AN EDUCATIONAL ROBOT TO ELEMENTARY SCHOOL CHILDREN FOR ACQUIRING STE(A)M COMPETENCES

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Abstract

STEM education, now also known as STEAM, is a multi-discipline approach to teaching. STEM education is a teaching approach that combines science, technology, engineering, and math. Its recent successor, STEM, also incorporates the arts, which can expand the limits of STEM education and application. STEM is designed to encourage discussions and problem-solving among students, developing both practical skills and appreciation for collaborations, according to the Institution for Art Integration and STEM. Many works have been done to acquire students STEM competency such as digital competence and creativity. This study focusses on using the robot technology in this purpose. Robots are becoming an integral component of our society and have great potential in being utilized as an educational technology. Many studies were presented in the field of robots in education to engage this technology in classrooms and to promote a deeper understanding of the area. Educational robots enable students of all ages to become familiar with and deepen their knowledge of robotics while at the same time learning other cognitive skills. The paper presents the design and the implementation of a simple robot to education process that could help children to acquire STEM competences. The robot has a cubic shape attached with a camera colors sensor. A teacher chooses a color by pressing on a switch, then children are asked to find the required color from the color board. The robot sensor decides if they could find the correct color and provide a flag. The robot can be used as a selector in multiple choice game using the color sensor and as an educational tool for children at elementary school.
Keywords: STE(A)M, competence, skill, robot.

Introduction

Research problem can be defined as an analysis of implementing robot technology as nontraditional educational method and instrument to engage pupils to acquire Stem competences such as digital competence and creativity.

Research relevance. The quick improvement of technology during the last decades increases using modern tools in the field of education. Despite the normal technology applications, robotics starts to have a role in schools. In addition, children prefer to play more with technologically devices during playtime (Beran et al., 2011). A number of research discussed the effect of using robot on children's interaction, language, social development, and cognition (Kozima & Nakagawa, 2007; Wei et al., 2011; Kahn et al., 2012; Shimada, Kanda & Koizumi, 2012). Research mentioned that using the robot increases interactive learning, helping children to be more involved in the learning activities. This growing research on the educational application of robotics needs a look at the direction in order to illustrate a roadmap for next studies (Chen, Quadir & Teng, 2011; Highfield, 2010).

The main points that Mubin tests identified were the role of robot, the kind of the physical form, behavior as capacity and interaction ability, the kind of learning activity and the place where the learning occurs if inside or outside classroom (Mubin et al., 2013). The study differs by pointing out the various roles played by the robot in education – as tutor, tool, or peer. The work of Benitti found similarities in the topics on which robots are used in education – language learning, science, and technology (Benitti, 2012).

Research object is implementation the robot technology to educational process and analyze how it helps elementary school teachers to involve students to learning activities and acquire Stem digital competence and creativity.

Research aim is to introduce an educational tool in a form of robot to help elementary school teachers to deliver the colors concepts to pupils and develop STEM competencies such as digital competence, creativity. The suggested robot can be used for obtaining other concepts by using it as the selection tool which a child uses to choose the correct from alternatives.

Research tasks:

1. To review scientific researches that address the issue of using robot in classrooms in various field of education with different ages of students.
2. To review scientific literature that studies the perception of the stakeholders including parents, teachers, and students about using robots in classrooms.
3. To design and implement a robot to young pupils to for acquiring some STEM competencies.

Research methods: review of scientific literature; programming with Arduino microcontroller which includes developing the code and creating its circuit.

1. Robots in education

This part presents several studies that connect robot with education including using robots for developing educational concepts and the various perception about it. The significant role for robots in education is to facilitate the acquisition of educational concepts such as scientific, mathematical, and technological concepts, besides developing some skills like language and cooperation skills. The current literature review focuses some important issues related to robots.

Robots for developing the scientific and technological concepts.

The research by Barak and Varney were made to examine how robotics is changing education, helps to prepare children with 21st century skills to life and raises students' interest in robotics (Barak, 2009; Varney et al., 2012). Robots have also been seen as a significant tool for improving students' team skills (Varney et al., 2012). Employing robots in several activities with young children supports constructivism as a method of learning. Robots get students excited to debate to solve problems, work with their peers and pool their knowledge to build their own robots. In the work of Chang, the work results also confirm that robots can create an engaging and interactive learning experience (Chang et al., 2010).

In elementary school robots help the children to develop their cooperation and problem-solving skills as they became engaged in the process and building of their own artifacts for their robotic projects. The study of Hong highlighted this point. Through the research robots allowed children to involve in deep thinking while solving problems and collaborating with their peers, both of which enhanced their own learning experience (Hong et al., 2011).

Baker and Ansorge's research examine student achievement scores using robots in the science course. Robots were found to be effective at teaching science, engineering, and technical concepts to students aged 9-11 years (Baker and Ansorge, 2007). Results of another trial study by Kazakoff emphasis the use of robotic programming like CHERP, a concrete program that helped increase sequencing skills in pre-kindergarten and kindergarten (Kazakoff et al., 2013).

The robot was used to help non-English speaking students to develop their understanding of science concepts through the study of Whittier and Robinson (2007). The study results explain that students had adequate gains in scientific conceptual knowledge with an increase from 26.9 proc. in the pre-test to 42.3proc. in the post-test. Robots are used with middle school students to develop the skills of problem-solving, inquiry, and engineering design. Robots have also been used to develop and improve the learning of science and technology concepts and problem solving, which is further supported by Barak qualitative analysis of observations, interviews, and reflections of students working on their projects (Barak, 2009). In addition, the study of Highfield showed that robotic games can be a catalyst for solving mathematical problems by engaging in a multifaceted approach by integrating interrelated and overlapping concepts and skills through dynamic tasks (Highfield, 2010). Using robots to improve knowledge of physical content showed a clear difference between acquired competences (Williams et al., 2007). Table 1 displays a summary of the skills in which the robot has a positive impact.

Table 1. Robots for scientific and technological development

Papers	Skills
Mousa et al, 2017	The study suggested a robot CR-Cube for kindergarten children for obtaining the mathematical and colors concepts. The work presented the details of designing and implementing it using LEGO robots.
Kazakoff et al., 2013	The study revealed that ability of sequencing increased for pre-kindergarten and kindergarten children by working with robots and programming.
Slangen et al., 2011	The study proved that robots could assist children to analyze, predict, manipulate, and reason.
Highfield, 2010	The research revealed that children involved in mathematical processes. They showed responsiveness and perseverance.
Bers, 2010	The work demonstrated that boys are better than girls in properly constructing robots and programming.
Barak, 2009	The work showed that children provide new solutions to problems by using robots in education.
Whittier & Robinson, 2007	The study demonstrated that children acquired gains in understanding concepts. It showed a clear increase of the mean post-test by 15.4proc. from the pre-test by.
Barker & Ansorge, 2007	The research revealed an increase in the average scores between the pre-test and the post-test explaining that robots were effective in the learning process in studying science, technology, and engineering.
Williams et al., 2007	The results indicate a major difference on understanding physics knowledge.

Robots for language skills development. The research presented by Chang used a robot to teach a second language in an primary school. The study results showed that robots could create interactive and engaging learning experiences where children responded with great motivation (Chang et al., 2010). Using robots for developing language has been proved to be beneficial as it also allows the demonstration of mobile behavior and extensive repetition. The study of Sugimoto employed robots for storytelling, and the robot was used in student learning and the opportunity for children to learn in a mixed reality environment (Sugimoto, 2011). The children actively participated in expressing the story and acted in a coordinated manner while also participating in creating their own story with their robots. The study of Slangen found that students can work on projects using LEGO and Mindstorms and engage in an iterative process of comparing their test results with their goals and expectations, and in improving their conceptual knowledge and skills. Table 2 summarizes articles dealing with the use of robots to develop language skills (Slangen et al., 2011).

Table 2. Articles with focus on language skills development

Papers	**Overview of paper on language skills development**
Varney et al., 2012	The research results showed the effectiveness of using LEGO robot programming in fostering student's interest
Varney et al., 2012	The study proved the effectiveness of the educational robot as a tool to improve team skills for children.
Chen, Quadir & Teng, 2011	The research proved that using robots with computer developed the concentration of children in learning English.
Hong et al., 2011	The results revealed that students were engaged and reflective through construction of the artefacts.
Sugimoto, 2011	The results of the research showed that children involve in story expression and acted in a coordinated manner.
Bers, 2010	The study implemented TangibleK robotics with early childhood by integrating other disciplines.
Young et al., 2010	Quantitative results showed that 95proc. have positive attitude towards tangible learning companions/robots. They become more active in practicing conversation.
Chang et al., 2010	The study showed that educational robots were able to provide an engaging and interactive environment for children.
Michaud, et al., 2005	The work used Roball robot children development studies.
Ruiz-del-Solar & Avilés, 2004	The research revealed the importance of using robots for fostering the interest of students in engineering.

2. Perception about educational robots

Picocricket Invention Kit was a robot kit introduced by Rusk for developing the participation of children and educators in robotics efforts through workshops, after-school programs, and professional development programs. The workshops give the students a chance to work on broad topics according to their own interests. The students had the chance to merge art and engineering, and they were encouraged to employ storytelling and presentation, and introduced to new technologies as the result their interest in robotics increased (Rusk et al., 2008).

The study of Levy and Mioduser provided anecdotal data by children on descriptions and explanations of robots' behavior (Levy and Mioduser, 2008). In addition, the results clarify that when teachers interact with the students, they could shift into more complex technological rules. Another study by Beran conducted with 184 showed that a significant proportion of the students ascribe cognitive, behavioral, and affective characteristics to robots (Beran et al., 2011).

The study of Woods involved 159 children and asked them to evaluate forty images of robot through questionnaires to discuss how children describe the appearance of robot. The research showed that children perceive robots' intentions and capabilities based on robot appearance (Woods, 2006). Children judged human-like robots as aggressive and machine-like ones as friendly. The work of Sullivan and Bers showed using the TangibleK programme that the boys scored significantly higher than girls in properly attaching robot components and programming (Sullivan and Bers, 2012).

The studies of Liu (2010), Ruiz-del-Solar and Avilés (2004) discussed the opinions of teachers, parents, and children about using of robots in the learning process. The results of Liu (2010) showed that most parents consider robots to be useful for their children. On the other hand, they felt less confident when playing and teaching their children how to use robots.

The research of Ruiz-del-Solar and Avilés (2004) investigates the satisfaction of children on using robot, the required level of competence and their eventual concern to pursue an engineering career. The research involved seven hundred teachers and children and 86proc. of them agree to study in an engineering or science university in the future. The work of Bers (2010) improves the computational thinking and learning about the engineering design process by introducing the TangibleK programming. It merged other disciplinary education in a developmentally suitable way for children. Table 3 shows the list of articles and the comments on stakeholder about the use of robots with children.

Table 3. Perception about robots for stakeholders

Papers	Perception
Lin et al., 2012	The research showed that parents assumed robots as useful tool for using with their children.
Beran et al., 2011	The study suggested that the most children proportion ascribe affective characteristics and cognitive, behavioral to robots.
Liu, 2010	The study result indicated that children account robots as plaything, regard studying robotics as a connection for employment and consider learning of robotics as a method to advanced technology.
Woods, 2006	The work suggested that the young children could feel the difference between robots and human, and they found that robots trigger a feeling of repulsion and discomfort.

3. Programming of robot

This part explains the steps of building robot involving the electric circuit used and the programming code that present the instruction for the robot to do its job.

Robotics requires several skills and competencies that can be easily developed with tools like Arduino. These skills and competencies are related to the areas of knowledge used for the development of robotic applications, such as computer science, electricity, electronics, and mechanics. This section presents Arduino as the resources used for developing an educational robot.

Programming instrument. These days Arduino has become a popular microcontroller because it makes dealing with electronics easier due to the simplified version of C++ and the already made Arduino microcontroller. Arduino is an open-source platform used for constructing and programing of electronics. It can receive and send data to many types of devices, and even through the internet to give instructions to the specific electronic device. Arduino uses a hardware called Arduino UNO circuit board and software program that is a simplified C++ to program the board (Galadima, 2014).

As any microcontroller an Arduino is a circuit board with chip that can be programmed to do numerous numbers of tasks, it can send data from the computer to Arduino board and then to a specific circuit or machine with multiple circuits to execute the commands. Also, Arduino can read data from input devices such as sensors, antenna, trimmer, and can also send information to output devices such as LED, Speakers, LCD Screen, DC motor (Mellodge and Russell, 2013).

The Arduino platform has become well known with people into electronics, unlike most previous programmable circuit boards, the Arduino does not have a separate piece of hardware in order to load new code onto the board, you can simply use a USB cable to upload, and the software of the Arduino uses a simplified version of C++, making it easier to learn to program, and it provides you with an easier environment that bypass the functions of the micro-controller into a more accessible package (Yasin et al., 2018).

The Arduino board hardware consist of components that combine to make it work. The main component on the board is USB plug which is connected to computer to upload the instructions to the microcontroller and has a regulated power of five volts that is the power Arduino board. External power supply: it is only used to operate the board, and it has a regulated voltage of 9 to 12 volts. Reset button: It is used to resets the board, when it is pressed, it means to clear the current program. Microcontroller: this is the device which sends and receives command to the respective circuit. Analog Pins: they are analog input pins from AO to A5. Digital I/O Pins: They are the digital input, output Pins 2 to 13. The Arduino IDE: is the software which contains instructions that informs the hardware of what to do and how to do it. It is called Arduino Integrated Development Environment, IDE for short (Bashir et al., 2019).

Methods. The circuit consists of an Arduino UNO board (Figure 1), a color sensor TCS230, two push button, five resistors 1K ohm, red led, green, red, and blue led. The circuit is connected (Figure 2) consuming 10 Arduino pins in total as in Table 4. Each led or button is connected to an Arduino pin from a side and connected to ground through a resistor from the other side. The color sensor requires five Arduino pins beside two other connections to ground and 5 volts. The final shape of the circuit is declared in Figure 3. Finally, this robot circuit could be reduced to the cubic shape by decreasing by shorten the wires and welding the components to appear as in Figure 4.

Arduino uses C++ language to manage the components connected to the microcontroller. The current code loop starts with listening to the two push buttons, if the button 1 is pressed the code turn on the red led and turn the other two, if button 1 pressed again the code turn on the green led only, then the blue led for the next time. The circle continues for more pressing on button 1. If the button 2 is pressed the code reads the color of the square and compare it with the lighted led color. If they are the same, all three led turn on to show that the selection is correct else nothing occurs waiting the next attempt. The code details are in Figure 7 and Figure 8.

Table 4. Arduino pins connections

	Component	Arduino pin
Led	Red led	2
	Green led	3
	Blue led	4
Button	Push button 1	5
	Push button 2	6
Sensor	Sensor out	8
	Sensor S2	9
	Sensor S3	10
	Sensor S1	11
	Sensor S0	12

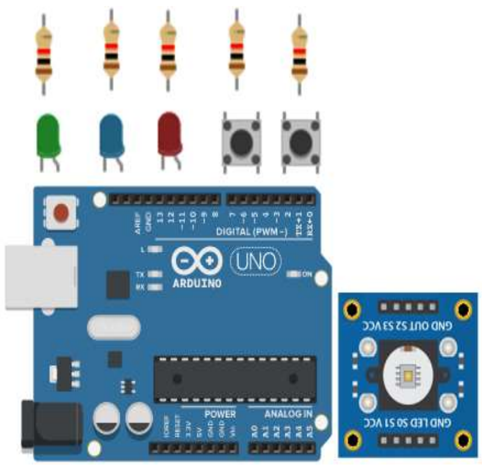

Figure 1. Components of the circuit

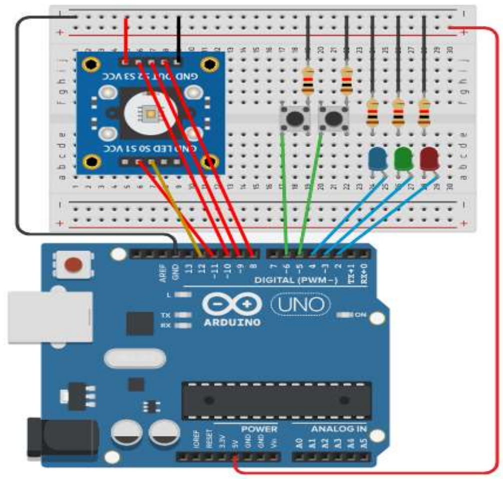

Figure 2. Robot circuit design

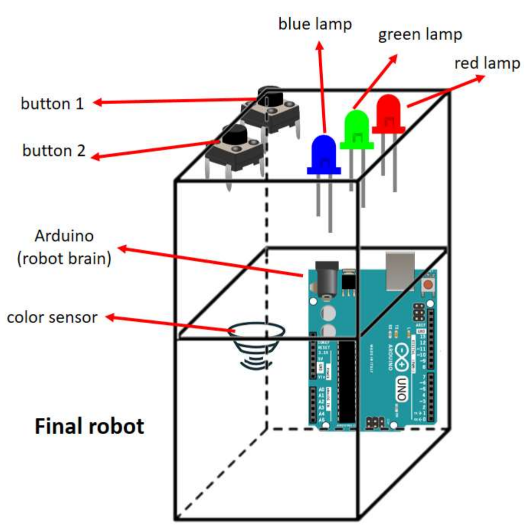

Figure 3. Robot circuit implementation

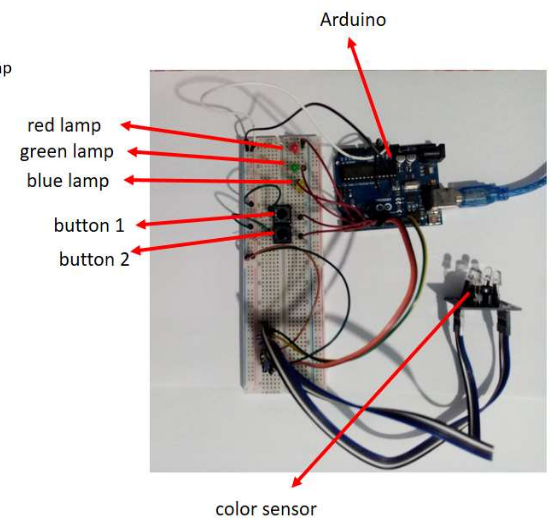

Figure 4. Robot circuit as a cube

Results and discussion. The aim of the study is to make a small robotic game to children to learn color, numeric or language concepts depending on the shape of the gamepad used. Consider the color gamepad in Figure 5, it consists of squares of colors. The teacher presses on the push button 1 to choose one color from the available led: red, green or blue. Let the teacher keeps press until reach the green color, then the green color lights indicating that the green color is selected. Then, the child tries to search for the green color in the gamepad, place the cubic robot on it and press the push button 2. If the color is correct the three led light turn on to show that the child success otherwise nothing takes place, and the child tries again.

The game can be used with other concepts such as language or numeric by using another gamepad as in Figure 6. The idea is to write a number or the letter on each square and the teacher choose the color corresponding to the required letter of number. Therefore, the game can be used a selector device for other concepts or for other games.

The tests of the robot circuit are in the following links: https://youtu.be/BBs0O40B3U0; https://youtu.be/NRcoJ0dSCnw.

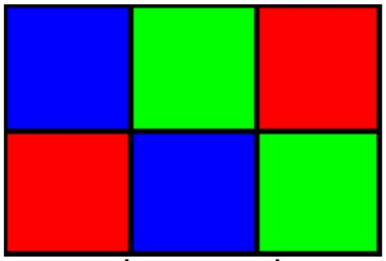

Figure 5. Color gamepad

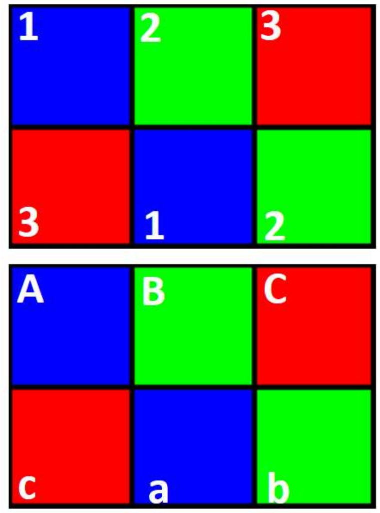

Figure 6. Numbers and language gamepad


```
#define LMP_R 2
#define LMP_G 3
#define LMP_B 4
#define BTN_S 5
#define BTN_T 6
#define S0 11
#define S1 12
#define S2 9
#define S3 10
#define sensorOut 8

float sum = 0, R = 0, G = 0, B = 0, r = 0, g = 0, b = 0;
String C = "not_clear", c = "";

void setup() {
  pinMode(LMP_R, OUTPUT); digitalWrite(LMP_R, LOW);
  pinMode(LMP_G, OUTPUT); digitalWrite(LMP_G, LOW);
  pinMode(LMP_B, OUTPUT); digitalWrite(LMP_B, LOW);
  pinMode(BTN_S, INPUT_PULLUP);  pinMode(BTN_T, INPUT_PULLUP);

  pinMode(S0, OUTPUT);  pinMode(S1, OUTPUT);  pinMode(S2, OUTPUT);  pinMode(S3, OUTPUT);
  pinMode(sensorOut, INPUT);
  digitalWrite(S0,HIGH);  digitalWrite(S1,HIGH);

  Serial.begin(9600);
}

void read_color() {
  digitalWrite(S2,LOW);   digitalWrite(S3,LOW);    r = pulseIn(sensorOut, LOW);  delay(100);
  digitalWrite(S2,HIGH);  digitalWrite(S3,HIGH);   g = pulseIn(sensorOut, LOW);  delay(100);
  digitalWrite(S2,LOW);   digitalWrite(S3,HIGH);   b = pulseIn(sensorOut, LOW);  delay(100);
  sum = r + g + b;   r = r / sum * 100;    g = g / sum * 100;    b = 100 - r - g;
  c = color_name(r, g, b);
  print_color(r, g, b, c);  Serial.print("\t");  print_color(R, G, B, C); Serial.print("\n");
}

void reset_lamp() {
  if (C == "red") set_lamp(1,0,0);
  if (C == "green") set_lamp(0,1,0);
  if (C == "blue") set_lamp(0,0,1);
  if (C == "not_clear") set_lamp(0,0,0);
}
```

Figure 7. Code - page 1

```
void pickup_color() {
  read_color();
  R = r;   G = g;   B = b;   C = c;
  reset_lamp();
}

void change_color() {
  if (C == "red") C = "green"; else if (C == "green") C = "blue"; else C = "red";
  print_color(r, g, b, c);  Serial.print("\t");  Serial.print(C); Serial.print("\n");
  reset_lamp();
}

String color_name(int red, int green, int blue) {
  if (red < green && red < blue) return "red";
  if (blue < red && blue < green) return "blue";
  if (green < red && green < blue) return "green";
  return "not_clear";
}

void set_lamp(int red, int green, int blue){
  digitalWrite(LMP_R, red);
  digitalWrite(LMP_G, green);
  digitalWrite(LMP_B, blue);
}

void print_color(int red, int green, int blue, String color) {
  Serial.print("(");
  Serial.print(red);    Serial.print(",");
  Serial.print(green);  Serial.print(",");
  Serial.print(blue);   Serial.print(",");
  Serial.print(color);  Serial.print(")");
}

void correct(){ set_lamp(1,1,1); }
void not_correct() { reset_lamp(); }
// //////////////////////////////////////////////////// //
void loop() {
  if (digitalRead(BTN_T) == HIGH) {
     //pickup_color();
     change_color();
  }
  if (digitalRead(BTN_S) == HIGH) {
    read_color();
    if (C == c) correct(); else not_correct();
 }
 delay(500);
}

Done Saving.
```

Figure 8. Code - page 2

Conclusions

1. Educational robots are used to allow students to pick up skills in a range of Science, Technology, Engineering, and Mathematics (STEM) disciplines, which are increasingly important in a world in which technology is advancing rapidly. The robots facilitate learning and introduce students to robotics at a young age. In primary education settings, students can learn how to build and program a robot to perform a range of basic tasks.

2. The current work presents several studies that discusses engaging the robotic technology in education. The studies evidence the importance of this technology in classrooms. It can be used to students for obtaining the mathematical concepts. Also, it is useful when studying science, technology, and engineering. In addition, robots and programming increase the sequencing for young children. Robots can help pupils to analyze, predict and manipulate, and encourage children to provide new solutions to problems. The study also provides research that discussed the issue of the perception of stakeholders about robots. The research show that parents consider robots as a beneficial tool in education. Moreover, children proportion ascribe affective characteristics and cognitive, behavioral to

robots. Also, even young children feel the difference between robots and human. Some of them assume that robots trigger a repulsion feeling and discomfort.

3. This work demonstrates a suggested robot to young pupils and presents its design and implementation. The new robot is designed for acquiring some STEM competencies. The research succeeded to construct the robot circuit and develop the code that manages the game behavior. The current work presented an attempt to enter the robotic game as beneficial tool for acquiring digital competence, creativity, reflective and independent thinking, problem solving, communication and learning. Dealing with robot is more interesting for children than ordinary methods for teaching and more than modern tools as computer. The robot shown in this research can be used to obtaining children the educational concepts. It could be considered as a separate device for selection for other games.

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EDUKACINIO ROBOTO PASITELKIMAS PRADINĖJE MOKYKLOJE MOKINIŲ STE(A)M KOMPETENCIJŲ UGDYMUI

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Santrauka

STEM ugdymas, labiau žinomas kaip STEAM, yra integralus kelias disciplinas jungiantis ugdymas. STEM ugdymas – tai mokymas, sujungiantis technologijas, inžineriją, matematiką bei meną ir kūrybą į vieną visumą. Meno ir kūrybos integravimas praplečia STEM ugdymo sampratą ir pritaikymo ribas. Viena iš problemų mokymo procese yra ta, kad tradiciniai mokymo/si metodai daugeliui vaikų yra neįdomūs, tačiau mokytojai vis dar neskiria pakankamai dėmesio inovatyviems IT technologijomis pagrįstiems mokymo metodams. Šis straipsnis atskleidžia, kaip integruoti vaikus į ugdymo procesą panaudojant roboto technologiją Straipsnio tikslas pristatyti ugdymo priemonę – robotą, kuris padėtų pradinių klasių mokytojams išmokyti vaikus pažinti spalvas, ugdyti/s STEM skaitmeninę ir kūrybinę kompetencijas. Roboto technologijos panaudojimas gali būti naudojamas pamokose, kada vaikai mokomi pasirinkti vieną iš siūlomų sąvokos alternatyvų (aplinkos pažinimo pamokose, matematikos pamokose ir t.t.). Straipsnio pradžioje pristatomi keli tyrimai, kurie pagrindžia robotų technologijos sąsajas su ugdymu, įskaitant robotų naudojimą mokyklose ugdant mokinių kompetencijas. Ankstesni tyrimai rodo, kad robotai atlieka svarbų vaidmenį ugdant mokinių tiriamąsias, matematines ir skaitmenines kompetencijas, lavinant tokius įgūdžius kaip kalbos ir bendravimo. Nagrinėjamos mokslinės literatūros apžvalgoje ypatingas dėmesys skiriamas aktualiems su robotų technologijos įtraukimu į ugdymo procesą susijusiems klausimams, pvz., pateikiama keletas tyrimų, kuriuose aptariamas ugdymo proceso dalyvių vertinimas apie robotų įtraukimą į ugdymą. Tyrimai rodo, kad tėvai robotų įtraukimą į ugdymą laiko naudinga metodine priemone. Be to, kas yra svarbu - vaikai robotams priskiria/suteikia emocines, pažinimo, elgesio savybes. Tačiau kai kurie tėvai mano, kad robotai sukelia atstūmimo ir diskomforto jausmą. Šiame straipsnyje pristatomas robotas, skirtas pradinių klasių mokiniams, aptariamas roboto dizainas ir roboto integravimas į ugdymo procesą. Darbas su robotu vaikams yra įdomesnis nei įprasti mokymo metodai ir modernesnis nei paprastas kompiuterio naudojimas. Naujasis robotas skirtas kai kurioms STE(A)M kompetencijoms įgyti. Tyrimo metu pavyko sukurti roboto grandinę ir sukurti kodą, valdantį žaidimo eigą. Straipsnis pristato bandymą integruoti roboto technologiją kaip žaidimą ugdant skaitmeninės kompetencijos, kūrybiškumo, reflektyvaus ir savarankiško mąstymo, problemų sprendimo, bendravimo ir mokymosi kompetencijas

Reikšminiai žodžiai: STE(A)M kompetencija, įgūdis, robotas.