ORIENTED ROBOTIC EDUCATIONAL ARM IN STEM (SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS) FOR STUDENTS OF MIDDLE LEVEL EDUCATIONAL INSTITUTIONS

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Abstract. *The present work of titration consists of a robotic education arm printed in 3D oriented in STEM (Sciences, Technologies, Engineering and Mathematics) for students of educational institutions of average level, to be controlled by means of the use of personalized bookstores generating a greater facility in the programming process.*

The robotic arm consists of the arm, forearm and hand thus generating the movements of a human arm because it has all the degrees of freedom of a real one, the arm was implemented in the Educational Unit July 17 where I cause great interest in part of the teachers and students because it is also presented with a teaching strategy, because it is a project focused on STEM to motivate students to cross any of these branches in the University.

It allows students to encourage their creativity thus strengthening their skills and abilities, while developing programming skills and logical reasoning by encouraging teamwork and generating greater communication and understanding among peers demonstrating that you can play and at the same time to generate knowledge promoting the use of technological tools.

This prototype is presented as a didactic tool to avoid boredom within the classrooms creating new learning environments and changing pedagogical practices and generate a more active role in the teaching - learning process.

Keywords

STEM, robotic arm, teaching methodology, servo motor.

I. Introducción

In Ecuador, according to the (INEC, 2014) has 80% of adolescents in academic units, nationally 58% of this sector has access to technologies in education; Educational robotics oriented to STEM is a learning methodology that allows to develop skills and abilities, as well as to be better incentivized in the innovation and technological development taking advantage of the time they occupy in front of a computer.

The change of the productive matrix is the most important strategic axis of Ecuador, in consequence the lack of software and hardware didactic tools that help to stimulate the students to manifest their ideas in a creative and organizational way, while they develop skills of logical thinking, through constructive practices with an interactive education helping students to begin to train as agents of change familiarizing themselves with the digital era as in first world countries, all of these relate directly or indirectly to the proper use of technology, unfortunately statistics are still seen in education efforts have not been sufficient and there must be change actors in the citizenship itself to accelerate the process of technification in education.

CTIM is a form of education that is related to educational robotics, awakening in young people of upper secondary level a greater understanding and taste on scientific, mathematical and technological subjects, stimulating them to pursue careers in those areas. In the country there are no didactic software and hardware tools that help stimulate students to express their ideas in a creative and organizational way, while developing logical thinking skills, in the development of robotics through constructive practices with a education where each person has the ability to create their own knowledge.

The robotic arm in 3D as a way to show new ways of offering interactive programming through electronics with this innovative tool, to awaken the ingenuity and identify skills in young people in this area of robotics. The development of this system aims to provide motivation and tools to the technological community to create more applications with this technology that facilitate and transform the traditional educational practice, towards an education that is on par with the technological advances to apply them in the student community of our country.

II. BASIC CONCEPTS

A. Educational Robotics

The Educational Robotics is a means of learning, in which the main motivation is the design and construction of own creations. These creations are given first mentally and then in physical form, which are built with different types of materials and controlled by a computer system [1]

Educational robotics is based on the pedagogical principles of constructivism and constructionism:

• Constructionism

This is based on the use of ICT in education. Granting in this way students an active roll and designers of their own projects and their learning, learning that appropriates the environment, imagines it, simulates it, creates it, recreates it and innovates it, projecting the student. These are the most active students in their teaching-learning process. It is intended that students build their own knowledge.

• Constructivism

Constructivism is a didactic way in which the teacher is a tool to help solve problems, demonstrating that it is the teaching and learning process with a dynamic and interactive act, where the learner builds his knowledge and the method for interior design , in this method of pedagogy, the student's prior learning is taken into account so that an assumption is made of someone who wants to learn and knows because he has the previous knowledge and the only thing that he looks for the most useful resources, help with Guided work or guidance that helps with advice, information and solutions for the student who needs help knowledge. [1]

B. CTIM

CTIM is a curriculum that is based on the idea of educating students through four disciplines (Science, Technology, Engineering and Mathematics) by taking advantage of the similarities and common points of these four subjects to develop an interdisciplinary approach to the subject. teaching and learning process, incorporating contexts and situations of daily life, and using all the necessary technological tools. [2]

The STEM concept began to take shape in the nineties at the NSF (National Science Foundation). Many were those who were interested in this initiative but it was not until the year 2010 that they took importance with emphasis on the governmental policies of the United States of America.

1) Science: It is very broad category, because it covers many disciplines. At the present time, archeology kits are very popular, which consists of unearthing a dinosaur skeleton, and then arming it. There are also packs of utensils that are used to find insects, parts of microscopes to later mount them, games that allow to carry out experiments with water, electricity, or chemistry, planetary systems, or the classic Human Body.

2) 2) Technology: In this area the games to build programmable robots dominate, nowadays it is common to find the Dash and Dots, LEGO Mindstorms, Makeblock, etc. There are also computers and educational tablets from Vtech or Fisher Price. Photo cameras, electronic circuits, etc. A good example of this is Teebot that allows users to learn programming and fundamentals of robotics, had its presentation in Ciudad Yachay.

3) 3) Engineering: In this field the LEGOs stand out a lot. But there are also many systems based on magnets like Geomag, Nanoblocks, plasticine, carpentry, first tools.

4) 4) Mathematics: The STEM toys of this category manage to pose problems of logic and mental challenges in this way they force to anticipate and to use lateral thinking.

C. Teaching strategy

It is an activity that is carried out jointly between the student and teacher where they interact and in which one depends on the other, the teaching process is to transmit knowledge through some kind of techniques or some rule: [3]

1) Brainstorming: These resources are important because they can draw attention or distract, also promote interest and motivation.

2) Illustrations: It is a visual representation of the concepts, objects or situations of a specific theory or topic (photographs, drawings, diagrams, graphs, dramatizations, etc.).

3) Workshops: They imply, as their name says, a place where they work and work. It is a way of teaching and learning by doing something, that is, learning by doing. In this strategy, learning about teaching predominates and is privileged.

4) Practical classes: There should be other audiovisual and information technology related resources that facilitate the presentation of the practical applications of the contents

through the contribution of examples and experiences and the development of exercises or problems.

5) Resolution of exercises and problems: It is based on exercising, rehearsing and putting into practice the previous knowledge, in which students are asked to develop appropriate or correct solutions through the exercise of routines, the application of formulas or algorithms, the application of procedures to transform the available information and the interpretation of the results.

6) Cooperative learning: Cooperative learning is a way of organizing small group teaching, to promote the development of each one with the collaboration of the other members of the team.

D. Robotic arms

A robotic arm is a normally programmable mechanical and electronic element and are designed according to human anatomy capable of simulating the functions of a human arm, this can be the sum total of mechanisms or can be part of a robot using electronic elements, etc. . It can be controlled by programming or through joints that allow remote controls.

Figure 1. Myoelectric robotic arm

E. Servo motor

Servomotors are a device mainly similar to direct current motors, but unlike normal motors, servomotors have small gears and a very small electronic plate inside that controls the angle of rotation, being able to locate in any position within its range. of operation, and stay stable in that position.

Figure 2. Servo motor

F. Arduino

It is an open hardware plate so its design is free distribution and use. Arduino is an open source electronic platform based on easy-to-use hardware and software, aimed at people interested in carrying out any type of interactive project.

In recent years Arduino has been the brain of thousands of projects. Among them, a large number of manufacturers, students, amateurs, programmers and professionals have made great use of these boards of this open source platform, focusing on approaching and facilitating the use of electronics and programming of embedded systems [4].

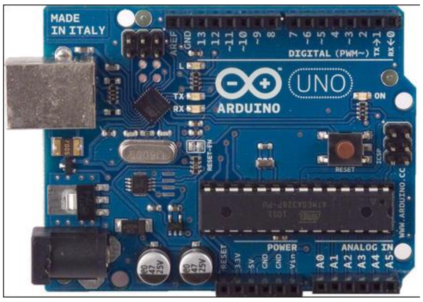


Figure 3. System Block diagram.

III. DESARROLLO EXPERIMENTAL

A. Analysis of the Current Situation.

An interview was held with the teachers of the electrical and automation laboratories and a survey of the students of the Educational Unit 17 of July. The teachers of the institution mentioned that in the educational institution they mentioned that they receive courses within the institution that are constantly trained especially in the use of Arduino boards at a very basic level but due to the academic curriculum of the subject they can not share the knowledge It is also a great problem to use the equipment because there are no materials to share with the students because the institution does not have the materials and for that the students should pay for it and this is prohibited in the institution, so the teachers they do not have the right to ask for any material that has nothing to do with the subject they dictate.

Students have a great interest in the realization of projects that have to do with the use of new technologies and that have to do with programming, because they only see in computers or cell phones technological advances and in this way generates in them A great interest in learning related topics to be able to give practical solutions and quickly to the needs that are presented.

B. System Requirements

For the analysis of the requirements of the system, reference is made to the ISO / IEC / IEEE 29148: 2011 standard, whose function is to relate the need presented by the San Martín adult care center with the solution that the project can provide through parameters that the system must comply with. [7] The standard defines the construction of a good requirement that provides attributes and characteristics taking into account the reiterative application throughout the life cycle of the system. ISO / IEC / IEEE 29148: 2011 is closely related to previous standards for the application process of requirements, such as ISO / IEC 12207: 2008 and ISO / IEC 15288: 2008.

C. Selection of Hardware and Software.

Once the system requirements were analyzed, the Arduino Ide software and 3D Blender modeling were selected, and in hardware the Arduino Uno embedded system, for the hand the Dextrus template was chosen and the servomotors to be used are: HV2060MG, MG995 and SG90.

D. System design

As part of the system design, the block diagram that will guide the operation and processes to develop the project is shown below.

The block diagram of Figure 1 shows the structure of the system that is formed by three main blocks: arm, control system and processing system.

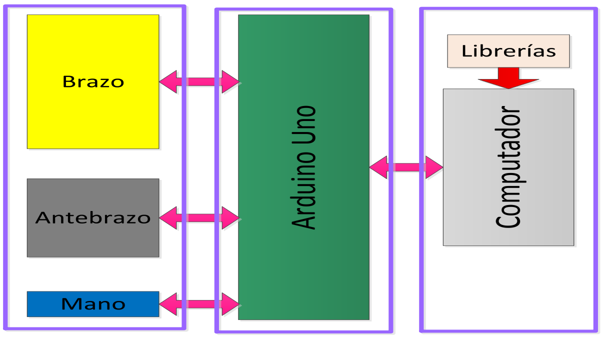


Figure 1. System Block diagram.

1) Arm: In the first block the design of the arm will be taken into account according to the requirement and the anthropometric parameters to be taken into account, the materials with which it will be built, besides the calculations of the servos for each part of the arm must be made which will be directly connected to the Arduino.

• Servos

SG-90S due to the size since these are located on the inside of the hand, this has a torque of 1.8Kg.

MG995 due to its torque is much stronger adapting perfectly to the wrist and forearm, this has a torque of 15Kg.

HV2060MG due to its greater torque of 60Kg are the servos that will support the entire system because they will be located on the elbow and shoulder.

2) Control System: The Arduino will be responsible for sending the signals to the servos connected in the arm to achieve the movements that are sent from the computer.

• Arduino Uno

The Arduino is the brain, is responsible for receiving the instructions by interpreting the angles in PWM pulses to send data to the servos thus generating the movements. [4]

3) Processing System: In the third block will be created the libraries of movement in which we must enter angles from 0º to 180º which will be interpreted by the Arduino board, in the computer will be the means of connection between the user and arm system robotic

• Computer

It will be the graphical interface in which the programming will be developed to achieve the movement of the arm. In addition, the libraries will be created to move the servos in the specified angle.

• Bookstores

They will be created to achieve movements in the servos according to the angle that is inscribed, thus avoiding using the libraries that previously come in Arduino, in this way custom libraries will be used for each part of the arm. [5]

E. Initial design

The arm is designed to have five degrees of freedom, which allows it to cover a large space of mobility. The degrees of freedom available to the robot are: two at the base of rotation of the shoulder, another at the elbow joint, a quarter at the rotation joint of the palm and finally a wrist-type rotation joint that serves to give orientation to hand. In Figure 2 you can see the initial basic design of the arm with its components.

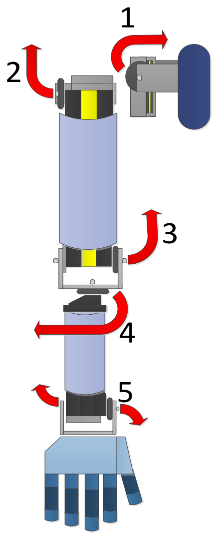


Figure 2. Initial basic design of the arm

Table 1- Position of the servos for the start and end

DESCRIPTION	Ángle
Shoulder	0º
Arm	0º
Elboe	0º
Forearm	90º
Doll	90º
Menue	180º
Cancel	180º
Medium	180º
Índex	180º
Trumb	180º
Lower Thumb	90º

- System diagram

The circuit diagram that makes up the whole system, where only the microcontroller is placed and you ask them where they should go connected, this is shown in Figure 3 below.

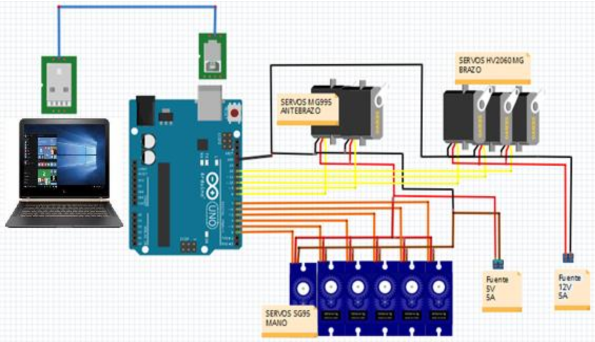


Figure 3. Connection diagram.

- Mobility of the arm

It is the study of the physical and functional dimensions of the human body, where flexibility and reach are taken into account based on the human anatomy. [6]

DESCRIPTION	PARAMETER
Shoulder	< 170º
Arm	< 170º
Elbow	< 120º
Forearm	< 180º
Wrist	< 180º
Dedos	< 180º

Table 1. Arm mobility angles

- Design of the bookstore for the servo

The servo is controlled by pulses of variable duration, depending on the manufacturer varies its waiting pulse but usually wait 2.5 milliseconds (ms) after this duration the next pulse serves to determine the angle of rotation of the servo, usually a pulse of 1.5ms is equivalent to 90º, 0.5 ms is 0º and 2.5ms is 180º.

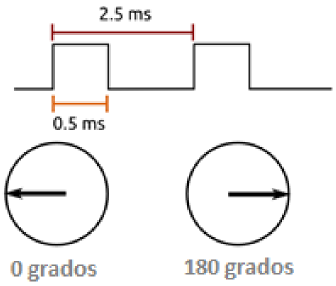


Figure 7. Displacement of pulses and in degrees.

In order to calculate the angle of rotation, a rule of three is made. Knowing that 180º is 2500 us but it should be taken into account as 2000 us and at the end we should add the 500 us because it is its value in 0º. In Equation 6, you can see the formula of the wait time in microseconds.

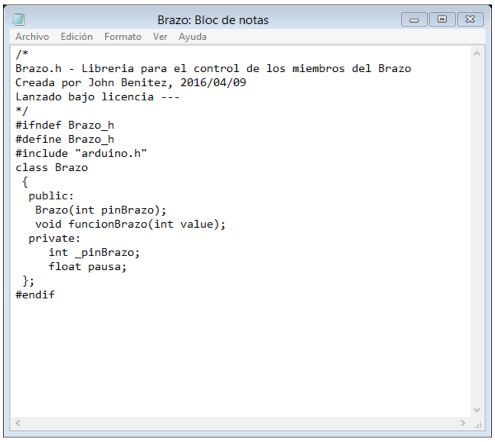
$$time = (angle * 2000) / 180 + 500$$

Equation 1. Formula of the waiting time in microseconds.

- Structure of the bookstores

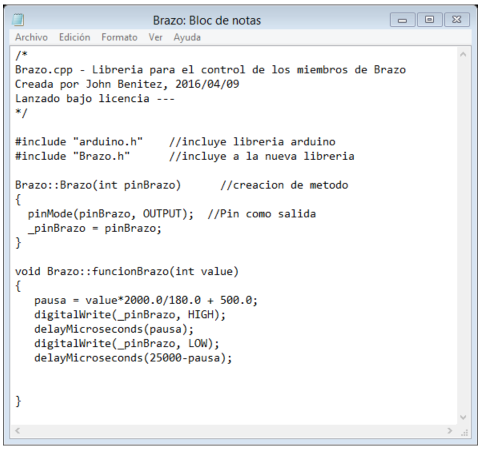
The programming is based on the use of codes and functions in a repetitive way in projects, so a library is called a library or a file to a series of functions written in C code that can be linked and used in a project. The files we use are:

- Brazo.cpp
- Arm.h
- Keywords.txt



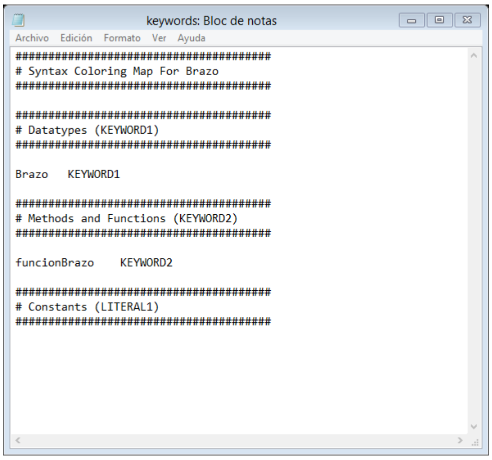
```
Brazo: Bloc de notas
Archivo  Edición  Formato  Ver  Ayuda
/*
Brazo.h - Libreria para el control de los miembros del Brazo
Creada por John Benitez, 2016/04/09
Lanzado bajo licencia ---
*/
#ifndef Brazo_h
#define Brazo_h
#include "arduino.h"
class Brazo
 {
  public:
   Brazo(int pinBrazo);
   void funcionBrazo(int value);
  private:
     int _pinBrazo;
     float pausa;
 };
#endif
```

Figure 8. Fila Arm.h



```
Brazo: Bloc de notas
Archivo  Edición  Formato  Ver  Ayuda
/*
Brazo.cpp - Libreria para el control de los miembros de Brazo
Creada por John Benitez, 2016/04/09
Lanzado bajo licencia ---
*/

#include "arduino.h"    //incluye libreria arduino
#include "Brazo.h"      //incluye a la nueva libreria

Brazo::Brazo(int pinBrazo)       //creacion de metodo
{
  pinMode(pinBrazo, OUTPUT);  //Pin como salida
  _pinBrazo = pinBrazo;
}

void Brazo::funcionBrazo(int value)
{
   pausa = value*2000.0/180.0 + 500.0;
   digitalWrite(_pinBrazo, HIGH);
   delayMicroseconds(pausa);
   digitalWrite(_pinBrazo, LOW);
   delayMicroseconds(25000-pausa);

}
```

Figure 9. File Arm.ccp



```
keywords: Bloc de notas
Archivo  Edición  Formato  Ver  Ayuda
#######################################
# Syntax Coloring Map For Brazo
#######################################

#######################################
# Datatypes (KEYWORD1)
#######################################

Brazo    KEYWORD1

#######################################
# Methods and Functions (KEYWORD2)
#######################################

funcionBrazo     KEYWORD2

#######################################
# Constants (LITERAL1)
#######################################
```

Figure 10. File Keywords.txt

IV. IMPLEMENTATION

It was held in the Educational Unit July 17, with students of the higher levels for which has spoken with the teachers in charge so that they can give some hours of class for the realization of this practice. Finally, when developing the electronic system of the robotic arm giving an orientation to the STEM, which promotes creativity and awakens in young people the interest in scientific and technological issues.

- Introduction

In this part, the subject was made known for which a few slides were made publicizing the topic to be discussed. The following photograph was taken in the classroom of the electricity laboratories of the Educational Unit July 17. See Figure 4.

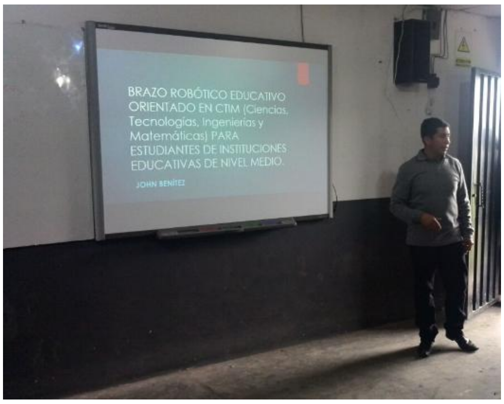


Figure 4. Introductory theme in the U. E.17 of July

The presentation was made in the electricity laboratories the teacher who was in charge of that time was Mr. Jorge Flores and he worked with a total of 20 students for the presentation, which was very well received by the students. which showed great interest, because it was a novel and technological subject, where theory and practice and manipulation with the elements were going to be seen.

- Brainstorming

The reference diagram was taken and they were asked to complete the diagram according to their criteria, then order the ideas and give an approach in relation to what they want to deal with. Where the students themselves should present their ideas once the diagram is finished. Brainstorming diagram developed in Visio according to the ideas presented by the students, see Figure 5.

Figure 5. Brainstorming diagram in the U. E.17 July

The students showed their interest in carrying out the brainstorming by awakening in them a curiosity about what they intend to do and in the same way it was possible to clear some doubts through the development of the activity, making known the majority of requirements and specifying other that they were not taken into account, generating a greater emotion for the students to continue.

- Illustrations

Through an illustration, creativity could be determined by expressing their ideas and concepts through a collage made on robotic arms and robotic hands and mentioning that this is not only developed abroad but also can be developed here in the country and why not in the classroom. See Figure 6.

Figure 6. Robotic arm collage illustration.

When speaking with students about this subject, they are more aware of them than other subjects because they feel more interested in this type of activities, generating their own concepts and being a participation activity they can share their knowledge with the rest of their classmates. of class. Where they got to appreciate the types of arms and the type of hands besides the utilities that can be given to him.

- Workshop

The workshop that was proposed was solved in the computer lab for which he was instructed how to download and install Arduino in all the computers of the laboratory and they were shown how to download the bookstores from the arm, see Figure 7. Next for the positions the hand and the Arduino so that they can identify the materials with which to work in addition to a servomotor of which he is integrating the hand.

Figure7. Installation of Arduino by the students.

They were then given the programming structure in Arduino and tests were done of the libraries 'Finger' making a small example to show the order of the programming lines and the degrees of mobility of the servo. Once they became familiar, they continued with the resolution of the workshop in which the hand must be opened and closed, see Figure 8.

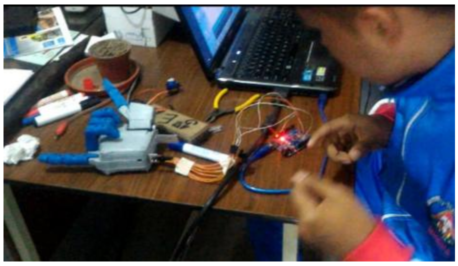


Figure 8. Student in the resolution of the workshop.

The student is the volunteer to do the practical part in which he was in charge of the connection of the Arduino as well as the connection of the hand servos in each pin of the Arduino, where he did not have any kind of problem with the connection of all the elements and could quickly master the use of the hand with programming.

- Practical lesson

The practical case was given in the computer lab where the counters were used and the if () condition to make counters to be able to achieve sequences and in the servos HV2060MG to control the speed of the movements, see Figure 9 , where it was possible to explain the structure of the conditions for the generation of sequences to later perform with them a practice for a better understanding.

Figura 9. Clase práctica en los laboratorios.

Most of the students demonstrated a quick understanding about the structure and use of the counters as well as the generation of the movement sequences for speed control and movement control of the different parts of the arm, some students stated that It is very complex to make the sequences of movement but it is also exciting when trying the programming.

The students of the institution were able to demonstrate what they had done in the workshop in the open house with their arm, see Figure 10.

Figure 10. Position I like the Practice Class.

- Resolution of exercises and problems

In the resolution of the following activity, it has a greater degree of complexity due to the fact that more sequential movements must be generated in which more movement of the extremities will also be generated, in order to achieve an object to be delivered to someone and to return to the initial position. Before the realization of sebe take into account the use of the sequences that should be used for which is the same as the previous ones always starts with an initial position and a final one. For which a student is taken to explain to peers the process of how movements should work to generate greater understanding in them, see Figure 11.

Figure 11. Arm extension

- Cooperative learning

In order to develop this activity, the decision was made to create working groups to achieve this exercise because some students still see some complexity so that they can share knowledge and exchange ideas, generating problems and solutions to it. weather. For this activity it is suggested to make the game of stone, paper or scissors. Where they had to use counters for the control of sequences so because some movements must be used. See Figure 12.

Figure 12. Cooperative learning groups.

V. RESULTS

At the terminal the project the teachers and students agreed that the communication skills of leadership and the enrichment of each one of the actors of group work have been improved, besides that the skills and abilities were strengthened.

This project changes pedagogical practices in one way or another, helping technification in education and has a direct relationship with the proper use of technology, fostering logical thinking, encouraging programming.

With this project confidence and security grows and you think that you can play and learn at the same time, in this way you can stimulate creativity and innovation, generating critical thinking to solve problems based on your own concerns that are solved with the practice.

It is believed that through these practices, the unification of subjects and the unification of interdisciplinary projects are encouraged, as well as the use of technological tools that serve to generate teaching materials for educational institutions that generate interest in technological areas by the students.

It is considered a new learning methodology that plays an active role in the teaching and learning process and encourages the construction of intuitive self-learning, where the project is considered as a new didactic tool that helps avoid boredom thus creating new learning environments.

VI. BENEFITS

Below are the benefits of the implementation of the educational robotic arm oriented to STEM for students of middle-level educational institutions.

Develop skills or abilities

Through the robotic arm students develop their creativity and much more if their ideas can be translated into reality, by allowing students' ideas to be embodied in a program and that this program be executed in real time motivates and influences the development of the creativity of the students.

Teaches systematic reasoning in problem solving

Students when making programs and being able to see their execution can develop the ability to solve problems in case the robotic arm does not perform the desired actions.

Promotes the culture of technological development

One of the objectives of the robotic arm is to promote technological development in educational institutions by teaching programming and in this way that students stop being consumers of technology and become creators.

Promotes the teaching and learning of group work through educational robotics

The robotic arm is an instrument that provides important guidelines for the introduction to programming, being a collective teaching option, each participant contributes to the solution and enriches the learning of each of the actors, where it helps students to facilitate their learning and increases the motivation and taste for acquiring knowledge.

Ideal for people who wish to have a start in STEM education

Although it is aimed at students of medium level robotic arm, it can be used by children, youth or adults of any age who want to program, the student to be able to solve a task or a problem grows confidence and security in him, generating a leadership capacity for future challenges.

VII. CONCLUSIONS

This project is focused on STEM which is directly related to educational robotics and the ability to motivate and generate an interest that not all areas have from the beginning, since it is not only leaves the theory as such and passes to the practical part that provides several tools encouraging students to know more about the subject, in which they develop learning skills and that students acquire knowledge.

The factor of success or failure of this methodology is not the technological resources that an educational institution can have but the change in pedagogical practices, which implies for the educational and teaching institutions the challenge of innovating strategies, where learning and teaching is transformed in a spiral of knowledge and experiences.

An electronic prototype was developed through Open Source platforms for the application of the educational institution, this project seeks the way to integrate several subjects so that students develop skills in the construction of the prototype based on the programming and logical reasoning demonstrated in the tests with students and supported by photographic and audiovisual evidence and sequences transformed into simple code lines.

Personalized bookstores were created for the hand and arm avoiding using the copyright of the bookstores already established in Arduino, which is one of the main advantages of free software and hardware platforms, thus contributing to the technological community.

To potentiate the use of the robotic arm, a technical manual and a teacher and student manual were written, which indicates how each of the elements of the prototype should be presented to the students. It also contains an explanation of the functionalities and possible challenges that mainly help in initialization and familiarization.

The tests of the robotic arm were made with a total of 14 students comprised between second and third year of high school where it was possible to show the acceptance by the teachers and mainly of the students, where their great predisposition could be observed; At first, the difficulty of understanding the use of the control elements was noticed, mainly in the students who did not have programming knowledge, but little by little they were developing new programs.

The present project of the robotic arm oriented to the STEM that was developed by the students in an exhibition for the festivities of the Educational Unit 17 of July was very well received by the students and parents present for entering into the technology and motivating them to continue ahead.

VIII. RECOMMENDATIONS

The project opens the way in the topic of educational tools for use in educational institutions and therefore it is recommended that engineering students and mainly of our career observe the potential offered by this area of teaching, to develop prototypes for this area taking advantage of them as much as possible for the benefit of schoolchildren.

It is recommended to read first the technical manual included in this project in order to avoid problems in the use of the prototype and avoid any threat to the integrity of the robotic arm in case of any inconvenience.

It is recommended to know each and every one of the electronic elements to be used in the implementation of the robotic arm, to know its dimensions, technical and operational characteristics, having at hand the datasheet in order to avoid failures, element burn and short circuits during the implementation .

It is recommended the use of free software under Open Source Architecture allowed for low resource countries like ours, because they are tools developed by work teams and institutions that aim to improve already established processes and that the technology and code community be bigger, the programs that have been used throughout this work as Arduino IDE.

It is recommended that engineers take this work as a reference to focus on improving the design aspect, greater functionality, more striking, more compact among other things that can be improved and refined.

This project opens studies to future projects as personal recommendations is to make this a prototype of a bonic arm using a muscle signal sensor or you can also have an application as a trainer for sign teaching.

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