THE MICRO:BIT AND COMPUTATIONAL THINKING. EVALUATION RESULTS OF A COMPUTATIONAL PROJECT

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ABSTRACT

The overall project *Denken lernen - Probleme lösen* has been expanded in recent years after an initial sub-project in elementary school to include one for the lower secondary level. Schools throughout Austria were provided with the micro:bit and related materials. A training initiative for teachers was rolled out. In this article I would like to present a part of the evaluation results of this project. The investigation covers two aspects: the students' ability to solve problems and the students' opinions and views on working with the micro:bit.

KEYWORDS

Computational Thinking, Computer Science, Creativity

1. INTRODUCTION

The project *Denken lernen - Probleme lösen* (Learning to think - solving problems, in short DLPL) was coordinated by the University College of Teacher Education of Styria and the Private University College of Teacher Education of the Diocese Linz and was carried out from September 2018 to April 2020. The aim of the project was to implement coding and robotics with the help of the microboard micro:bit in secondary level I schools. Computational Thinking is a term coined by Jeanette Wing (see section 2). The OER textbook for micro:bit was developed by people from six University Colleges of Teacher Education and the Graz University of Technology. This textbook does not contain instructions for reproduction, but ideas and approaches on how to use BBC micro:bits in a comprehensive way. This approach was intended to promote the activation of the learners and to raise their creative potential.

On the part of the project management, a multi-level concept of information events and training courses was developed. Meetings and training sessions were held with the state coordinators and the Education Innovation Studio contact persons at the universities of teacher education. Passing on information about the project and training the teachers in the schools was then the responsibility of the state coordinators of the project *Denken lernen - Probleme lösen*. The training courses were organized according to local conditions and were partly held on site in the schools.

The content concept of the project is designed for interdisciplinary use. The main focus is on working with micro:bit in the subject *Digitaler Grundbildung* (Digital Basic Education), but objects such as works of art, visual education, geometric drawing or physics are also suitable.

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2. PROJECT DESCRIPTION

2.1 BBC Micro:Bit

The hardware used in the project consists mainly of the BBC micro:bit and a small motor in combination with Matador components, which is also reflected in the project title "Computational Thinking, Coding and Robotics". This was accompanied by rolling cases with convertible laptops/tablets - depending on the wishes and availability for the participating schools.

As the name "BBC micro:bit" suggests, the British Broadcasting Corporation (BBC) is also behind this initiative - an allusion to the home computer "BBC Micro", which was used by the BBC in the 1980s for teaching and learning purposes on television. In October 2016, the project was transferred by its founders, including names such as ARM, Microsoft, Lancaster University, British Council, and others, into a non-profit foundation (Micro:bit Educational Foundation, 2016). Since then, this foundation has been responsible for the further distribution and support of the single-board computer, which is also available to private individuals through electronics retailers - currently priced between 16 and 28 EUR (as of December 14, 2020).

2.2 Scope of Functions

As can be seen in the schematic diagram (see Figure 1), the micro:bit has a size of four by five centimeters and is based on an ARM Cortex processor, similar to that used in today's low-cost smartphone. It has all the sensors usually associated with it, such as Bluetooth, temperature, compass, acceleration, brightness, and can be expanded via pins for external measurement and control and can be connected to a motor, e.g. with crocodile clips.

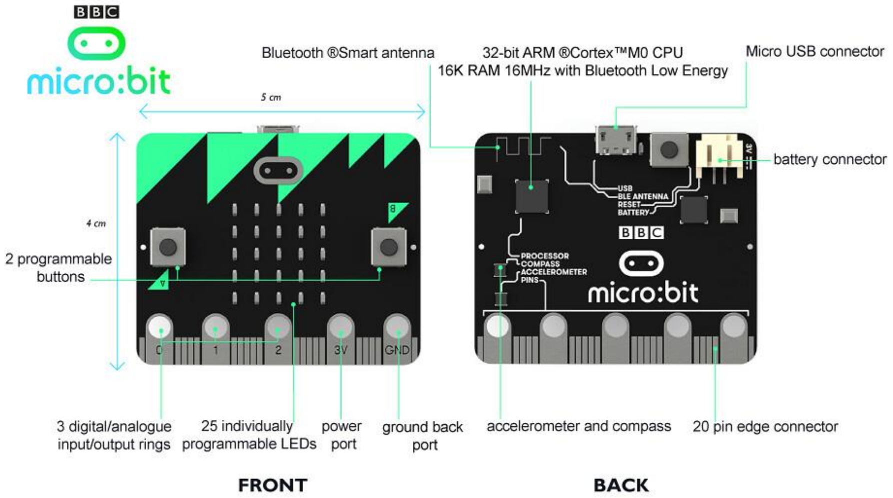

Figure 1. Front and back of the micro:bit, Gereth Halfacree, CC BY-SA 2.0, https://www.flickr.com/photos/120586634@N05/

To power the device, either the battery connector located on the top rear panel with a standard battery pack (2 AAA batteries) or the Micro-USB connector is used. This also serves to transfer the finished program to the micro:bit.

The 25 LEDs or the two programmable buttons on the front panel are used for input and output. On the back side between the Micro-USB connector and the battery connector is the reset button to reset the device and restart the current program.

The micro:bit is programmed with very little effort using MakeCode (Microsoft MakeCode, 2020). This visual, block-based programming interface, similar to Scratch (Scratch Foundation, 2020), runs without any installation in the browser and, in addition to the blocks, allows for advanced display in JavaScript - since the latest update even in Python. You can switch between the different views of the programming environment with a simple mouse click. Furthermore there are several other ways to program the micro:bit, which are not officially supported by the Micro:bit Educational Foundation. Worth mentioning are an offline Python editor with Intellisense for text input and the possibility to program directly in C/C+. For the work in the project the view in blocks was used throughout, suitable for the age level of the secondary school from 5th to 8th grade.

3. THE STUDENTS' ABILITY TO SOLVE PROBLEMS

The project *Denken lernen - Probleme lösen (DLPL)* pursued, among other things, the goal of promoting the students' problem-solving abilities. Computational Thinking as a concept was to be improved by the micro:bits as well as the materials created and made available. It is obvious to investigate whether this goal was achieved within the project. The research question for this part of the evaluation is therefore: To what extent was the problem-solving ability of the students promoted within the DLPL project?

3.1 Research Design

In order to answer the hypothesis, testing is preferable to observation or content analysis due to its construction (Schnell, Hill & Esser, 2011, p. 314). From the point of view of research design, the quantitative research method of a written survey using an online questionnaire was therefore chosen.

Computational Thinking is a concept of teaching and learning that consciously focuses on (digital) problem solving and thinking strategies of general relevance. The term refers "to the individual ability of a person to identify and abstractly model a problem, to break it down into sub-problems or steps, to design and elaborate solution strategies and to present them in a formalized way so that they can be understood and executed by a person or even a computer" (Eickelmann, 2018, p. 20). Learning is not primarily the digitalization of processes, but rather an individual problem-solving competence for action and decision-making - also independent of technical devices - which implies an own, very specific approach to the world and the environment. This is characterized by the following didactic design elements: (1) Decomposition - to logically structure complex problems into smaller parts, (2) Pattern Recognition - to recognize and describe patterns, (3) Algorithm Design - logical-analytical instructions and the design of solution structures, (4) Abstraction - the abstract development of concepts and (5) Generalize (Patterns and Models) as a recognition and understanding of generalized patterns and models in order to make them usable for different contexts of action (Himpsl-Gutermann, Brandhofer, Bachinger & Steiner, 2017; Brandhofer & Wiesner, 2018).

It had to be clarified how the construct problem solving capability can best be operationalized (Brandhofer, 2017; Brandhofer & Wiesner, 2018). A pragmatic approach was chosen: According to the Beaver Contest on Computer Science, task collections on computational thinking are available for secondary schools according to self-definition. The Bebras Initiative was founded in Lithuania in 2004. In the meantime numerous countries participate in the beaver competitions (Bebras, 2020). The tasks of the Bebras Initiative are described as follows: "Computational thinking involves using a set of problem-solving skills and techniques that software engineers use to write programs and apps. The *Bebras* challenge promotes problem solving skills and informatics concepts including the ability to break down complex tasks into simpler components, algorithm design, pattern recognition, pattern generalisation and abstraction" (Bebras, 2020). According to their own description, the authors of the Bebras materials aim to use the materials to quantify the students' problem solving ability. It was obvious to use these questionnaires to measure problem-solving ability. For the survey, the existing materials were used to create online test sheets. Each of the four questionnaires contained five tasks.

The goal of this evaluation was to explore the effect of a particular setting. Therefore, a longitudinal study was conducted with pre-testing, a treatment and a post-intervention test. To increase the quality of the results, the sheets were additionally presented to a control group that had not worked with the micro:bit and associated materials. Since the research question aims at a detectable clear change through an intervention, alternatives to the chosen method would have been less appropriate for answering the research question.

3.2 Pre-Test and Test Execution

To check the clarity and comprehensibility of the questions, to optimize the design and to estimate how much time should be available for the review, a pre-test was conducted with two school classes. The pre-test was also used to fine-tune the four questionnaires and to adjust their level of difficulty.

The survey was carried out by means of online questionnaires in the classroom. The teachers received the necessary instructions. The survey was carried out partially anonymously, student names were replaced by codes. Demographic data was collected on the type of school, grade level, date of birth, state and mother tongue. In addition, there were questions about the number of micro:bit teaching units, the subject in which the work with the micro:bit was carried out, and the use of the OER textbook. A total of 1341 students took at least one test, of which 778 students took both the pre-test and the post-test, 553 of which were students from the DLPL project classes. 129 students took the post-test but not the pre-test. Of the participating students, 79 stated that they were in the fifth grade, 84 in the sixth, 254 in the seventh and 181 in the eighth grade, with the rest not specified. The survey was conducted between March 2019 and April 2020.

3.3 Descriptive Evaluation

Most of the students who took part in the online survey came from Lower Austria, Styria and Salzburg. Vorarlberg and Burgenland were not represented. The majority of the students who took part in the online survey attended a general secondary school (AHS). In 80.5 % of the cases the BBC micro:bits were used in computer science. In addition, the BBC micro:bit was also used in math, physics, works, music, Education in arts and crafts, movement and sport, religion, descriptive geometry as well as in project teaching (e.g. MINT) or in social learning.

The students needed on average 10 min 43 s for the Pre-test. The maximum was 31 min 41 s, the minimum 2 min 22 s. For the Post-test, the average duration of work was slightly longer at 12 min 54 s (min = 2 min 28 s, max = 36 min 51 s). A closer look at the results shows that the student with the shortest working time achieved a slightly below average but good result in the Pre-test with 24 points. The student who took the least time to complete the post-test achieved a score of 40 points, well above the average.

3.4 Evaluation of Problem Solving Ability

The mean value of the achieved performances increased slightly in the DLPL Group 5/6 ($M = 30.59$ / $M = 31.37$). The post-test showed a slightly lower standard deviation ($SD = 14.85$ / $SD = 12.79$). The control group 5/6 fell slightly behind in the post-test ($M = 35.14$ / $M = 33.43$). The standard deviation remained almost constant ($SD = 14.79$ / $SD = 14.93$).

In the Pre-test, the mean value of the services performed was significantly higher in the control group. The difference in post-test performance between the DLPL group 5/6 and the control group 5/6 is not significant ($p = 0.957$), nor is it significant in the pre-test ($p = 0.233$).

The mean value of the achieved performances slightly decreased in the DLPL group 7/8 ($M = 33.65$ / $M = 33.41$). The post-test showed a slightly lower standard deviation ($SD = 13.52$ / $SD = 16.64$). The control group 7/8 achieved slightly lower values in the post-test ($M = 26.89$ / $M = 25.91$). The standard deviation was slightly higher in the post-test ($SD = 13.93$ / $SD = 14.34$).

The difference in post-test performance between DLPL group 7/8 and the control group 7/8 is significant ($p = 0.032$), while it is not significant in pre-test ($p = 0.867$).

The online survey also asked for the number of teaching units in which the micro:bit was used. The analysis of these results clarifies the picture very clearly: Within the DLPL group, micro:bits were used with varying intensity. There were also students in the DLPL groups who did not work with micro:bit in any of the lessons and thus could be assigned to the control group. Therefore, the following analysis of the values was based on the number of teaching units worked with the micro:bit.

A correlation analysis of the number of teaching units with the micro:bit and the results obtained in the post-test yields a correlation of 0.87 between these two values. The correlation according to Pearson is significant ($p = 0.03$). This means that there is a significant correlation between the number of teaching units in which the micro:bit was used and the ability to solve problems.

More detailed analyses show that the scores achieved by the students who worked with the BBC micro:bit in the 5th and 6th grade were about 4 points higher than those of the boys, both in the pre-test and in the post-test. In the 7th and 8th grades, girls scored better on the Pre-test (M = 34.1) than on the Post-test (M = 31.44). While the scores of boys increased, those of girls decreased. When the Pre-test and Post-test results are added together, the girls' overall performance (M = 66.07) was significantly (p = 0.035) better than the boys' (M = 63.00).

Among the students participating in the survey were 120 students whose first language is not German. The evaluation showed that in the DLPL group 5/6, the results of students with a first language other than German were about 7% worse in both the pre-test and the post-test, and about 3% worse in the DLPL group 7/8. It is therefore reasonable to assume that the complexity of the respective task text has an influence on the results achieved. However, a text analysis with regard to the readability of the analysis tools LIX3 and Wortliga4 did not show a clear correlation between the difficulty of the text and the respective mean value of the achieved points for the corresponding question. The Pre-test showed that example 5 was the most difficult text to read for grades 5 and 6 (LIX: 40.8; Wortliga: 34), while example 3 was the most difficult text for grades 7 and 8 (LIX: 47.3; Wortliga: 33).

4. STUDENTS' OPINIONS AND VIEWS ON THE PROJECT *DENKEN LERNEN - PROBLEME LÖSEN*

In addition to the study of problem-solving ability, the opinions and views of the students were also of particular interest. The question that interested us: What are the opinions and views of the pupils on the project *Denken lernen - Probleme lösen* and its concrete implementation at the school location? This can be divided into the following sub-questions: What did the pupils like about the project, what did they like less? How did the concrete work with the micro:bit in class look like? How were different teaching materials used? What is the students' opinion about micro:bit, programming and computer science education? How was the social environment of the students involved in the project?

To answer the research question and the sub-questions, the guideline interview with open questions was chosen as the survey instrument. The guide for the interviews comprised 14 questions. The interview partners were students from the secondary school of the University College of Teacher Education Lower Austria. The aim was to reconstruct the subjective view of the interview partners. The guideline provided orientation within the topic and was intended to make the individual interviews comparable with each other.

For data backup purposes, the interviews were recorded with the consent of the respondents. All data was anonymized. The data preparation was done by transcription. Subsequently, the transcripts were evaluated using the qualitative content analysis according to Mayring (2003). For this purpose, the answers were first paraphrased, then generalized and reduced so that a categorization was possible. The categorization was deductive and was based on the content areas of the questionnaire (Mayring, 2015, pp. 97-114).

4.1 Presentation of the Results

In January 2020, seven interviews were conducted and the subjects were chosen at random. The sample consisted of students in grades 4D and 4F of the Practical Secondary School of the University College of Teacher Education Lower Austria. According to the timetable, the students of this school have one hour of computer science lessons per week from the 2nd to the 4th grade. Further interviews at two project schools were planned for spring 2020. Due to the pandemic-related changeover of teaching to distance learning, the interviews could not be conducted.

4.2 The Lessons with the Micro:Bit

One result of the categorization is that the topic of teaching design was the most frequently represented, accounting for about 20% of the responses. The students were very satisfied with the use of this topic in class. A total of ten teaching units were used for the micro:bit. After a theoretical introduction, the students were able to learn how to use and program the micro:bit using concrete examples. Subsequently, more open tasks were set, which could then be solved individually or in a team. Some students were unfamiliar with this type of task. Student A said: "And when I made the Blackjack, I was only given the assignment, I was not given precise instructions." Again, student A: "Then you had to try and experiment and do it yourself."

In case of questions, the teaching materials, the classmates or the teacher could be consulted. Pupil A: "If you were stuck, then Mr. N. helped a little." The handbook as well as the wiki were used as framing. The students also had to answer the questions about the beaver contest on computer science (Bebras, 2020). The difficulty of these questions was judged very differently by the pupils. Schoolgirl S.: "Some questions were difficult. In contrast, student E.: "They were about logic and actually not very difficult." These different points of view are important and must be taken into account in the further roll-out of the project.

4.3 Tasks and Examples for Micro:Bit

In 11% of the statements of the students, concrete tasks and examples were programmed in class or at home (materials: Bachinger & Teufel, 2018a, 2018b; Micro:bit Educational Foundation, 2016). They mainly reported on the development of the tasks 'Scissors, Rock, Paper', 'Blackjack', 'Ping' and their own creations. They also remembered more difficult tasks, such as the communication between two micro:bits. The examples were well received. Student A: "You could enter many commands, you could be creative." In summary, the tasks corresponded to the students' level of knowledge and were well graded. Step-by-step examples were followed by more open tasks.

4.4 Technical Challenges

Technical peculiarities and problems when working with the micro:bits were also addressed. However, the problems described were obviously not based on bugs of the micro:bits, but rather on misjudgements in the handling. One student reported that his created program was not saved, a student told that her mico:bit crashed and the program was lost. In the interviews, however, the shortcomings described were very minor, rather the technical possibilities of the micro:bit were mentioned. Mentioned was the stand-alone version with the battery pack and the possibility to continue programming on the platform at home.

4.5 Learning with the Micro:Bit, Challenge Reading

According to the categorization, 9.4% of the students' statements could be assigned to the area "Learning with the micro:bit". Initial ambiguities (student D: "At the beginning I did not understand anything because it sounded like computer language to me.") were quickly followed by feelings of success (student A: "Yes, that actually explains itself with the micro:bit"). The pupils recognized that one had to work already exactly, precisely (pupil D) and bring along an understanding for variables (pupil S).

Due to the numerous mentions, a separate category was created for the topic "reading", 5.1 % of the statements referred to it. The students found it particularly challenging to read, analyze and implement the tasks. Student D: "Only my weakness is reading. I hate to read. And you always had to read. "Student E's statement summarizes this very well: "If you can read, you have an advantage."

4.6 The Social Environment

The students were also asked with whom they had talked about the project from their family and circle of friends. What is striking about the answers is that they were not asked by their parents, but some of them reported back home. The parents were informed in advance by the project. Pupil D: "Nobody at home asked about it now and then I just told them. Similarly, student T: "I told my dad, but he doesn't understand all this. More frequent were discussions about the project with older and younger siblings. Some of them also worked together on a project at home. Pupil A finally got two micro:bits as a Christmas present from her brother, and they experimented with them afterwards.

4.7 The Micro:Bit, Opinions about the Project and the Professional Future

The personal opinions on the work with the micro:bit comprise 10.6% of the answers. The result is a heterogeneous picture: While some were enthusiastic about the board, others saw it in a more differentiated way and two initially stated that they did not like the project that much. Schoolgirl K: "It was once a change and was pretty cool."

A noteworthy development occurred with student D during the interview. When asked at the beginning what he liked about the project, he said: "Should I be honest? Not at all. I hate working with these things." In the course of the interview, however, he expressed his satisfaction with the introduction of the micro:bit in class: "Yes, I also think Mr. N. explained it well." He then reported in detail about the individual examples and that he enthusiastically told his brother about the project. It finally turned out that his initial reluctance was more related to the fact that he had to read through assignments. Student D: "You had to read through the assignments. Then I just read through them. I also checked it, but you had to read through it several times. You also have to understand it. In retrospect, I understood it anyway."

A homogeneous picture can be drawn by the statements of the students about the meaning of the work with the micro:bits for the vocational future. The unanimous opinion is that if one wants to become a programmer later, the experience with the micro:bit is valuable. If one does not intend to do so, it is interesting, but not necessary. As an example for this, the statement of student K can be used: "For someone who wants to become a programmer later on, it is fine because it is an experience, but for me, for example, it is not really useful". And student S: "Only, I know that I don't need this for the rest of my life, because I won't be programming or something." Similarly student E: "I liked the fact that you could program games together with others." Student C states: "This is a kind of programming for beginners. If someone wants to be a programmer, I would say, yes, that's very good and important. Two students stated that they want to become programmers later.

5. SUMMARY

The evaluation of the data confirms the hypothesis that working with the micro:bit has an effect on the students' problem-solving ability. The longer the students worked with the micro:bits in class, the better the results of the post-test with the beaver tasks. Within the DLPL group, the school classes worked with the micro:bits with very different intensity.

Overall, the girls scored better on the assignments. The understanding of the text is probably a relevant factor in the processing of the tasks, this thesis is confirmed by the interviews with the pupils.

The design of the lessons with the micro:bit, the increasing difficulty of the tasks and the accompanying materials were perceived positively by the students. The problem-oriented, open learning setting was unusual for some. The technical problems were limited and were not necessarily micro:bit-specific. The reading of tasks turned out to be the biggest hurdle, which was also recognized by the students themselves. The class teacher also noticed that some students had little stamina for certain tasks. The parents asked the children very little about the project, but with their siblings the students partly had an intensive exchange about the possibilities of micro:bit. In summary, it can be said that the project was well planned and implemented in a goal-oriented manner from the perspective of the students at the respective school. Some aspects that emerge from the answers are not limited to the micro:bit project, but must be seen more comprehensively (text comprehension, ability to concentrate, communication, professional expectations).

In summary, the results of the evaluation of the project Denken lernen - Probleme lösen, Secondary Level I are consistent with the findings of the project Denken lernen - Probleme lösen, Primary Level (Himpsl-Gutermann et al., 2018, see also Antonitsch & Hanisch, 2014 and Repenig, 2016). As other studies have also shown (Denning & Tedre, 2019; Eickelmann et al., 2019, p. 382), it has been shown that computational thinking as a metacognitive ability is in itself difficult to teach or promote and must always be embedded in contexts - in this case, the system micro:bit. The project was conceived on the basis of the discourse on computational thinking and the orientation of computer science in schools (Gesellschaft für Informatik, 2016; Bollin, 2016, p. 23, Bollin & Micheuz, 2018), so the results are also relevant for the further development of computer science in Austria.

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