Coding with Block Programming Languages in Educational Robotics and Mobiles, Improve Problem Solving, Creativity & Critical Thinking Skills

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Abstract—The purpose of the article is to highlight how students' computational thinking, which is a critical thinking skill, can be developed through educational robotics and programming. It is a fun and engaging learning activity that encourages students to collaborate, delve into a problem, construct knowledge, and cultivate critical thinking. Educational robotics is therefore an innovative teaching tool, which contributes to the implementation of the above goal and follows the principles of building, specifically the construction of knowledge (Mikropoulos & Bellou, 2010). It develops students' critical thinking, strengthens their mental models, and activates known learning mechanisms leading them to a deeper level of understanding and assimilation of knowledge, which cannot be accomplished with traditional teaching methodologies. It has also been proven to be able to help students solve complex problems as well as contribute to the development of computational thinking skills (Atmatzidou & Demetriadis, 2014), which should characterize the entire literate population and complement the other three basic reading skills, writing, and mathematics (Mavroudis, Petrou & Fesakis, 2014).

Keywords—STEM, STEAM, robotics, educational robotics, programming languages, mobiles, critical thinking, problem solving, block-based programming, curriculum, coding

1 Introduction

Nowadays people's communication, information, shopping, and entertainment are done through computers and smart devices. Social media has replaced classic communication via phone and text. All these processes of computers and smart devices are controlled by an instruction set consisting of lines of code. The artificial language used for human interaction with computers is called a programming language.

Analyzing more of the data in the field of IT, we notice that today's children grow up surrounded by technology. This dynamic development of technology required the adoption of new teaching methods. These new methods included the introduction of computer science into primary and secondary education.

In education, in the Computer Science course, learning the basic concepts of coding through visual programming languages based on blocks (block-based languages) has been introduced. Blocks contain ready-made sections of commands which are organized into different categories. The blocks are like puzzle pieces, which when put together create the final program. Writing a program in a block-based environment takes the form of drag-and-drop instructions. If two statements cannot be joined to form a valid statement, then the environment prevents them from being stuck together, and the user is informed that there is no logical order between these statements.

2 Programming languages

Computer programming is the process of solving problems using a coded programming language. The user in this way gives instructions to the computer, the set of instructions is called code. The ultimate goal of programming is to create something. This could be a web page, a piece of software, or a program. This is also the reason why programming is often described as a combination of art and science. It requires both technical and analytical skills but also requires the creativity of the user.

Compared to natural language, the programming language is structured, aims to eliminate ambiguity, and is based on rules of formal logic and mathematics. It is also similar to natural language in that it uses grammar and symbols.

Learning to code is the basis for developing programming skills, which through the play-based approach aims to:

- To develop problem-solving skills
- In the development of computational thinking
- To improve critical thinking
- In the development of creativity

3 Learning goals in education

Programming with the leaps and bounds of technology is becoming more and more common. Children can now use smartphones and tablets at ages 3 or 4, even before they can read (Calvert, 2015). There is no doubt that today's children will interact with technology throughout their lives, regardless of their career choice.

In primary education, children begin their engagement with computer science through:

- Visual programming environments
- Games
- Writing simple algorithms on paper, etc.

The English Department for Education (Department for Education, 2013) in the National Curriculum for Computing at Key Stage 1 (ages 5 to 7) states that pupils should be taught concepts to:

1. Understand what algorithms are and how an algorithm is executed as a program on a digital device
2. To create and identify any errors in simple programs
3. To develop logical thinking to predict the behavior of simple programs

However, the learning of computer science concepts in children around the age of 5 depends to a large extent on the teaching methods and programming tools used (Shein, 2014). To achieve this, it requires that all teachers are properly trained to teach the new technologies in computer science as well as that there is equipment available from government agencies to serve the new needs.

According to Passey et al.2017, the main arguments for teaching computer science in compulsory education are summarized as follows:

- Economic argument
  Education should develop those skills which are most likely to support a future IT-based economy.
- Organizational argument
  Large organizations increasingly require highly skilled people to support their systems.
- Community argument
  Computing facilities are increasingly being used by 'communities' for social purposes, in addition to organizations and individuals.
- Educational argument
  Because of the speed at which technology is developing, students need to become aware and understand how it should be used responsibly.
- Learning Argument
  Develop problem-solving, collaboration, creativity, and logical thinking skills.
- Learner Argument
  Engaging students in computer science early on so they have the opportunity to see how it can impact their future.

4 Computational thinking and programming

According to the World Organization ISTE (International Society for Technology in Education) computational thinking (CT) is a problem-solving process that includes the following characteristics:

- Formulating problems in a way that enables us to use a computer and other tools to help solve them.
- Logical organization and analysis of data.
- Representation of data through abstractions such as models and simulations.
- Automating solutions through algorithmic thinking.
- Identify, analyze and implement potential solutions to achieve the most effective combination of steps and resources.
- Generalize and transfer this solution process to a wide variety of problems.

According to Wing (2006), computational thinking is a fundamental skill and refers to a set of generally applicable skills that everyone, not just computer scientists, would be willing to learn to use. Regarding the abilities of each child in writing, reading and arithmetic we should add computational thinking, which includes: solving problems, designing systems, and understanding human behavior and is based on the basic concepts of computer science. Computational thinking is thinking in terms of preventing, protecting, and recovering data from the worst-case scenario, through redundancy, damage limitation, and error control. Creativity is also linked to Computational Thinking through divergent thinking, 'challenging' new methodologies, finding patterns, and engaging in ill-defined problems which are a key component of the 'integrated STEAM approach' but also favor STEM skills, 21st-century skills needed for new forms of work.

Programming is the set of procedures for writing a computer program, usually as the implementation of some algorithms after careful design, for the automated execution of tasks or solving a computer problem. Programming also includes checking the program to verify its accuracy and correctness (debugging) and preparing the instructions with which a computer will execute the commands specified in the program specification. Programming languages consist of a set of rules for writing commands while writing code, called syntax. They have a compiler that converts the code into machine code so that it can be understood by the computer, the computer executes the code and returns results, and the set of instructions that direct the computer to perform a specific task is called a program.

In this educational programming research article, programming languages for beginners will be discussed. In more detail, visual programming environments (VPEs) and programming learning platforms along with their benefits in each educational context.

5 Visual programming

Visual Programming Languages (VPLs) were created to be accessible to novice users of all ages. The novice programmer can design programs according to his interests and the immediate feedback provided by the programming environment (creating stories, animations, games, etc.). Visual programming languages are used to create programs through ready-made blocks of commands that are listed in blocks and organized into categories. The user joins the blocks and creates the final program. No need to write commands textually and this is the advantage of visual languages over traditional languages for the novice programming user.

Repenning (2017) describes three levels of features that make a successful visual programming environment:

1. Syntax: The use of blocks/icons, forms, and diagrams help to reduce and eliminate syntax errors.
2. Semantics: Visual environments provide some mechanisms to reveal the primitive concepts of programming. Semantics plays an important role in the time it takes a student to create a project.

3. Pragmatics: Visual environments give information about what a program means in a particular situation, for example how a program works when data is added.

Programming languages are designed in such a way that they provide enough functionality that allows users to avoid basic errors while providing the ability to immediately correct the error in a non-executable program. Several studies have been conducted to examine the complexity and associated difficulties students face while learning to program. The results show two main factors related to the learning process. The way of approaching teaching and the motivations that can be developed. Felder and Brent (2005) categorized students into 3 areas based on their learning profile, approach to study and orientations to learning, and intellectual development and concluded that teachers could more effectively promote the intellectual development of students if they could identify key differences in these areas by designing different learning activities and adopting different teaching methods.

The New York City government agency's education department in15 developed a program called CS4ALL SEPjr., which would provide computer science education to every public school student for the next ten years. The SEPjr curriculum consists of four main modules:

1. Basic principles of computer science
2. Robot
3. Project-based learning
4. Physical computer use

The goals of the program were to increase the number of elementary school students in public schools learning computer science and developing computational thinking and problem-solving skills in real-world settings. The tools teachers used were block-based programming languages, like Scratch, and open-source educational platforms

6 Educational coding platforms

The following educational platforms have been created to develop students' skills. They are aimed at Primary and Secondary education students and offer them dynamic and interactive learning experiences making full use of IT and communication technologies by international standards and in particular, by the relevant European directive on new digital schools. In this way, students are introduced to the programming way of thinking from an early age, with the result that they are overall better trained in the way of thinking required by science courses.

6.1 Tynker

Tynker is an online creative coding education platform that enables students of all ages to learn to code at home, at school, and on the go. It uses visual programming and aims to help children develop coding skills such as game design, web design, animation, and robotics. The programming languages used are Blocky, Swift, Python, Javascript, and HTML/ CSS. Tynker's platform approaches learning more interactively since exercises and code are explained by cartoon characters, designed by the user himself, or by short videos and mini-games. In addition, the user can play ready-made games that promote computational thinking through basic programming concepts.

6.2 Tinkercad

Tinkercad is a free, online educational platform that equips the next generation of designers and engineers with the fundamental skills related to 3D design, electronics, and coding. Users through tinkercad can build circuits and program them. The commands used on this platform are similar to the commands used on the rest of the available platforms, so any student who learns to write code commands on one platform can easily learn many corresponding platforms as well.

6.3 Code Combat

Code Combat is an educational role-playing video game for learning software programming concepts and languages. This game is recommended for students ages 9-16. Students learn coding languages such as JavaScript, Python, HTML, and CoffeeScript, as well as the fundamentals of computer science. CodeCombat has 11 modules, 3 game development modules, 2 web development modules, and 6 computer science modules. The first module, Computer Science 1, is free for all students and teachers. Users choose the character, their so-called hero, that they prefer from a set of characters with different abilities. Every hero has strengths and weaknesses. Once the player is selected, the objectives and instructions appear. The game has levels of escalating difficulty. Each level focuses on different learning objectives. For example, Unit 1 focuses on basic programming concepts such as syntax, variables, methods, and parameters. To complete the mission, players must create a working code that controls the character to perform specific tasks, required to complete the level. Once the player finishes writing the coding instructions, the execution of the program begins with an animation based on the instructions: the player character moves locates, and fights enemies. Code Combat's coding editor guides objectives. In addition, it provides a set of commands (methods) and the student must select the appropriate command to perform the corresponding function. The auto-complete and auto-correct functions allow the user to receive instant feedback and continuous support during the game.

6.4 Code

Code.org is a non-profit organization dedicated to expanding schools' access to computer science. The organization's vision is that every student in every school should have the opportunity to learn computer science as part of their basic education. Code.org is supported by donors including Microsoft, Facebook, Amazon, Infosys Foundation, Google, and more. The platform uses a visual programming language, blocky. The logic followed to create a program is drag and drop, ready code sections organized into categories, and compose the final program. In addition, the editor also can display the code of the blocks in JavaScript.

6.5 Leopard

The Leopard platform is a library that makes it easy to create games in JavaScript. It is designed to be easy to use, with the design of the Leopard library closely mimicking that of the Scratch programming language, allowing for direct and easy translation from Scratch to JavaScript. The final code is clear and concise, just like the Scratch project that was created.

7 STEM completion

In today's era, where the cognitive area of "complexity" has come to the fore, traditional cognitive areas "struggle" to understand the problems that appear to be solved. As a result, there has been a strong interest in developing ways of "integrated" research methodologies, thus crossing the methodological, epistemological, and ontological assumptions of a single cognitive domain (Psycharis & Kalovrektis, 2021). Also according to (Psycharis & Kalovrektis, 2017), "the integrated STEAM approach" epistemologically belongs to the interdisciplinary or trans-disciplinary approach. The literature shows that many researchers give different interpretations and approaches to the terms "STEM education" and "STEM completion". Interpretations differ on the concepts of multidisciplinarity and transdisciplinary, the meaning of "crossing the boundaries of cognitive domains" and what we mean by the concept of "integration". In the reference (English, 2016), there is a very large number of articles where STEM 'education' and 'completion' are defined in various ways, where the spectrum of definitions starts from monodisciplinary and proceeds continuously to interdisciplinary (e . e.g. Moore and Smith, 2014; Vasquez et al., 2013; Bryan and Guzey, 2020; Bryan et al., 2015), where the distinction is related to the terms "integration" and "crossing cognitive domains", while sometimes "integration indicators/integrating factors" are also used. A report that presents some of these elements coherently is by (Vasuez et al., 2013).

Content integration focuses on bringing together knowledge areas into a single curricular activity that will emphasize the big ideas (the cross-cutting ideas/concepts) that will come from different knowledge areas, while context integration will focus on the content of one knowledge area and will leverage contexts from other cognitive domains to make connections between cognitive domains. Our view is that STEAM integration is an interdisciplinary approach, where through content integration we design a learning activity that aims to teach concepts from all STEM knowledge areas as a unique curricular activity. In this view, the transversal concepts we mentioned, which are implemented through border objects, play a central role. According to the above, we believe that - and according to (Sengupta & Shanahan-, 2017), the emphasis on "STEAM integration" leads to the "union/integration/coexistence" of distinct cognitive areas and practices in a way that reveals the transversal ideas and new practices that cross or unite isolated cognitive areas, i.e. cross-cutting concepts can be 'boundary objects'. One view of the interdisciplinary approach - which we agree with some modifications - is that expressed by (Boon Ng, Soo, UNESCO, Exploring STEM competencies for the 21st century, https://learningportal.iiep.unesco.org/en/library/exploring-stem-competencies-for-the-21st century, 2019). "In the interdisciplinary approach, there is a high level of integration of cognitive areas through a focus on a 'common concept' of what we referred to as 'transversal concepts' (Psycharis & Kalovrektis, 2021; Psycharis, 2021), while learners will be involved in Computational Experiments.

8 Educational robotics

Robotics today is considered as the fourth R of learning "Reading, writing arithmetic and Robotics", which modern students must master if they wish to be "present" in a modern world that is constantly evolving. Robotics integrates all the fields of STEM (Science, Technology Engineering, Mathematics), while its educational activities, with an interdisciplinary character, give children the opportunity to approach areas experientially, such as Mechanics, Electronics, Automatic Control, and still the sciences of Computers, Technology, Mathematics, Physics, and Architecture (STEAM).

Educational robotics is a flexible learning approach that encourages students to build and control robots using programming languages. This way it combines education with play and turns education into a fun activity. Educational robotics is the branch of education designed to actively introduce students to Robotics and Programming from a very young age. Nowadays there are many educational robots for children and young people. Among them, the most popular are Photon Edu, Botley, Marti, Artie, Finch, Ozo Bot, Blue-Bot, Bee-Bot, Edison, Codey Rockey, and education with Lego. In the case of secondary and higher education, advanced educational robots help students deepen their knowledge of robotics and programming. In addition, high-cost humanoid robots programmed to teach any subject are useful to have in classrooms to attract students' attention and interest in subjects such as computer science, programming, and robotics. Through play, educational robots help children develop computational thinking and cognitive skills through the collaborative process promoted in robotics class.

A very important achievement of robotics is familiarity with the science of programming as a multitude of job vacancies can offer them the professional rehabilitation they desire. Following are some of the most known educational robotics.

8.1 Ozobot

Ozobot is a programmable robot that helps students' computational skills, programming skills, and analytical and logical thinking to be developed. It is a small interactive toy that by its sensors recognizes the different coloured lines. Ozobot is a small robot weighing 17 g, but the robot offers users many options. The first is the use of commands that are a combination of lines of colour (color code language). There are many resources and printable worksheets on the Internet that can be useful for teachers.

8.2 LEGO Mindstorms EV3

This robot is recommended for children over 10 years old. It is a robotics set that includes several sensors, three servo motors, and over 500 LEGO Technic components. Using them students can create different robots that can move, shoot, crawl, etc. It is controlled by a simple and intuitive programming interface. LEGO robotics allows students to design and control robots by LEGO constructors – a favorite game of many children. This is an effective and fun way for students to learn and apply knowledge in the fields of physics, mathematics, computer science, information technology, and even English. With several motors, sensors for light, sound, distance, and touch, a powerful "thinking part" and a little imagination from a LEGO constructor, students build a LEGO robot that can do (almost) everything. LEGO Mindstorms EV3 allows reaching key ideas of STEM disciplines using an easy programming platform. Students are allowed to build design thinking in practice and generate ideas. They easily use LEGO components, design, test, and build models and solve specific problems in teams.

In general, the most popular educational robots include according to Iberdrola, a global energy leader are:

1. Makeblock mBot (a robot with wheels designed to introduce children to robotics, programming, and electronics.)
2. Robo wunderkind (set of blocks that the children can connect as they wish to build their robot.)
3. OWI 535 (suitable for young people aged 13 or over.)
4. LEGO Mindstorms EV3 (robotics set that includes several sensors, three servo motors, and, over 500 LEGO Technic components.)
5. NAO (It is a 58-cm high humanoid robot that is constantly evolving.)

By educating students in a learning environment that is used and programmed by the students themselves educational robots develop many skills. One of the most important skills is discovery learning which encourages the active participation of individuals and promotes motivation. It enhances autonomy, responsibility, and independence and develops creativity and problem-solving skills.

Another skill that develops is that of inclusion. Through robotics, students are assigned roles, they are asked to adapt to unknown content that requires quick specialization and critical thinking. The result is that students boost their self-confidence.

Overall through STEM and robotics students learn and master the following skills.

- Metacognitive opportunities
- Problem Solving Strategies
- Variable control approach
- Algorithmic thinking
- Connection of Virtual and Tangible

- Fine motor skills
- Orientation
- Spatial perception

9 Conclusion

The incorporation of digital technologies in education domain is very productive, successful and facilitates and improves the educational procedures via Mobiles [74-83], various ICTs applications [84-116], AI & STEM [117-127], and games [128-133]. Additionally the combination of ICTs with theories and models of metacognition, mindfulness, meditation and emotional intelligence cultivation [134-156] as well as with environmental factors and nutrition [70-73], accelerates and improves more over the educational practices and results. Above all and beyond the aforementioned benefits, digital technologies improve the students mental abilities and theirs way of thinking.

More specifically, with the contribution of robotics and programming to the learning process, with the tools mentioned in this article, the educator can focus on cultivating and developing critical skills in young people that the 21st century now demands. In particular, the skill of teamwork, problem-solving, innovation, project management, planning, communication as well as valuable mental processes (analytical and synthetic thinking, creativity and critical thinking, and ability).

The vision of educational robotics is for all students to develop the above skills, which in the context of globalization are imperative for preparing tomorrow's citizens to be able to contribute positively on a global scale.

Through available programming learning tools and combined with appropriate teaching approaches, students can develop skills and knowledge in science, technology, engineering, and mathematics. The goal of all these tools is not to learn proto programming perfectly but to develop computational thinking and problem-solving skills as well as to develop cooperation through the creation of projects to achieve the end goal. Most tools are associated with block-based visual programming because of its ease of use and simple syntax, which encourages users and especially young learners to engage in programming quickly and easily. Users can share their creations, then get feedback from other users and be able to make improvements to their code thereby enhancing the learning outcome. This research study aims to inform parents and teachers about the benefits of programming beyond computer knowledge but also for the acquisition of skills such as problem-solving skills and the acquisition of critical thinking, important benefits for the entire working years of the individual to survive in large companies but also to stand out in a student and work environment.

As educators are called upon to use sciences such as robotics and programming to improve all of the aforementioned skills of children, teachers and educators need to identify how they can also take advantage of children's engagement with smart mobile phones. From a very young age, children become familiar with the use of smart devices and the Technology they bring to their daily lives. Educational robotics and programming can also be taught through mobile devices through the corresponding applications during the hours when young people use mobile phones in their free time through educational platforms. However, the teachers themselves must have the necessary knowledge to convey the information required to their students. The very everyday life of individuals forces us to realize that technology is here to stay and the only way for future generations to benefit from it is to have all the necessary knowledge to pass it on to them.

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