International Journal of Business, Human and Social Sciences
ISSN: 2517-9411
Vol:11, No:7, 2017

A Robotic Cube to Preschool Children for Acquiring the Mathematical and Colours Concepts

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***Abstract*—**This work presents a robot called Conceptual Robotic Cube, CR-Cube. The robot can be used as an educational tool for children from the age of three. It has a cube shape attached with a camera colours sensor. In addition, it contains four wheels to move smoothly. The researchers prepared a questionnaire to measure the efficiency of the robot. The design and the questionnaire was presented to 11 experts who agreed that the robot is appropriate for learning numbering and colours for preschool children.

***Keywords*—**CR-Cube, robotic cube, conceptual robot, conceptual cube, colour concept, early childhood education.

I. Introduction

NOWADAYS, using multi-media tools in education has increased due to advances in technology in the 21st century. Several schools employ modern educational tools for children in classrooms as a QR-code [1]; while, others use computers and cartoons as a way to provide information and concepts [2].

Educational robots are a learning environment in which the individuals involved are stimulated through designing and creating of objects similar to those in our lives and controlling them by a computer system, which is called modelling or simulation; internationally, schools have started to incorporate robots into the educational process [3]. Children prefer playing with technical devices during playtime or in their spare time [4]. Many researchers investigated the effects of using robots on the cognition, interaction, moral, and social development of children [5]-[7].

It was found that using robots encourages interactive learning; furthermore, it attracts children’s attention, making them more engaged in the learning activities [8], [9].

According to the findings of previous studies in this field, there are several major factors to consider when using robots in education [10]: 1) the physical form, which depends on the type of the robot, 2) the behaviour of the machine, which is determined by the capabilities and interaction capacity, 3) the type of learning activity, and 4) the venue where the learning occurs, such as inside or outside the classroom. Research also shows that to a large extent, there is a similarity with regard to the topics that robots were used for; however, the robots were used in different roles such as tutor, tool, or peer [10], [11].

Robots can be used to improve problem-solving abilities. They were used by high school students to produce creative solutions to problems [12]. Moreover, some robotic kits such as LEGO Mindstorms provide students the opportunity to work in small groups while developing their projects. Robots can be used for acquiring team work skills [13], [15], because the children can work in small group while constructing the robot parts [14].

Another study focused on the use of robotic programming for developing the sequencing skills of pre-kindergarten and kindergarten children [3]. Furthermore, robots managed to support non-English speaking students in understanding science concepts. This study succeeded to increase the students' understanding from 26.9% in the pre-test to 42.3% in the post-test [16]. Furthermore, robots were used to develop learning of science concepts, technology and problem-solving [12]. Robots have also been used as a catalyst for solving mathematical problems [8], while in another study they were used to improve physics content knowledge [17].

Language skills development is another important field in education, and in the one study, robots have been used to teach a second language in a primary school [14]. In this study, the robots managed to create interactive learning experiences, to which the students responded with high motivation. Another research used robots for storytelling [18]. The results showed that the children engaged strongly in the stories provided by robots. In this study, robots gave children a chance to learn in a mixed -reality environment. Another study used LEGO and Mindstorms in a project with students [19].

Actually, robots are not only useful for primary students, but they are important for young children as well. This work focuses on using robots to teach young children colour and mathematical concepts.

The base of the Mindstorms NXT system with contains a microprocessor, four sensor ports, three motor ports, a USB 2.0 port for downloading programs, a speaker, control buttons, and an LCD screen. The motor ports send control signals to the motors and receive feedback from them—recording how many rotations they have made, for example. The LCD screen can be configured to display information from the sensors, or commands, or text messages. The buttons used for navigating menus on the screen can also be configured as touch sensors. Fig. 1 shows the different parts of the robot where

1. The NXT: the computer-controlled brain of the Mindstorms robot
2. Touch Sensor: enables the robot to feel and react to its environment
3. Sound Sensor: enables the robot to react to sound
4. Light Sensor: can detect light and colour
5. Ultrasonic Sensor: allows the robot to measure distance and react to movement
6. Servo Motors: ensures the robot moves with precision

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Fig. 1 Mindstorms NXT

With the first generation of Mindstorms kits, it was hard to build robots that could travel in a straight line, as one of the wheel-mounted motors, as seen in Fig. 2, might be slightly stronger than the others. Some hobbyists worked around this problem by adjusting the wheels manually or by designing their own rotation sensors.

The NXT motors, however, have built-in rotation sensors. A tachometer measures the speed of the motor and produces a voltage proportional to that speed. That voltage is compared with a reference voltage corresponding to the speed that the programmer has set for the robot, and the motor's speed is then automatically adjusted. The sensors can also measure how far each wheel has turned, allowing for precise turning commands.

Fig. 2 Mindstorms NXT wheel-mounted motors

The touch sensor, Fig. 3, can accommodate an axle that can extend the length of a bumper, which triggers the sensor when the robot comes into contact with an object. The light sensor is more sensitive than the previous version.

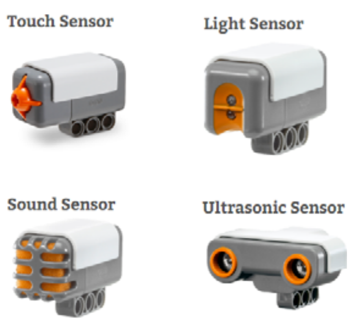

Fig. 3 Mindstorms NXT sensors

The sound sensor, which is new to NXT, can measure sound levels, so that the same command given softly or loudly can elicit a different response. Also new is the ultrasonic sensor, which allows a robot to judge its distance from objects by sending out a signal and tracking how long it takes to return.

II. Method

The paper presents the design of an educational robot named Conceptual Robotic Cube, CR-Cube. The proposed robot can be used to teach preschool and kindergarten children inside and outside classrooms.

Fig. 4 demonstrates the design of the CR-Cube. The robot is attached with a motor and four wheels to allow moving easily. In addition, there is a colour sensor on the base of the robot to detect the colour which the cube is moving on. A screen mounted on the top of the cube displays the commands, which are either asking about certain colours or numbers.

To begin, the cube is placed on either the colours background (Fig. 5) or the number background (Fig. 6). Each background consists of nine squares with different colours or numbers. In the case of the colours background, the cube can distinguish its square by the colour sensor on the bottom. In the case of the numbers background, the colour sensor can detect the square because each number has a different colour.

Next, the screen displays a command according to the background. Consider that the background is the number one and the command is the number five. According to the command on the screen, the child must try to move the cube to the right square, as in Fig. 7.

Each square has a position, colour and number; these data are stored as a database III. For example, if a child places the robot on square number eight. Then, the colour sensor will detect the colour brown according to the table. Moreover, the robot will detect the location of the square which is at X = 2, Y = 3. If the child succeeds to move the cube to the right square, the screen will display a message of congratulations; otherwise, the cube will move automatically the right square.

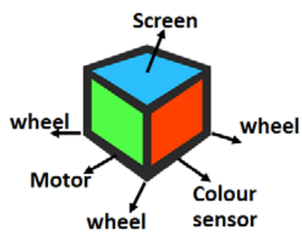

Fig. 4 Design of CR-Cube

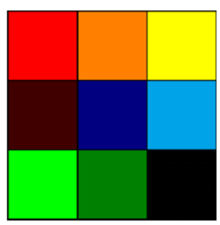

Fig. 5 Background of colours

Fig. 6 Background of numbers

Fig. 7 Cube is on square number five

This robot can be created by a programmable robotics kit such as LEGO Mindstorms NXT, which was released by Lego in 2006. The advantages of this kit are that it comes with NXT-G programming software which allows the user to write the robot commands [20]. The algorithm of that describes the robot behaviour:

1. Display number X on the screen. Then, wait until the robot is moved and the OK button is pressed.
2. Determine the current square/location using the sensor.
3. If square of displayed number X = the current square, then display a congratulations message.
4. If the square of number X ≠ the current square, then:
   a. if X is to the left of the current square, then move the robot one square to the left.
   b. if X is to the right of the current square, then the move robot a square to the right.
   c. if X is front of the current square then move robot a step to the front.
   d. if X is front of the back square then move robot a step to the back.

For example, if the current place of robot is at the square number 3 and it is required to move to the square number 8. The following steps will take place:

1. The colour sensor will detect that the colour is Red=255, Green=255 and Blue = 0, which is the colour of number 3.
2. The robot will search in the database, Table III, and detect that the current square is number 3 which is located at $X_1 = 3$ and $Y_1 = 1$.
3. Then, the robot will detect the destination, number 8 or Dark Green, which is Red = 0 Green = 64 and Blue = 0. According to Table III. It is located at $X_2 = 2$ and $Y_2 = 3$.
4. The mission now is moving from $X_1 = 3$, $Y_1 = 1$ to $X_2 = 2$, $Y_2 = 3$.
5. Since $X_1 > X_2$ then the robot will move one square toward the left. Now, $X_1 = 2$ ($X_1 = X_2$)
6. Since $Y_1 < Y_2$ then the robot will move one square to the front. Then another square in the next step. $Y_1 = 3$ ($Y_1 = Y_2$)

As part of the study the researchers prepared a questionnaire, the results of which are shown in Table I. The questionnaire aimed to assess the appropriateness and capability of the robot in teaching children to understand the colour and number concepts. The researchers asked the expert about their opinion in these items:

1. Provide children with a degree of organization and understanding of the reality of the concepts of colour and numbers.
2. Encourage children to make experiments by trying and learning from mistakes.
3. The children will be able to take responsibility for the robots they use.
4. Create a relation between the provided concepts and the children's mental knowledge
5. Increasing the ability for switching between the different mathematical and colour concepts.
6. Improving the knowledge about the colour and mathematical concept.
7. Improving the child's ability to play collectively in groups.
8. Monitoring the attempts to reach the concept through sharing and playing.
9. It can be used in inside classroom.
10. It can be used in outside classroom.

TABLE I
THE EXPERTS RESPONSE TO THE CR-CUBE'S AIMS

	Item	Agreement (%)
1	Provide children with a degree of organization and understanding of the reality of the concepts of colour and numbers.	82%
2	Encourage children to make experiments by trying and learning from mistakes.	100%
3	The children will be able to take responsibility about the robots they use.	75%
4	Create a relation between the provided concepts and the children's mental knowledge	94%
5	Increasing the ability for switching between the different mathematical and colour concepts.	98%
6	Improving the knowledge about the colour and mathematical concept.	100%
7	Improving the child's ability to play collectively in groups.	64%
8	Monitoring the attempts to reach the concept through sharing and playing	62%

Another important aspect related to the design of the presented educational tool considers the age of the children and their capabilities. The main points of the design is the shape of the robot, its dimension and is it flexible to be used inside and outside classrooms, where Table II gives the response of the experts

1. Robot shape: The study suggests being a cube rather than any other shape to be easier for holding. Moreover, the cube is supplied be motors to allow it to move easily.
2. Robot dimension: Basically, this factor depends on the age of the child. The cube dimension is suggested to be from 10 cm to 15 cm.
3. Design flexibility: It is a significant factor particularly when the educational tool message is for young children.

It gives an indication of how easy it is to use the robot inside and outside of classrooms.

TABLE II
THE EXPERTS RESPONSE TO THE CR-CUBE'S DESIGN

	Item	Agreement (%)
1	Robot shape	89%
2	Robot dimension	92%
3	Flexibility inside classroom	100%
4	Flexibility outside classroom	100%

TABLE III
THE DATABASE OF THE SQUARES

Number	Colour				Location	
	name	Red	Green	Blue	X	Y
1	Red	255	0	0	1	1
2	Orange	255	128	0	2	1
3	Yellow	255	255	0	3	1
4	Brown	64	0	0	1	2
5	Blue (dark)	0	0	128	2	2
6	Blue (light)	0	160	230	3	2
7	Green	0	255	0	1	3
8	Green (dark)	0	64	0	2	3
9	black	0	0	0	3	3

III. RESULTS

The response of experts shows that the suggested robot can be used in the educational environment to help children understand colours and mathematical concepts inside and outside classrooms. The shape and the dimensions are convenient for use by children.

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