 2. – should be managed flexibly according to the pace of progress of learners, using available and developable self-learning tools, materials and mediation technology, including traditional and technology-based learning management procedures. The basic class of the digital culture subject is 68 hours.

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Grades/ hours</th>
<th>Grades/ hours</th>
<th>Grades/ hours</th>
<th>Grades/ hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital culture</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>34</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>34</td>
</tr>
</tbody>
</table>

The educational program shall take into account the content of the renewed NAT when teaching the subject (Oktatási Hivatal, 2020). As provided by the framework curriculum for grades 3-4, the digital culture subject develops the key competencies set out in the National Core Curriculum in the following ways:

- **Learning competencies**: Educating digital culture enables the learner to search for knowledge elements that can be acquired in a digital environment.

- **Communication competencies**: The digital culture subject improves the use of tools, in particular the use of communication tools.
- **Digital competencies**: The digital culture subject primarily develops digital competencies. The student will be able to apply them in other fields of knowledge and in everyday life. The subject also helps to develop and form the skills necessary for creative activity.

- **Mathematical and thinking competencies**: The activity carried out in the framework of digital culture develops the analytical and synthesizing thinking of the student when solving problems.

- **Personal and social relationship competencies**: The activity carried out in the framework of the digital culture subject helps to develop a communication style appropriate for the expectations of the online space.

- **Competences of creativity, creative creation, self-expression and cultural awareness**: The activity carried out in the framework of the digital culture subject develops the solid and coherent competencies that allow for a wider presentation of self-expression activities.

- **Employee, innovation and entrepreneurial competencies**: The activity carried out in the framework of the digital culture subject improves the student's ability to adapt to a changing environment, to be able to constantly review and update his/her knowledge, and to apply it to solve problems (Oktatási Hivatal, 2020).

As shown in Table 3 the topic “The digital world around us” focuses on problem-solving and it is covered in 6 lessons. There are also other themes in the curriculum which are displayed below.

### Table 3 - Topics and recommended number of hours

<table>
<thead>
<tr>
<th>Topic Name</th>
<th>Recommended number of lessons</th>
</tr>
</thead>
<tbody>
<tr>
<td>The digital world around us</td>
<td>6</td>
</tr>
<tr>
<td>Using digital devices</td>
<td>14</td>
</tr>
<tr>
<td>Creation using digital tools</td>
<td>18</td>
</tr>
<tr>
<td>Acquiring information in the e-World</td>
<td>8</td>
</tr>
<tr>
<td>Protecting against the dangers of the digital world</td>
<td>6</td>
</tr>
<tr>
<td>Basics of robotics and coding</td>
<td>16</td>
</tr>
<tr>
<td><strong>Total hours:</strong></td>
<td><strong>68</strong></td>
</tr>
</tbody>
</table>

It is not primarily about material conditions but about technological solutions, digital literacy and culture. The emphasis here is not on the technical solution of the specific problem but on the development of an approach in which children can understand the problems and related groups of problems that often arise in the digital environment and the information society.

By teaching the topic of using digital tools, the main goal is to give students a comprehensive idea of the tasks that digital tools in all areas of life can solve and not in the least to be aware of the need to apply them. The students will understand that these tools make our lives easier, make certain activities faster, for many people bridge geographical distances, and time distances, make communication cheaper, and not in the least make the process of solving tasks available to everyone.

When teaching the "Creation using Digital Tools" topic, we review the areas where some digital solution is used, however, this is always performed through a problem taken from the lives of children. It is extremely important that children are not presented with self-standing ready-made solutions, but are given a repertoire so that they can solve problems in an inspiring IT environment with the help of digital tools. In each case, this process is illustrated by specific examples taken from a reality the children are familiar with.
During the topic of "Acquiring Information in the e-World", students are engaged in the acquisition, storage, evaluation and creative use of information. They gain insight into the various info-communications technologies, learn to look for and use simple information on topics of interest to them, and on issues arising from the learning of other subjects, e.g. during lectures, collecting work and projects.

In "Protecting Against the Dangers of the Digital World" confronting children with the problem that there is much false and misleading information and that there may be dangers in the digital space.

The topic of robotics and coding basics is emerging in education. Its approach is clearly problem-centred, focusing on how to detect a particular problem, finding the right solution, or adapting the solution algorithms developed for other problems to the specific task, and adapting the algorithm in the event of a minor change to the problem. This topic does not necessarily require a computer and IT environment, at least in its foundation phase. We need to collect problems and algorithms from children's lives to identify the characteristics of the algorithm that should be taught at this age. Such as the sequence of elementary steps, the fixed order of steps, or, in the case of identical input data, the creation of the same output data for the algorithms. We have to ensure different circumstances and play situations so that the algorithms are played out and experienced by the children. This can be the play of every day, often repetitive activities, discussing their steps, skipping or swapping individual steps in funny situations, and judging the outcome of the algorithm based on this. There are algorithms that students should observe in each of the lower-secondary curricula. For example, in mathematics, the solving of textual tasks, the solving of open sentences by trial, and the ability to perform written actions are all algorithms (Oktatási Hivatal, 2020).

The main purpose of the topic “Basics of robotics and coding” is the development of algorithmic thinking. Initially, students without robots, using various devices or even their own bodies independently perform an action, for example, travel routes, which later become the basis for controlling robots. To do this, students use not complicated algorithms (Abonyi-Toth A., 2021).

Digital culture in the lower school lays the foundations for the knowledge elements and attitudes that students will need in later learning of the subject and enable digital competence to be applied in other fields of knowledge. The main principle of implementation can be considered to be activity-centeredness, taking into account age characteristics, since direct experience is key at this age. It is very important that students face examples and opportunities that they can experience in their immediate environment, and that they are an integral part of their daily lives. From this environment, the development process will be realized, as a result of which they will be able to learn, have fun, play and experiment in the digital environment by knowing the advantages and dangers of digital technology and by integrating it into knowledge elements of other subjects. They come into contact with digital learning materials, portals, knowledge bases and development applications that help them to learn independently and in groups, satisfy their individual interests, develop talents and catch up, taking into account the specificities of the 8-10 year-olds. The activity-centred development of algorithmic and programming thinking according to age characteristics, also influences learning, learning outcomes and attitudes towards learning in a positive direction (Oktatási Hivatal, 2020).

**2.3 Slovakia**

In the Slovak Republic, computer science education, like mathematics, develops pupils' thinking, and their ability to search for solutions to problem tasks and verify them using ICT. Systematic basic
education in the field of Informatics and the use of its tools ensure equal opportunity for all primary school pupils to acquire basic digital literacy.

According to the State educational program Informatics, the goal of computer science education in primary school is familiarization with the computer and the possibilities of its use in everyday life. Through age-appropriate applications, pupils acquire basic skills in using the computer. Using appropriate topics from other subjects (Slovak language and literature, mathematics, art education, music education) pupils will get acquainted with the possibilities of drawing, training in counting, writing, and other most typical types of applications (ŠTÁTNY VZDELÁVACÍ PROGRAM INFORMATICKÁ VÝCHOVA, 2020).

In the subject of computer science, pupils are prepared to understand the basic concepts and mechanisms for solving a wide variety of problems using ICT. Pupils learn to use the tools of the internet to communicate, learn for themselves and to solve problems, to obtain and convey information. Pupils get algorithmic thinking and the ability to think about solving problems through ICT.

Content standard:
- Familiarization with the computer, control of the keyboard, mouse, printer and scanner.
- Familiarization with the environment of a simple graphic editor – effectively using free online tools of a graphic editor when drawing images (drawing using geometric shapes, straight lines, selection, copying, moving, etc.).
- Creating simple animations.
- Working with a text editor, simple formatting of the text, inserting images into text, copying, deleting and moving the text.
- Creating, saving, deleting a document and creating folders.
- Familiarization with tools, viewing and searching, the use of the internet as a source of entertainment, but also for information in both text and image form, the use of e-mail, safe and decent behavior on the internet.
- Launching games and music from CDs and the internet, control of simple games.
- Working with multimedia, recording sounds.
- Getting the basics of algorithmic thinking.
- Use of ICT capabilities in solving tasks within the project teaching, and project presentations.

The educational content of computer science in the state educational program is divided into five thematic areas (ŠTÁTNY VZDELÁVACÍ PROGRAM INFORMATICKÁ VÝCHOVA, 2020):
- Information around us
- Communication through ICT
- Procedures, problem-solving, algorithmic thinking
- Principles of functioning of ICT
- Information society

The teaching material on the topic of information around us is also key for lower grades education. The concept of information, types of information (text, multimedia, etc.), and application to the processing of specific information are very important for understanding the mechanisms that solve all sorts of problems with the help of ICT. Pupils should be taught from the first classes and should teach to work with basic computer applications to
1. knew the basic procedures for working with text and simple presentation,
2. acquired the first skills in drawing in a graphic environment and processing graphic
information,
3. understand the recording and playback of sounds and videos,
4. understand the ways of representing the basic types of information (representation colors and images),
5. with the help of ICT, they are able to realize partial tasks and outputs from the project teaching.

The next thematic heading *communication through ICT* is devoted to the use of tools of the internet for communication, self-learning, and also for solving school problems, to obtain and convey information. Pupils should
1. learn to work with e-mail,
2. understand the method and mechanisms of searching for information on the internet,
3. be aware of security risks when working with the internet,
4. understand how to define a keyword search by keyword,
5. master the selection of the necessary information.

In the topic “*Procedures, problem-solving, algorithmic thinking*” pupils will become familiar with specific procedures for solving problems through ICT. Getting acquainted with concepts such as algorithms, programs, and programming. The greatest benefit of this circuit will be that pupils acquire the basics of algorithmic thinking and the ability to think about solutions to problems using ICT. They will learn to consider different efficiency parameters of different solving problems. They learn different procedures and mechanisms for solving tasks from different areas.

The thematic heading “*Principles of functioning of ICT*” is devoted to the description and understanding of information and communication technology mechanisms. Pupils should get acquainted:
1. with input and output device capabilities,
2. different areas of software destination,
3. with the acquisition of basic skills in working with files and folders,
4. with the elementary functions of the local network and the internet.

*The Information Society* theme deals with ethical, moral, and social aspects of computer science. Introduces possible risks and methods to address these risks. Pupils should
1. read the instructions on how to use ICTs in everyday life,
2. understand that the use of ICT requires a critical and considered approach to the available information,
3. lead to the responsible use of Interactive Media – understand the risks involved are located here.

In the educational programs of the given countries, the main emphasis is placed on the ability to program in the Logo and Scratch environment. It allows younger students to learn new topics with interest, study algorithms, and help them develop algorithmic and programmatic thinking.

**Conclusion**

Working with primary school students means that we, teachers and parents, have to help them develop their individual skills. And in this case, the study of the subject of computer science contributes to the formation and development of algorithmic and programming thinking as well as critical thinking.
in the conditions of working with large amounts of information. At the same time, computer science plays an important role, which is put at the forefront in the educational programs of three countries. In the educational programs of the three countries we have considered in the programming section, the main emphasis is placed on the ability to program in the Logo and Scratch environment. It allows younger students to learn new topics with interest, study algorithms, and help them develop algorithmic and programmatic thinking.

In addition, the literature review demonstrates that algorithmic and programming thinking play vital roles in children’s lives and impact their ways of learning and developing.

In the given article, the author presented the emergence of the development of algorithmic and programmatic thinking in the national educational programs of the three countries.

References


**Contact:**
Aliya Katyetova, doctoral student, master of Informatics
Doctoral school of Informatics, Faculty of Informatics, Eotvos Lorand University
Budapest, Hungary
E-mail: akatyetova@inf.elte.hu, katyetova@mail.ru