Experiences in Developing and Testing BBC Micro:bit Games in a K-12 Coding Club during the COVID-19 Pandemic

Miguel A. Garcia-Ruiz
School of Computer Science and Technology
Algoma University
Sault Ste. Marie, Canada
miguel.garcia@algomau.ca

Omar Alvarez-Cardenas
School of Telematics
University of Colima
Colima, Mexico
xe1aom@ucol.mx

Adriana L. Iniguez-Carrillo
Dept. of Computer Science and Technology Innovation
University of Guadalajara
Ciudad Guzman, Mexico
adriana.iniguez@academicos.udg.mx

***Abstract*—The COVID-19 pandemic has changed the traditional teaching and learning process, moving students' educational hands-on activities carried out in the classroom to home activities that include the use of online tools. Here we describe an after-class online coding club conducted for a month, where elementary (primary) school students programmed and tested games running on the BBC Micro:bit microcontroller board. By developing gaming mini-projects, the students learned computing topics such as logic, sensors, random number generation, game development and programming, and how small physical computing mini-projects were conducted. In this paper, we describe how students and an instructor developed and tested games made for the Micro:bit, running an online simulator and physically using the Micro:bit at home. The paper shows lessons learned on developing games with the BBC Micro:bit in the coding club, and challenges that students encountered in the game development with the BBC Micro:bit. Future work includes multisensory educational gaming projects with the BBC Micro:bit.**

Keywords— serious games, physical computing, Micro:bit, microcontroller board, visual coding, testing, COVID-19

I. Introduction

The COVID-19 pandemic caused by the SARS-CoV-2 virus started in the Spring of 2020. It has changed the traditional teaching and learning process in all levels of K-12 schools around the world [1], moving students' educational face-to-face interactions in the classroom to home activities that include the use of collaborative online tools. This move was implemented in an attempt to flatten the number of COVID-19 infections in the schools [1]. Online (virtual) schooling has made students learn and collaborate through virtual classroom sessions in many countries [2,3]. K-12 education generally includes hands-on learning activities from science, technology, engineering and mathematics (STEM) topics. STEM K-12 education should include the use of technology in class supporting students' understanding of how things work [4]. Schools containing STEM in their curricula often include physical computing applications in class, incorporating microcontroller boards (small computers containing enough circuitry necessary for conducting useful tasks that support experimentation and prototyping), digital and analog electronic components, sensors, motors and other related technological tools that will allow students to carry out active learning of STEM topics through individual and group projects. Physical computing can be used to support the student acquisition of valuable computing skills, such as logic coding, software debugging and testing, and sensor reading among other science and technology aspects [4]. However, STEM activities have been disrupted during the COVID-19 pandemic [3].

A number of studies have been conducted on K-12 students' use of microcontrollers in STEM education (for example [13,14, 17]). [15] argues that the use of physical computing (e.g. microcontrollers boards) in class projects can enhance learning of physics topics such as electricity and electronics, and could improve STEM literacy through hands-on projects. The microcontroller board's applications in elementary schools fall within STEM applications, where students can learn through hands-on activities and technology-based small projects. For instance, [16] studied the use of Arduino microcontroller boards along with an Android cellphone app in a gamified project to learn about electrical circuits.

However, running online learning involving hands-on activities with technology has been challenging. In typical face-to-face classes, teachers and school technicians are physically present in the classroom, giving technical support to students and helping them if they get stuck, for example, setting up computers, running software applications, etc. In online learning, students need to use a personal computer from home, often relying on their parents or guardians for helping them setting up their computers. In addition, there are reports that some teachers from online classes have not provided enough correcting feedback to students yielding to low student participation, and also it is common to find inadequate family support on online STEM learning [5]. Those problems arise because it is often difficult for the teachers to monitor online how students are using technology in their homes, among other issues. involving technology in classes has been challenging during the school closures due to COVID-19, since in regular classes many of these activities are done with the students meeting physically in groups, which is not happening during the COVID-19 pandemic.

This paper describes how a group of K-12 students programmed and tested games and other applications on BBC micro:bit microcontroller boards in an online extra-class coding club. In it, the students learned computing topics such as logic, sensors, game development, and programming, and how small physical computing projects were conducted. The paper also describes how students and the instructor tested games that students made for the Micro:bit, and problems that students encountered in the game development. The next section describes the BBC Micro:bit microcontroller board, including its technical capabilities, how the students programmed it and interacted with it.

II. THE BBC MICRO:BIT

The BBC Micro:bit [7] is a versatile microcontroller board designed by the British Broadcasting Corporation (BBC), following a long-standing legacy of sponsoring the development of personal microcomputers for educational use. The Micro:bit version 1.5 was used in the coding club described in this paper, although the newer version 2 was released after we ran the coding club. Version 1.5 measures 51.6mm (width) x 42.00mm (height) x 11.6mm (depth), and contains a 5 x 5 LED matrix, two programmable user push-buttons and a reset button, a micro-USB port used as a power source and for uploading (flashing) programs to it, and also a battery connector. Users can read or send analog and digital data to/from the board through three general purpose input/output (GPIO) pins with edge connectors. The board also provides ground and 3.3 volt pins. Interestingly, the Micro:bit has an on-board 2.4 gigahertz radio transceiver to communicate digitally with other Micro:bit boards, a motion sensor, an on-board core temperature sensor, and a low-energy Bluetooth 4.1 module. In the coding club, students only used the push-buttons, the temperature sensor and the LED matrix, and the USB port was used to flash the code to the microcontroller board. The LEDs can also be used to measure ambient light via software. This board has 16 kilobytes of RAM and 128 kilobytes of ROM for code storage, running at 16 megahertz. Figure 1 shows the front and back of the Micro:bit.

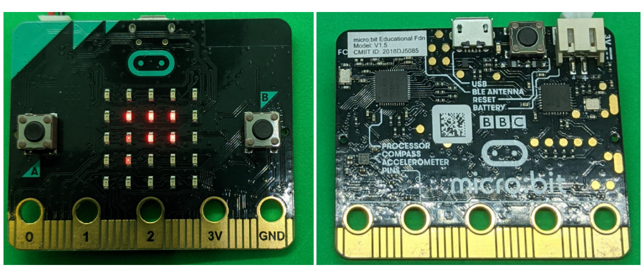

Figure 1. The Micro:bit version 1.5

The BBC Micro:bit can be simulated online at [8], where learners can program applications on the simulator using either block coding (a type of visual programming where students drag and drop blocks representing coding instructions) or JavaScript programming language. The coding blocks resemble the Scratch visual programming style. Learners can also download, open and run already-made games for the Micro:bit from [8]. Figure 2 shows a screenshot of the Micro:bit online simulator. It can also be used to transfer programs simulated on it to a physical Micro:bit via a USB port, a process called flashing. Once the program has been flashed to the Micro:bit, it will run independently on the physical Micro:bit by connecting a battery set to it (see Figure 4).

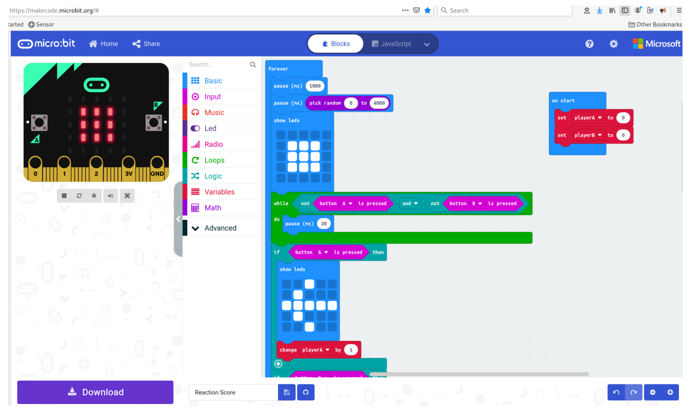

Figure 2. The Micro:bit online simulator

III. THE CODING CLUB

The first author ran an after-class coding club for a month with students from a local elementary school from Sault Ste. Marie, Ontario, Canada, where seven students aged 9-11 years old participated regularly. The club structure is organized by Code Club Canada [6], a Canadian network of coding clubs intended for elementary school children aged 8 to 12, belonging to the not-for-profit organization Kids Code Jeunesse. This organization is supported by the Government of Canada, the UNESCO and private companies. Code Club Canada has posted on its website [6] interesting programming mini-projects for kids, including coding html, Python and Scratch software applications for personal computers. Some of those mini-projects, including games, are intended to run on physical computing such as the BBC Micro:bit microcontroller board. The official Micro:bit web page also publishes interesting STEM projects [7]. Before the club started, each student received a BBC Micro:bit kit through their school office containing the Micro:bit version 1.5, electronic components, a battery holder, two AA batteries, and wires. Some of the kits were donated by Code Club Canada and the rest of the kits were acquired by the first author.

All the coding club sessions were successfully conducted on Google Meet, a popular online videoconferencing and collaboration tool. The instructor used a microphone, a webcam, as well as Google Meet's chat window and screen sharing features. Each session lasted about one hour, which ran once a week, and each contained a mini-project to be completed during each session. Each session structure was organized as follows:

- Greetings and introduction to the day's activity
- Review of previous session
- Explanation of instructions for the session's mini-project.
- Coding the mini-project on the online simulator
- Testing the Micro:bit application on the online simulator and then flashing it to the physical Micro:bit. Testing it again on the physical Micro:bit.
- Conclusions

Figure 3 shows a screenshot of a coding club session that ran on Google Meet where students and the instructor are comparing the same game running on the Micro:bit.

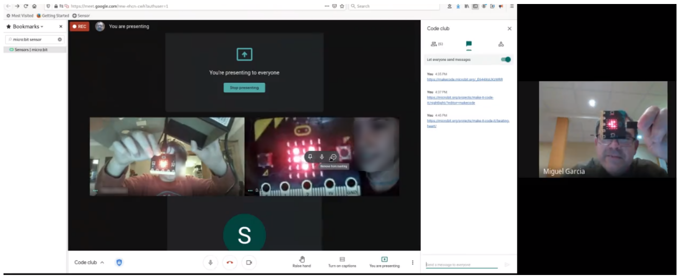

Figure 3. Showing a game running on the Micro:bit

IV. Examples of Mini-projects Coded for the Micro:bit

At the beginning of the coding club, the instructor explained what a microcontroller board is, and how it can be programmed using coding blocks. In each session, students completed self-contained mini-projects with the necessary background information to complete them, from very simple to more complex mini-projects for the Micro:bit. The students started testing some of the Micro:bit features such as how to program for the Micro:bit that displayed the classic "hello world" message on the 5x5 LED matrix. Then, they coded and tested an electronic dice that showed a random number between 1 and 6 on the LED matrix after they shook the Micro:bit activating its motion sensor [9] and learning how random numbers are generated. Students enjoyed testing it, comparing numbers and playing who had the highest number. Figure 4 shows the Micro:bit running a game with a set of two AA-type batteries. Students could run the game on the Micro:bit as a stand-alone application after the game was flashed to the Micro:bit using a USB cable.

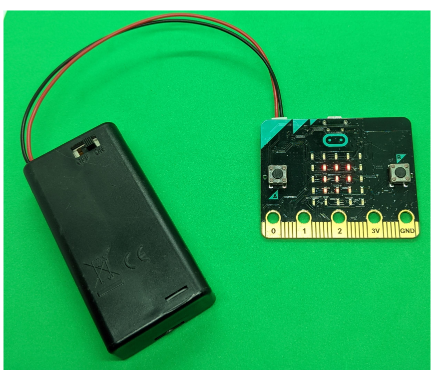

Figure 4. The Micro:bit running a game.

Another compelling mini-project was to code a 2-player game called Reaction [10], where it checks who of two players has the fastest reaction. The Micro:bit has two programmable push buttons (labeled A and B) on the front. Whoever presses their push button first is the winner. The two players needed to wait for a block to display on the micro:bit LEDs after a random number of seconds, and then press button A or B first to see who is the fastest. The Micro:bit showed an arrow on the LEDs pointing at the winner.

V. Lessons Learned

Following the students' and the instructor's experiences in the coding club sessions, we have devised these lessons learned for testing games on the Micro:bit in online classes:

Previous to the sessions:

- Sanitize the equipment and devices that students will use in the coding sessions. We sanitized the Micro:bit sets with sanitizing wipes before giving the Micro:bit sets to the students' parents/guardians. This ensured that the students could handle and test the Micro:bit games safely at home and prevent any disease transmission.
- Explain clearly to the parents/tutors and students how to connect the Micro:bit to their computer via USB port and how to flash the game to the Micro:bit. We suggest to make a video or a diagram showing this. The micro:bit connection to the computer with the USB port was one of the main challenges that the students and parents/tutors faced in the first coding club session.

During the sessions:

- Ask the students to test out the game on the simulator first and then flash it to the physical Micro:bit later. This will save time and effort, testing the game safely on the simulator.
- The instructor should use a high-resolution and high-quality webcam for the sessions. Do not rely on the laptop webcam's resolution, because sometimes the instructor will need to show fine details with the Micro:bit such as its buttons and LED matrix, which otherwise can be difficult to show to the students with a low-resolution camera. The instructor used in the coding club a Logitech C930e webcam running at 1080p (HD).
- We recommend that the students should test out parts of the game separately and incrementally, for example, testing the game inputs first, and then code another game part and test it and so on. This modular (unit) testing can be useful for small and mid-size game development projects. Unit testing is a straight-forward practice and is widely used in game development [11], and coding club students should take advantage of it.

End of the sessions:

- Encourage the students to communicate their testing results and "compare notes" among each other and with the instructor about testing each part of the code and the gameplay as a whole. For this, students can use online videoconferencing tools such as Zoom or Google Meet.

VI. Conclusions

We used the BBC Micro:bit microcontroller board successfully in an online extra-class coding club intended for elementary school children. By developing games that ran on the Micro:bit, students learned and practiced STEM topics, including logic coding, random functions, using sensors, and running small physical computing projects by coding games that used electronic features from the Micro:bit such as a motion sensor. Testing games made for the Micro:bit was an engaging and learning-by-doing activity within a community of practice [12]. Using the Micro:bit in the after-class sessions allowed the students to carry out hands-on activities that comply with STEM objectives [4] and supporting students' technology literacy [12]. The main challenge that we found was to provide enough technical support for parents/tutors and students on how to physically connecting the Micro:bit to their computers, since it was difficult for the instructor to monitor online how the students and parents/tutors were doing it. This challenge has been found before [5]. In addition, the Micro:bit code flashing process was cumbersome for some students and parents/tutors. Future work will include online sessions in the coding club with multisensory gaming projects with the BBC Micro:bit, exploiting other Micro:bit features such as connecting external sensors to it. We plan to develop practical mini-projects about multi-sensory serious games where students will learn the sciences, such as physical and chemical phenomena. In addition, we are considering preparing informative materials for the parents/guardians on how to use the Micro:bit technology, which in turn should improve the students support.

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