Robotics-Enhanced Natural Science in Primary Schools

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Abstract. The challenges of the 21st century and the modern age require people to have knowledge of the natural sciences and information technology [1, 2]. Ideally, these two disciplines should be combined in everyday life inside classrooms. However, this is often not the case, and students often only have access to such activities outside the classroom (e.g.: in workshops). As part of my research, I develop good practices that allow us to integrate projects from computer science (digital culture) classes into the natural science classes.

In my article I would like to present the first experiences of the practical implementation of my doctoral research, in which I am implementing natural science lessons with 5th grade children, where robotics is used as an illustrative, and modelling tool for different topics. This method has provided an opportunity to link information technology (IT) and natural science in primary schools, and to allow interoperability between the subjects in the framework of different projects.

My class of 22 students and I are using robotics as a visual aid in several places per topic. The specificity of my model is that students make these teaching tools themselves during IT lessons. In the process, children also acquire a basic knowledge of programming. The projects are carried out in groups, which allows them to develop several soft skills during these IT lessons, this adaptability and development are also very important skills in this day and age [3]. The natural science lessons are also carried out in a manner that provides new and exciting exemplification for all students, which is designed to increase and maintain motivation. In this article I would like to describe the themes of the lessons and the tools used. I will then describe children's results and their views on this way of learning, analysed through questionnaires and interviews.

Keywords: STEM · Robotics · Natural science

1 Introduction

Today, STEM subjects have a high priority in the labour market and unemployment rates in this field are below the EU average [4]. From the curricula that are built around and focuses on STEM, the good ones are those that provide opportunities for integrated education [5]. In Hungary, the National Curriculum and the Framework Curriculum based on it provide this possibility, but do not give teachers sufficient support or help in the practical application [6]. Therefore, it is important to develop a methodology

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that would stimulate children's motivation in these areas and allow for a high level of integration in natural science and technology, taking European educational trends into consideration. This would be necessary also because Hungary is below the EU average in the number of BA and MSc degrees in STEM subjects [7] and because the number of students entering higher education in STEM fields is decreasing [8].

Therefore, I would like to present a method that integrates robotics to a high degree in the natural sciences and uses technology as an illustrative tool in everyday lessons, but not in a ready-made form, rather prepared by the students. In this way, their skills in STEM, or more recently STEAM, are strengthened, as their creativity [9] and other soft skills are developed through design and implementation.

2 Presentation of Lessons and Tools Used

The lessons were implemented in normal classroom conditions in the upper, 5th grade of public education. It was essential that I taught both the natural science and IT subjects to the students. The group consisted of 22 students (11 girls, 11 boys). Two important factors were essential for the implementation. The first was the possibility of cross-curricular transfer. As I am also the class teacher, I had the flexibility to use the group's lessons. The other factor is having the right IT tools. At the moment, I think that this method can be achieved if one teacher teaches the two subjects. Unfortunately, this kind of cooperation between teachers is not really present in the Hungarian education. In the structures of the lessons, I will explain in more details why a very high level of cooperation would be necessary during these lessons.

2.1 The Tools Used

After reviewing the available IT devices on the market, and considering the feasibility, I decided to use the BBC micro:bit V2 board (Fig. 1). Several studies in the UK have demonstrated the effectiveness of these tools, highlighting that they can help girls to become more involved in IT and that a high proportion of girls would choose this career [10].

The hardware design of the device also influenced the decision, as the new version of the micro:bit chip has a speaker and a faster processor, and its energy-saving mode allows for longer use and also demonstrating the importance of sustainability for the young generation [11]. Finally, the price/performance ratio and the compactness of the device were considered, allowing the devices to be moved from one classroom to another. The tool was programmed in a block environment by the children.

However, given the specificities of natural science, it was necessary to expand the number of sensors[1] installed, since many of the processes that take place in nature are due to some other effects. For the extension we used the KS0361 (KS0365) keyestudio 37 in 1 Starter Kit for BBC micro:bit (Fig. 2).

[1] The basic device has the following sensors: accelerometer, compass, light sensor, thermometer, microphone.

Fig. 1. The new BBC micro:bit [11]

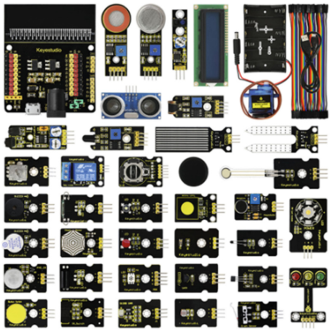

Fig. 2. Keyestudio 37 in 1 Starter Kit for BBC micro:bit [12]

2.2 Structure of the Lessons

The first step in delivering robotics-enhanced natural science lessons was to change the structure of the IT (now called digital culture) lessons. During the first semester, this was easier because the focus was on programming by default.

Children were introduced to microbits in a special way, as in some cases during the learning process we made tools with them in the digital culture lesson, which act as visual aids in the natural science lesson, as tools for independent models or experiments. And the integration of the use of these tools is and has been ongoing as the science curriculum has progressed throughout the years.

Considering this, every natural science lesson where we have used or will use the microbit should be preceded by a digital culture lesson where children could create and program the tools that we would later use in our learning. So, the subjects had to be in perfect sync with each other. If it had been implemented with more teachers, it would have required daily communication, full transparency and interoperability between the two subjects. I believe that this would only be possible in a few exceptional cases in our country. The situation is further complicated by the implementation of the digital culture curriculum at a time when the main focus is not on programming but on other subjects. In such cases, a flipped classroom approach was adopted, with a focus on independent task solving, and micro:bit emerged as a recurring curriculum for 1–1 lessons. The advantage of this is that the children's programming knowledge is kept up to date. The disadvantage may be that it requires more effort from the teacher's point of view to hold possible consultations and manage the class.

2.3 Presentation of Specific Topics Processed Using Robotics

During the first semester, two questionnaire surveys and one interview session were carried out. At the time of writing, three additional curricula have been integrated, but the results are still to be evaluated and the semester grades will provide a basis for comparison.

In addition to these, there were two smaller installations of micro:bit, but these were not surveyed separately. In one case, a purring kitten was implemented at the touch of the touch sensor, while in the other case I demonstrated the principle of the magnetic doors using a magnetic sensor, illustrated with an LED bulb. These demonstrations were not assessed separately because they were not created by the students but were presented as demonstrations used in a traditional way during lessons, as a simple experiment would be.

Body Structure of Plants - The Germination Process. In this project, we created a simulation to show students how the germination process takes place in nature. The existence of the conditions for the initiation of germination was monitored using a thermometer (P0) and a moisture sensor (P1). If all the external factors were present, the micro:bit display showed a plant emerged from the seed (Fig. 3).

The exercise is suitable for demonstrating simple condition checking and logical relations. Development possibility: to show the wilting process, the plant withers if it does not get enough light.

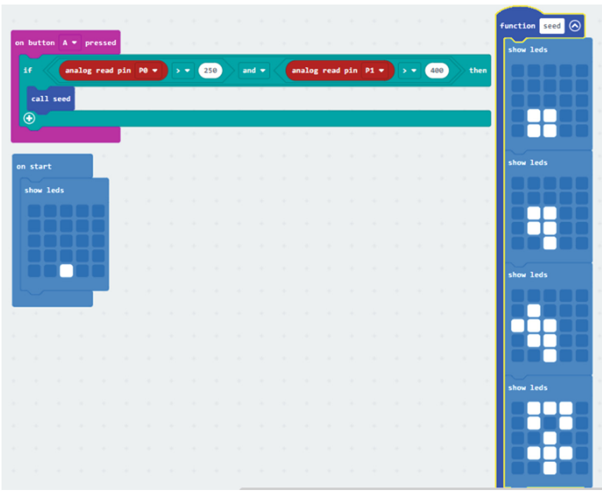

Fig. 3. The code of the germination project[2]

Animals Body Structure - the Honeybee. During the project, we needed two micro:bits that communicated with each other via a radio link. One device acted as

[2] https://makecode.microbit.org/_aVJVcWaEKaMM.

the flower and the other as the bee. The micro:bit acting as the bee made a buzzing sound when it moved, while the display showed an animation of a flying bee (Fig. 4). The other device initially displayed a flower on a tree, which would turn into a crop if the bee spent enough time near the flower to pollinate it (Fig. 5).

The exercise is suitable for demonstrating the principles of sending different radio packets, programming switches, and using variable handling.

A further link with mathematics was the introduction of the concept of absolute value, which was needed to handle the displacement of the micro:bit, since the acceleration strength alone did not provide a solution due to the effect of gravity.

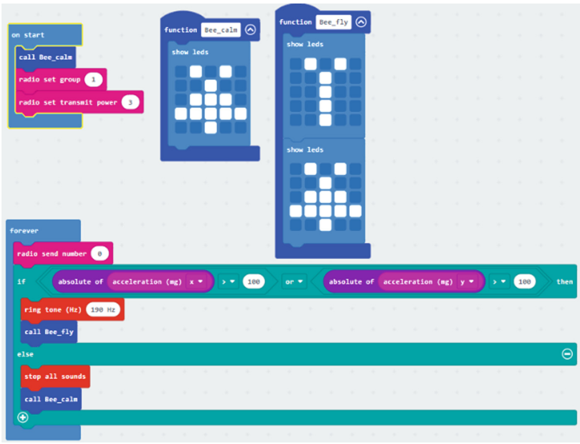

Fig. 4. The code of the bee[3]

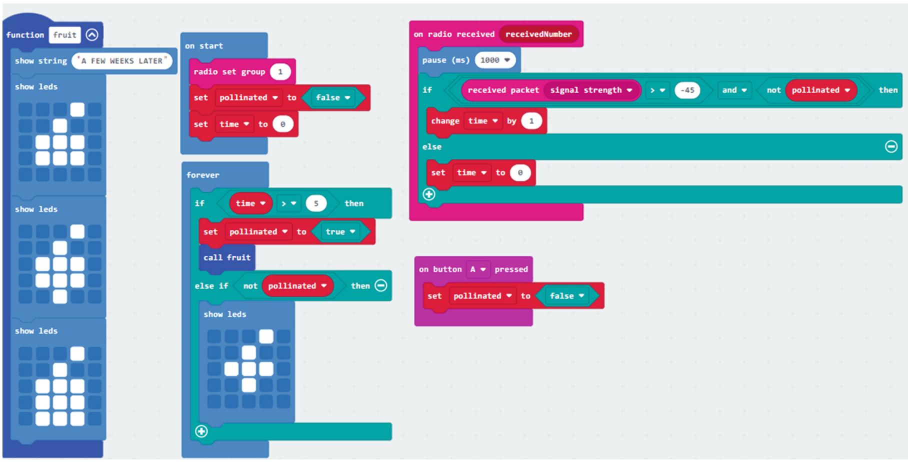

Fig. 5. The code of the plant[4]

3 https://makecode.microbit.org/_Yo3YcKi1MMPf.
4 https://makecode.microbit.org/_hFk4HACXqcRr.

Materials and Their Properties - Fire Alarm. In the next project with fire protection, we created a fire alarm with an LCD display that sends a text message to the user while a siren sounds if the flame sensor detects a fire.

The exercise is a good way to introduce cycles and to demonstrate how to connect the device to an external display, and to link the concept of the frequency of sound to physics. It can also be used to introduce the concept of multithreaded programming (Fig. 6).

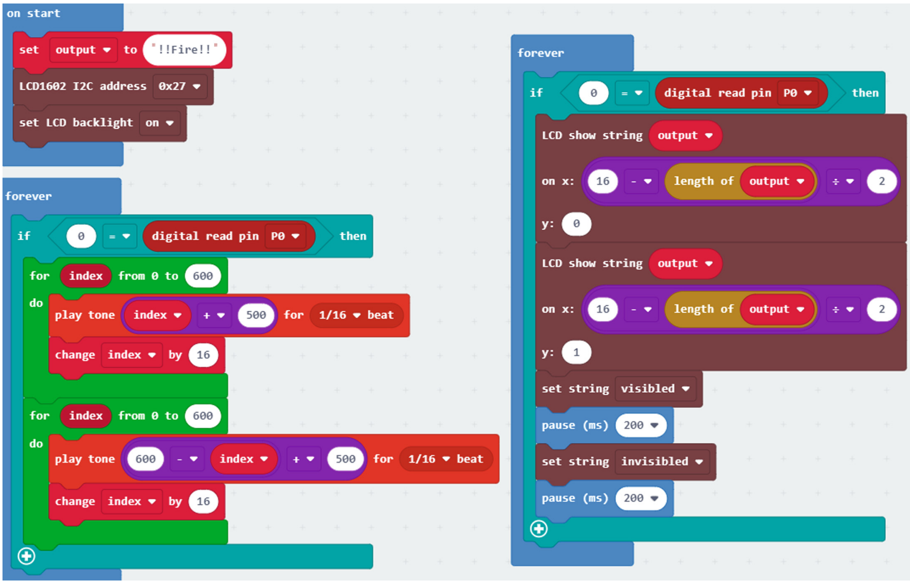

Fig. 6. The code of the flame detector

3 Students' Results Compared to Previous years

My students' grades are shown in the graph below in comparison to the results of the previous year group and the current 5th grade students.

It should be noted that during the school year, the grading options from teacher to teacher and the content of the end-of-term tests may vary, they are not standardised, but all classes follow the framework curriculum and use a uniform book on which teachers base their tests. Although the emphasis may differ in some places, but the topics and the outcome objectives are in any case the same. Accordingly, I have used the end-of-semester average rather than the total marks for my comparison (Table 1).

Looking at the trend of the semester averages, the best result is obtained by group 5.a, where the experiment is conducted. In terms of score, they scored 0.25 higher than any group in the last two years during the semester.

Table 1. Semester averages and class sizes of the examined classes

	5.a(2021–22)	5.b(2021–22)	5.a(2020–21)	5.b(2020–21)
Averages	4,64	4,20	4,39	4,11
Headcount	22	15	23	27

However, the groups differ greatly in terms of headcount, so it may be interesting to examine the proportion of the distribution of each grade[5] (Fig. 7).

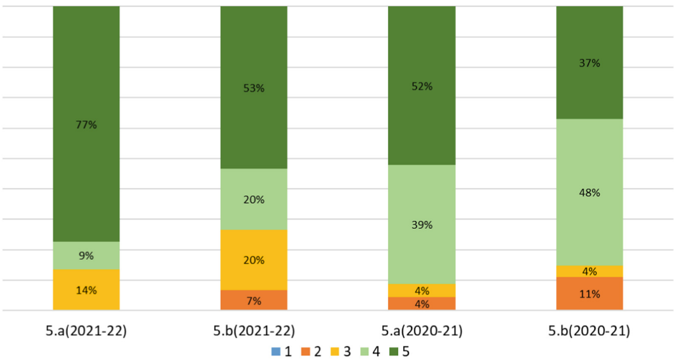

Fig. 7. Proportional distribution of natural science marks by class for the semester

I think the result is still telling, as more than three quarters of the group scored the highest marks, and no one scored a 2 compared to the other groups.

4 Feedback from Students

4.1 Feedback Through the Interview

I measured the students' impressions after the first session through an interview. In this context, I asked them if they had ever done programming before, how did they like this type of nature class, if they would like more, and what their feelings were and are before and after the session.

Of the participants, 5 had prior knowledge of programming. The session was not considered difficult by the majority, although there were 4 people who considered it moderately difficult. In the session where the tool was demonstrated, apart from one person who was not present for the demonstration, everyone gave positive feedback on how they felt about it. Unanimously, everyone wanted more classes like this. In this regard, 5 of the children said that the integration of robotics made it easier to understand the natural science material, 5 found the presentation of the processes interesting and

[5] In Hungary, this is on a scale of 1 to 5, with 5 being the best available.

good, and the rest gave the feedback that they simply liked it or found it exciting. From these results it seems that for everyone this was a positive experience, which could even have a positive impact on learning and the learning process. When asked how they felt before the lesson, most of the answers showed excitement and that they could not quite imagine how it could be done.

I also discussed the collaborative way of working during the interviews. All the respondents described positively what it was like to work in a self-organising team. One team had a problem with a team member with a confirmed attention deficit. The team was very patient with him, and this was reflected in his perspective as he was having a good time. Half of the respondents highlighted the fact that they could help each other and rely on each other. This confirms that the positive effects of this way of working includes building confidence, self-esteem, and a supportive environment [13].

None of the students would change the implementation of making, programming, and testing together in computer science class, and then using the tools as a demonstration tool in science class.

4.2 Results of the Two Questionnaire Surveys

In the following, I would like to review the results of the questionnaires completed after the two sessions. These questionnaires were conducted after the models were made, used, and presented. The questionnaires were completed digitally. Anonymity was not expected, as I developed the lessons based on these questionnaires in the meantime, however, giving their names was not mandatory. The relevant questions asked during the research were:

1. *How interesting does micro:bit make natural science lessons?*
2. *How much does micro:bit used in science class help you understand the given part of the curriculum?*
3. *How good do you think it is that I present certain parts of science with the help of robots?*
4. *Are you looking forward to the next time we use robots in a natural science class?*
5. *How exciting do you find these natural science lessons?*
6. *How often should micro:bits be used in natural science lessons?*

For **question 1**, there was one case of negative feedback on the first topic. In both cases, more than three quarters of the students said that the tool made the lessons interesting. The student who gives negative feedback is the finest student in the class. The background of the negative feedback was the new kind of tasks. In the process, it was often necessary to invent the solutions with their own ideas, and it was not possible to prepare for them at home, so the source of the problem was the fear of uncertainty in his case. In my opinion, one of the greatest problems of the Hungarian education system is that it gives little room for creative thinking and it puts more emphasis on lexical knowledge (Fig. 8).

For **question 2**, the numbers are more evenly distributed. Negative feedback was also received from one student, who in this case is the same respondent as the one who gave negative feedback earlier. At the end of the questionnaire, he commented that natural

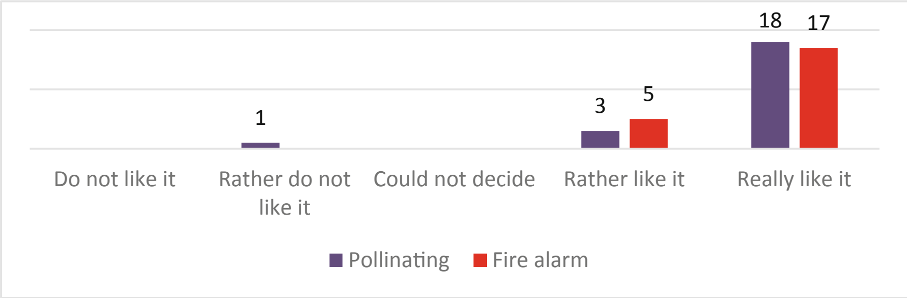

Fig. 8. Question 1: How interesting does micro:bit make natural science lessons?

science is interesting enough without robots. In my opinion, it will not be possible to talk about trends for this question in the future, since the difficulties of the processed material are not always the same, in this case the pollination process is much more complicated than the operation of a fire alarm (Fig. 9).

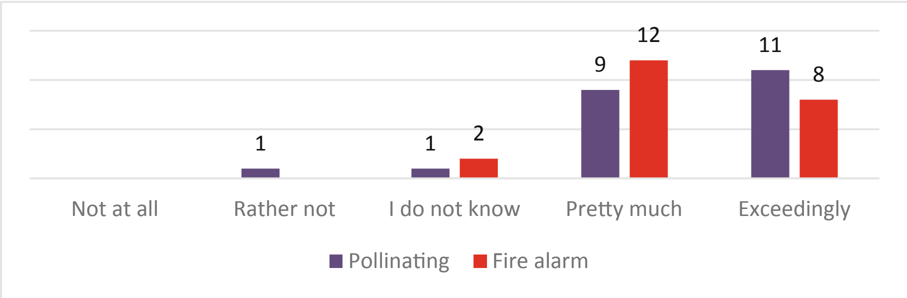

Fig. 9. Question 2: How much does micro:bit used in science class help you understand the given part of the curriculum?

For **question 3**, everyone gave positive feedback in both cases. The first session was marked in a 18–4 ratio and the second session was marked in a 20–2 ratio with the very and the quite options.

In **question 4**, 1 person indicated that they did not want to do more of the pollination project, 1 that they did not know and 20 that they would like to do more. For fire alarms, 21 people would like more and 1 did not know.

In response to **question 5**, 1 person also indicated that they were less looking forward to the next opportunity. 4 students were mostly looking forward to the next occasion and 17 were very much looking forward to the next occasion. After the fire alarm project, 4 people are "mostly" looking forward to the next robotics-enhanced natural science lesson and 18 are very much looking forward to the next one (Fig. 10).

According to the answers to **question 6**, after the pollination lesson, 17 people said that we should use the tools as often as possible. This number was 19 after the fire alarm. The monthly option was selected by 4–2 people and every two to three months option was selected by 1–1 people.

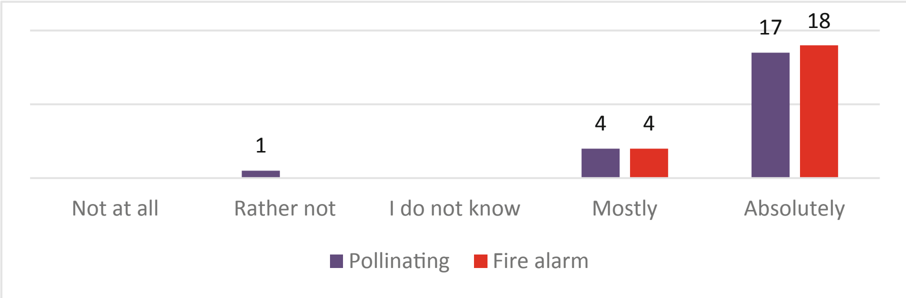

Fig. 10. Question 5: How exciting do you find these natural science lessons?

5 Summary

Overall, the questionnaires show that, looking at the average of the responses, we can see the beginning of an upward trend, with one exception. The aim of the sessions is to keep children's motivation for natural science and robotics at a high level.

However, the current domestic trends are in the opposite direction, which is why the survey could be considered successful even if the overall average of the converted value of the responses were stagnant. This would show that the interest and desire for further occupations would not wane, and in my opinion, this could be an influential factor in the direction of students' further studies. Of course, the integration of robotics is also important to improve students' understanding of the material, but it can also be used to stimulate their attention and motivation.

However, it is important to note that natural science education should not rely exclusively on robotics. The lack of experimentation in the classical sense is also a problem. It is necessary to find the proportions and to consider when it is worthwhile to approach the material from a slightly different angle, rather than the usual experiments and videos. Therefore, there is no concrete suggestion as to the intervals at which these tools can be used during the lessons. In addition to the above, the structure of the curriculum may also influence the possibility of integration.

The feedback from the first part of the research shows that it was a success, and an encouraging sign that robotics does have a positive impact on students, just as much as non-conventional teaching and learning methods. These include cross-curricular interoperability and modern 21st century ways of working, which natural science lessons are a perfect synthesis subject, offer great opportunities for.

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