# Robotics in First Year Engineering Students: An Experience in Learning Concepts of Linear Motion

Eveling Castro-Gutierrez[1], Sebastián Bobadilla-Chara[2], Diego Mendoza-Pinto[3], Whinders Fernandez-Granda[4] and Caterine Chara-Barreda [5]

[1,2,3,4,5] Universidad Católica de Santa María

{ecastrog, 70669699, 70799893, wfernandezg, ccharaba}@ucsm.edu.pe

**Abstract.** Given the complexity of the learning process, it is a great challenge getting students to be actively involved in it. There is a concern for professors to use new teaching-learning strategies that playfully approach, motivate and increase the attention span of students in the learning sessions. The objective of this study is to use educational robotics (RE) for the teaching of "concepts of particle movement in one dimension". The sample is made up of 69 students of the Physics course of the third semester (second year), of the Professional School of Systems Engineering. The differences found between the pre and post-test of both groups are not statistically significant. From that we conclude that a single learning session is not enough to obtain results similar to the actual values. However, the use of educational robotics "improves the attitude" towards learning in students.

**Keywords**: Educational robotics, learning outcomes, learning environment, learning tool, pedagogical approach, robotics, physics.

## 1 Introduction

The "Ability to apply knowledge of mathematics, science and engineering" [1], is one of the eleven skills that engineering students must possess when they finish their studies, based on the Criterion 3 of ABET, an entity that granted Accreditation in 2019, to the Systems Engineering degree[1] of the Catholic University of Santa Maria (UCSM). Mathematics framework according to PISA 2021, involves engagement in the application of knowledge of the number, the understanding of measures, magnitudes, units, estimation, etc.[2], in a wide variety of environments. This leads to the interest

[1] https://www.ucsm.edu.pe/ingenieria-de-sistemas/

of using different teaching and learning techniques in [3],[4],[5] and [6], Science, Technology, Engineering and Mathematics (STEM) students.

Achieving a more personalized and inclusive education is one of the challenges in today's education. It is of most importance to know which learning style is better according to the different profiles of our students [7].

The new learning models to transmit and build knowledge, require tools, resources, and instruments that help the students shape their ability to think and act with scientific criteria in solving the different situations presented to them.

Given the complexity of the processes related to learning, especially in physics related courses, it is a great challenge to get students to be actively involved in their learning, and a challenge for the present research, because the transmission of knowledge is highly theoretical with just a few practical sessions. This motivated us to propose new teaching and learning strategies that playfully approach the student and at the same time motivate and increase the attention span in the learning session.

This article is organized as follows: Section 2 presents the related works; Section 3 describes the materials and methods used. Then in Section 4 the results and discussion according to the proposed experience are presented, we finish by presenting our conclusions.

## 2 Related Works

During the review of the state of the art, several studies were found that conceptualize Educational Robotics (ER):

### 2.1 Educational Robotics

According to Pittí et. al [8] consider ER as a learning tool that has the potential to improve creativity and learning skills, being its ultimate goal for the student to "achieve learning". ER is described as a systematic and organized process in which robotic platforms and software participate. It is applied in the study of three relevant components in the teaching and learning process: a) concepts: robotics, technology, computer science, mathematics, and physics; b) procedures, managing to strengthen some cognitive, social, and metacognitive skills, among others; c) attitude, and attitude changes towards science and technology.

In another work, the authors demonstrated [9], that ER or pedagogical robotics try to create conditions of "appropriation of knowledge", so that students manufacture their own representations of real-world phenomena and make their transfer to different areas of knowledge.

Suggested by Gonzales, J et. al [5] and Eteokleous, N et.al [10], the constructivist theory asserts that knowledge is not transmitted but is constructed, meaning that it is actively created in the student's mind, however constructionism also considers that in order to achieve it, the individual should build something tangible which has a personal meaning for him. This last pedagogical theory was based on many of the main advancements in educational robotics.

When applying the experimentation, in order to achieve our goals, we aim to strengthen significant knowledge going from the abstract to the tangible.
In the production of new knowledge imagination and creativity are very relevant. In order to develop these characteristics students need to make use of the information captured by their senses, test their limits, and obtain feedback [11],[12].

## 2.2 Learning Object (LO)

Ibarra et al. [13] showed that the development of the learning object is based on a strategy oriented to student's learning and to fulfill the objective its design must have an internal structure that has different elements. The design of the learning object has the following aspects: a) pedagogical reference which is the pedagogical practice developed based on the competences of the course based on the theory of constructivism learning and playful learning; b) technological reference, tangible digital objects such as robots are used; c) contextual reference: The LO is designed according to the following sequence: Curriculum design, Learning Routes, Learning Unit and finally the Learning Session.

## 2.3 Robotic Kit

The main objective of this research is to evaluate a learning session including methodological innovation through the programming of a technological element (a robot), available in the market called Dash and Dot ® robotics kit, to fulfill a specific function in the topic of: Movement of Particles in one Dimension, as a learning resource in physics, and replicating it with other work groups. We use educational robotics (ER) as support for the development of learning [11] (one of its many uses). This approach uses robots within the class as a teaching resource where learning is facilitated by inquiry and errors are taken as a learning opportunity. The code for this project is in GitLab[2] and the schema for the robot session is in Fig. 1.

[2] https://gitlab.com/lokdex/learning-retention

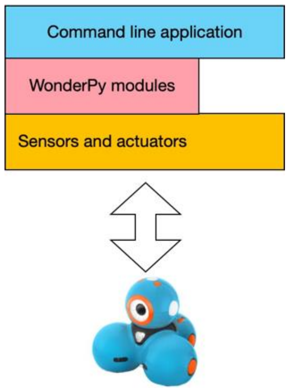


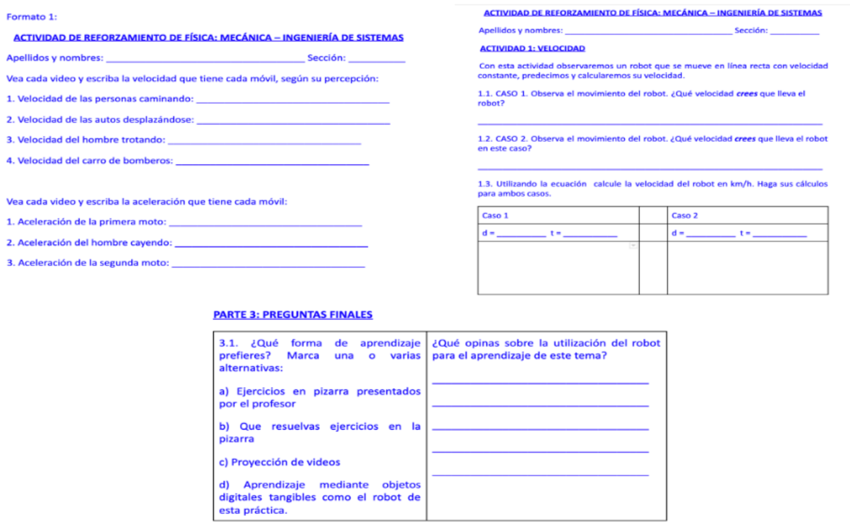

**Fig. 1.** Proposal schema of robot kit (Dash & Dot) for learning physics concepts

## 3 Materials and Methods

A longitudinal, analytical study was carried out with 69 students of the third semester of the Systems Engineering degree at the Catholic University of Santa María.
For this research, a programmable Dash and dot ® robotics kit was used. Robot programming was done with the module provided by the manufacturers, obtained from the GitHub repository of Wonder Workshop called WonderPy. This module gives access to all the sensors and actuators of the robot, thus allowing us to give instructions and obtain data from the various sensors that these devices have.
The programming language used was Python 2.7, used to develop an application executed through a command line.
This program already includes the different options necessary to carry out the experimental part of the topic proposed in this investigation, being necessary to enter data such as the distance you want the robot to travel or the speed at which you want it to move.

### 3.1 Sequence of the learning session

**Learning competence** of the course in the topic “Movement of Particles in One Dimension”:
Analyzes, interprets and exemplifies the movement of particles in free space by establishing relationships in problem solving, executing experiments, assuming critical and reflective attitude, valuing the importance of particle movement in their professional training, respecting international standards.
**Pedagogical reference:**
Chapter 2: Movement of Particles in a Dimension, topics to be discussed: displacement, time, and average speed, instant speed medium and instantaneous acceleration. Movement with constant acceleration. Bodies in free fall.
**Instruments**
In this item, we presented two session of practices that we formulated, see figure 2.



Formato 1:

ACTIVIDAD DE REFORZAMIENTO DE FÍSICA: MECÁNICA – INGENIERÍA DE SISTEMAS

Apellidos y nombres: ______________________ Sección: __________

Vea cada video y escriba la velocidad que tiene cada móvil, según su percepción:

1. Velocidad de las personas caminando: ______________________
2. Velocidad de las autos desplazándose: ______________________
3. Velocidad del hombre trotando: ______________________
4. Velocidad del carro de bomberos: ______________________

Vea cada video y escriba la aceleración que tiene cada móvil:

1. Aceleración de la primera moto: ______________________
2. Aceleración del hombre cayendo: ______________________
3. Aceleración de la segunda moto: ______________________

ACTIVIDAD DE REFORZAMIENTO DE FÍSICA: MECÁNICA – INGENIERÍA DE SISTEMAS

Apellidos y nombres: ______________________ Sección: __________

ACTIVIDAD 1: VELOCIDAD

Con esta actividad observaremos un robot que se mueve en línea recta con velocidad constante, predecimos y calcularemos su velocidad.

1.1. CASO 1. Observa el movimiento del robot. ¿Qué velocidad ***crees*** que lleva el robot?

______________________

1.2. CASO 2. Observa el movimiento del robot. ¿Qué velocidad ***crees*** que lleva el robot en este caso?

______________________

1.3. Utilizando la ecuación calcule la velocidad del robot en km/h. Haga sus cálculos para ambos casos.

| Caso 1 | | Caso 2 |
|---|---|---|
| d = _______ t = _______ | | d = _______ t = _______ |
| | | |

PARTE 3: PREGUNTAS FINALES

| 3.1. ¿Qué forma de aprendizaje prefieres? Marca una o varias alternativas: | ¿Qué opinas sobre la utilización del robot para el aprendizaje de este tema? |
|---|---|
| a) Ejercicios en pizarra presentados por el profesor<br>b) Que resuelvas ejercicios en la pizarra<br>c) Proyección de videos<br>d) Aprendizaje mediante objetos digitales tangibles como el robot de esta práctica. | ______________________<br>______________________<br>______________________<br>______________________<br>______________________ |

**Fig.2.** From left to right, we have the practices session of the physics Learning of Movement of Particles in one Dimension with the videos and subsequently evaluated with the support of a robot. At the bottom there is a final survey regarding the practical session.

**First experiment**

**A. Participants**

The research was conducted with the students of the two sections of the third semester of the UCSM Professional School of Systems Engineering, distributed as follows: Experimental group (EG): section A, composed of 31 students and Control group (CG): section B, composed of 38 students.

**B. Learning Object**

The development of the learning object is based on a strategy oriented to the student's learning of the Physics course. The design of the Learning Object has the following steps:

**a) Problematic situations**

Both groups (EG, CG) were exposed to 7 seven situations, the first four referring to the issue of one-dimensional speed and the remaining three to the issue of acceleration in a straight line, which were numbered as shown in Table 1.

| N | Activity description | URL of the video for each activity |
|---|---|---|
| 1 | People walking | https://www.youtube.com/watch?v=bX4ag0ocAMI |
| 2 | Cars moving | https://www.youtube.com/watch?v=17IhMKtAPN8 |
| 3 | Man jogging | https://www.youtube.com/watch?v=HcHZbgBIGYU |
| 4 | Vehicle moving | https://www.youtube.com/watch?v=A1pxxwDajQU |

| | | |
|---|---|---|
| 5 | Motorcycle accelerating | https://www.youtube.com/watch?v=V6NS-tHQewM |
| 6 | Man, in Fall | https://www.youtube.com/watch?v=l0XjrJlod3M |
| 7 | Moto accelerating | https://www.youtube.com/watch?v=hKiKtLmvJ1Q |

**Table 1.** Situations of one-dimensional movement and their URL

b) **Process**
The following activities are proposed:
**First:** Both the EG and the CG, simultaneously but in separate rooms, watch each of the videos.
At the beginning of the session, in each group, the teacher explains the activity they will develop, with the objective of quantifying the degree of accuracy of their perception of speed or acceleration that a certain object has, according to the videos listed in table 1.
Then the participants write down the results on the worksheet.
**Second:** The CG received the traditional learning session, inside the classroom the teacher solves problems on the blackboard. On the other hand, the EG, conducted this session outside the classroom, with the "robot" as a teaching resource.
**Third:** Again, both groups (EG and CG) watched the videos. Subsequently, they completed the questions proposed in the worksheet.

**Second Experiment**

**A. Participants**

Only students from EG take part in this activity.

**B. Learning Object**

The design of the Learning Object has the following steps:

a) **Problematic situations**
**Constant Speed:** the robot is programmed to move at two speeds: 0,2 m/s and 0,4 m/s.
**Constant acceleration:** the robot is programmed to move with 0,1 $m/s^2$ and 0,3 $m/s^2$ of acceleration.

b) **Process**
The following activities are proposed:
**First:** Outside the classroom, participants observe the movement of the robot in each of the problematic situations.
**Second:** Each participant makes an intuitive calculation of the speeds and accelerations proposed in the worksheet (fig. 2).
**Third:** Finally, using instruments, they performed the measurements of space and time, data that they will use to perform the respective calculations.
Then the students write the results on the worksheet (fig. 2).

**Data Analysis**

The data analysis was performed with the Statistical Package for the Social Sciences (SPSS) software, version 26. The calculation of descriptive and analytical statistics was included. Nonparametric statistics were used: Wilcoxon to analyze the results of the experiment before and after using the technological resource; U Mann-Whitney to compare the results of the two groups. A value $p \leq 0,05$ was considered statistically significant.

## 4 Results Analysis

Of the 69 students with whom the study began, 23 (8 from the experimental group and 15 from the control group) were excluded because they presented incomplete assessments.

Table 2 (first experiment) shows the results obtained for each of the problematic situations raised in the didactic experience, see Appendix A.

When performing the statistical treatment for related samples, before and after the application of the didactic resource, only statistically significant difference ($p < 0.05$) was found in the control group of the situation 2.

Likewise, when comparing the control and experimental group, only a significant difference was found ($p < 0,05$) after the application of the didactic resource in the situation 1, observing smaller differences between the real and calculated value of the experimental group ($\bar{x}$ control = 0,64 m/s; $\bar{x}$ experimental = 0,31 m/s).

It is important to mention that in situations 4, 5, 6 and 7, after using the didactic resource, there is greater dispersion, especially between the third quartile and the maximum value of the results.

Table 3 (second experiment) shows the results obtained intuitively and after taking measurements, finding that there is a significant difference ($p < 0,05$) between the values calculated for the two accelerations, the differences between the real value and the one calculated in the group that performed the measurements.

Figure 3 shows a greater dispersion of the intuitive results corresponding to the measurement, both of acceleration 1 and 2.

| Statistics | Results of second experiment | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Speed 1 (m/s) | | Speed 2 (m/s) | | Acceleration 1 (m/s) | | Acceleration 2 (m/s) | |
| | Intuitive | Measured | Intuitive | Measured | Intuitive | Measured | Intuitive | Measured |
| As | 3,08 | 1,05 | 2,95 | 4,09 | 1,62 | 3,05 | 1,27 | 2,88 |
| Vmin | 0,00 | 0,01 | 0,00 | 0,03 | 0,00 | 0,00 | 0,10 | 0,00 |
| Vmax | 3,80 | 0,30 | 6,60 | 7,38 | 2,90 | 0,40 | 4,70 | 0,66 |
| $Q_1$ | 0,10 | 0,06 | 0,10 | 0,07 | 0,05 | 0,02 | 0,20 | 0,01 |
| Mean | 0,42 | 0,11 | 0,78 | 0,62 | 0,65 | 0,06 | 1,24 | 0,10 |
| Median | 0,10 | 0,10 | 0,15 | 0,20 | 0,40 | 0,05 | 0,70 | 0,04 |
| $Q_3$ | 0,15 | 0,16 | 0,40 | 0,37 | 0,90 | 0,06 | 1,70 | 0,14 |
| $R_{iq}$ | 0,05 | 0,10 | 0,30 | 0,30 | 0,85 | 0,04 | 1,50 | 0,13 |
| P valor (related) | 0,106 | | 0,749 | | 0,001 | | 0,000 | |

**Table 3:** Comparison between solving methods using a technological tool.

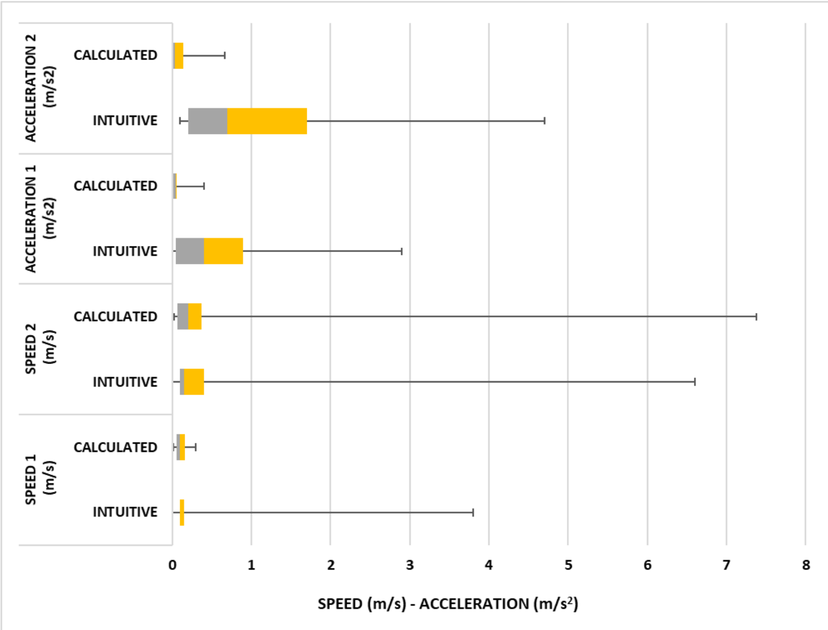



**Fig 3:** Box and whisker plot for intuitive and calculated results of the experimental group (second experiment)

## 5 Discussion

The educational environment it is quite known that subjects such as physics, mathematics, among others, generate in students feelings of demotivation due to the difficulty that comes along with the resolution of different situations that they have to face in reality. That is why, numerous researches make proposals for innovative strategies that allow improved success in the teaching and learning process in these areas, one of them being the use of technological resources. Due to their inherent characteristics they capture the attention of the students, allowing to develop different skills with their manipulation. Hypothetically, we think that the use of a technological resource would surely improve student performance, however, according to the results obtained in this research, it was not possible to obtain significant differences ($p > 0,05$) when comparing the results. This may be due to the fact that students are not familiar with its handling, and mainly because a single learning session would not be enough to achieve full understanding of the topics treated in the practice session. Similarly, when comparing intuitive results with calculated results, significant differences ($p < 0,05$) were found for acceleration measurements, which were measured at the end of the experiment, being an important observation that allows us to mention that students need to repeat the same practice more than once in order to acquire the desired competence. The use of the robot, as a pedagogical resource, has allowed us to clearly observe that students become active actors in their learning, improving their attitude towards the learning of physics. The 23 students of the experimental group mentioned that “it is more didactic, entertaining, dynamic, and the best way to approach reality". Although they still lack intuitive and critical thinking when assessing a real problematic situation.

## 6 Conclusions and Future Works

The use of a technological resource improves the attitude of learning. A single learning session is not enough for the student to develop an accurate intuition of the speed and acceleration of objects. Both methodologies successfully teach the required competences for the student. However, by using the "robot" they actively take part in the learning-teaching process.
The future work will be to apply this technique for more than one session in the same physical topic for the next edition of the course.

## References


1. Aedo M, Vidal E, Castro-Gutierrez E. Implementation of a Software Engineering Curriculum based on ACM and ABET: A Peruvian experience. Proc LACCEI Int Multi-conference Eng Educ Technol. 2019;2019-July(July 2019):24–6.
2. EDU/PISA/GB(2018)19. PISA 2021 Mathematics Framework(Draft). OECD. 2018;53(9):1689–99.
3. Sullivan FR, Heffernan J. Robotic construction kits as computational manipulatives for learning in the STEM disciplines. J Res Technol Educ. 2016;48(2):105–28.
4. Nugent G, Barker B, Grandgenett N, Adamchuk VI. Impact of robotics and geospatial technology interventions on youth STEM learning and attitudes. J Res Technol Educ. 2010;42(4):391–408.
5. Eteokleous N, Ktoridou D. Educational robotics as learning tools within the teaching and learning practice. IEEE Glob Eng Educ Conf EDUCON. 2014;(April):1055–8.
6. De Cristoforis P, Pedre S, Nitsche M, Fischer T, Pessacg F, Di Pietro C. A Behavior-based approach for educational robotics activities. IEEE Trans Educ. 2013;56(1):61–6.
7. Pereira S, Fillol J, Moura P. Young people learning from digital media outside of school: The informal meets the formal. Media Educ Res J. 2019;27(58):41–50.
8. Pittí Patiño K, Curto Diego B, Moreno Rodilla V, Rodríguez Conde MJ, Rodríguez-Aragón JF. Using robotics as a learning tool in Latin America and Spain. Rev Iberoam Tecnol del Aprendiz. 2014;9(4):144–50.
9. Bravo Sánchez, Flor Ángela; Forero Guzmán A. Robotics As A Resource To Facilitate The Learning And General Skills Development. TESI. 2012;13(2):120–36.
10. Gonzales J, Jiménez J. La robótica como herramienta para la educación en ciencias e ingeniería. Rev Iberoam Informática Educ. 2009;10:31–6.
11. Muñoz-Repiso AGV, Caballero-González YA. Robotics to develop computational thinking in early Childhood Education. Media Educ Res J. 2019;27(59):63–72.
12. Hoogerheide V, Visee J, Lachner A, van Gog T. Generating an instructional video as homework activity is both effective and enjoyable. Learn Instr [Internet]. 2019;64(June):101226. Available from: https://doi.org/10.1016/j.learninstruc.2019.101226
13. Ibarra MJ, Soto W, Ataucusi P, Ataucusi E. MathFraction: Educational serious game for students motivation for math learning. Proc - 2016 11th Lat Am Conf Learn Objects Technol LACLO 2016. 2016;

# Appendix A

| Situations | GROUP | TEST | As | Vmin | Vmax | $Q_1$ | Median | $Q_3$ | $R_{IQ}$ | p valor[3] (Wilcoxon) | p valor[4, 5] (U Mann-Whitney) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | CONTROL | Before | 0,13 | 0,05 | 0,95 | 0,2 | 0,45 | 0,84 | 0,64 | 0,281 | 0,231<br>0,017 |
| | | After | 0,30 | 0,05 | 1,45 | 0,25 | 0,45 | 0,95 | 0,70 | | |
| | EXPERIMENTAL | Before | 0,17 | 0,01 | 0,95 | 0,05 | 0,45 | 0,75 | 0,70 | 0,069 | |
| | | After | 0,19 | 0,01 | 0,85 | 0,05 | 0,35 | 0,45 | 0,40 | | |
| 2 | CONTROL | Before | 1,57 | 0,17 | 9,00 | 1,00 | 1,56 | 2,89 | 1,89 | 0,035 | 0,774<br>0,886 |
| | | After | 1,65 | 0,00 | 5,00 | 1,00 | 1,22 | 2,00 | 1,00 | | |
| | EXPERIMENTAL | Before | 0,58 | 0,11 | 5,72 | 0,67 | 1,56 | 3,17 | 2,50 | 0,550 | |
| | | After | 1,19 | 0,00 | 6,00 | 0,20 | 1,56 | 2,06 | 1,86 | | |
| 3 | CONTROL | Before | 0,51 | 0,10 | 2,00 | 0,67 | 1,00 | 1,50 | 0,83 | 0,235 | 0,774<br>0,062 |
| | | After | 0,19 | 0,50 | 2,00 | 1,00 | 1,00 | 1,50 | 0,50 | | |
| | EXPERIMENTAL | Before | - 0,06 | 0,00 | 2,00 | 0,50 | 1,10 | 1,50 | 1,00 | 0,522 | |
| | | After | 0,31 | 0,00 | 2,00 | 0,50 | 0,94 | 1,22 | 0,72 | | |
| 4 | CONTROL | Before | 0,22 | 0,67 | 7,61 | 1,28 | 3,44 | 4,89 | 3,61 | 0,099 | 0,207<br>0,938 |
| | | After | 3,40 | 0,67 | 54,00 | 0,67 | 4,75 | 9,00 | 8,33 | | |
| | EXPERIMENTAL | Before | - 0,16 | 0,67 | 9,00 | 2,11 | 4,89 | 6,22 | 4,11 | 0,356 | |
| | | After | 2,04 | 0,67 | 22,00 | 2,11 | 4,00 | 6,22 | 4,11 | | |
| 5 | CONTROL | Before | - 0,32 | 3,00 | 13,00 | 7,00 | 9,00 | 10,00 | 3,00 | 0,051 | 0,921<br>0,441 |
| | | After | 1,80 | 7,00 | 17,00 | 9,00 | 9,33 | 10,00 | 1,00 | | |
| | EXPERIMENTAL | Before | 0,25 | 1,00 | 17,00 | 5,00 | 8,00 | 11,00 | 6,00 | 0,754 | |
| | | After | 2,13 | 2,00 | 39,00 | 3,00 | 8,00 | 12,90 | 9,90 | | |
| 6 | CONTROL | Before | - 0,52 | 0,00 | 15,00 | 7,00 | 9,00 | 10,00 | 3,00 | 0,925 | 0,955<br>0,674 |
| | | After | - 1,00 | 0,00 | 14,00 | 7,00 | 9,00 | 9,00 | 2,00 | | |
| | EXPERIMENTAL | Before | 1,17 | 0,99 | 24,00 | 7,00 | 9,00 | 9,50 | 2,50 | 0,394 | |
| | | After | 2,58 | 0,90 | 89,00 | 3,00 | 8,80 | 14,00 | 11,00 | | |
| 7 | CONTROL | Before | - 0,32 | 0,00 | 10,00 | 0,00 | 6,00 | 10,00 | 10,00 | 0,183 | 0,430<br>0,065 |
| | | After | 0,32 | 0,00 | 10,00 | 2,00 | 5,00 | 6,00 | 4,00 | | |
| | EXPERIMENTAL | Before | 1,81 | 0,00 | 30,00 | 5,00 | 6,00 | 10,00 | 5,00 | 0,737 | |
| | | After | 2,28 | 0,00 | 40,00 | 2,00 | 7,00 | 10,00 | 8,00 | | |

**Table 2:** Comparison of the results obtained before and after a learning session with traditional teaching resources and tangible digital object: robot (first experiment).

## Legend

As: asymmetry coefficient
Vmin: minimal value
Vmax: maximal value
Q1: first quartile
Q3: third quartile
RQ: interquartile range

[3] The values represent the comparison of related samples: data before and after the learning session.

[4] Superior result, represents the comparison of independent samples, values of EG and CG before the learning session.

[5] Lower result, represents the comparison of independent samples, EG and CG values after the learning session.