European Institute of Knowledge & Innovation

Journal of Effective Teaching Methods (JETM)
ISSN: 2755-399X

Research Article

Scientific hability by using DNA and robotic activities in the science class

Gina Suescun Otero[1*], Alejandro Bolivar[1], and Francisco Ruíz Rey[2]

[1] Pedagogical and Technological University of Colombia, Colombia
[2] University of Málaga, Spain
* Correspondence: gina.suescun@uptc.edu.co

https://doi.org/eiki/10.59652/jetm.v2i3.271

Abstract: Educational robotics as an area of pedagogy is a discipline whose objective is the development of robotic prototypes that support the learning of natural sciences, demonstrating its potential as a didactic proposal that integrates technology into transdisciplinary thinking favoring digital thinking in the 21st century, in which we can mention scientific ability and the development of solutions to problems that favor scientific thinking. This educational research aims to connect the fields of chemistry and biology with the growing technology of educational robotics. A descriptive interpretive methodology was applied to a group of 80 high school students; They conducted experimental activities such as extracting DNA from tomatoes and observing the stages of mitosis in onion apical meristems. After observing the chromosomes in a microscope, the students use an augmented reality application, contrasting the information and creating a robotic model with recyclable material, programmed using the open-source ap-plication Arduino. No significant differences were found during the development of the activities between public and private schools, showing that 90% of the students obtained the DNA and 67% managed to develop robotic programming activities.

Keywords: scientific hability; DNA; robotic, biology and chemistry

1. Introduction

What is educational robotics? Educational robotics is a discipline that is being used in schools as a discipline that aims to develop skills that would be necessary for the working life of the 21st century, due to the increase in technologically prepared professionals in the construction of prototypes that contribute to solving everyday problems through creativity and interconnection with new knowledge. (Castro Rojas & Acuña Zuñiga, 2012; Cáceres Zapatero et al., 2017; Stylos et al., 2023). It is a new pedagogical model for teaching and learning, producing a range of possibilities that contribute to reasoning spatio-temporal perception programming when building electrical circuits and 3D printing achieving the active participation of students by learning from their own experiences. (Nuangchalerm et al. 2022; Sultan et al., 2021; Viscaino Zuñiga et al., 2023).

In the 1980s, the notion of constructionism was introduced where learning occurs when the learner builds a tangible artifact and reflects on his experience of solving problems in a way that is meaningful to him, due to the questioning of the facts and phenomena that motivate him to build a prototype. Based on this conception, the curricula in this subject focus on learning and problem solving, which encourage students to "learn by doing" for which there is bidirectional learning by developing conceptual comprehension skills that favor creativity by dividing complex tasks into simple actions for their learning. (Papert, 1998; Lepuschitz et al., 2018; Merdan et al., 2020). The theoretical foundation of educational robotics is based on constructivism due to the argumentation that is needed to design and build prototypes, achieving the integration of technological processes in everyday life, which facilitates learning by inquiry and has generated a series of investigations with diverse approaches and uses that have contextually contributed that students learning begins from what they know and experience. (Anderson et al., 2016; Samani et al., 2019; Correa Ortiz et al., 2019).

Why work with educational robotics?

Received: July 27, 2024
Accepted: August 16, 2024
Published: August 23, 2024

Educational robotics allows a multidisciplinary approach by integrating various areas of learning such as science, technology, mathematics, arts and engineering with the aim of solving every day or non-routine problems in their classroom activities, where students learn in a bidirectional way with their teachers by collecting information by performing the laboratories and adjusting the programming input and output codes in a computer system until obtaining a satisfactory result. (Sullivan, 2009; Sendag & Odabashi 2009; Scaradozzi et al., 2015)

Why work on educational robotics in the natural sciences?

Educational robotics in science is an integrating element for our pedagogical practice because it includes topics in the curriculum as an integrating and transdisciplinary element such as steam activities and the opportunity it provides when solving problems, missions or challenges that follow the steps of a scientific method with different levels of complexity for which we can mention. The observation that develops not only the ability to see under a microscope, but also to interpret how the reagents act on the substrates or mix with each other to be able to distinguish the cells that in our experiments were the phases of mitosis in the prophase, metaphase, anaphase, telophase, thus applying the first step of the method in our classrooms. The hypothesis: to pose questions relating how science and technology allow the development of new knowledge strategies, following experimentation processes to design, analyze and carry out simple laboratory tests that allow me to verify my concerns through experiments that favor learning and socialization by sharing with my classmates at school. (Sáez-López et al., 2019).

2. Literature Review

The acronym STEAM stands for science, technology, engineering, art, and mathematics. It represents a new approach to education that emphasizes skills needed for the 21st century, including problem-solving, research, creativity, communication, critical thinking, and teamwork. Currently, science and technology are crucial for a thriving economy, but there is a shortage of professionals in these fields, and women are underrepresented. This may be due to the perception of science as too abstract and complex, as well as the lack of support for computational thinking. Encouraging curiosity, innovation, and entrepreneurship is essential to engage students and prepare them to solve real-world problems. This approach requires a new way of teaching and learning that integrates everyday issues with global challenges. (Ortega & Asensio 2018; Gamboa-Cordero & Bosco 2022; Tesconi, 2018).

The formative and pedagogical processes include the interdisciplinarity of the areas of science, technology, mathematics, art and engineering as a tool that develops skills and competencies in students around the world. (Phetsrikran et al., 2018; Viegas & Villalba; 2017). With the above purposes, robotics can be addressed from the curriculum. For Colombia, one of the curricular proposals describes a spiral design structure distributed in three axes: the first called broad, which consists of consolidating the social approach with digital skills; the second is long which refers to the perspectives of knowledge inherent to the area with its interdisciplinary and social relationships, the last depth where the know how allows the students to reach the solution of a situation (Pérez Acosta & Mendoza-Moreno, 2020).

Robotics has currently positioned itself in our Society due to the fact that robots are becoming part of our daily life, making these machines integrate electronic and mechanical components into computer programming systems which are based on algorithmic thinking that through input and output codes with the aim of solving problems with different levels of complexity in an increasingly technological society and which currently include the artificial intelligence to improve their performance (Ucgul & Cagiltay, 2014; Pina-Calafi,2017; Sullivan & Bers, 2016;Viegas & Villalba, 2017;Vizcaino Zuñoiga et al., 2023)

The classroom is a space where questions are asked naturally, and where classes are fun and develop systemic thinking processes educational robotics is one of these methods, where you learn by doing, designing, or generating prototypes, thanks to 3D printing, augmented reality, and gamification. These emerging technologies allow for interactive learning activities between teachers and students, promoting bidirectional interaction through the contexts of their daily lives. This approach aims to solve local and global problems that are relevant to a specific context. (Fanchamps et al., 2022; Matthew et al., 2024).

3. Materials and Methods

To obtain DNA from vegetables, the private school used strawberries (*Fragaria vasca*) and then public school used tomatoes (*Solanum lycopersicum*) the following materials were used for this procedure:

- 2 strawberries or 1 tomato (fresh or frozen, but remove the green leaves)
- 2 teaspoons of dish detergent
- 1 teaspoon of salt
- 2 plastic cups
- 1 coffee filter
- ½ cup of cold rubbing alcohol
- 1 coffee stirrer
- ½ cup of water
- A resealable plastic bag

2.1. Procedure

Strawberries or tomato juice were placed in a bag. After closing the plastic bag, the fruits were crushed for about 2 minutes until they are well crushed. The DNA extraction solution was then prepared by adding the following reagents to the first plastic cup: 2 teaspoons of dish detergent, 1 teaspoon of salt, and 1/2 cup of water. Afterwards, students waited for the liquid to drip through the filter into the plastic cup and they poured half a cup of cold isopropyl alcohol. Next, you gently move the cup in circles to observe how the whitish material formed in the top layer of liquid. That's the DNA of the strawberry. Finally, they used the coffee stirrer to collect the DNA from the liquid. After extracting the DNA, the students placed an onion bulb (*Allium cepa*) in water for 8 days. The goal was to encourage root growth and observe the stages of mitosis (prophase, metaphase, anaphase, and telophase) in its apical meristems. The following materials were used for this lab experiment:

- Coverslip
- Slide
- Needle
- Sterile lancet
- Staining bucket
- Pincers
- Chopsticks
- Washing bottle
- Scissors
- Alcohol lighter
- Filter paper
- Beaker
- Watch glass
- Orcein A
- Orcein B
- Microscope.

2.2. Sample Preparation

To observe the growth of rootles, fill a beaker with water and place an onion bulb in it, secured in place with two or three

Toothpicks so that the lower part of the bulb is submerged in the water. After 8-9 days, you will notice numerous rootless.

Growing to about 2-3 cm in length. To observe the rootlets under a microscope, take one of the rootlet tips with tweezers and place it on a slide. Add a drop of orcein B and leave it for 1 minute. Carefully place a coverslip over the rootlet. The preparation obtained can then be observed under a light microscope with the lowest magnification objective(10x) and then

With higher magnification (40x and 100x) across different fields. Look for the following phases: 1. Interface: This is the phase where the intact nucleus, chromatin, and nucleolus are easily visible. 2. Prophase: The nuclear membrane begins to disappear, and the chromatin network starts to condense to from chromosomes. 3. Metaphase: The chromosomes are condensed and aligned in the equatorial plane. 4. Anaphase: Chromosomes separate and move to opposite poles of the cell. 5. Telophase: This place marks the point where chromosomes reach the poles, and the nuclear membrane begins to form again.

2.3. Elaboration of Chromosomes on Paper and Robotic Programming

After the theoretical conceptualization of the theme of DNA, the observation of

chromosomes in the phases of mitosis, the students make in recyclable material, cardboard or paper the two pairs of sex chromosomes xx or xy with a minimum size of 15 cm and a maximum of 30 cm, then they take photographs of their model with which they observe in the augmented reality application called arlopa. At the end of the activity, they make a system of turning LEDs on and off that are located in the center of the chromosome to be programmed with an Aduino for its operation.

3. Results

In 2023, a study was conducted with 80 adolescents. There were 26 male and 54 female participants, all with an average age of 15 and in ninth grade. Forty students attended a public school in Giron, Santander, while the other 40 attended a private school. The public school activities took place during biology and chemistry classes in March, April, and May. Meanwhile, the private school activities were part of the makers' week at US-Colombia Binational Center in Bucaramanga. Public school students used tomatoes to obtain DNA samples, while private school students used strawberries. It's important to note that there were no differences between the plant samples used in the laboratories. When developing the experience, 90% of the students obtained the DNA of the fruits; only 65% were able to cut the roots of the onion and making their preparation, they observed the phases of mitosis. 100% made the chromosomes from recyclable material, and only 67 % managed to program the Leds of the autosomes of their chromosomes using the Arduino, figure 1.

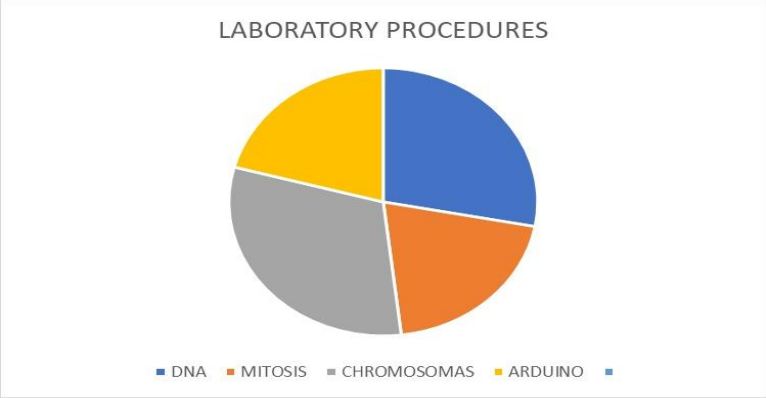

Figure 1. Percentages of student for each laboratory procedures.

For experiment two: it was identified that mitosis in plants occurs in the meristems that correspond to the tissues that allow plant growth and are mainly found in stems and roots. Mitosis is the process by which cells divide equally by distributing their genetic material between two daughter cells. The students observed that when organic onions were placed in water, they grew faster. In the teaching of biology, it is necessary to identify the differences of cellular structures, among them we mention the nucleus as the unit that stores genetic information, which is a fundamental part of the topics seen in the 4th grade of high school and that allows it to relate how through the history of science and through the help of technology scientists have been able to show their finds. When the topics are explained, it is done in a bidirectional way where the students bring previous information, then a brainstorm is done and then the work of the characters in science is recognized, for which a class is dedicated to this topic to recognize the value of women scientists, for which the work was exalted through the biography of Rosalind Franklin and her contribution to obtaining the images of the DNA, for the development of the activities, a plan of science class. Table 1 summarizes the lesson plan for these labs in science class.

Table 1. Lesson plan for the DNA theme.

Phases	Objectives	Actions developed
Diagnosis	Identify the student's prior knowledge of DNA	Brainstorming Preparation of the guide
Structuring	Elaboration of the guide in its theoretical construct for which questions on the subject are	Theoretical review on the internet through the teacher's blog and student reviews.

	elaborated and resolved	Video observation on YouTube, elaboration of class room tasks. Biography of women and their contribution to the sciences
Laboratory development	Carry out the laboratories in class taking into account the steps of the scientific method: observation, elaboration of hypotheses, development of the activity, sharing of experiences, conclusions.	Laboratory 1: DNA extraction from strawberries and/or tomatoes. Laboratory 2: observation of the phases of mitosis by means of onion roots.
Elaboration of the robotic model	Designing a scale model of chromosomes using creativity using recyclable materials	Chromosome model Electrical Circuit Arduino Programming

4. Discussion

Constructionism is an educational theory proposed by Papert, based on the constructivism of Jean Piaget. It sees educational robotics as a learning process in which students learn basic concepts of construction and programming by working in teams. This process helps them develop skills in competencies such as explaining phenomena and using scientific knowledge comprehensively in chemistry and biology laboratories, which relate activities to their daily lives. The learning of natural sciences in the subjects of chemistry and biology requires the diagnostic phases where students brainstorm from a research question about the previous ideas of DNA, they identify the organic molecule as the structure it contains the genes for the phenotypic and genotypic characteristics that they have inherited from their parents. Emphasis is placed on the importance of recognizing our origin as a species and how the characteristics have taken years of evolution.

It begins with the development of the guide that allows us to identify phenotypic characteristics such as hair color, eyes and blood type, relating these to the characteristics that are inherited from their parents, that is, we are a common line that continues with genetic and metabolic processes influenced by environment. Structuring phase: In order to understand these process, students must carry out a theoretical review about what DNA is, which determines its structure, because this molecule is so important in our body, that it is a chromosome, what is the difference between autosome and sex chromosomes, which is a test of paternity of grand parenthood, how a possible murderer can be identified, what traces they can leave at a crime scene, how this molecule contains the information of life, and what is its helical structure due to. For this topic, a space for reflection was dedicated to the role of women in science.

For this purpose, Rosalind Franklin's biography was read with the aim of inspiring readers about the life of a scientist who decides to make a transcendental decision for her life, accessing the University of Cambridge by his own means and how his constant work allowed us to obtain a clear image of the structure of DNA in which it was possible to establish that its molecules were formed in a helical manner. It is important that in our classrooms the value of research is recognized and how it reaches society with the aim of contributing to improvement processes in different fields of knowledge.

For the development of the laboratories with respect to the extraction of DNA, 90% obtained the DNA from the strawberry or tomato juice preparation; the 10% that did not achieve it were those who did not follow the instructions or varied the quantities of the reagents. Additionally, the roots of the onions were allowed to grow with the objective of observing their meristems, which are the tissues that allow the growth of the plant, the phases of mitosis, which is a process by which the cells divide so that their material genetic material is distributed equally in its daughter cells. The function of orcein A is to soften the cell

membrane, and orcein complements the staining process to be able to observe the phases.

Pressure must be placed on the slide with the preparation to achieve an extension of the meristem preparation. Only 65% of the students did it because many of them placed too much pressure on the covers; additionally, when spreading the cells, they did not place the reagents in order. After obtaining a good preparation, the students observe the chromosomes that are stained purple by orcein, identifying the phases of prophase, metaphase, telophase and anaphase. Robotic models and programming: the dynamics of the chemistry and biology classes include the theoretical component and its respective practical application, for which the students are practiced with small exercises or challenges during the sessions, the augmented reality application arlopa was used so that they could see the chromosomes.

The sample studied was 80, distributed among 54 women and 26 men. Of these 65 students, they made XX chromosomes and 15 made XY. Only 67% programming with the arduino. To make the chromosomes, recyclable materials are used, such as newspaper, cardboard, lids or plastic bottles. They make a pencil model that is then made with recyclable materials. They begin the work in pairs, but at the end, a model is delivered by each person. Student, letting them use their creativity. At the end, the group gives feedback on the work, explaining what they liked most when preparing it and briefly explaining why this DNA molecule continues to be the basis of our genetic structure, which as humans we keep from generation to generation. In each generation, at the end of their work, they are exhibited at the science fair, showing themselves to their primary school classmates and to an invited audience who may be parents or members of the educational community.

5. Conclusions

Robotics as a pedagogical proposal was developed as a face-to-face workshop that privileges the student with learning focused on the recognition of how emerging technologies allow learning in a bidirectional way, since in this way the student is able to transcend until reaching the best model and we as educators, we become mediators of the teaching-learning process, being generators of skills, including scientific skills, recognizing how science positively influences the new knowledge society.

The teaching of natural sciences is of vital importance, since teaching life processes shows the role of teachers in favoring learning in a bidirectional way where learning is not by repetition but by the integration of knowledge, for the experiment there of the 80 students, 80% chose xx allosomes and 20% xy allosomes, they were facilitated to relate the parts of the chromosome that they made with recyclable material with the one they observed with the augmented reality application. The most commonly used LED colors for the centromere was red followed by yellow.

The integration of robotics in science classes was conceived as a mediator of a learning process because this methodology invites teachers to analyze their pedagogical practice and take extra courses to be willing to integrate emerging technologies as a process, continuous improvement, which seeks meaningful learning for its students as well as being willing to recognize that when explaining a fact or phenomenon, centuries of multidisciplinary learning have passed that, together creativity and communication, will become processes that develop skills for the 21st century.

Collaborative learning experiences between peers should be privileged as actions that allow the construction of meaningful learning, the promotion of teamwork through the exchange of ideas, as well as the realization of projects that allow the development of particular skills, among others. We observed communication where it was evident how, through drawings, you can design your chromosomal robotic model. Thus, we remembered that although we are in the digital age, we cannot leave aside creativity, oral, written and corporal expression in our daily pedagogical practice.

Funding: This project is part of the funded projects for the management of strengthening and productivity of doctoral students' research I-FP-P03-F03 at the Pedagogical and Technological University of Colombia (Uptc).

Acknowledgments: We would like to thank all the students for welcoming us and collaborating on the project.

Conflicts of Interest: The authors declare no conflict of interest.

References

Anderson, E., Buchko, A., & Buchko, K. (2016). Giving negative feedback to Millennials: How can managers criticize the "most praised" generation. *Management Research Review, 39*(6), 692-705. https://doi.org/10.1108/MRR-05- 2015-0118.

Cáceres Zapatero, M. D., Brändle Señán, G., & Ruiz San Román, J. A. (2017). Sociabilidad virtual: la interacción social en el ecosistema digital. *Historia y Comunicación Social, 22*(1), 233-247. https://doi.org/10.5209/HICS.55910

Castro Rojas, M. D., & Acuña Zuñiga, A. L. (2012). Propuesta comnitaria con robótica educativa: valoración y resultados de aprendizaje. *Revista Teoría de la educación: Educación y cultura de la sociedad de la iformación, 13*(2), 91-118.

Correa Ortiz, L. C., Vallejo Jiménez, M. M., Martínez Puerta, J. J., &Trujillo Posada, J. A. (2019). Herramienta de ro- bótica educativa basada en Lego Mindstorms y VEX Robotics mediante software 3D y diseño mecatrónico. *Risti. Revista Ibérica de Sistemas y Tecnologías de Información, 34*(1), 1-19. https://doi.org/10.17013/risti.34.1-19

Fanchamps, N., Slangen, L., Specht, M., & Hennissen, P. (2022). Effect of SRA-programming on computa-tional thinking through different output modalities. *Journal of Computers in Education*, 1–30. https://doi.org/10.1007/s40692-022-00236-w

Gamboa-Cordero, Y., & Bosco, A., (2022). La robótica y el movimiento maker en primaria: un desafío pedagógico. *UTE Teaching & Technology Núm, 2*. https://doi.org/10.17345/ute.2022.2.3381

Lepuschitz, W., Merdan, M., Koppensteiner, G., Balogh, R., & Obdržálek, D. (eds.) (2018). *Robotics in education. Latest results and developments.* Springer. https://doi.org/10.1007/978-3-319-62875-2

Matthew, N., Bismark, N., & Salamatu M. (2024). Prioritizing STEAM Education from the Start: The Path to Inclusive and Sustainable STEAM Education. *International Journal of STEM Education for Sustainability, 4*(1), 54-69. https://doi.org/10.53889/ijses.v4i1.322

Merdan, M., Lepuschitz, W., Koppensteiner, G., Balogh, R., & Obdržálek, D. (eds.). (2020). *Robotics in Education. Current Research and Innovations.* Advances in Intelligent Systems and Computing. Springer. https://doi.org/10.1007/978-3-030-26945-6

Nuangchalerm, P., Islami, Z., & Prasertsang, P. (2022). Science attitude on environmental conservation of Thai and Indonesian novice science teacher students. *International Journal of STEM Education for Sustainability, 2*(2), 148-155. https://doi.org/10.53889/ijses.v2i2.62.

Ortega, B., & Asensio, M. (2018). Robótica DIY: pensamiento computacional para mejorar la resolución de problemas. Revista *Latinoamericana de Tecnología Educativa, 17*(2), 129-143.

Papert, S. (1998). Child power: Keys to the new learning of the digital century: Presentation and videotape.Colin Cherry Memorial lecture on communication, Imperial College of London. http://papert.org/works.html

Phetsrikran, T., Massagram, W., Phoka, T., & Harfield, A. (2018). A Feasibility Study of Arducation Bot: An Educational Robotics and Mobile Application Kit for Computational Thinking Skills. *22nd International Computer Science and Engineering Conference (ICSEC)* (pp. 1-6). https://doi.org/10.1109/ICSEC.2018.8712671

Pérez Acosta, G., & Mendoza-Moreno, M. (2020). Robótica educativa: propuesta curricular para Colombia. *Educación y Educadores, 23*(4), 577-595. https://doi.org/10.5294/edu.2020.23.4.2

Pina-Calafi, A. (2017). Robótica educativa en educación primaria: ¿por qué y cómo? In G. Perez Acosta, P. Castellano, and C. Pina (eds.), *Propuestas de innovación educativa en la sociedad de la información* (pp. 15-27). Adaya.

Sáez-López, J.-M., Sevillano-García, M.-L., &Vazquez-Cano, E. (2019). The effect of programming on primary school students' mathematical and scientific understanding: Educational use of mBot. *Educational Technology Research and Development, 67*(6), 1405–1425. https://doi.org/10.1007/s11423-019-09648-5

Samani, M., Sunwinarti, S., Putra, B. A., Rahmadian, R., & Rohman, J. N. (2019). Learning strategy to develop critical thinking, creativity, and problem-solving skills for vocational school students. *Jurnal Pendidikan Teknologi dan Kejuruan, 25*(1), 36-42. https://doi.org/10.21831/jptk.v25i1.22574

Scaradozzi, D., Sorbi, L., Pedale, A., Valzano, M., & Vergine, C. (2015). Teaching robotics at the primary school: An innovative approach. Procedia. *Social and Behavioral Sciences, 174*, 3838-3846. https://doi.org/10.1016/j.sbspro.2015.01.1122

Sendag, S., & Odabashi, H. (2009). Effects of an online problem-based learning course on content knowledge acquisition and critical thinking skills. *Computers &Education, 53*(1), 132-141.

Stylos, G., Siarka, O., & Kotsis, K. T. (2023). Assessing Greek pre-service primary teachers' scientific literacy. *European Journal of Science and Mathematics Education, 11*(2), 271-282. https://doi.org/10.30935/scimath/12637

Sullivan, A., & Bers, M. (2016). Robotics in the early childhood classroom: learning outcomes from an 8-week robotics curriculum in pre-kindergarten through second grade. *International Journal of Technology and Design Education, 26*(1), 3-20. https://doi.org/10.1007/s10798-015-9304-5

Sullivan, F. R. (2009). Risk and responsibility: A self-study of teaching in second life. *Journal of Interactive Learning Research, 20*(3), 337-357.

Sultan, A., Henson Jr., H., & Lickteig, D. (2021). Assessing preservice elementary teachers' conceptual understanding of scientific literacy. *Teaching and Teacher Education, 102*, 1-10. https://doi.org/10.1016/j.tate.2021.103327

Tesconi, S. (2018). *El docente como maker. La formación del profesorado en making educativo.* Universitat Autònoma de Barcelona.

Ucgul, M., & Cagiltay, K. (2014). Design and development issues for educational robotics training camps. *International Journal of Technology and Design Education, 24*(2), 203-222. https://doi.org/10.1007/s10798-013-9253-9

Viegas, J. V. D., & Villalba, K. O. C. (2017). Educación y Robótica Educativa. *RED, 54*, 1-13. http://dx.doi.org/10.6018/red/54/11.

Viscaino Zúñiga, P. I., Cedeño Cedeño, R. J., & Maldonado Palacios, I. A. (2023). Metodología de la investigación científica: guía práctica. *Ciencia Latina Revista Científica Multidisciplinar, 7*(4), 9723-9762. https://doi.org/10.37811/cl_rcm.v7i4.7658