CONSTRUCTION OF TYPES OF QUADRILATERALS WITH A SIX-LEGGED EDUCATIONAL ROBOT

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Abstract

Opportunities to create geometric figures by programming and using a mobile application with a six-legged educational robot are presented. Some ideas are described for creating scenarios to support information technology education, computer modeling, technology and entrepreneurship, and mathematics, as well as extracurricular robotics activities.

Keywords: *STEAM; Robotic Systems; Mathematics; Information Technologies; Education; Digital Competence.*

INTRODUCTION

In the Strategic Framework for the Development of Education, Training and Learning in the Republic of Bulgaria (2021 - 2030), emphasis is placed on creating conditions for students to "increase the level of digital competences and focus the educational process on mathematics, technology and engineering skills; on working with algorithms, the formation of flexibility and adaptability skills... Thus, they will be prepared to flexibly adapt to emerging new professions" [1]. According to the same strategic framework in Priority Area 6. Educational innovation, digital transformation and sustainable development, one of the objectives is "improving the educational environment by creating school and out-of-school centers with a STEM environment". According to the national program "Building a school STEM environment", funds continue to be invested for the construction of STEM classrooms in schools in the country, including the creation of a National STEM center on the territory of Sofia Tech Park, Sofia city [2], [3].

Taking into account the dynamics of new technologies, the environment and the studied subject areas in modern schools, we will consider some options for using robotic systems during a lesson for the development of mathematical and digital competence, critical and creative thinking [4]. We will present concrete examples of the creation of geometric figures using a mobile application, as well as in an electronic environment, suitable for use by beginners in programming, mathematical modeling and working with electronic applications for robotic systems.

TOBBIE II – EDUCATIONAL ROBOT

Tobbie II, micro:bit Robot Educational Building Kit includes head, 2 decorative arms, six legs, 360^0 rotatable body, 2 motors with connector, battery holder with connector, PC board, micro:bit board [5]. The Micro:bit board is from the V2 series and has available:

- LED display with 25 LEDs;
- 2 programming buttons and 1 reset button;

- sound output – speaker reproducing sounds;
- sound input – can capture and react to sounds;
- accelerometer – capturing left and right, backward and forward, up and down movements;
- temperature sensor – giving an approximate estimate of the air temperature;
- a sensor allowing a reaction according to the level of light;
- a compass that detects magnetic fields - it is calibrated when the robot is turned on for the first time;
- touch sensor – capacitive;
- USB interface (Fig. 1).

Fig. 1. Tobbie II robot

The method used to move the robot is based on biomimetics, based on the movements of six-legged insects [6], [7], [8], [9]. In this case, the six legs are arranged in two triple legs.

Here are some ideas for creating quadrilaterals using the Tobbie II robot. Some of the models were presented during the international conference "Dynamic Mathematics in Education" on February 17, 2024, at the Institute of Mathematics and Informatics at the Bulgarian Academy of Sciences [10].

Mobile Application for Working with Tobbie II Robot

The specially created mobile application for working with the Tobbie II robot allows movement through a joystick and/or a gyroscope, which is activated when the phone is tilted in a given direction [11], (Fig. 2).

The micro:bit board is located in the head of the robot. One option for creating quadrilaterals is by marking specific points in the mobile application and pressing the "Send" button, which sends the image to the LED matrix in the robot board. Several ready-made figure models are available in the application itself (Fig. 3).

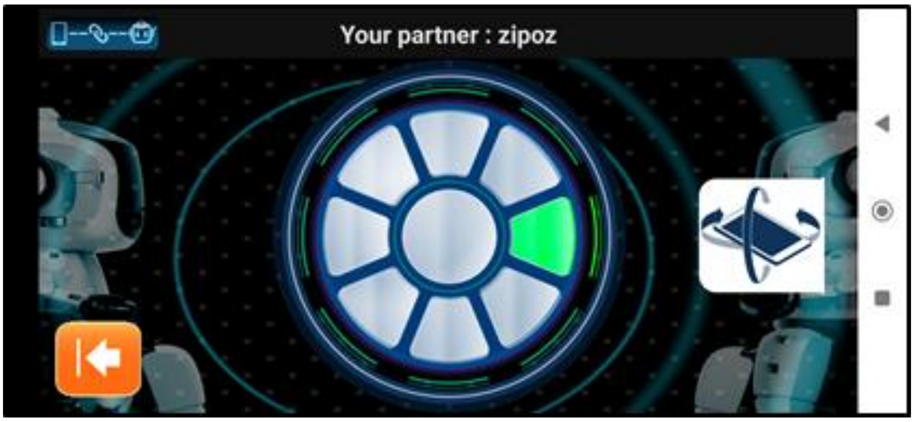

Fig. 2. Gyroscope movement from a mobile app for working with the Tobbie II robot

Fig. 3. Ready-made models of figures, from a mobile application for working with Tobbie II robot

MAKERCODE.ORG ELECTRONIC ENVIRONMENT FOR WORKING WITH MICRO:BIT BOARDS

In the Makecode.org programming environment [12], for micro:bit boards, specific shapes can be created using block programming, JavaScript and Python. After creating a program using block programming, the JavaScript and Python variants are automatically created. Ready-made models for the LED display also include several figures on the subject. In Fig. 4, a variant of three geometrical ready-made figures is presented using the three specified programming methods. The used figure models in JavaScript and Python are named – “LeftTriangle”, “Square” and “Triangle”. By analogy with other block programming programs, a concrete action must be specified to start a program - in this case, after pressing the "A" button on the micro:bit board.

Author models can be created using the "show leds" block and by clicking on the desired fields (Fig. 5). The mode of operation allows to save and execute the last set program that was sent to the board.

During the independent work of students and/or amateurs in the considered programming environment, it is appropriate to give the task of constructing a quadrilateral both by contour (Fig. 4) and by a filled model. When setting several consecutive patterns of figures, their duration of display must also be determined, for example by means of intermediate pauses (Fig. 6).

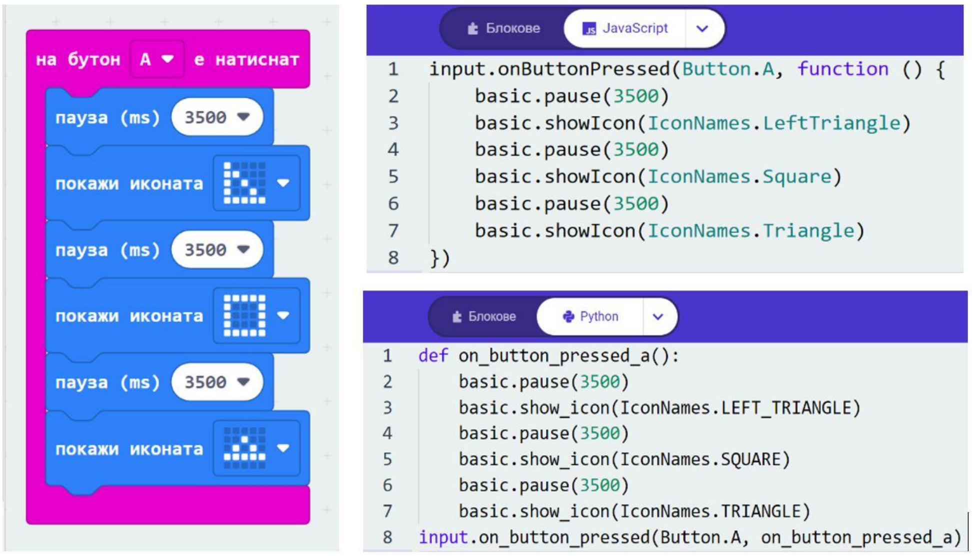

Fig. 4. Ready-made models of geometric figures using block programming, JavaScript and Python at Makecode.org

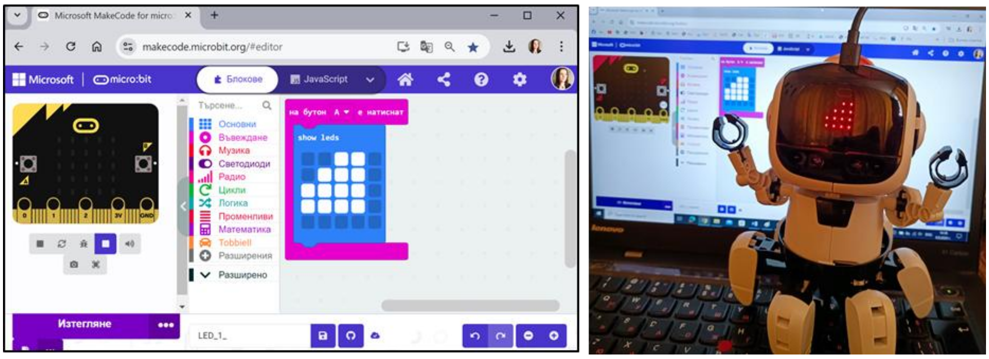

Fig. 5. An arbitrary quadrilateral in a LED display at Makecode.org

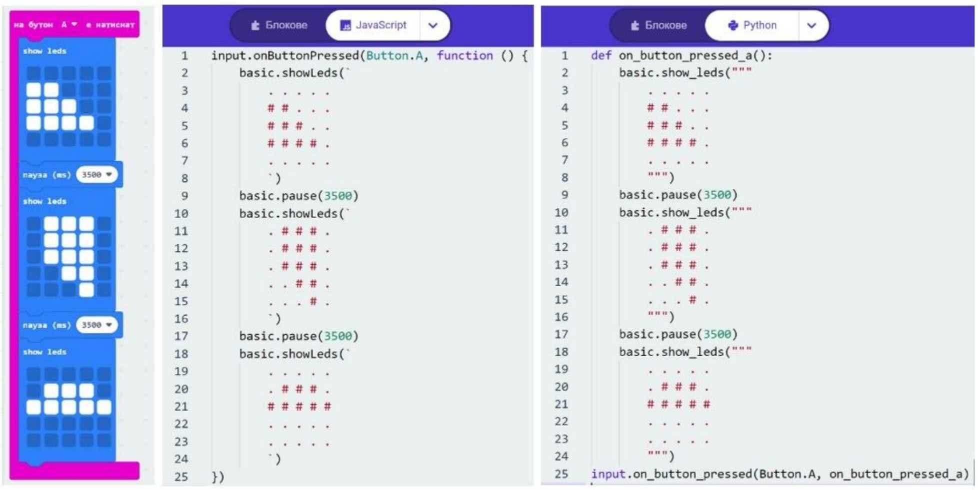

Fig. 6. Construction of Quadrilaterals, in the Matrix, Using Block Programming, JavaScript, and Python at Makecode.org

In Makecode.org an extension "tobbiell" is available, the activation of which allows to program the movements of the robot legs as well. While working with the robot, it was found that it can only move on horizontal surfaces. During attempts to move on an incline and/or on non-smooth surfaces, the robot loses its balance and falls. To save the program in the robot's board, the "Download" button must be pressed for the transfer to start, using a cable (Fig. 7).

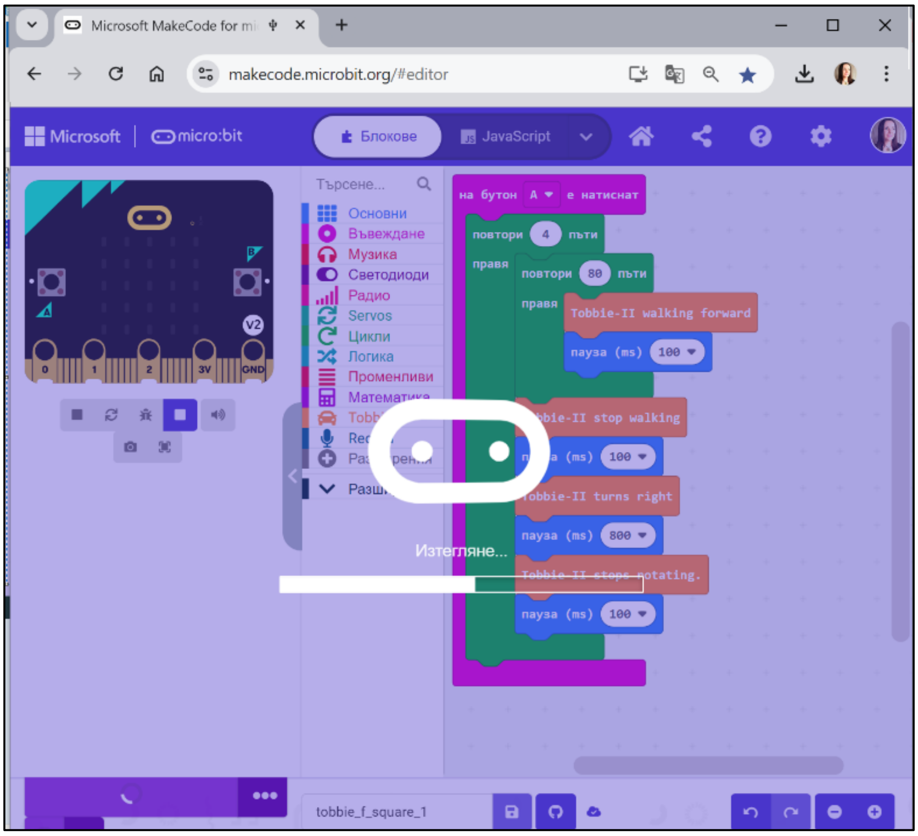

Fig. 7. Sending a program from Makecode.org to the robot via cable

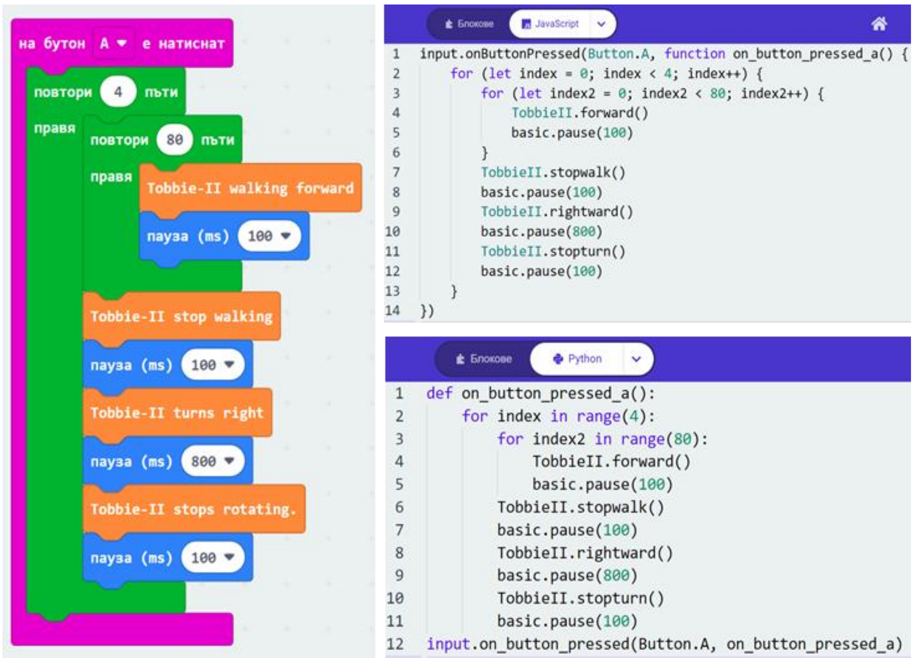

Fig. 8. Programmed square with "tobbiell" extension, using block programming, JavaScript, and Python in Makecode.org

In Fig. 8, a variant of the creation of a square by a nested loop of movements is given, using the three available programming environments. What is specific about working in this electronic environment is that any set motion will run indefinitely if no duration is specified for it. In the case of moving forward, the "loop" button is chosen to be used. It includes movement and the minimum pause that the program allows - 100 ms. According to the desired distance, the number of times to repeat this loop of movements is set. By analogy, the figure square can also be programmed. A "loop" is applied to repeat 4 times the forward motion and right angle rotation. To select an exact angle, it is necessary to specify how many ms to rotate the robot's body around its axis. After some experiments, it was found that to rotate 90 degrees it is necessary to rotate the robot body for 800 ms. In the considered electronic environment, it is necessary to add a button "Tobbie-II stop rotating" to stop the movement.

The output of the program is presented in Fig. 9 and can be viewed at youtube.com [13]. The program is executed under different surface conditions - on smooth tiles, woven fabric flooring, wooden laminate parquet. The robot legs are made of plastic material and there is a noticeably different degree of displacement from the previously indicated trajectory of movement due to slippage on individual surfaces. We note that the way the legs are gripped and their ability to maneuver is not at the highest technical level, and this also reflects in the movement of the robot. When working in class, it is appropriate to demonstrate other six-legged robots, of a different levels; other n-legged robots, of a higher level; to consider the differences and similarities in the programming of the limbs and their movements; to consider the advantages and disadvantages of working with ready-made applications and deeper environments based on programming languages [14], [15], [16], [17].

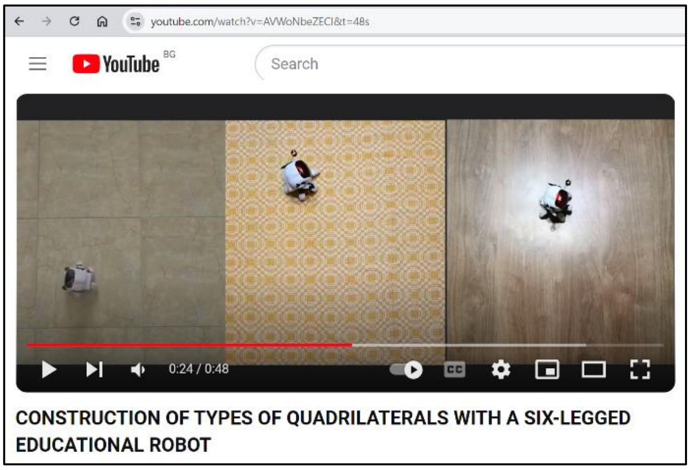

Fig. 9. Programmed square via Makecode.org, featuring Tobbie II robot, on various surfaces [13]

It is suitable to program other types of quadrilaterals and execute them with the mobile application and the electronic environment of Makecode.org, which were discussed so far. The Microbit board also allows working with it in the Scratch programmable environment, the study of which is embedded in the discipline "Computer Modeling" since primary education in the country. The block programming options available in the individual programming environments can be compared, as well as the availability of other programming languages for working with the robot.

DISCUSSION

From the point of view of STEM classes or extracurricular training, it is appropriate to hold discussions and stimulate research activities related to both programming elements and specific features of the robot, for example, related to the trajectory of turning and its movement, the influence of the terrain on his course, etc. [18].

For the purposes of training, it is good to set reverse tasks - observing the movement of the robot with a previously prepared program, to guess what the figure is and with what algorithm it was realized.

We recommend using its available sensors in order to set a trajectory for movement by: following an object, following a pre-drawn trajectory, detecting a light source and others [19], [20].

It is useful to examine the footprint left by each of the six legs of the Tobbie II robot, for example by placing a marker or other coloring agent on each leg, to compare the footprint of pairs of legs [21].

We recommend comparing the six-legged robot Tobbie II with other n-legged, wheeled, tracked, Lego and other robots, looking at the robot's turning radius, drive wheel size, center of gravity, maneuverability, etc. [22], [23], [24], [25].

With this lesson, there is propaedeutics of an exterior angle, of the sum of the angles of a quadrilateral, of a property of parallel lines related to adjacent angles, therefore we recommend placing emphasis on each of the details related to these concepts and properties.

After working with the robot in class, it is appropriate to do a SWOT analysis and make recommendations for future work with it, according to the assigned STEM topic. Table 1 presents a version of a SWOT analysis based on the used options for working with the robot.

Table 1. SWOT analysis of Tobbie II robot

Advantages	**Disadvantages**
• Low cost for a robotic system; • Drive by batteries that are quickly replaceable; • Does not require loading time; • Compact size for storage; • Availability of a ready-made mobile application from the manufacturer; • Ability to work with Scratch, Python, Java script, block programming; programming environments allowing work with micro:bit boards; • Possibility of assembly is provided, i.e. to expand the element "engineering"; • Provides variety of demonstration of robots of this class through the number of limbs and the presence of a large number of sensors.	• Requires initial assembly; • There is some instability of the construction and easy possibility of separating some of the parts; • The head is large, which increases instability when moving; • The 5x5 pixels are insufficient to create a precise enough shape; • The hands do not provide a good opportunity to hold a writing instrument; • No possibility to move on inclined surfaces; • Cannot overcome obstacles; • Sending ready commands from the Makecode.org e-programming environment, via cable; • Noisy when moving.
Opportunities	**Threats**
• Development of skills for working with micro:bit boards; • Getting to know sensors and their applications; • Motivates to study movements of six-legged insects.	• Risk of breaking its parts when they are initially separated from the assembly kit; • Improper assembly of parts; • The finished mobile application is not actively supported by the manufacturer and there is a risk of not being able to use it effectively.

Conclusion

The presented ideas for creating scenarios for working with a mobile application and in an electronic environment, using block programming, JavaScript and Python, are suitable for use in addition to classes in information technology, computer modeling, technology and entrepreneurship, mathematics, when working in STEM centers. In the context of STEAM education, the emphasis here is on mathematics, information technology and engineering, i.e. we may use the notation $STEAM^{(3)}$, meaning to note the number of subject areas that are included in a particular STEAM education [26]. But it can also be organized $STEAM^{(5)}$ – for example, when including studying insects and obtaining artwork related to types of quadrilaterals.

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