Reference:

López-Caudana, E.O., Rodríguez-Abitia, G., Martínez-Pérez, S., Antón-Ares, P. & Ramírez-Montoya, M. S. (2021). Scenarios of the use of robotics as a support tool for teaching: challenges, learning and experiences in Mexico. In *Proceedings of the 9th International Conference on Technological Ecosystems for Enhancing Multiculturality* (TEEM 2021). University of Barcelona. Spain.

Scenarios of the use of robotics as a support tool for teaching: challenges, learning and experiences in Mexico.

Experiences of the use of assistive robotics in Mathematics learning at different school levels in Mexico.

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Robotics in the classroom allows not only for the study of automation and process control in the areas of technology and computer science, but it also serves as an aid in the learning of different areas of knowledge. Robots awaken interest in students, as they are eye-catching concrete objects. An educational robotics proposal was implemented under an approach that takes into account the learning environment, the planning of activities, the resources, the time required for the realization of each of these, and the methodology to perform them. This paper shows the results of approaching robotics as a support in mathematics classes, in various educational scenarios in Mexico, resulting in favorable ideas and experiences for the motivation of students, as STEAM education tools.

KEYWORDS • Social Robotics • Assistive Robotics • Higher education • Educational Innovation • STEAM

1 Introduction

STEAM (Science, Technology, Engineering, Arts, and Mathematics) education is essential for the development of digital skills and competencies in students from different areas and/or educational levels. In reviews [1], it has been found that the application in STEAM education is quite common and increases the motivation of students, which can improve their learning and also increase their engagement with the disciplines related to these areas. Within different tools related to STEAM, educational robotics is established as a didactic and very motivating resource for students. The use and promotion of robotics generates suitable and motivating environments in many ways. As an example, in [2], it is shown that robotics in primary education uses strategies such as logical thinking, different programming languages, and mathematical and visualization challenges, representing a significant strategy for change in educational practices. Thus, robotics applied to teaching and learning processes, explores and encourages in its practice, numerous possibilities of adding multiple sources of value, such as the conjunction of the development of technical and emotional skills, like logical thinking, problem solving, inquiry-research processes, questioning, scientific intuition, creativity, and achievement motivation.

These aspects are enriching and positive for all students, but it is worth considering that the inclusion of robotics in the curriculum at different educational levels also serves to involve and bring students closer together and is an opportunity to include it in training programs. The results suggest that promoting programs, both transversal and specific, through activities in which robotics is applied, could have a great potential for cognitive and socio-educational development at different educational stages. Robotics as a didactic tool, allows for meaningful educational processes. This is the case described in [3], where the results directed towards the strengthening of skills and competences on programming and computational thinking are observed; and the effect of a training program using educational robotics in the acquisition of computational thinking skills was evidenced.

There are studies that establish factors that influence the trust that can be developed between students and robots, such as age, duration of interaction and robot performance [4], these aspects were considered for the iterations given as shown in the following section. So, the aim of this paper is to measure attention through the indicators of concentration (accuracy and recall), habituation, dishabituation, distraction (carelessness), interest in the task (motivation and enthusiasm), in the integration of robots in primary, secondary and baccalaureate education scenarios, into mathematical learning processes. We present the method used in three educational contexts: primary, secondary and high school, where protocols were used to measure the acceptance, motivation and effectiveness of using robotics to support mathematics learning. The results are located at the three educational levels and analysis and conclusions are presented.

2 Social Robotics and the NAO Robot

In [5], three dimensions that support education today are shown: technological, pedagogical and organizational, and different factors that influence the choice and availability of the use of technologies, robotics among them, are established. Social robotics could be considered the next generation of robots since social robotics does not follow a conventional design or operational processes. Social robotics integrates social features that allow incrementing the communication between robots-humans and robots-machines. As a result, the robots are designed for accomplishing end-user needs. However, some needs are not primarily detected, so specific social sensors and digital decision-makers could be integrated into the robot. In [6], a new generation of social devices is studied. When the information about the end-users' needs increases, the robot's performance will be incremented as well. Since end-users could not be aware of their own needs when they work with robots, it is necessary to have sensors to detect natural social behavior and non-natural behavior. Digital transformation has to improve individuals and societies' well-being, so knowing the end-user needs by social robotics will reach this goal, as mentioned in [7].

In training environments, the integration of robots has had multiple uses. As shown in [8], where they conducted a study for students to learn about robotics concepts and to put them into practice. They used laboratory practices covering aspects such as communications, control, microcontrollers, etc., having all of these topics a focus on the discipline of mechatronics. In [9], the construction and implementation of a telerobotic system used for manipulation tasks in underwater environments is detailed. This system includes a robotic arm, and it was designed for use in any aquatic scenario. The prototype that has been made has a tele-operation system and details of the design, modelling and various scenarios of experimentation with the developed system can be found in the work. In this case, no reference is made to a teaching process, rather it was a development of postgraduate studies by the author.

Of course, robotics is an innovative and attractive tool for young people seeking a path in engineering. In [10], the construction and programming of robots was carried out using the LEGO MINDSTORM system. The participants, all of them being between the ages of 15 and 17 years old, designed and assembled a system based on this educational platform. They had to solve problems involving mathematics and science. As a contribution to this work, the surveys and means of opinion gathered stand out, which resulted in an interest in the area of engineering and worked well as a means of university recruitment. Also, another collaborative work between Chile and France, presents a pedagogical platform developed to carry out practical experiments with advanced mobile robots [11]. This pedagogical environment used the Khepera IV robot, as well as a vision system to work as a multi-agent system in control and mechatronics, and control problems. Its main objective was to support students in the area of control and to be able to access technical situations present in a laboratory, but with the innovation of robotics within their reach.

NAO Robot

The NAO robot is a humanoid robot that can be used in different fields either professional or educational. This type of robot emerged in 2006 and new versions have been created to improve it [12]. This type of robots can be programmed in 3 different ways: block programming, python programming and "C" programming. In the case of block programming, the Choregraph software is used, which already has libraries and the blocks used by the NAO robot, each block has a code in Python which can be modified for the user's needs.

The technical characteristics of the NAO robots include WiFi connectivity, touch sensors, directional microphones, HD cameras, speakers, sonars, prehensile hands with sensors, LED eyes, and bumpers.

The software used to program the NAO robot is Choreographe, which is a multiplatform software for PC that allows creating animations, testing them in a simulation of a NAO robot and to control and program the NAO robot. The Choreographe software also allows simulating and programming complex behavior such as interaction with people, dancing, and others. This software is of a graphical type, so block programming is used, but if required, a code can be created by the user in Python language. The add-ons are a window to monitor the video, a window to observe the behavior of the code, a toolbar, a digital view of the robot for debugging purposes and a timeline to synchronize the movements at an exact moment. The Choreagraphe software has a very user-friendly interface so it is relatively simple to use and understand how it works. When connected to a NAO robot, Choreographe allows visualization of the cameras in real time so you can see what the robot's cameras are detecting. An advantage is the internet connection with which Choreographe is managed, since it is possible to see the status of each component of the NAO, be it the sensors, motors or cameras.

3 STUDY CASES: NOTES, FINDINGS AND ANNOTATIONS.

In [13], the appropriate conditions are established, using robotic technology, when using active learning strategies, to contribute to improve the results in the teaching of mathematics.

The results are presented below for three educational settings: elementary, middle and high school. In the different contexts, different protocols were used, but in all of them, the objective was to measure, in some way, the acceptance, motivation and efficiency of the use of robotics to support mathematics learning.

In all scenarios, attention was measured, which is the means by which we actively process a fraction of an enormous amount of stimuli through the senses and other cognitive processes [14]. It consists of the following indicators: concentration (accuracy and recall), habituation, dishabituation, distraction (carelessness), task interest (motivation and enthusiasm).

Based on the definition of attention and its component indicators, operational definitions of these indicators were developed and subsequently translated into observable items of the dimensions of attention. These dimensions were tested and reviewed by a team of educational psychologists in discussion meetings until agreements were reached on the feasibility of their observation in the classroom. The care tests designed by Mazón for each of the scenarios were adapted [15].

3.1 Primary School

For the elementary school level, an appropriate exercise was carried out for the school, which has the Montessori model as its teaching model. Because of this, a session was held with interaction in which not only was an explanation given of the mathematics topic requested by the school administration, but also didactic material was provided for the students. The groups in this model were mixed, with students in 4th, 5th and 6th grades. The activity that was carried out was focused on 5th grade topics, so teams of 3 or 4 members with at least one student from each grade were formed. Psychology students were present in this session to observe the interaction of the teams and to record the results of a behavior scale to measure the attention paid during the activities.

The session was applied in 2 groups, but in order to observe differences, only 1 group with the robot was used. In this session, the topic of fractions was explained and examples were given for the students to observe. Afterwards, exercise 63 from the book of mathematical challenges for 5th grade students would be carried out. At the end of the session, a test was given to measure the knowledge acquired.

During the session, no team was able to completely solve the activity, so the results were directly observed in the tests that were applied. The results obtained were obtained from the pre-test, post-test and a question that was asked to the students during the session, and each section is evaluated on a scale from 0 to 3 with 3 being the maximum score. It was observed that the scores in which there was robotic interaction were better than in the sessions without this interaction from the initial knowledge test; this is because the students were more enthusiastic to perform the activity when the robot was present, as we will be able to see in the scales of observation and problem solving.

Since the number of students in each group was different, this graph was obtained by taking the total average where the maximum value was variable, depending on the number of questions in each section. Figure 1 shows the results of this scale, which has 7 sections: (1) Problem Identification; (2) Problem definition: (3) Construction of a strategy for the solution of the problem; (4) Organization of information about the problem; (5) Allocation of resources; (6) Monitoring the problem solution; and (7) Evaluating the problem solution

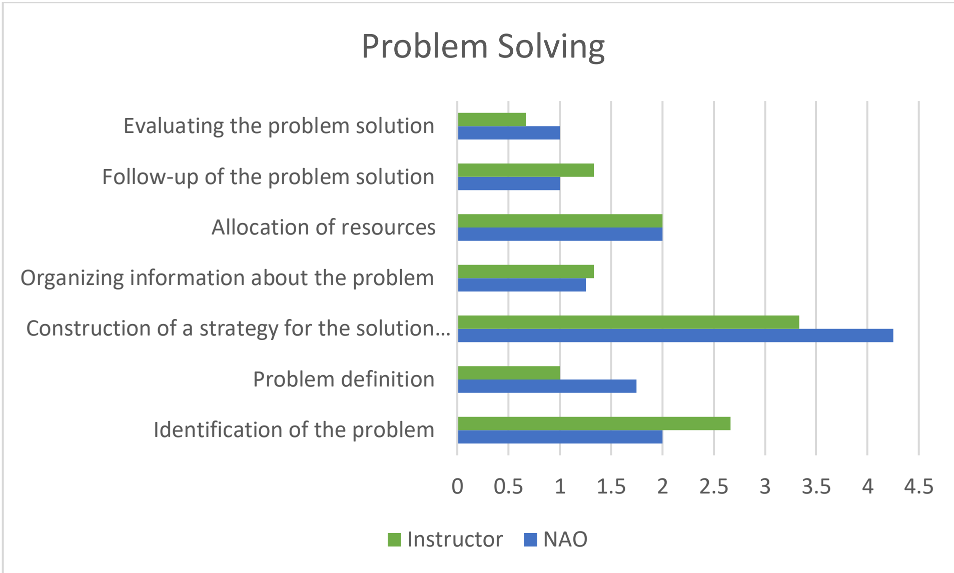

Figure 1: Problem solving scale for Primary School

By observing the graph it can be determined that there are favorable and unfavorable sections of the robot compared to the classes with the teacher. As with the observation scale, the analysis was carried out with the help of the observation scales. On the positive side, in general, the session with NAO made the children more motivated by the activity and they participated more as opposed to the session only with the instructor. In addition, they looked for solutions that were more viable. That is, in the session with the NAO robot, children resorted to drawings, and operations; while in the other session they only used operations. In turn, on the negative side, the NAO robot cannot give a long and oversaturated explanation of concepts, because the activity can become tedious. So, the activities with the robot should be more dynamic and the robot should give specific explanations not general ones; if the robot gives a topic it has to be supported by other tools to better explain it to a child, for example some projection, something that is more visual for the child. Additionally, it cannot answer questions or repeat information if the child requests it or has a doubt, i.e. NAO does not fulfill the possibility of answering questions at the moment. There is always a possibility that the NAO presents technical problems, hindering the appropriate conduction of the class. Finally, it does not represent a figure of authority for the children, which means that they pay more attention to the indications of a teacher than to those of a Robot, therefore the NAO cannot be in charge of controlling a group.

3.2. Secondary School

For this scenario, the project was divided into 4 parts. The first was to decide the focus of the project; this refers to the delimitation of the project. Subsequently, we continued with the search for the scenario. During this stage, several meetings were held in which the criteria to be covered were established. The second grade of the afternoon shift at the participating school was chosen for the intervention. The meetings involved not only the school's teachers but also a group of psychologists, who were in charge of carrying out the necessary analyses to quantify the students' motivation levels. We worked with two groups of secondary school sophomores. One group took their normal classes, while being observed by the psychology students; the other group took their class with the support of the robot, and was also observed by the students.

In collaboration with the psychology group, the school administration, the teachers and the parents, it was decided that the robot would interact with the students during 4 sessions of the Mathematics class, on Fridays at 7:35 pm. The group that did not interact with the robot was observed during their math class on Friday at 14:30 hours. Prior to each session, both teachers would provide the subject matter for the class and the robot would be prepared for interaction.

Lesson planning was done in conjunction with the teacher. For each class, the way in which the robot could assist in the class was resolved. The ways in which the robot could interact with the class depended on the topic to be covered during the session. It should be emphasized that the robot was used as a tool to support the teacher, not to replace her. Among the forms of interaction were mainly instruction provision for the exercises, the response to those same exercises, answers to doubts that may have arisen during the class and even participating as a student during the class.

At the end of the four sessions, the results obtained were analyzed. There were three different ways to analyze the effectiveness of the sessions in the students' learning. The first was a pre-session test, or pre-test, and a post-session test, or post-test. These exams were used to evaluate how much the students knew about the topic and whether they learned the topics seen.

Additionally, interviews were conducted with both the teacher and some of the students. This was in order to find out their opinion of the classes, how they felt during the sessions and any ways in which, in their opinion, they could improve.

Finally, during the sessions, the psychologists were in charge of observing the students and filling out an observation scale. This scale consisted of a questionnaire that was filled out with yes and no answers. Each question was given a weighting and, depending on what was observed, the results were obtained. The scale measured 5 dimensions that determined the student's level of attention: Concentration (precision and memory); Habituation; Dishabituation; Distraction; and Interest in the task (enthusiasm and motivation)

The results obtained showed that the students who interacted with the robot showed more enthusiasm and felt more motivated than the students in the other group. Likewise, in the traits of habituation and dishabituation, a difference could be observed between the two groups. These two factors are important for the research, due to the fact that the existence of a novel object, such as the robot, can attract and increase the attention of the students during class. It was observed that the teacher had a positive attitude towards the class. The teacher was more interested in learning how the robot worked, and had a favorable position on the introduction of new technologies in education. He also stated that the group was more attentive and easier to control.

Through the interviews with the students, it was observed that most of them considered that the presence of the robot made the class more interesting. Some even claimed that the robot helped them understand the subjects, and most denied feeling uncomfortable with the robot's presence. From Figure 2, it is observed that greater attention is achieved in the class mainly, once the robot's company was more common and the teacher used it in a more natural way.

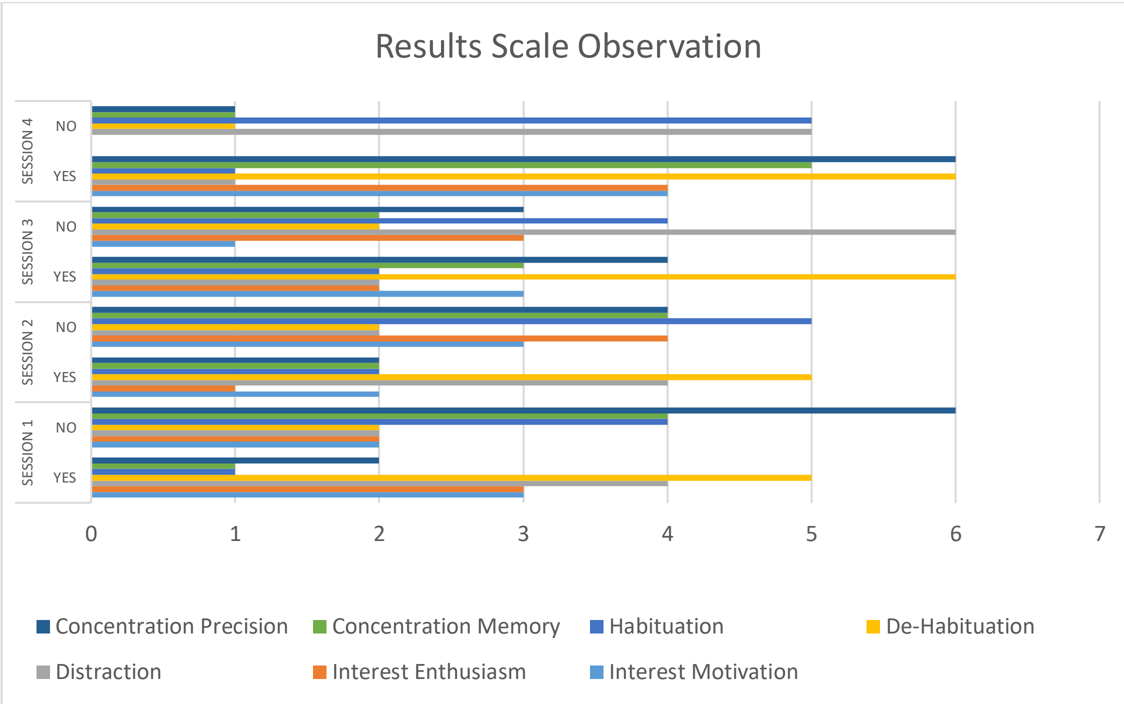

Figure 2: Frequencies observed in the sessions for the experimental group for Secondary School

3.3. High School

This scenario was carried out over a year and a half, in which experimental phases would be undertaken, divided into periods of six months each. The first phase consisted of the design and planning of the sessions to start preparing the programming of the robots, following a script, structured by the teaching team of the Mathematics Department of the high school of the Tecnologico de Monterrey Campus Ciudad de México. This phase focused on the detection of errors in the robot programming and on the dynamics of class teaching and its respective evaluation.

The second phase consisted of a class taught by a NAO robot and a mathematics teacher, following a script also structured by the high school teaching team. With this, it was expected that the explanations and topics taught by the robotic platform would follow the same thematic guide used in the high school's syllabus.

It is expected that the explanations given by the robot will complement the theory given by a teacher, while at the same time the students will maintain their focus and attention. The ultimate goal is for students' academic performance to improve.

In conjunction, student behavior will be analyzed through the application of a behavioral observation protocol. It is expected that such observations will allow reaffirming the moments in which the interaction between the teacher, the robot and the student will improve the attention of the latter.

As a result of the study, Figure 3 shows the relative percentage of occurrences of the different behaviors organized by the dimensions of the observation scale during a class session (concentration, habituation, dishabituation, distraction and motivation). The percentage is used because the groups are not equivalent in number of students and in total frequency of the behaviors, so they are weighted on percentage so that all are comparable.

It is observed that the most concurrent dimensions are concentration and motivation among all groups. The results of the control group (without the robot) are compared against the experimental group (with the robot).

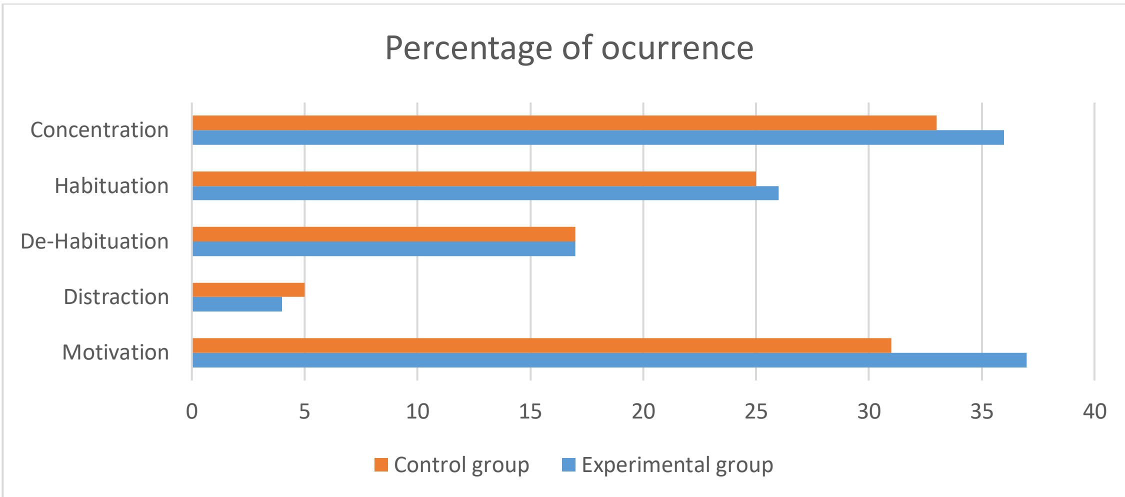

Figure 3: Results observation scales in High School.

4 Discussion

From the results presented above, some common features can be identified. First, the presence of the robots in class fosters interest and attention, especially at the beginning. This can be somewhat counterproductive as it also provides room for distraction. This effect also seems to be potentiated in younger students, who may be naturally prone to get excited about the robot, but not necessarily about the class itself. When applied correctly, the robot can be a very valuable aid to enhance learning departing from traditional instruction. This effect could be expected to wear off naturally as the students become more familiar with the robot. Yet, the capacity of the robot to attract attention to the class can also be diminished.

In any case, the role of the instructor, and very careful class planning are paramount for success. As with any other technology, it cannot be expected that the technology will produce learning by itself.This planning should include the variation of stimuli, so that the students remain engaged. Including different activities and objectives of the robot intervention needs to be considered to maintain the appropriate stimuli to perform the planned tasks, without distracting the attention to undesired ends.

It should be noted that this research follows an additive approach, thus causing the observations at the different levels explored not directly comparable. Based on the experience of the first observations, those at the elementary school, the class planning and the measurements became more complex. The same happened when transitioning from secondary to high school levels. The interventions became longer, planned with more detail, and measured through different means. The elementary school observations only included pre and post measures, as well as a question during the class intervention. Immediately after, at the secondary school intervention, more dimensions were being considered, and not only scales were used, but rather complemented with qualitative data obtained from interviews. Furthermore, for the high school experience, direct observation and score recording complemented the previous measures. Therefore, when increasing the complexity of the research design, based on the lessons learned from the previous one, also the richness of the data collected increased. This approach is closer to ethnographic and/or action research than to the traditional experimental one.

All in all, this dynamic design proved stronger to understand the underlying factors that facilitate or inhibit the effectiveness of using robots in a class, considering that those exist at all levels and only vary in their level of importance, rather than to compare factors among levels.

The identification of causal relationships and their respective validation, or statistical comparisons between different populations to enable confirmation of the findings remains a limitation of this work, and it needs further exploration in future research. This study has focused on an exploratory approach, and its main contribution lies in the identification of factors that affected the learning process in established settings at different educational levels, aiming at drawing the interest of other researchers to provide triangulation to the findings.

5 Conclusions

We conclude this work by pointing out that, although the NAO Robot does not represent a figure of authority nor is capable of answering any doubts that may arise at different educational levels, it does provide a new perspective capable of enhancing the teaching-learning processes. In this sense, the integration of educational robotics, and therefore the use of technologies in the classroom, in the different curricula encourages the acquisition of certain skills, the understanding of concepts and topics to be dealt with, increases creativity, motivation and student participation.

In addition, we would like to point out, on the one hand, that the study points out the importance of educational robotics, and therefore technologies, in hybrid teaching in innovative learning environments; and on the other hand, how the use of robots in different classrooms: a) encourages active learning; helps to present content in a different way to the "usual", where motivation and interest in new "methodologies" and resources attract students' attention; and c) requires basic training, beyond "instrumental" competence, in terms of didactic use and the deployment of didactic strategies. In this way, critical thinking skills, digital skills and teamwork skills are enhanced.

ACKNOWLEDGMENTS

The authors would like to acknowledge the financial support of the Writing Lab, Institute for the Future of Education, Tecnologico de Monterrey, Mexico, in the production of this work.

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