Programming and Technical Skills of Students Using a Microcontroller

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DOI: https://doi.org/10.53349/re-source.2026.is1.a1544

Abstract

The article presents an analysis of some research results. The research was conducted using a pre-test and post-test. The test was conducted before and after the practical part of the project, the aim of which was to verify the development of students' knowledge and skills in the field of BBC micro:bit microcontroller programming and technical skills. The testing focused on a basic understanding of the principles of the BBC micro:bit microcontroller, the ability to navigate the MakeCode environment, and the application of knowledge in solving simple tasks. The research was conducted at an elementary school and involved students in grades 5–9. Eighty-four students took the entrance test, and 65 students took the exit test after completing the course using specially designed teaching aids. The results indicate a positive impact of experimental teaching on the development of students' programming and technical skills.

Keywords: BBC Micro:bit, STEM Education, Elementary School

1 Introduction

Education in the 21st century requires a change in teaching approaches that reflects the modern needs of society and technological progress. The STEM concept represents an educational approach in which the fields of science, technology, engineering and mathematics are interconnected into a single coherent system that enables pupils to acquire knowledge through application, inquiry and practical problem solving. Within primary education, theoretical teaching without sufficient connection to practice still dominates, which may limit

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the development of pupils' ability to link knowledge across subjects and to understand its relevance in real life. Integrating microcontrollers into teaching represents an effective way to support interdisciplinary education. The BBC micro:bit microcontroller is a suitable tool for primary schools due to its simple design, the availability of sensors and intuitive programming in MakeCode. By incorporating real measurements into lessons, pupils can observe physical phenomena in practice, analyse the measured values and apply theoretical knowledge when solving problems. This type of instruction supports the development of practical technical skills, digital competencies and algorithmic thinking. As part of the research, a teaching intervention was designed that focused on the use of the BBC micro:bit microcontroller and several external sensors, through which primary school pupils measured water temperature and air humidity. The aim of the research was to quantify the impact of this experimental teaching method on pupils' knowledge of the software and hardware of the BBC micro:bit microcontroller. The research was conducted using a pre-test and post-test and focused on changes in the level of knowledge in programming and working with sensors.

2 The STEM Concept in Teaching

National policymakers in the field of education, along with educational institutions worldwide, are placing increasing emphasis on providing students with an education that reflects contemporary needs and labour market demands of the twenty-first century (Skinner, Saxton, Currie, Shusterman, 2017, p 2433–2459). Many contemporary school environments still fail to engage students effectively in learning, as they continue to rely on educational models that are more than half a century old (World Economic Forum, 2017, p 7-12). Most education at primary and secondary schools (ISCED 1–ISCED 3) continues to focus more on theory than on the application of theory in practice, and teaching is carried out in a way that does not strengthen links between individual subject areas (Nadelson, Seifert, 20217, p 221 –223).

Given the growing demand for a workforce with knowledge in the field of STEM education, national efforts in educational policy are intensifying worldwide. In the scholarly literature, the STEM approach to education is described in various ways (Bybee, 2013, p 1-7). For example, Vasquez, Comer and Gutierrez (Vasquez, Comer, Gutierrez, 2020, p 11-23) state in their publication that STEM education is an interdisciplinary approach to teaching and learning that removes the traditional barriers between the four disciplines of science, technology, engineering and mathematics and integrates them into relevant learning units that are applicable for students in real life.

According to Dugger (Dugger, 2020, p 2-5), STEM is an educational approach that aims to provide students with the ability to communicate in an interdisciplinary way, to work in teams, to think creatively, to engage in inquiry-based research, and to create and solve problems with an emphasis on integrating knowledge and skills from science, technology, mathematics and engineering into instruction based on engineering design (Kelley, Knowles, 2016, p 2-11). In the article A conceptual framework for integrated STEM education, the authors Kelley and

Knowles (Kelley, Knowles, 2016. p 2-11) describe the STEM approach in education as relating to teaching, learning and integrating the disciplines of science, technology, mathematics and engineering into science topics with an emphasis on solving modelled real-world situations and practical tasks. In this approach, students acquire key competencies and complex cognitive skills. These skills are necessary for creating meaningful connections in the processing of knowledge, which leads to interdisciplinary, meaningful understanding.

The authors Spelt, Biemans, Tobi, Luning and Mulder (Spelt, Biemans, Tobi, Luning, Mulder, 2009, 365-378) define interdisciplinarity as the ability to integrate knowledge from two or more disciplines to achieve cognitive progress in a way that would be impossible or unlikely when using the resources of a single discipline.

STEM education is perceived as an interdisciplinary approach that connects science, technology, engineering and mathematics into meaningful, reality-oriented tasks. Its aim is to develop teamwork, creative and critical thinking, problem-solving skills and the ability to integrate knowledge across disciplines. Interdisciplinarity is understood here as the integration of knowledge from several fields in such a way that it enables cognitive progress which a single discipline could not achieve on its own.

3 Microcontrollers

A microcontroller is a small computer system located on a single integrated circuit. Typical examples of such systems include Arduino boards or the BBC micro:bit. An embedded system is a computer with a specific, precisely defined function that is usually not designed to be reprogrammed later (e.g., engine control units, implanted medical devices, household appliances, etc.). Microcontrollers are particularly suitable for tasks such as reading data from sensors and implementing control algorithms, and it is important to realize that they are digital devices. To interface with the analogue world, they use digital-to-analogue conversion (DAC) to convert binary values into a real output voltage, and analogue-to-digital conversion (ADC) to convert an analogue input signal into digital data that the microcontroller can process.

The most used microcontroller platforms include the BBC micro:bit, Arduino and Raspberry Pi, while older types such as PIC microcontrollers may be suitable for alternative didactic approaches. Individual microcontrollers differ in size, available features, the ratio of functionality to size, software architecture, number of input–output (I/O) pins, power requirements, processing speed and other parameters (Lambert, 2017, p 4 - 7).

In this paper, we focus on the BBC micro:bit microcontroller. It is a small programmable microcontroller that combines several sensors and components: an LED display, buttons, an accelerometer, a compass, a temperature sensor and Bluetooth. It works in such a way that pupils create a program on a computer, tablet or smartphone (for example in the MakeCode environment using block-based programming), upload it to the micro:bit, and the device then executes the given commands it displays an animation, measures temperature, reacts to movement, controls external devices, etc.

The BBC micro:bit microcontroller is programmed in the MakeCode environment. MakeCode is a visual programming platform developed by Microsoft for easily creating programs for microcontrollers. It is intended primarily for educational purposes and enables block-based programming, where pupils intuitively assemble blocks in a way like a puzzle. The MakeCode platform runs directly in a web browser and does not require any software installation. Each block in a program represents a particular command or function, such as a measurement, a calculation, a condition or data display. In addition to the block interface, MakeCode also offers the option to switch to text mode in JavaScript or Python, which allows pupils to gradually transition to more advanced forms of programming. In the MakeCode environment, pupils can create interactive projects, work with sensors, LEDs, displays and other extension modules. The platform supports experimentation and provides immediate feedback the result of a program can be simulated directly in the browser or transferred to a real device via a USB cable.

For education in Slovak primary schools, the BBC micro:bit is suitable for several reasons:

- **Low entry barrier** – block-based programming is understandable even for younger pupils; they do not need prior coding experience.
- **Connection to real life** – pupils can create concrete projects (measuring classroom temperature, a pedometer, a simple alarm), which helps them better understand the purpose of programming.
- **Support for cross-curricular links** – the BBC micro:bit makes it possible to connect informatics with physics, technology, mathematics or science (measurement, experiments, projects).
- **Safety and availability** – the device is robust, safe to use and relatively affordable even for Slovak schools, and there is a large amount of teaching material available in Slovak.

This makes the BBC micro:bit a suitable tool for developing digital competencies, logical thinking, and interest in STEM fields in the first and second grades of elementary school.

4 The Research

We pursued the research objective by implementing an activity designed by us with the BBC micro:bit microcontroller. The activity, focused on measuring water temperature and air humidity using the BBC micro:bit and external sensors, was carried out with lower-secondary pupils in the subject of Technology as a model example of working with a microcontroller and sensors from the Smart home kit. Pupils worked in small groups (2–4 students) and built on a short introductory explanation by the teacher, who clarified the aim of the activity, reviewed the concepts of temperature and air humidity including their units, introduced the microcontroller, the sensors used, and the basic safety rules for working with electronics and water. In the first phase, in the computer lab, pupils created a simple program in the MakeCode environment which, in an infinite loop, read values from the sensors and displayed them on the micro:bit's LED display or in the serial monitor. In the second phase, they practically assembled the measuring circuit on an expansion board and carried out measurements of water temperature and air humidity under different conditions (cold/warm water, various environments in the classroom and its surroundings), continuously interpreting changes in the measured values. The final discussion focused on reflecting on the observed phenomena and on how the sensors and the microcontroller helped them better understand the behaviour of water temperature and air humidity in real situations.

The activity is aimed at developing pupils' ability to connect knowledge from multiple subjects, understand their interrelationships and use them when solving concrete tasks. Within this interdisciplinary approach, pupils use mathematical skills when processing measured data, physics knowledge when interpreting the results, and informatics skills when programming and visualising the data. At the same time, it fosters environmental awareness by having pupils monitor physical quantities related to phenomena in nature. This type of instruction can lead to a deeper understanding of the relationship between technologies, humans and the environment, which is one of the main goals of interdisciplinary education.

The Research sample

The research was carried out with primary school pupils in grades 5–9 who took part in instruction focused on block-based programming and working with sensors in the BBC micro:bit and MakeCode environments. A total of 84 pupils participated in the pre-test, with gender evenly distributed (50% boys and 50% girls). The same knowledge test was subsequently administered after completion of the teaching module as a post-test, in which 65 pupils responded, of whom 55.4% were boys and 44.6% were girls.

The difference between the number of respondents in the pre-test and post-test (a decrease of 19 pupils, i.e., approximately 22.6%) is due to a natural rate of attrition (absence at the second measurement, organisational reasons, non-participation in the entire module, etc.). The analysis of the results is therefore based on two partial samples: one for the initial knowledge level (N = 84) and the other for the final level (N = 65).

The pupils represent a typical lower-secondary school population becoming familiar with block-based programming and sensors through a practically oriented project. This target group is didactically relevant, as it is an age at which pupils first encounter programming, abstract thinking and the concepts of measuring physical quantities using sensors in a more systematic way.

Structure and content of the test

The research instrument was a knowledge test (a questionnaire with closed-ended items) that was administered at two time points as a pre-test and a post-test. The test consisted of multiple questions, but for the purposes of this article we used seven selected closed-ended questions focused on key areas:

1. *Block-based programming and working in the MakeCode environment*
    - What does “block-based programming” mean?
    - How can you test your program in MakeCode to find out whether it works correctly?
    - What is the purpose of the “repeat every” block?

These items verify whether pupils understand the basic nature of block-based programming (visual blocks instead of text-based code), the principle of simulation in MakeCode, and the use of timing/control blocks (periodic repetition of actions).

2. *Sensors, measurement and technical components*
    - Which of the following sensors is used to measure the temperature of a liquid?
    - What are the pins on the expansion board at the bottom of the board used for?
    - On what principle does the soil moisture sensor work?
    - What type of data does this sensor detect?

This group of items specifically examines understanding of the functions of sensors (temperature sensor, soil moisture sensor) and of the technical infrastructure (expansion board, connecting sensors via pins). Pupils must be able to match a sensor to the quantity being measured and understand that a sensor operates on a specific physical principle (e.g., a change in the electrical conductivity of soil as its moisture changes).

The content of the test is thus targeted at the cognitive level of understanding and basic application – the pupil should be able to explain concepts (block-based programming, simulation, timer), assign a sensor to its purpose, and interpret what a given sensor measures.

Item form and scoring

All items were designed as closed-ended questions with a single correct answer. Pupils selected their answer from the options provided.

- Each correct answer was scored with 1 point.
- Each incorrect answer was scored with 0 points.
- The total score for an individual pupil therefore ranged from 0 to 7 points.

The construction of the knowledge test was based on the objectives of the teaching module:

- to introduce pupils to block-based programming in the MakeCode environment,
- to develop understanding of sensors (temperature, soil moisture, etc.) and their use in controlling simple technical systems.

From a methodological perspective, this is a content-focused knowledge test that complements practically oriented instruction.

5 Pre-test and Post-test Evaluation

After summing all correct answers across items, pupils in the pre-test answered correctly 207 times out of 588 possible responses, which corresponds to an average success rate of approximately 35.2%. In the post-test, we recorded 195 correct answers out of 455, i.e. an average success rate of approximately 42.9%.

The average proportion of correct answers per item thus increased from 35.2% (pre-test) to 42.9% (post-test), which represents:

- an average increase of 7.7 percentage points,
- a relative improvement in the average success rate of approximately 22% (≈ +21.8% relative to the baseline value).

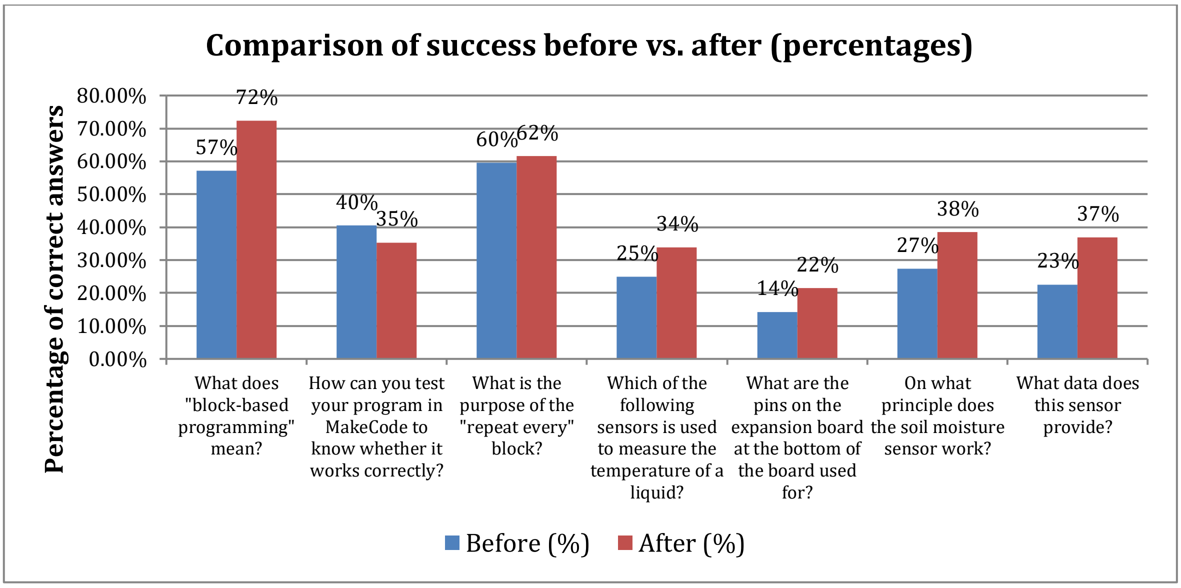

Figure 1: Comparison of pre-test and post-test results.

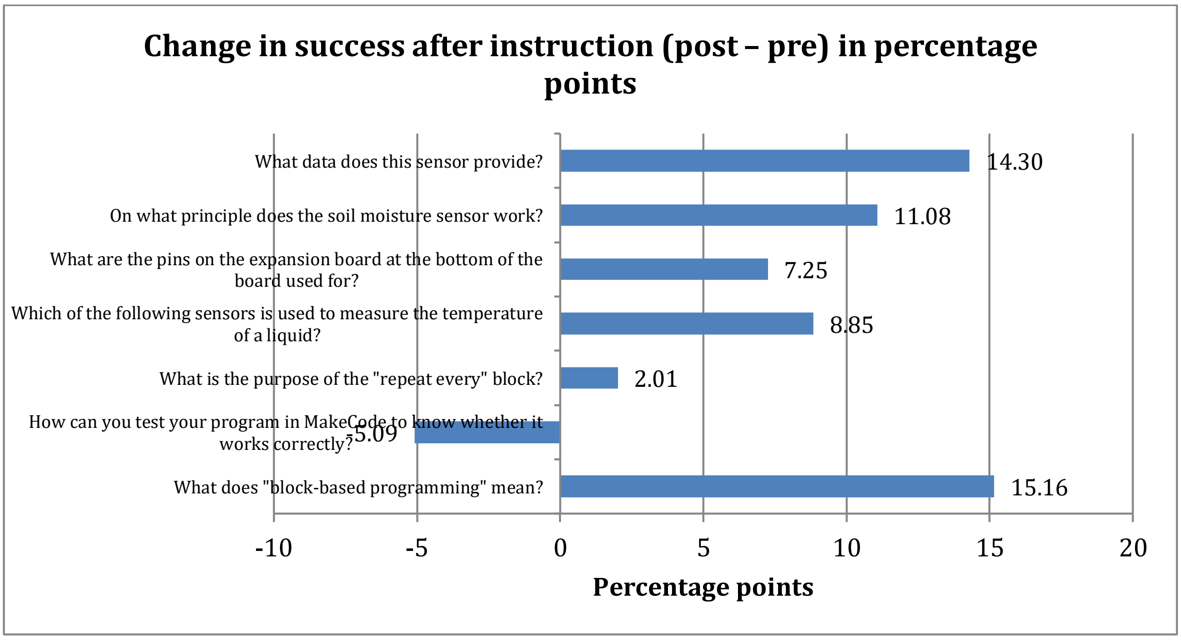

Figure 2: Representation of the change in pupils' success rate in percentage points.

In Figure 2, the change in success after the instructional intervention is shown in percentage points, with a mean value of 7.65 percentage points. This means that a typical item showed a slight shift towards higher success. However, the spread between items is relatively large (from –5.09 to +15.16 percentage points), which suggests that some concepts were learned much more strongly than others, while in one item there was even a slight deterioration.

Area 1: Block-based programming in MakeCode

Definition of "block-based programming"

The first item examined whether pupils understand the basic concept of block-based programming.

- Pre-test: 48 out of 84 pupils answered correctly, which represents 57.1%.
- Post-test: 47 out of 65 pupils answered correctly, i.e. 72.3%.
- Change: +15.16 percentage points.

This is the highest increase among all items. The initial level of understanding was already relatively good in the pre-test (more than half of the pupils), but after the intervention the proportion of pupils with the correct answer increased substantially. The effect can be characterised as small to medium (Cohen's h ≈ 0.32), which, given the short intervention, represents a favourable outcome. From a didactic perspective, this suggests that working with concrete examples in the MakeCode environment, visual blocks and program demonstrations effectively supported conceptual understanding of what block-based programming is.

Testing a program in the MakeCode environment

The second item focused on the process of testing a program, i.e. checking whether it works correctly.

- Pre-test: 34/84 pupils, i.e. 40.5% correct answers.
- Post-test: 23/65 pupils, i.e. 35.4%.
- Change: –5.09 percentage points.

This is the only item that shows a slight deterioration. However, the effect is small (Cohen's h ≈ –0.10), which indicates stagnation rather than a dramatic decline. Compared to the other items, it appears that while pupils relatively well grasped the conceptual side of block-based programming, the practical procedure for testing a program remains unclear for part of them. In the future, it would be appropriate to include more activities in which pupils consciously verbalise the testing procedure and compare different options (simulator, physical device, step-by-step debugging).

Function of the "repeat every" block

The third item focused on the concept of a timing loop (the "repeat every …" block).

- Pre-test: 50/84 pupils, i.e. 59.5% correct answers.
- Post-test: 40/65 pupils, i.e. 61.5%.
- Change: +2.01 percentage points (Cohen's h ≈ 0.04).

Success was already relatively high in the pre-test and increased slightly after the intervention. The change is minimal – it rather confirms that the concept of repeatedly executing commands at regular intervals was already familiar to some pupils at the outset. From a pedagogical point of view, this area does not seem to represent as pronounced a bottleneck as some of the more technical aspects of sensor work.

Summary for the area of block-based programming

If we average the success rates of the three programming-related items, we obtain:

- Pre-test: on average 52.4% correct answers,
- Post-test: on average 56.4% correct answers.

The average increase in this area is therefore approximately 4 percentage points. Overall, this means that pupils already had a relatively good intuitive understanding of the basic principles of block-based programming at the beginning, and the intervention further slightly strengthened it, especially regarding the definition of the concept of "block-based programming". From a didactic perspective, it is necessary to define and elaborate more precisely the procedural steps related to testing a program.

Area 2: Sensors and hardware components

The remaining four items concern the specific soil moisture sensor and the related hardware (expansion board, pins, type of signal). The initial success rate in this area was markedly lower than in programming, which reflects pupils' more limited prior experience with electronic hardware.

Identification of the soil moisture sensor

The fourth item (choosing the correct sensor from the options offered):

- Pre-test: 21/84 pupils, i.e. 25.0% correct answers.
- Post-test: 22/65 pupils, i.e. 33.8%.
- Change: +8.85 percentage points, small effect (Cohen's h ≈ 0.19).

After the project, pupils were better able to identify which hardware component is the soil moisture sensor, but even after the intervention the success rate remains at only about one third. This may also be due to the complex names of sensors composed of numbers and letters; pupils may not have remembered these names correctly.

Function of the pins on the expansion board

The fifth item asked about the purpose of the pins on the expansion board:

- Pre-test: 12/84 pupils, i.e. 14.3%.
- Post-test: 14/65 pupils, i.e. 21.5%.
- Change: +7.25 percentage points, small effect (Cohen's h ≈ 0.19).

This is the item with the lowest absolute success rate in both the pre-test and the post-test. Although the direction of change is positive, most pupils still do not clearly understand what the individual pins are used for. From a didactic point of view, this points to the need for more explicit visual labelling and step-by-step explanation of their function.

Operating principle of the soil moisture sensor

The sixth item examined whether pupils know the basic physical principle on which the sensor operates:

- Pre-test: 23/84 pupils, i.e. 27.4%.
- Post-test: 25/65 pupils, i.e. 38.5%.
- Change: +11.08 percentage points (Cohen's h ≈ 0.24).

The increase is more pronounced than for the identification of the sensor or understanding the function of the pins. This suggests that the explanation of the physical and technical principle (change in conductivity at different soil moisture levels or another mechanism) was didactically effective, but it is still a concept with which about 60% of pupils have difficulties. At primary school level, this already represents somewhat more abstract content that may require more experimental activities.

Type of output data from the sensor

The seventh item examined what kind of data the sensor provides:

- Pre-test: 19/84 pupils, i.e. 22.6% success rate.
- Post-test: 24/65 pupils, i.e. 36.9%.
- Change: +14.30 percentage points, small to medium effect (Cohen's h ≈ 0.31).

This is one of the items with the most pronounced relative improvement, although the absolute success rate remains moderate. The result suggests that after completing the activity, pupils had a much clearer idea of what kind of data the sensor provides.

Summary for the area of sensors and hardware

The average proportion of correct answers in this area was:

- Pre-test: 22.3%,
- Post-test: 32.7%.

The average increase thus reaches approximately 10.4 percentage points, i.e. higher than for the programming items. At the same time, however, the absolute success rate remains lower than for block-based programming: even after the intervention, only about one third of pupils answered correctly. From a didactic perspective, this means that the intervention was able to improve understanding of sensors and hardware more markedly, but this is an area in which pupils started from a very low baseline level and would probably need more time, repetition and visual support to achieve a similar level of confidence as in programming.

The analysis of the seven items of the knowledge test shows that the implemented educational activity led to:

- an overall slight increase in the average success rate (from 35.2% to 42.9%, i.e. +7.7 percentage points),
- a more pronounced improvement in sensors and hardware (≈ +10.4 percentage points),
- a more modest improvement in block-based programming (≈ +4 percentage points),
- the greatest gains in defining basic concepts (block-based programming, type of data provided by the sensor),
- and persistent difficulties in procedural and hardware-related details (testing the program, function of the pins on the expansion board).

From the perspective of effect size, most items show small effects (Cohen's h approximately 0.19–0.32), which is to be expected for a one-off or short-term intervention at primary school level. The exception is the item on testing a program, where the effect is slightly negative and points to the need to revise the didactic design of this part of the content.

Verification of results based on age

When evaluating the data, we also focused on the pupils' results by age. We were interested in whether pupils' age influenced the knowledge acquired.

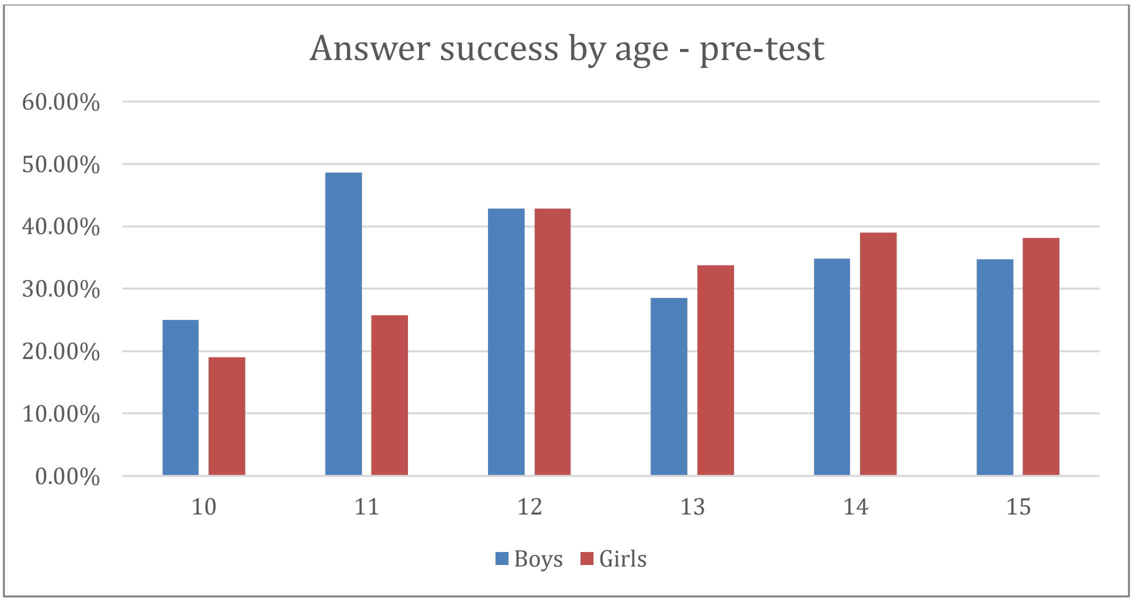

Figure 3: Success rate of pupils' answers by age in the pre-test.

In the pre-test, the success rate of answers ranges approximately between 20–50%. We do not observe a simple linear trend of "the older, the better"; rather, there is a local maximum around 11–12 years of age:

- **10 years:** boys achieve a success rate of about one quarter of correct answers, while girls are even lower (below 20%). At this age, boys thus have a slight advantage, but the overall level of knowledge is low.

- **11 years:** this is the group with the highest success rate for boys in the entire pre-test (almost 50%), whereas girls are only at about one quarter of correct answers. A pronounced gender asymmetry in favour of boys is evident here.
- **12 years:** boys and girls achieve very similar performance (around 40–43%). This is the only age category in which the genders are practically equal in the pre-test.
- **13–15 years:** among older pupils, success rates range around 30–40%. In these age categories, girls have a slight advantage: their bars in the graph are systematically a few percentage points higher than those of boys.

The pre-test thus suggests that:

- in the lower grades (10–11 years), boys are somewhat more successful in the tested knowledge,
- from around age 13 onwards, performance gradually shifts in favour of girls,
- there is no simple increasing trend between age groups, which may be related to differences in prior experience with the topic and differences between classes.

Distribution of success rates in the post-test

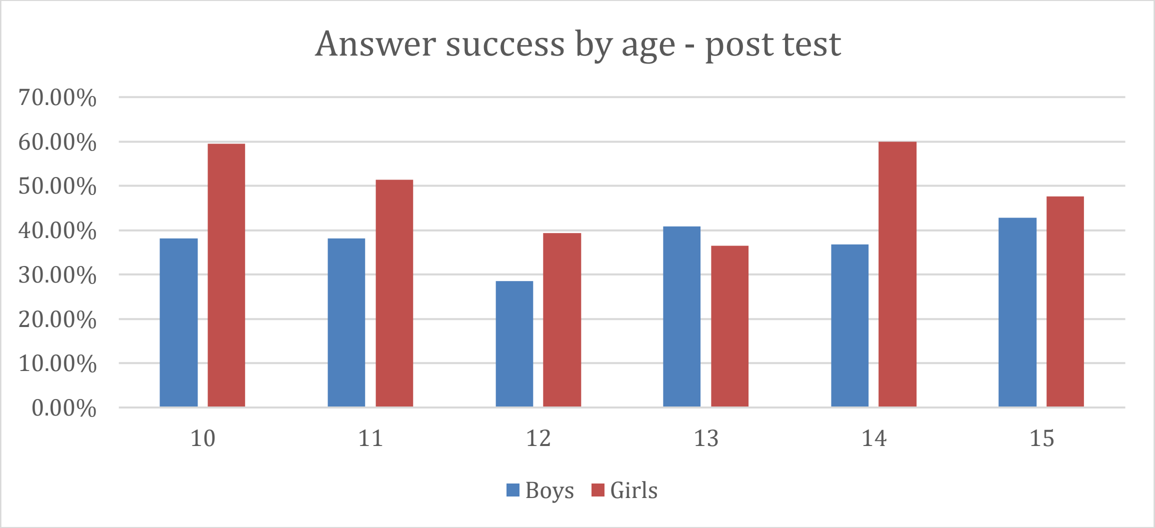

Figure 4: Success rate of pupils' answers by age in the post-test.

In the post-test, the overall level of knowledge shifts upwards – most bars are higher than in the pre-test, especially for girls. The spread of values ranges approximately between 30–60%.

- **10 years:** boys improve to roughly 40%, while girls reach almost 60%. The difference between genders after the intervention is very pronounced in favour of girls.
- **11 years:** boys slightly decrease to around 38%, whereas girls improve to approximately 50%. The original advantage of boys from the pre-test shifts in favour of girls.

- **12 years:** after the intervention, boys have a lower success rate (around 30%) than in the pre-test, while girls are slightly above 40%. Here too, after instruction there is a clear shift in favour of girls.
- **13 years:** in one of the few groups, boys are more successful after the intervention (around 40%) than girls (just under 40%). However, the difference is considerably smaller than among 10- or 14-year-olds.
- **14 years:** boys remain approximately at the pre-test level (around 37%), while girls improve markedly to about 60%. This is the largest observed gender difference in favour of girls.
- **15 years:** both boys and girls improve their results (boys to approximately 43%, girls to almost 50%), with girls maintaining a slight advantage.

The post-test thus clearly shows that girls benefited from the intervention more strongly than boys in most age categories. Gender differences, which in the pre-test were rather small and local (except for 11-year-olds), increase considerably after instruction in some ages (10, 11 and 14 years) in favour of girls.

Changes between the pre-test and post-test

When comparing the two graphs, several patterns can be identified:

1. **Overall trend of improvement**. In most of the age × gender combinations, the post-test bar is higher than in the pre-test, which indicates an overall positive effect of instruction. The exceptions are some groups of boys (especially 12-year-olds), where success rates decreased after the intervention.
2. **Strong effect among younger girls**. Among 10- and 11-year-old girls, there is a shift from low values (around 20–25%) to levels above 50%. This is the most pronounced relative increase in the entire dataset, which may suggest that project-based work with technologies activated a new interest in this group and supported rapid acquisition of basic concepts.
3. **Heterogeneous effect among boy.** Boys in most age categories show only a modest increase (e.g. 10, 13, 15 years), and in some cases stagnation or decline (11, 12, 14 years). This indicates that the intervention was not uniformly reinforcing for boys, and its effectiveness may be moderated by prior experience, motivation, or the way of working in classes, particularly.
4. **Change in the pattern of gender difference.** Whereas in the pre-test gender differences are often small and in the lower grades even in favour of boys, after the intervention the pattern changes: girls outperform boys in almost all ages except 13 years. This may mean that the implemented way of working is relatively more inclusive for girls and better supports their confidence in technical tasks.

From the results it can be concluded that the educational intervention leads to an overall increase in success rates in the tested knowledge. It has a particularly strong positive impact on girls in the younger and middle grades. At the same time, it changes the profile of gender differences from a slight advantage of boys in the lower grades in the pre-test to a prevailing advantage of girls after instruction.

6 Conclusion

The research findings indicate that a one-off experimental teaching intervention focused on working with the BBC micro:bit microcontroller and sensors in the MakeCode environment led to a modest but pedagogically meaningful improvement in pupils' knowledge. The average success rate in the knowledge test increased from 35.2% in the pre-test to 42.9% in the post-test, with a higher gain observed in sensors and hardware than in block-based programming. This suggests that a practically oriented activity involving real measurements and data interpretation can foster understanding of basic technical concepts, even when pupils start from a low baseline level.

In the area of block-based programming, pupils already possessed relatively good intuitive understanding of the basic concepts before the intervention, and the instruction further strengthened this understanding, particularly regarding the definition of "block-based programming." The procedural dimension, especially testing and debugging programs in the MakeCode environment, remained a weaker point. In the area of sensor work and hardware, the findings confirmed that pupils initially had very limited experience; after instruction, however, there was a noticeable increase in success rates on items focused on the operating principle of the soil moisture sensor and the interpretation of measured data, although the overall level of knowledge remains moderate.

The analysis of results by age and gender showed that the activity particularly benefited girls, who, after instruction, achieved higher success rates than boys in many age categories. This suggests that project-based work with a microcontroller can contribute to reducing traditional gender gaps in technical and programming domains and represents an inclusive approach for a broader spectrum of pupils.

At the same time, the results highlight certain limitations of the intervention. It was a relatively short teaching module, without a control group and with a natural drop in the number of respondents between the pre-test and post-test. For future work, it appears promising to expand the number of thematic blocks, include longer-term projects, and elaborate more thoroughly the didactic design of those areas in which pupils experienced the greatest difficulties (program testing, functions of hardware components). Despite these limitations, it can be concluded that the BBC micro:bit represents a suitable tool for developing basic programming and technical competences among lower-secondary pupils in the context of STEM and interdisciplinary education.

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