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Research Article

Developing computational thinking with microcontrollers in Education 4.0

József Udvaros*, Norbert Forman and Mihály Szilárd Avornicului

Faculty of Finance and Accountancy, Budapest Business School, Hungary

udvaros.jozsef@uni-bge.hu Email of the corresponding author

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Abstract – Industry 4.0 and Education 4.0 are two concepts that are closely linked, as both represent a shift towards a more technologically advanced and digitally driven future. Industry 4.0 is about the integration of advanced digital technologies into manufacturing and other industrial processes, while Education 4.0 is about the integration of technology, in particular digital technologies, into the teaching and learning process. The relationship between Industry 4.0 and Education 4.0 is mutually reinforcing. Education 4.0 aims to prepare learners for the demands of the 21st century workforce by equipping them with the skills and knowledge they need to thrive in a rapidly changing digital environment. The development of computational thinking skills is a key component of Education 4.0, as it is a foundational skill that underpins many of the digital technologies used in industry today. Computational thinking is a problem-solving approach that involves breaking complex problems into smaller, more manageable parts, identifying patterns and relationships, and creating algorithms to solve problems. Microcontrollers, also known as embedded systems, are small computers used to control electronic devices such as home appliances, cars and toys. Visualisation is an important tool in teaching about microcontrollers because it helps students understand abstract concepts and see how different components fit together. Visualisation helps students to gain a deeper understanding of how microcontrollers work and how electronic devices are controlled. This understanding can be particularly valuable for students who want to pursue a career in fields such as engineering, robotics or computer science.

Keywords – Computational Thinking, Microcontrollers, Industry 4.0, Education 4.0, IoT

I. INTRODUCTION

Education 4.0 is an educational paradigm that emphasises the integration of technology, especially digital technologies, into the teaching and learning process. It aims to prepare learners for the demands of the 21st century workforce by equipping them with the skills and knowledge they need to thrive in a rapidly changing digital environment. The development of computational thinking is a key element of Education 4.0, as it is a basic skill that underpins many of the digital technologies used in industry today.

Industry 4.0 relies on a workforce skilled in advanced digital technologies such as the Internet of

Things (IoT), Artificial Intelligence (AI), Machine Learning (ML) and robotics. Education 4.0 can provide individuals with the skills and knowledge needed to work effectively with these technologies, enabling them to contribute to the success of Industry 4.0. Education 4.0 can help individuals develop skills such as critical thinking, problem solving, computational thinking, algorithmic thinking, collaboration and communication that are essential to thrive in a rapidly changing digital environment. These skills are essential to enable individuals to adapt to changing workplace requirements and to collaborate effectively with others in the digital work environment [1].

II. Materials and Method

Industry 4.0 and Education 4.0 are two concepts that are closely linked and mutually reinforcing. Education 4.0 provides individuals with the skills and knowledge to thrive in a rapidly changing digital environment, while Industry 4.0 relies on a highly adaptable and flexible workforce skilled in advanced digital technologies [2]. The relation between Industry 4.0 and Education 4.0 highlights the need for education systems to adapt and evolve to meet the requirements of a rapidly changing technological environment. People's everyday lives are also significantly influenced by digital technology, whether for entertainment, leisure, information acquisition and transmission, communication, etc. There is a need to learn digital languages, which include competences to succeed in the digital world, coding to solve problems, and computational thinking as an operational paradigm [3].

Computational thinking is an essential skill for Education 4.0 learners because it allows them to approach problems systematically and logically. By breaking complex problems into smaller, more manageable parts, learners can create algorithms to solve these parts, leading to more efficient and effective solutions. Computational thinking is also a key component of programming, an important skill in Education 4.0 as many digital technologies in industry today require programming skills. Education 4.0 emphasises the use of technology to enhance the teaching and learning process. For example, digital tools can be used to create interactive learning materials, provide personalised learning experiences and facilitate collaboration between learners. The development of computational thinking skills is essential for learners to use these digital tools and technologies effectively, as it enables them to understand how these tools work and how they can be used to solve problems.

III. Results

There is a strong relation between Education 4.0 and the development of computer literacy. Education 4.0 emphasises the use of technology in the teaching and learning process, and the development of computational thinking skills is essential for learners to use these digital tools and technologies effectively. Computational thinking is an essential skill that underpins many of the digital technologies used in industry today, and it is essential that learners develop these skills to thrive in the 21st century workforce [4].

Industry 4.0 is the fourth industrial revolution, characterised by the integration of advanced digital technologies into manufacturing processes, including the Internet of Things (IoT), artificial intelligence (AI), machine learning (ML) and robotics. Developing computational thinking skills is essential for individuals to succeed in Industry 4.0, as many of these digital technologies rely heavily on computational thinking [5].

In the article [6] Wing wrote computational thinking is "solving problems, designing systems, and understanding human behavior, by drawing on the concepts fundamental to computer science", which provided a fresh perspective on the relationship(s) between humans and computers, and gave rise to a wave of research on computational thinking. Computational thinking is a problem-solving approach that involves breaking complex problems into smaller, more manageable parts, identifying patterns and relationships, and creating algorithms to solve the problem. Microcontrollers, also known as embedded systems, are small computers used to control electronic devices such as home appliances, cars and toys.

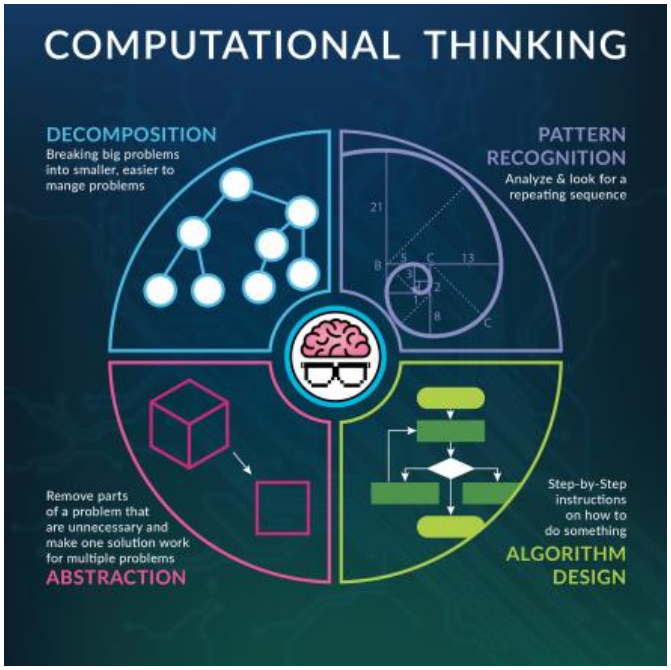

Fig. 1 Four main areas of computational thinking (source: https://learn.sd61.bc.ca)

Professional visualisation is essential for the development of computational thinking in programming. Visualisation helps students to better master basic programming concepts and control structures. They gain deeper knowledge [7]. Robots and microcontrollers are very good tools for visualisation. There are many more opportunities in secondary school programming, as the intellectual maturity of the students allows us to exploit the potential of more complex microcontrollers. Lego Mindstorms robot programming is very common. In the graphical development environment, students can easily learn the control structures, the operation and use of sensors.

Microcontrollers are inexpensive and easy to program, making them an excellent tool for teaching computational thinking. Students can learn to program microcontrollers using a variety of programming languages, including C, C++, Python and Scratch. By programming a microcontroller, students learn how to break down complex problems into smaller parts and develop algorithms to solve them. This helps them develop the computational thinking skills that are essential for success in computer science and other technical fields.

One of the advantages of using microcontrollers to teach computational thinking is that they give students immediate feedback. When students write a program and upload it to a microcontroller, they can immediately see whether the program is working or not. This feedback helps students learn from their mistakes and improve their programming skills. In addition, microcontrollers can be used to control a wide range of devices such as motors, sensors and displays, giving learners hands-on experience that helps them better understand the physical world and how technology can be used to control it [8].

Another benefit of using microcontrollers to develop computational thinking is that they are highly customisable. Students can design and build their own circuits and devices using microcontrollers, giving them a sense of ownership and pride in their work. This can motivate them to continue learning and explore new ideas in computer science and engineering. In addition, microcontrollers are widely used in industry, making them a valuable skill for students to acquire if they are planning a career in technology [9].

In summary, developing computational thinking through microcontrollers is an effective way to teach students problem-solving and programming skills. Working with microcontrollers, students learn how to solve complex problems, develop algorithms and control electronic devices. This hands-on approach to learning helps students develop a deeper understanding of computer science and engineering concepts and prepares them for success in technical fields.

Computational thinking is a problem-solving approach that involves breaking down complex problems into smaller, more manageable parts and creating algorithms to solve them. This approach can be applied to a wide range of fields from computer science to engineering and business. The development of computational thinking skills is important because it teaches individuals to take a logical and systematic approach, which is likely to lead to more effective solutions.

Microcontrollers, also known as embedded systems, are small computers used to control electronic devices. They are cheap and easy to program, making them an excellent tool for teaching computational thinking skills. By programming a microcontroller, students can learn how to apply computational thinking concepts to real-world problems. For example, they can create programs to control the temperature of a room or the speed of a motor. By breaking these problems down into smaller parts and creating algorithms to solve them,

students learn how to think as computer scientists and engineers.

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A variety of microcontrollers can be used in educational processes to teach computational thinking and programming skills. Some of the most popular microcontrollers used in education include:

Arduino: Arduino is an open source platform widely used in education. It is based on a simple programming language that is easy to learn, making it a great choice for beginners. Arduino boards come in different sizes and can be used to control a wide range of devices [10].

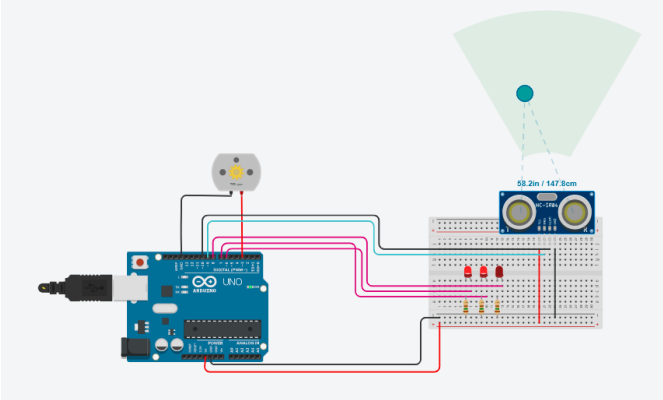

Fig. 2 Arduino Uno microcontroller in TinkerCad circuit

Raspberry Pi: The Raspberry Pi is a credit card-sized computer designed for educational use. It is based on the Linux operating system and can be programmed using a variety of programming languages, including Python and Scratch. The Raspberry Pi can be used to control a wide range of devices, including sensors, cameras and displays.

Fig. 3 Raspberry Pi microcontroller

Micro:bit: Micro:bit is a small programmable computer developed by the BBC in the UK. It is designed for educational use and has a range of sensors and inputs, making it a great choice for teaching computational thinking and programming skills.

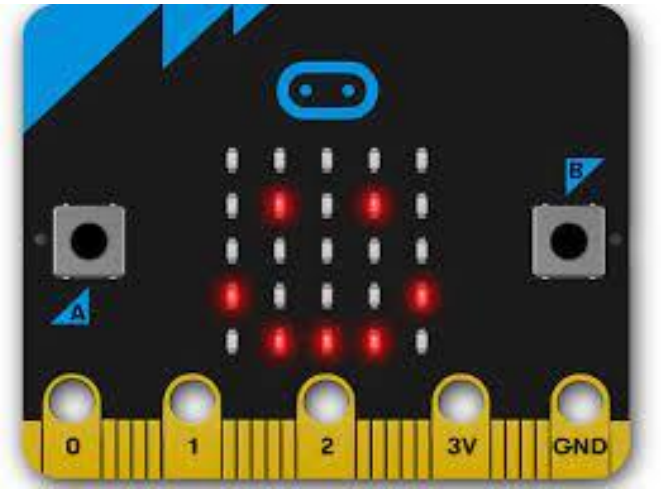

Fig. 4 Micro:Bit microcontroller

PIC microcontrollers: They are widely used in industry and can be programmed in a variety of programming languages, including C and Assembly. PIC microcontrollers can be used to control a wide range of devices and are an excellent choice for more advanced learners.

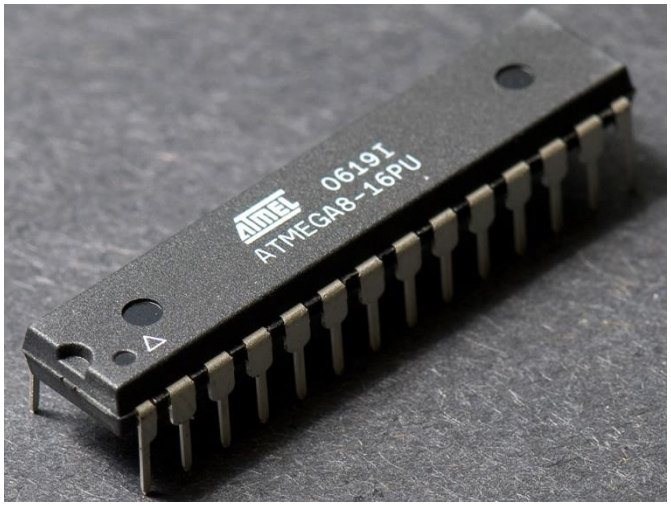

Fig. 5 PIC microcontroller

STM32 microcontrollers: They are widely used in industry and can be programmed in a variety of programming languages, including C and Python. STM32 microcontrollers are a great choice for advanced students interested in learning about embedded systems and real-time applications.

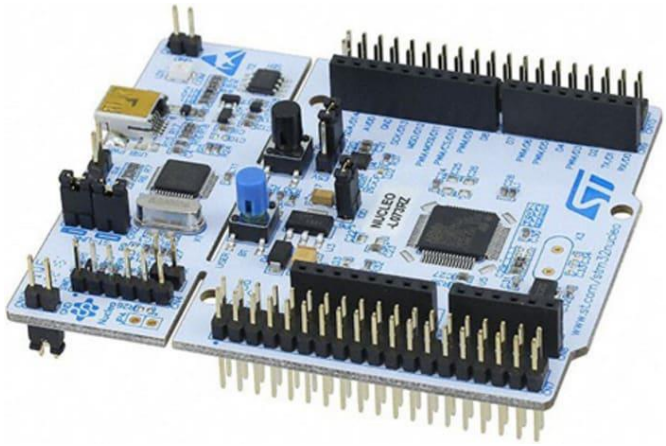
Fig. 6 STM32 microcontroller

There are a number of microcontrollers that can be used in educational processes to teach computational thinking and programming skills. The choice of microcontroller depends on the level of knowledge of the students, the type of projects they want to create and the resources available to the institution. However, Arduino, Raspberry Pi, Micro:bit, PIC microcontrollers and STM32 microcontrollers are all popular choices for education [11].

IV. DISCUSSION

The connection and communication between peripherals and controllers is a key factor in the implementation of systems under the Industry 4.0 concept, which has redefined the control and management of industrial processes. Industry 4.0 brings together these aspects [12]. Education must therefore also adapt to the challenges of this era. Its capability allows students to use software tools effectively and acquire methods to solve computational problems efficiently and intelligently. Computational thinking allows students to quickly master new software and model simulation solutions to solve real and abstract problems [13]. Computer scientists and researchers are now exploring how learning and teaching through digital technology is changing and how learning and teaching can be most effective using these tools [8] [14]. Sometimes there may not be opportunities for face-to-face training, such as during the Covid-19 pandemic. The lack of opportunities for students to physically program the components and microcontrollers used in education is a major barrier to education. This is made possible by the online application TinkerCad [15].

Visual programming is a new trend within programming to develop applications. Nowadays, visual programming is becoming very popular. The TinkerCad online application is very well suited for visual programming [16]. With the help of this online application, we can visually simulate the operation of the circuit we have created and then build it using real microcontrollers and electronic components. The undisputed advantage of simulations is that a simulated environment cannot be destroyed, all parameters can be freely modified, and there is no risk of damage or injury in these cases [17].

V. CONCLUSION

Developing computational thinking through microcontrollers is an effective way to teach students problem-solving and programming skills. Working with microcontrollers, students learn how to solve complex problems, develop algorithms and control electronic devices. This hands-on approach to learning helps students develop a deeper understanding of computer science and engineering concepts and prepares them for success in technical fields. There is a strong relation between Industry 4.0 and the development of computational thinking skills. As more and more manufacturing processes become automated and digitalised, the ability to think computationally will become increasingly

important for workers to be able to understand and program these systems effectively. Computational thinking skills are essential for individuals to succeed in Industry 4.0, as they enable them to approach problems systematically and logically, analyse data effectively, and work with advanced digital technologies such as AI and ML [18].

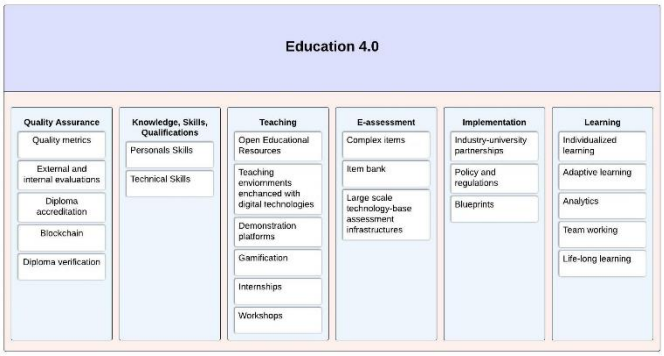

Fig. 7 Concept of Education 4.0 [18]

The relationship between Industry 4.0 and Education 4.0 is mutually reinforcing. Education 4.0 aims to prepare learners for the demands of the 21st century workforce by providing them with the skills and knowledge they need to thrive in a rapidly changing digital environment.

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