ICETA 2020

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Information and Communication Technologies in Learning

November 12-13, 2020

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Website: http://www.iceta.sk

ISBN: 978-0-7381-2366-0
IEEE Catalog number: CFP2038M-USB
Proceedings editor: František Jakab

Wearables: Educational Projects Made with the BBC micro:bit

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Abstract— **BBC micro:bit is becoming more and more spread in Slovakia last years. As it is spreading around the world, extensions allow to be more creative. One of extensions for BBC micro:bit is wearables. Wearable technologies in general can be smartwatches, fitness trackers, VR. As a BBC micro:bit extension it means to make wearable technologies from the very beginning. It is an opportunity for pupils to understand how things work in our everyday life. The article deals with BBC micro:bit and its extension, wearables, to create projects such as plushie toy, headband and postcard.**

I. Introduction

BBC micro:bit is a pocket-sized microcontroller or physical computing device. It is spread around the world, including Slovakia, past years. There is a built-in display, two buttons, Bluetooth Low Energy wireless communications or simple sensors for motion, temperature and light. It was made especially for educational purposes in comparison to other microcontrollers such as Arduino. BBC micro:bit was firstly presented in the United Kingdom as a part of Make it Digital in 2015 [1]. Nowadays it is programmable in block editor Microsoft MakeCode, MicroPython or JavaScript.

BBC micro:bit supports an approach where the knowledge is actively constructed by the student [2]. The approach is called constructivist learning theory. Papert introduced the term constructionism that connect constructivism and hands-on construction [3]. He believes the ideal learning is where the pupil is consciously engaged in constructing a tangible, real, visible thing – not matter if it is a sandcastle or a theory of universe. Stiller thinks physical devices such as BBC micro:bit follow a pedagogy of incremental problem-solving [4]. It means pupils can learn by building on existing knowledge and it causes and exploratory bricolage approach. Bricolage is a construction created from a mixed or variety of available things. The term things can be substituted for knowledge. Constructionist approach is present also in Slovakia [5].

Likewise, there are other advantages – motivation, tangibility, collaboration, and creativity [1] (Fig.1). When a programming task provides a practical, meaningful product or project, the outcome including the learning experience is motivating. Natural connections are supported by the tangible nature of BBC micro:bit. It can be iteratively debugging and refining tangible systems which causes a better understanding of programming concepts or the software development process. The output of the product is seen, held and perceptible by touch. The pupils can be divided to different roles by collaboration. When talking about BBC micro:bit, it can be case design, hardware interfacing, algorithm design or user interaction. Moreover, the pupils could not only collaborate but also compete. One way how to strengthen engagement with the task is a to implement creativity to the learning. Engagement is also one of the components of effective pedagogy [6].

Figure 1. Advantages of BBC micro:bit

II. BBC micro:bit in Slovakia

One of the first to introduce BBC micro:bit to Slovakia was Marek Mansell, who, as one of the co-founders of the project, founded the civic association SPy o.z. and deals with the issue of hardware programming [7]. The aim of the project is not to make all students of informatics, but on the contrary, to teach everyone at least the basic concepts of informatics and electronics so that students can use them in programming and use them in practice. As such, the project supports the algorithmic and logical thinking of students and leads them to self-education and creativity. It prepares them for orientation in the market based on IoT (Internet of Things) or Smart City concepts.

The materials created by the organization are not intended to replace today's curricula, but on the contrary - to enrich them and make them more engaging for students, to support their experimental and research activities and to develop problem-solving skills in teams [4]. Mansell makes his project known to teachers and students through workshops, where he presents educational materials created by SPy.

Nowadays, the SPy organization has its own project called Teaching with Hardware. One of the author of the contribution is in the team as a volunteer. In 2020 educational materials are increasing and dividing. At this moment there are lessons for lower-secondary and high schools from beginners. Advanced or extended lessons are wearables and people from the Python or BBC micro:bit community send us lessons in Slovak language which are developed by them as teachers or parents. Fig. 2 describes lessons or other form of educational materials.

Figure 3. Educational materials

III. PROJECT-BASED LEARNING

The described lessons of Teaching with Hardware uses the project-based learning. Connected to constructionism, it is a systematic learning and teaching method, which engages pupils in complex, real-world tasks resulting in a product which enable them to enhance knowledge or life skills [8]. Main connection to constructionism is the central activities involve the transformation and construction of new knowledge. The main aim is the project itself and defined as "an act of creation over time" what distinguish it from instructional approaches. Project has two components; a question that wants to be answered and motivate pupils, and product representing pupils' solutions or answer the question. Project-based learning has following attributes [9]:

- self-organization
  - the student learns to organize his activity, to plan, to make decisions,
- responsibility
  - strengthening motivation, self-confidence, responsibility for their education, participation in the creation of assignments and the method of implementation,
- product orientation
  - tangible result of work on the project to be evaluated,
- complexity
  - connection to the real world,
- practical activity
  - active and constructive work is required,
- orientation to the interests of students
  - increases internal motivation,
- situational aspect
  - the project results from a certain situation, adapts to the situations that have arisen,
- social interactions
  - communication in the team of researchers, comparing work with other classmates, communication with the teacher, evaluation of own and foreign projects.

Lessons described in the following chapters fulfill these attributes.

IV. CREATIVITY

One of attributes included in constructionism and project-based learning is creativity. Creativity is derived from the Latin word creatio, which means creation. There are many definitions what creativity is. One of them is the ability to create that exists in a potential state in every individual and at every age; an activity that brings hitherto unknown and at the same time socially valuable creations valuable not only for the creator but also for society; mental ability, which is based on cognitive and motivational processes, which include inspiration, imagination, intuition; it can be the ability to invent something new, the attitude to accept something new, for example change, a process characterized by work, systematic thought activity of creating new solutions [9]. Although every human being can be creative, some are more creative and some are less. Among the character traits of a creative personality we include optimism, responsibility and others defined in the Fig. 3.

Creativity has its place also in education. In 1956, Benjamin Bloom with teammates Max Englehart, Edward Furst, Walter Hill, and David Krathwohl distributed a system for sorting educational objectives: Taxonomy of Educational Objectives [10]. The taxonomy was divided into six significant categories: knowledge, comprehension, application, analysis, synthesis, and evaluation. Knowledge includes the review of specifics of methods and processes, the review of strategies and measures, or the review of a structure, setting or pattern. Comprehension alludes to a kind of understanding that the pupil knows what is being conveyed and can make use of the material or idea being imparted without essentially relating it to other material. Application alludes to the use of abstractions in specific circumstances. Analysis speaks to the breakdown of a communication into its constituent components or parts with the end goal that the overall progression of thoughts is clarified as well as the relations between thoughts communicated are made express. Synthesis includes the assembling of components and parts in order to shape an entirety. Evaluation incites decisions about the estimation of material and techniques for given purposes.

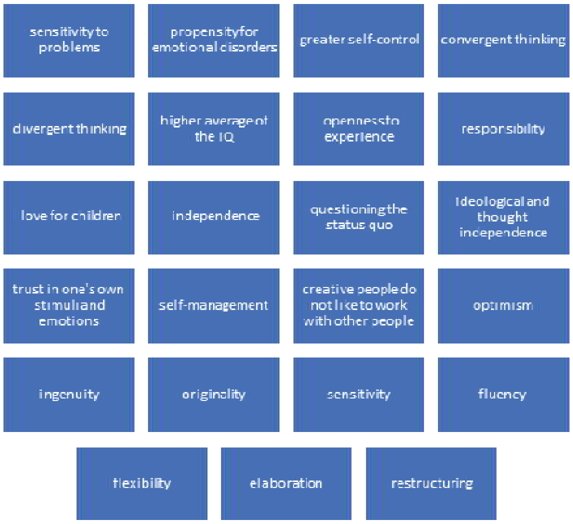

Figure 4. Attributes of creative individual

In 2001, specialists of cognitive psychology, curriculum theory, research and testing published a revision of Bloom's Taxonomy with a title A Taxonomy for Teaching, Learning, and Assessment [11]. The main aim was to focus on dynamic conception of classification. The creators of the changed taxonomy underscore this dynamism, utilizing action words and gerund ("ing" words) to name their classifications and subcategories (instead of the things of the first taxonomy). These "action words" are remember, understand, apply, analyze, evaluate and create. We can see the last two categories are changed as it seen in the Fig. 4 The highest order thinking skill is creativity.

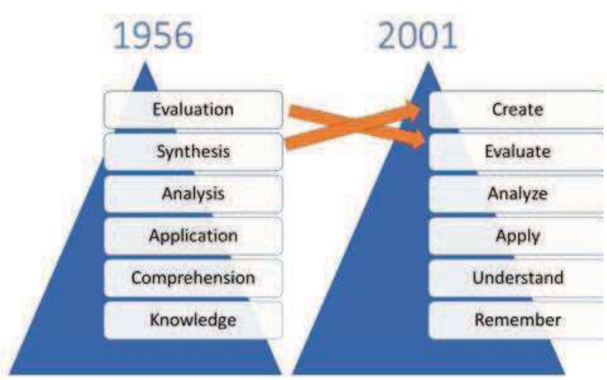

Figure 5. The Bloom's Taxonomy

M. Zelina, one of the leading Slovak authors in creativity, developed his own Taxonomy of Cognitive Functions [12]:

- sensorimotor functions,
- memory,
- lower convergent processes,
- higher convergent processes,
- evaluative thinking,
- creative thinking.

To elaborate, we can see how important creative thinking in education is.

V. WEARABLES

Wearable electronics are similar to wearable computers. The difference is in executing multiple tasks, where wearable electronics are mainly produced for a set of tasks. Most of them are worn on the body or linked to the wearer's body or clothes, e.g. with a conductive thread. One of universities pioneering in wearable technologies was Massachusetts Institute of Technology (MIT) [13].

When connecting wearables and BBC micro:bit, there are some components which differ from elementary project lessons used with BBC micro:bit. They are electrically conductive thread, LED diodes, MI: Power Board.

A. *Electrically conductive thread*

This thread replaces crocodile clip cables and is made of most silver parts or stainless steel (Fig. 5). It can be bent and when we sew it on clothes, it holds its shape.

Figure 6. Conductive thread

B. *LED diodes*

There is another difference between wearable and conventional electronics. These are LEDs designed for sewing on textiles (Fig. 6). What are their basic differences? First of all, it's their size. LEDs intended for sewing are smaller, their case is not as convex as with conventional LEDs. However, there is another difference, namely the legs. Instead, they have electrically conductive circular shapes on both sides, which are cathodes and anodes. In addition to these features, there is another that is very important. When connecting a common LED diode, we usually need a resistor, which we add to the electrical circuit. We don't need any resistors with a wearable LED diode, because they are already automatically built into the area where the LED is located. With such a solution, we get a great advantage - we do not have to sew a separate resistor and LED, or solder them.

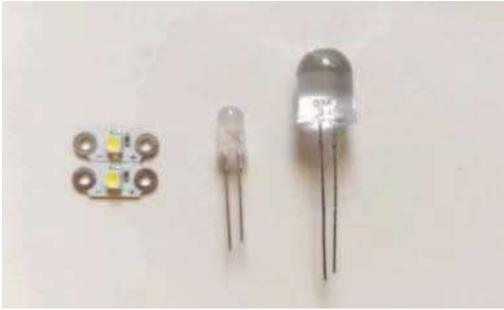

Figure 7. LED diodes

C. *MI:Power Board*

The third biggest difference is the power supply (battery). While commonly available AAA batteries are too large for wearable electronics and are also heavier, we use a round ("flat") 3V battery, which is inserted into the MI: Power Board (Fig. 7). The board is connected to the pins on the BBC micro:bit using screws and nuts (both are conductive), which will make our work easier when sewing. In addition, the board contains not only a flashlight holder with a switch, but also a small speaker.

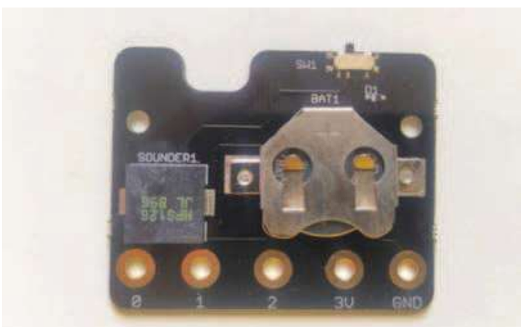

Figure 8. MI:Power Board

VI. METHODOLOGY

Our research was held in October 2020. We decided to include lower-secondary pupils from the School of Prince Pribina in Nitra, Slovakia. Our research method was observation if the educational objectives are accomplished. The cognitive objective has been*: The pupils are able to create projects of wearable electronics with the support of tutorial.* The affective objective has been*: The pupils have a positive attitude to the topic (wearables), BBC micro:bit and project-based learning.* The psychomotor objective has been: *The pupils are able to manipulate with the conductive thread and needle.*

VII. EDUCATIONAL MATERIALS

In the following chapters we would like to present our "lessons" which are educational tutorials based on project-based learning with the focus on creative thinking. Projects are called Postcard, Headband and Plushie. Some chosen parts of lessons are presented.

A. *Postcard*

The postcard can have a different shape, such as a rectangle, square, four-leaf clover, or heart. It should meet the following rules: it can be closed; both geometric shapes are connected in one part; both geometric shapes are the same size.

1) Connecting LED diodes

We connect the LED diode by sewing from the GND crocodile clip to the negative part of the LED and end sewing with a knot. We start a new sewing in the crocodile clip of pin 1, continue with the front stitch and end it with a knot in the plus part of the LED diode.

2) Programming

We want the micro:bit to do something only when the postcard is opened. So we have to measure the intensity of the lighting. Since we do not have such a sensor, we use an LED display built into the micro:bit, which measures the incident light on the LED display. The value of illumination ranges from 0 to 255, where 0 is complete darkness and 255 is the brightest light.

When will we measure the lighting level? Every time, because we don't know when we'll open the postcard. We will use the cycle always and in it the condition if the truth then otherwise from the category of logic. The condition must determine what to do. We will again use the logic category and select the comparison 0 = 0. In addition, we will select the lighting level from the input category. We will ask if the light level has any value, for example 20. We do not select zero because it is not guaranteed that there will be a complete zero when the postcard is closed. Thus, if the lighting level is greater than or equal to 20, something will be done. Otherwise nothing will be done (Fig. 8).

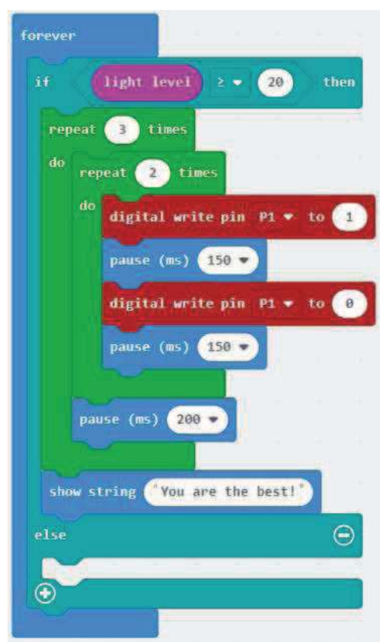

Figure 9. Postcard code

3) Heart palpitations (cycle in cycle)

Since the postcard is heart-shaped, we want the LED to flash like a heart when opened. That is, twice in a row and then a longer pause. Create a cycle to repeat 2 times and flash the LED using the commands digital write pin P1 value 1, pause (ms) 150, digital write pin P1 value 0, pause (ms) 150. Thus we have 2 flashes in a row. We still need a longer pause and we will create that by pausing after the cycle... We download the program, we can still beautify the postcard with shimmering glue and donate the Valentine's postcard (Fig. 9).

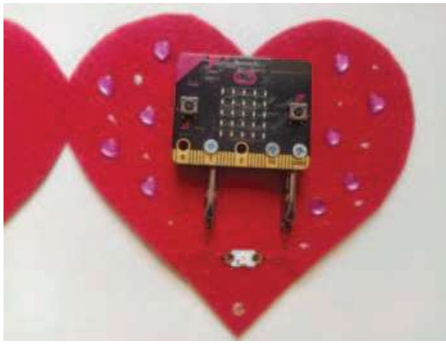

Figure 10. Created postcard

B. *Headband*

You will definitely know luminous headbands. Have you thought about creating a luminous headdress according to what you like? You will need components in the Fig. 10.

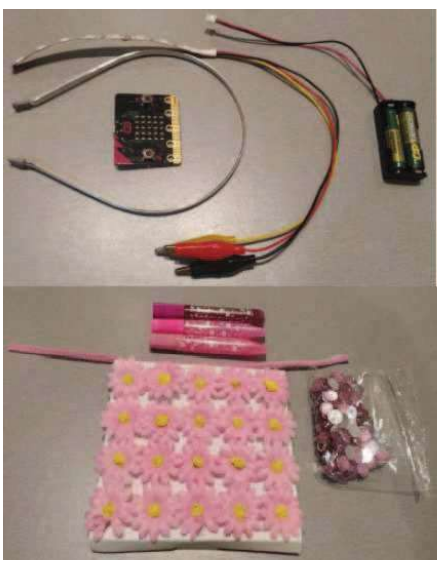

Figure 11. Components for headband

1) *NeoPixel strip*

A NeoPixel strip is a sequence of consecutive LEDs in parallel current. With the NeoPixel strip, we can program each LED individually and adjust its colour and light intensity (Fig. 11). How to connect? We connect the black or white cable to the ground, i.e. the GND pin. Connect the red cable to a constant voltage of 3V. Yellow or green cable means the data flow, i.e. instructions that determine the individual LEDs how to behave. We connect it to programmable pins. The LED strip should be sticked symmetrically to the center of the headband.

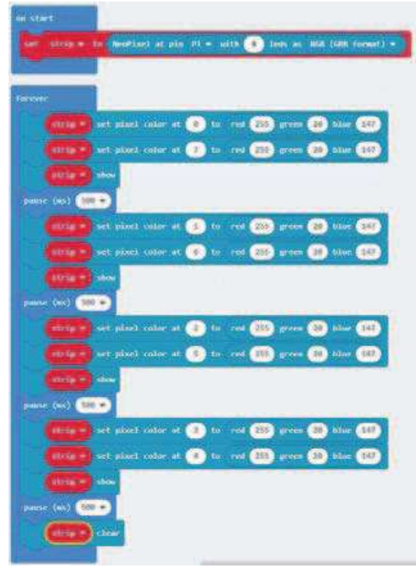

Figure 12. Headband code

2) *Gradual symmetrical lighting of the LED strip*

We want to light up the LED strip so that we start from the first and last LEDs, then they will light up along the following line and the last LEDs will light up in the middle (Fig. 12). This means that we split the LED strip in half in our minds and connect the positions that we want to light up together. Attention, the first LED has position 0, the last one has position 7:

- the 0th and 7th LEDs light up first,
- then the 1st and 6th LEDs,
- then the 2nd and 5th LEDs,
- finally, the 3rd and 4th LEDs.

You may notice that on the one hand we add, while on the other hand we remove. Thus x + 1 and y - 1.

Figure 13. Created headband

C. *Plushie*

We will use 2 wearable LED diodes with already built-in resistors and connect it to the micro:bit in parallel. We connect the crocodile clips to the micro:bit and place them so that the micro:bit fits inside. Then we start from pin 1 and find 2 wearable LEDs. Even with this project, we need to realize that we are sewing two parts - from pin 1 to the plus and from GND to the minus. The result is that the micro:bit with the crocodile clips will be inside, while the LEDs are on the outside (Fig. 13).

Figure 14. Inside the plushie

1) Programming

Let's try to determine a clear objective of the program: When we shake the toy, it will generate random music for us and at the same time it simulates a blinking through LED flashing (Fig. 14 and 15).

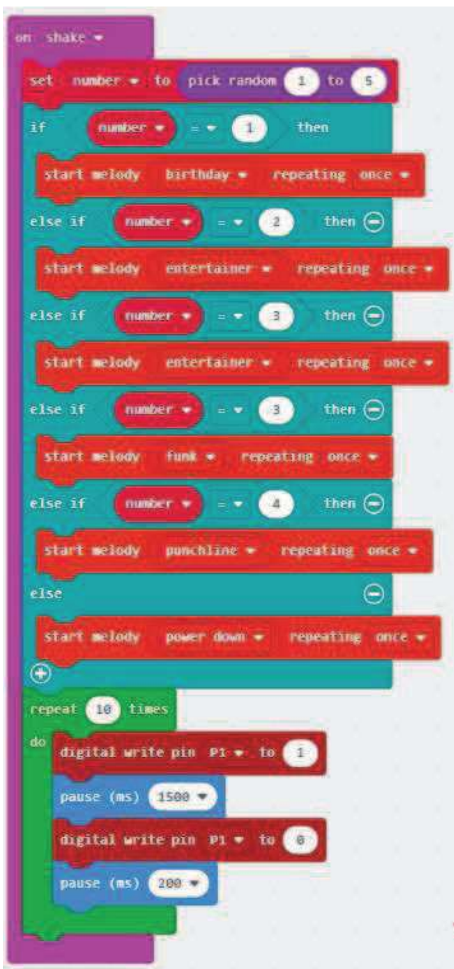

Figure 15. Plushie code

Figure 16. Created plushie

VIII. MEET AND CODE WORKSHOPS

The aim of Meet and Code is to present pupils and youngsters between the ages of 8 and 24 to the world of innovation and coding [14]. The functions are intended to show pupils how much fun coding can be and how it can help motivate new thoughts. By investigating a wide scope of innovation and advanced subjects and inventive coding, they will be encouraged to build up the digital skills they need in this world.

We presented our workshop in two events in October 2020. It was called Wearables and designed for the pupils from the school in Nitra as described in Methodology. The objectives were given. Due to the coronavirus, each workshop must be online. We created two videos and upload it to the forum.python.sk. Video were created for the pupils to pause it when they need and during events, we were online in chat where the pupils could ask or answer.

The first event was to create a postcard (Fig. 16). After the feedback, majority of the pupils did their postcard but two of them were not able to. They told us it was too hard. In total, there were 20 messages in chat and 71 views.

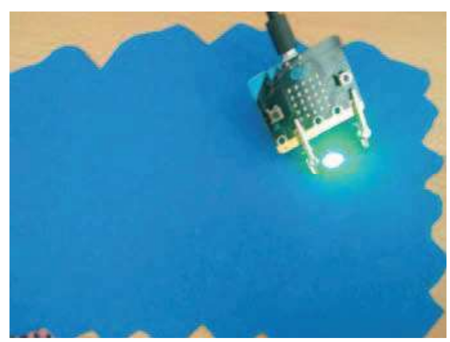

Figure 17. The pupil's postcard

The next week we created another video about headband and plushie (Fig. 17 and 18). We did two versions – simpler and harder. Simpler version of headband was to give defined colours in the code instead of RGB. In plushie, we focused only on random melodies, when shaking. In total, there were 35 views. After feedback and photos, all the pupils did the simpler version. These versions were still to meet the objectives.

Figure 18. The pupil's plushie

Figure 19. The pupil's headband

After the discussion in classes, we asked if they are still motivated and want to continue with the BBC micro:bit. They all agreed. We also told them, that there is another way, we can work with BBC micro:bit, we can still create projects but it will not be wearables, what means no thread, no needle. They disagreed. They told us they like wearables but maybe they need more time for creating such projects. The workshop included 3 projects and videos were recorded in almost 3 hours. Due to the photos and discussion, all of the mentioned objectives were achieved.

A. *Conclusion*

With the focus on project-based learning and creativity, we decided to make educational material on the topic of wearables with the BBC micro:bit. We created three lessons, postcard, headband and plushie, where conductive thread or other wearable electronics were implemented. We made an online workshop where the pupils created these projects and we focused on cognitive, affective and psychomotor objectives. The photos of created projects and discussion we elaborate that all of the objectives were achieved. We would like to continue with the topic of wearables with BBC micro:bit in the future with focusing on creative thinking. Codes represented in the mentioned tutorials were based on reproductive creativeness. In the future, we would like to focus on productive creativeness in coding.

ACKNOWLEDGMENT

The research for this paper was financially supported by granting Implementation of New Trends in Computer Science to Teaching of Algorithmic Thinking and Programming in Informatics for Secondary Education 018UMB-4/2020.

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