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THE APPLICATION OF ROBOTICS IN THE FORMATION OF MUSIC KNOWLEDGE

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Abstract. The purpose of this article is to present research on the capabilities of the STEM approach using robots in the music education of elementary school students. The objective is to use all available resources in schools to engage students' interest, to expand their knowledge, and motivation to develop artistic and creative skills. The target is to multiply the knowledge of Robotics and to suggest specific approaches for its use in increasing interest and motivation for learning music. The information is based on a special study among 96 students from the 4th grade in Bulgarian primary schools. The benefits of the approach for overcoming the physical lack of expensive musical instruments have been proven. Conclusions were drawn regarding the benefits of using acquired robot programming skills in the music education process. This research is useful to everyone who participates in building artistic and creative skills and competencies and has the intention to improve the students' results in the learning process.

Keywords: STEM education; educational robotics; Micro:bit; interdisciplinary learning; music education; robot programming skills; primary education; MakeCode platform;

1. Introduction

On a global and national scale, STEM (Science, Technology, Engineering, and Mathematics) has been established as a priority area in contemporary education that has the purpose of preparing young people at an early age for active participation in their own future (Sokolova, 2025; Kotsis, 2025). Since 2023, Bulgarian public schools have started the preparation of projects under the Recovery Plan valued at 480 million BGN[1], with which each of them will build its own STEM space. The goal is to sustainably improve the learning environment and to transform it by combining modern digital technologies and contemporary educational theories. Educational robotics is increasingly used as a tool for developing algorithmic thinking, problem-

solving skills, and interdisciplinary connections between science, technology, and the arts (Benitti, 2012; Alimisis, 2013).

2. Prerequisites and setting of the study

In the context of the modern educational environment, in which information and communication technologies are increasingly involved, the use of robots shows great potential to transform the way learning is done in schools (Orhani & Babuna, 2024; Flogie, 2025). Robotics helps develop analytical thinking, teamwork skills, and problem-solving skills by applying real-world scientific and technological principles. Constructivism focuses on active learning, discovery, and experiential education. Constructivist methods encourage students to be active in their learning, unlike traditional methods that only present facts. The constructivist pedagogical approach involves problem-solving, inquiry, and collaborative initiatives that deepen understanding. Students actively generate knowledge from their experiences. Discovery learning, associated with constructivism, uses inquiry to acquire knowledge. Students tackle problems that require critical thinking, reflection, and adaptability, encouraging curiosity and intrinsic motivation. Teachers facilitate learning by helping students find their own answers (Asrifan, 2025).

In this context, the present study aims to investigate the effects of using the Micro:bit board for stimulating the participation and involvement of students during music lessons and the formation of competencies in this artistic and creative field of knowledge (Önal, 2025). With music lessons involving piano and other musical instruments, even music schools often have difficulty providing enough instruments for each child. This leads to these lessons becoming theoretical, which reduces their appeal. Music is usually a subject that students find interesting, but in the case of a lack of practice, the classes prove to be less exciting. To address this issue, the STEM approach – specifically the Micro:bit board – is implemented[2]. The Micro:bit platform has become a widely used educational tool for introducing programming and digital technologies in school environments (Sentance et al., 2017). Not every school can provide access to a piano for each student; however, most schools are equipped with computers. The development of technology and technical equipment provides opportunities

to overcome such limitations, and educational robotics has been identified as an effective tool for supporting interdisciplinary learning and student engagement (Benitti, 2012).

The idea of this study is to propose a solution to how using available technological resources in the context of STEM in each school can serve to enhance young learners' engagement and, in particular, to provide a motivational basis for building musical competencies. The study focused on students from several schools in Ruse. Here, numerous third-graders from various schools have undergone training and are familiar with the MakeCode platform in mandatory Computer Modeling classes, and are using the Micro:bit skillfully. The tasks used in the article focus on the basic knowledge acquired by students during their previous education.

The Micro:bit (figure 1) is a small, programmable device that is gaining popularity in classrooms around the world due to its affordability, ease of use, and flexibility. It is a programmable microcontroller that integrates multiple functions. A systematic review of 37 studies published between 2012 and 2023 reveals that Micro:bit is used in a variety of science education contexts, including physics, chemistry, biology, and environmental sciences. Studies identify several benefits of using Micro:bit in science education, such as improving programming and computational thinking skills, improving students' understanding of scientific concepts, and increasing their motivation and engagement (Quyen et al., 2023).



Figure 1. Basic Micro:bit board kit

The program with which Micro:bit is programmed is Microsoft MakeCode[3]. This is a platform with a companion web application designed to simplify the programming of microcontroller-based devices in the classroom. For every device, MakeCode delivers a personalized end-to-end web browser experience consisting of code editors, a device simulator, a debugger, a compiler to machine code, and a linker to a precompiled C++

runtime, as well as documentation and a user guide (Ball et al., 2019). It is available for online and offline installation. The program allows for block or code programming.

In the city of Ruse, STEM training in Robotics is conducted in 11 schools, which is optional and complements the knowledge and skills acquired from training in Computer Modeling, which is part of the mandatory preparation in the 3rd grade of the primary stage of education. Robotics education offers interactive and fun ways to learn basic concepts in science, technology, engineering, and mathematics. With the help of these educational tools, teachers can inspire children to develop critical thinking, creativity, and teamwork.

The skills and knowledge that students have after completing robotics training can be grouped into the following main groups:

- **Logic and programming**
    - know the concept of variables;
    - know basic data types - integer, string, boolean;
    - know conditional statements;
    - know the **for** loop;
    - know a loop with a precondition;
    - know a loop with a postcondition;
    - use nested loops;
    - know the basic programming blocks;
    - know additional libraries.
- **Robotics and engineering**
    - know the elements of the **Micro:bit** board and the **Micro**:**Maqueen** robot;
    - can assemble the elements of the **Maqueen** robot;
    - understand the operation of the motors and sensors of the **Maqueen** robot;
    - are familiar with the accelerometer device;
    - understand the concept of wave and wavelength.
- **Information transfer and storage**
    - have knowledge of transferring and storing written code on various devices - board, computer, tablet, etc.

- **Mathematics**
    - know the concept of a coordinate system;
    - practice numeracy skills;
    - practice time-related problem-solving skills;
    - practice logical problem-solving skills.

Music education emphasizes a detailed examination of the blocks of music performance and composition, and students have the opportunity to develop new skills and expand old knowledge related to programming and logic. An example is the use of a loop when programming musical repetitions. If a melody is played on the piano, the pianist would have to play each musical repetition in the melody again. If the melody is programmed, the repeating parts can be placed in loops and thus programmed once.

3. Methodology

To assess the benefit of STEM education, particularly robotics, in developing life skills in different areas, we posed a research question: Can robotics increase students' engagement in the music learning process? At the beginning of the 2024/2025 school year, a survey was conducted among 4th-grade students from two elementary schools in Ruse. The study involved 96 students, divided into two groups. All experimental tests are anonymous and comply with legal and ethical requirements. The first group consists of 48 students and is taught using the long-established approach, where the teacher delivers instruction and has tools to support the learning process, specifically the reproduction of musical works. The second (experimental) group for the study consists of 48 students who were selected because they had studied Robotics in the previous year and possessed the knowledge and skills described above. For educational purposes, Micro:bit board is used in music classes. Specially designed tests were conducted to establish the input (Table 1) and output (Table 3) knowledge in both groups of students.

The establishment of the initial knowledge and skills takes place in the first lessons of music education in the 4th grade. The test was designed to obtain information about the theoretical and practical knowledge and skills of students before the music education in 4th grade, related to Musical Instruments, Metres, Musical Genres, Basic Music Literacy, and Listening

to Music. The proposed tasks are on these topics. They are part of the area of elements of musical expression. The tasks resonate with the competencies set by the Ministry of Education and Science regarding mandatory music preparation for the 4th grade[4]. The skills that students must develop and those they are expected to possess after the end of the training are the following:

- Define melody, character, tempo, dynamics, and timbre in musical examples.
- Know the main groups of instruments. Identifies by timbre and appearance wind, string, percussion, keyboard, electric and electronic musical instruments, and the principles of sound production.
- Determine sameness, difference and similarity in songs and instrumental works from the school repertoire.
- Recognize the metre and time signature for 2/4, 3/4, 4/4, as well as the metre for 5/8, 7/8, and 9/8 in appropriate examples.
- Recognize note values and rests up to eighth notes, a dotted quarter note rhythmic group, and an eighth note in sheet music examples.
- Use basic elements of music notation – the staff, treble clef, notes and pauses as a visual aid when playing a melody with tone names.
- Analyze types of melodic movement by ear and with the help of basic sheet music.
- Distinguish folk instruments from others.
- Assign the piano, accordion, organ, and keyboard to the keyboard instrument group.
- Comment on the capabilities of electric and electronic instruments.
- Create graphic models of songs from the school repertoire.
- Recognize the metre of music in 2/4, 3/4, 4/4, 5/8, 7/8 and 9/8.
- Compare and analyze graphic models of the studied metres.

Table 1. Tasks from the test for analyzing initial knowledge of music (maximum number of points 26)

№	Task	Theme
T1	Listen to the musical excerpts and determine the correct answer. [The teacher plays recordings.] (max 10 points 2x5): a) Pravo horo is in the metre: □ 2/4; □ 7/8; □ 9/8; b) Rachenitsa is in the metre: □ 2/4; □ 7/8; □ 9/8; c) Waltz is in the metre: □ 2/4; □ 3/4; □ 4/4; d) March is performed in the metre: □ 2/4; □ 3/4; □ 4/4; e) Paydushko horo is in the metre: □ 5/8; □ 7/8; □ 9/8;	Metre: Folk music Waltz March
T2	Determine the nature of the music [The teacher plays short musical excerpts] (max 5 points 1x5): a) happy/sad b) fast/slow c) dance/marching d) gentle/energetic e) folk/classical	Nature of music Tempo Music genres
T3	Measure the rhythm of "Pravo Horo" with clapping (max 5 points): a) rhythm accuracy b) keeping the tempo c) coordination	Rhythm Tempo
T4	Arrange the instruments piano, grand piano, synthesizer, electronic piano, accordion, organ in the correct group (max 6 points 3x2): a. Acoustic keyboard musical instrument: b. Electronic keyboard musical instrument:	Keyboard musical instrument

4. Entrance test result

The Mann–Whitney U test was used (Milton, 1964) to verify the research questions regarding the knowledge and skills of students from both groups before and after the training. This test is similar to the t-test for two independent samples by comparing medians. To do this, the output values for the interval variable are converted into ranks, and then the test checks whether the ranks for the two groups are statistically significantly different. For the data obtained from the preliminary tests, the hypothesis raised is that there is a difference in students' knowledge of the mentioned music topics. Using the Mann–Whitney U test formula $U = n_1n_2 + (n_1(n_1 + 1))/2 - R_1$ values were obtained $U_1=38$, $U_2=43$, and $p=0.825 > \alpha=0.05$. Since the obtained p-value exceeds α, the hypothesis of significant differences is rejected; therefore, students from both groups begin their studies without any difference in level (Figure 2). Differences in performance across topics were recorded for both groups. The most significant differences are reported in the results of questions related to topics rhythm, metre, and keyboard instruments. The average score of both groups on the entrance test is very good. The first group has a slightly higher overall score, but the difference is negligible when compared to the maximum possible score.

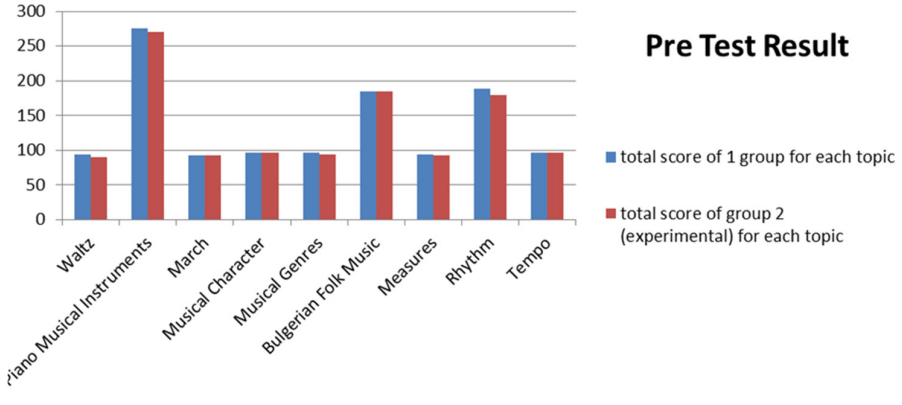


Figure 2. Comparison of the results of the entrance test of the first and second groups by topics

The knowledge and competencies regarding music that are addressed in the topics and questions of the initial survey are focused on:

- Recognizing musical instruments by timbre and appearance: clarinet, organ, accordion.
- Determining sameness, difference and similarity in songs from the school repertoire.
- Determining the metre of music in time signatures such as 2/4 2/4, 3/4, 5/8 and 7/8 in songs and instrumental pieces from the school repertoire, and 2/4, 3/4, and 4/4 in simple sheet music examples.

5. Key moments of learning in the experimental group

During the training in the experimental group, students are also expected to enrich their knowledge in Information Technology. The topics covered are Information, Working in a Visual Environment, and Managing Programmable Devices. The competencies that students must develop and those whose acquisition is expected to be mastered after the end of the training are the following:

- Indicate ways to obtain information and lists forms of information presentation (textual, numerical, audio, and graphic).
- Describe the main purpose of digital devices and recognizes that digital resources may not be free to use, copy, and distribute.
- Control actions depending on the truth of a given condition, arranges a finite sequence of blocks, implementing a branching algorithm.
- Create a branching algorithm that requires input from the user via the keyboard.
- Use arithmetic operators and blocks that represent them. Uses blocks for choosing a random number, for comparing numbers, for logical operators, and uses additional operators. Nests a block within a block.
- Explain the nature of variables. Creates and names variables. Assigns values and uses variables.
- Describe the functionality of buttons on a specific device. Uses buttons to specify a sequence of movements in different directions.
- Use blocks of commands to connect programmable devices to digital devices.

STEM education in music and IT in the experimental group from the 4th grade begins if the acquired knowledge and skills for programming the Micro:bit according to the above program are available. MakeCode has the ability to play and compose music. For the development and execution of tasks, the "play tone" function is used, which offers a virtual piano keyboard (Figure 3).



Figure 3. MakeCode virtual keyboard

To increase the interest and motivation of the students, the proposed tasks for performance are based on already known and studied melodies from the current and previous school years: ("My Dear Mom" ˛Lazar Nikolov (music) and Ivan Genov (lyrics) "Boryano, Boryanke" – Folk song "Star Wars" march – John Williams "Megalovania" – Toby Fox "Für Elise" – Ludwig van Beethoven). The program used to conduct the STEM classes in music and robotics is presented in Table 2.



Figure 4. Composing "To Eliza" in the MakeCode environment

As an example, topic number 2) "To Eliza" is presented (Figure 4). It is planned for 1 class hour of 40 minutes. At the beginning of the lesson, it is appropriate to spend some time introducing the topic and recalling the melody. It is possible to play the finished melody from a programmed board and have the students try to guess it. Then we move on to a brief introduction to the music blocks in MakeCode in the music section. The first few tones are programmed in parallel by the teacher and students in order to demonstrate and explain how to set notes and duration. The next part of the musical phrase is programmed by the students themselves.

Table 2. Program for programming melodies with MakeCode

Topic and number of teaching hours	**Practiced/new knowledge in Music**	**Practiced knowledge of robotics**
1) "My dear mom" – 1h.	• working with keyboard musical instruments • working with notes and octaves	• Working with information and digital devices • introduction to music blocks play a tone • the loop blocks
2) "Für Elise" – 1h.	• understanding the concept of dynamics • understanding the concept of timbre	• getting to know the possibilities of creating music through programming • developing skills for working with music blocks in MakeCode • understanding the relationship between musical notes and their programmatic representation
3) "Boryano, Boryanke" – 1h.	• Introduction to Bulgarian folk music in metre 2/4	• File management • Synchronizing actions in a visual block programming environment
4) The "Star Wars" March – 2h.	• Getting to know the pauses in music • metre 2/4	• blocks reset for • using a loop
5) "Megalovania" – 2h.	• Getting to know repetitions in music	• introduction to music "play tone" block • using a loop
6) Music playlist – 1h.	• Melody recognition • Recognition of compound and simple metre	• Using algorithms with conditions • working with buttons • using ready-made programs/functions

To help, a diagram (Figure 5) is presented, which guides them on which key and note should be pressed and for what duration. The next task for the students is to adjust the tempo of the melody and experiment with how it will sound if they slow it down or speed it up. When students have finished programming a task, they must test it in the virtual environment simulator, then upload it to the controller via USB and play the melody from the controller. Using the Micro:bit allows students to try out their melodies and programs on a physical device and learn through play and experimentation. An additional task for students who finish early is to combine music with LED lights, and for homework, to program the second musical phrase.

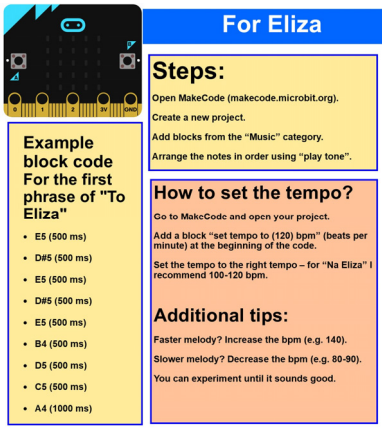


Figure 5. Helpful hints for students

6. Final test and results

The second part of the test of students' knowledge and skills is oriented to provide feedback on the acquired knowledge and skills for the practical application of acquired knowledge at the end of the 4th grade. Table 3 presents the questions from the final test.

The knowledge covered in the topics and questions of the final survey is related to the formation of the following competencies:

- Assign the piano, accordion, organ, and keyboard to the keyboard musical instrument group.
- Comment on the capabilities of electric and electronic instruments.
- Create graphic models of songs from the school repertoire.
- Recognize the metre of music in 2/4, 3/4, 4/4, 5/8, 7/8 and 9/8.
- Compare and analyze graphic models of the studied metres.

Figure 6 presents a comparison of the scores of the two groups from the final test by topic.

Table 3. Tasks from the test for analyzing the final knowledge of music

№	Task	Theme
T5	Listen to an excerpt from "Für Elise" and determine: (max 2 points 2x1): a. Tempo: b. The instrument:	Keyboard musical instrument Tempo Classical music
T6	When listening to the "Star Wars" march, identify (max 2 points 2x1): a. The nature of music is: b. The metre of music is:	March Metre Nature of music
T7	Listen to "Boryano, Boryanke" and answer (max 2 points 2x1): a. The nature of music is: b. The metre of music is:	Metre Folk music Nature of music
T8	Match the titles of the works with their authors. (max 10 points 5x2): The works: "My dear mom" , "Boryano, Boryanke", "Star Wars march", "Megalovania", "To Eliza" The authors: Ludwig van Beethoven, John Williams, Lazar Nikolov (music), Ivan Genov (lyrics), Toby Fox; Questions for the assignment (max 10 points 5x2): 1. Which of these works is a Bulgarian folk song? 2. Which work is part of film music? 3. Which piece is a classical piano piece? 4. Which work is from a computer game? 5. Which work has two authors - one for the music and one for the lyrics?	Melody recognition Music genres

The null hypothesis assumed that STEM education and the use of robotics do not have a significant impact on the formation of artistic and creative skills in music education. Again, using the Mann-Whitney test, the statistical significance of the hypothesis was verified. The above formula yields values for $U_1 = 62$, $U_2 = 16$, $p = 0.031$, and $\alpha = 0.05$. Since the obtained value for p is less than α, the hypothesis that there are no significant

differences is rejected; therefore, students from both groups completed the study with a significant difference in level. It can be seen that the proposed approach has the greatest benefit in acquiring knowledge on the topics of musical genres and rhythm.

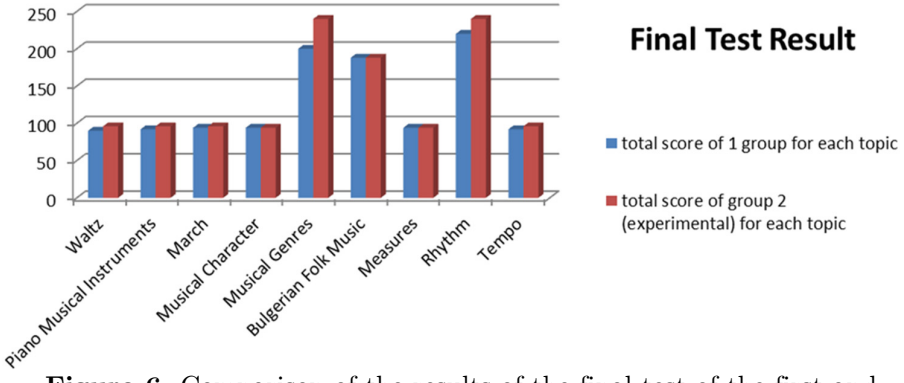


Figure 6. Comparison of the results of the final test of the first and second groups for each topic

In musical genres, the total number of points of the control group is 200 points (80%) out of 250, and the experimental group shows a result of 240 out of 250 points (96%), or the absolute difference between the two approaches is 16%. Regarding the knowledge of musical rhythm, a difference of 8% in favor of the experimental group was established. Students from the experimental group show better results by at least 6% on all topics covered in the final test. The average performance of both groups on the final test is very good, but the second group has a higher overall score, which is due to the better practical skills of the students after the end of the training. A comparison is observed between the groups and the ratio of their results to the maximum possible result. Differences in performance across specific topics were observed. The most significant differences are reported in the results of the questions related to the topics of Musical Genres and Melody Recognition. The questions and tasks from these two topics are most strongly tied to practical knowledge, and from these findings, it can be concluded that a significantly better performance in practical tasks is observed among students from the second group.

7. Conclusion

This study aimed to identify and analyze the opportunities that STEM education, and in particular robotics, provides for the implementation of the constructivist approach in education. The study was conducted among 96 primary school students. The acquired knowledge of working and programming with Micro:bit and MakeCode was used. In the process of practical work with students, the available knowledge and skills regarding the methods of obtaining and presenting information, the main purpose of digital devices, the management of actions depending on the truth of a given condition, the arrangement of a finite series of blocks, and the creation of various types of algorithms in practical music education are used. The conducted experiment aims to answer the question of whether it is possible to increase the engagement of students to the acquisition of knowledge in music. The results of the final test show significantly better indicators on all studied musical topics. A difference of 6 to 16% was reported, suggesting greater student engagement in music education. This research may be useful for teachers and educational professionals in the process of supporting students in developing confidence in their musical skills, facilitating the creation of a learning environment in which everyone participates more and learns more.

NOTES

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