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Robotics in agriculture and the teaching of mathematics

Abstract

Robotics is a valuable tool for teaching mathematics as it allows students to see the practical applications of mathematical concepts in real-life situations, students can use robotics to learn about geometry and spatial reasoning by designing and programming robots to move through specific paths or shapes, in addition also use robotics to explore algebraic and numerical concepts by programming robots to perform calculations or model real-world problems. As well, robotics develop problem-solving and critical thinking skills as they design, build, test, and refine their robots. Overall, incorporating robotics into mathematics education can help make math more engaging and relevant for students.In conclusion, robotics in agriculture and the teaching of mathematics provide students with opportunities to develop critical thinking and problem-solving skills through hands-on learning, analytical thinking, quantitative decision-making, problem-solving strategies, and collaborative work.

Keywords: robotics, agriculture, teaching, mathematics

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Introduction

Integrating mathematics into robotics education in the context of agriculture can be done in various ways.

1. **Programming logic:** Teach students how to code and program robots for agricultural tasks. Use mathematics concepts such as algorithms, conditionals, loops, and variables to develop logical and efficient code. This will help students understand the importance of precise mathematical calculations in robotics.
2. **Sensor integration:** Discuss how sensors are used in robotics for data collection in agriculture. Teach students about measurement units, data analysis, and statistical concepts to interpret the sensor data accurately. This involves understanding mathematical representations, units of measurement, and calibration.
3. **Navigation and mapping:** Introduce concepts like Cartesian coordinates, mapping, and GPS systems to help students understand how robotics navigate through agricultural fields. Teach them about distance, angles, geometry, and trigonometry to calculate coordinates, plan routes, and optimize navigation.
4. **Kinematics and motion planning:** Explore the mathematics behind robotic arm movements used in agricultural tasks like harvesting or planting. Teach concepts such as joint angles, inverse kinematics, and trajectory planning. Students can learn to calculate angles, distances, and velocities for precise movements.
5. **Data modeling and analysis:** Agriculture robotics generates a vast amount of data. Introduce mathematical modeling techniques like regression analysis, machine learning algorithms, or statistical methods to analyze and interpret this data. Students can learn to identify patterns, make predictions, and optimize agricultural processes using mathematical models.
6. By incorporating these mathematical concepts into robotics education in agriculture, students can develop a deeper understanding of both subjects and apply their knowledge to solve real-world challenges effectively.

Materials and methods

In mathematics, systematic reviews are common this is demonstrated by; García,[1] Jou,[2] Castro,[3] Zabala-Vargas,[4] Plaza,[5] Ojeda,[6] Salazar,[7] Méndez,[8] Kanobel,[9] however, in this work, a semi-systematic review of the literature was carried out, that is, a mixture of narrative review and systematic review whose definitions are exemplified by Reyna,[10] and Moreno,[11] since some steps of the systematic review and others were omitted because the main objective is to highlight the importance of mechatronics in the teaching of mathematics, the steps that were followed from the systematic review were; define the research questions, review the search for evidence, extract the data and present the results, the omitted steps were; specify the inclusion and exclusion criteria of the results and evaluate the quality of the studies. The search was carried out in academic Google, and the questions was Robotics in Mathematics teaching, and Robotics in Agriculture.

Results

Robotics in mathematics teaching

Robotics is a valuable tool for teaching mathematics as it allows students to see the practical applications of mathematical concepts in real-life situations, students can use robotics to learn about geometry and spatial reasoning by designing and programming robots to move through specific paths or shapes, in addition also use robotics to explore algebraic and numerical concepts by programming robots to perform calculations or model real-world problems. As well, robotics develop problem-solving and critical thinking skills as they design, build, test, and refine their robots. Overall, incorporating robotics into mathematics education can help make math more engaging and relevant for students (Table 1).

Table 1 Robotics in mathematics education

Author	Description	Year
Zhong, et al.[12]	Analyzed 20 empirical studies on how to teach and learn mathematical knowledge through robotics. The 20 papers suggest that robotics generally plays an active role in mathematics education; however, there are indeed situations in which no significant improvement was found in students' mathematical learning.	2020
Gerretson, et al.[13]	Made a small study for further examining ESD issues involved with implementing new technologies and integrating associated activities into the existing mathematics and science curricula to develop an interdisciplinary approach	2008
Felicia, et al.[14]	Review on educational robotics, its advantages to educational fields, the hardware design and the common programming software used which can be implemented among Malaysian students.	2014
Leoste, et al.[15]	Presents the results of the pilot study and discusses the pros and cons of using robots in math education.	2019
González, et al.[16]	Presents the progress of the development of a project where robotics is implemented for the teaching of mathematics in preschool and first-grade students, for which three public schools were selected and a series of recreational activities were developed, using low-cost robotic tools.	2019
Castro, et al.[17]	Concludes in a study that a simulated environment provides sufficient tools to learn basic notions of robotics, without the need for a physical kit, which can be used for educational purposes. for teaching mathematics.	2022
Alzate, et al.[18]	Presents the use of the Botnifacio robot as a playful proposal to teach mathematics (arithmetic) at the preschool level in two schools in Guasave Sinaloa during 2018. Through an action research method and a phenomenological construction, it was found that all children maintain their attention in the activity of Botnifacio, even when they do not have the robot in their hands since it is oriented to the playful dimension	2019
Seckel, et al.[19]	Showed that in general, there is a positive predisposition towards the addition of robots in the learning and teaching of mathematic processes during the first years of school, even though teachers claim there is a struggle to incorporate robots in their lessons due to the high number of students and the reduced space in their classrooms.	2021
Muñoz, et al.[20]	Design, develop and implement educational robotics to improve logical-mathematical skills aimed at preschool and first-grade students in public schools, using programmable educational robots.	2020
Lopez, et al.[21]	Analyses the conditions that are necessary for achieving an effective learning of Mathematics, aided by a robotic platform, results show an impact on the attention and motivation of the students, and they allow for establishing the conditions that need to be met for an effective relationship between the teacher and the technological tool, so that better learning outcomes in Mathematics are more likely to be obtained.	2020
Fernandes, et al.[22]	Present and discuss an activity realized with K-8 level students using robots to learn functions in the mathematics classroom. Research presented is framed by project DROIDE which is a three-years project.	2006
Caudana, et al.[23]	Developed and implemented an experimental protocol that allows us to improve the levels of focusing on Mexican high school students during a math class using an NAO robot. Three different scenarios were studied.	2019
Saez-Lopez, et al.[24]	This study highlights the importance of an educational design that includes robotics and programming through a visual programming language as a means to enable students to improve substantially their understanding of the elements of logic and mathematics.	2019

Agricultural robots in México

Agricultural robots, also known as agri-bots or, are advanced technological systems designed to assist in various farming tasks. These robots can automate processes such as planting, harvesting, irrigation, fertilization, and crop monitoring. In Mexico, the adoption of agricultural robots has been gaining momentum in recent years. These technologies are being embraced to enhance efficiency, productivity, and sustainability within the agriculture sector. Some notable applications of agricultural robots in Mexico include: 1. Harvesting: Robots can be employed for the automated picking of crops like fruits, berries, and vegetables to reduce labor-intensive efforts. 2. Weed control: Autonomous robots equipped with vision systems and artificial intelligence can identify and selectively remove weeds, minimizing the need for herbicides. 3. Crop monitoring: Drones equipped with sensors and imaging technologies are used to capture data on plant health, identify areas needing attention, and optimize resource allocation. 4. Irrigation management: Smart irrigation systems integrated with robots allow for precise water usage and efficient irrigation practices, conserving water resources**.** 5. Soil analysis: Robots equipped with sensors can analyze soil quality and make intelligent fertilizer recommendations, optimizing nutrient application. These advancements in agricultural robotics aim to improve productivity, address labor shortages, reduce environmental impacts, and enhance overall farm management practices in Mexico.

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It is important to note that while the integration of agricultural robots is growing, their adoption may vary across different regions and farm sizes.

Agricultural mechanization is the only way to dramatically increase productivity, being that in the XXI century is to be applied at the highest level, automation and robotics. In the country's efforts are minimal research and development of agricultural robotics. Being in full disadvantage to countries like Brazil, Argentina and Chile have already started research in this segment of robotics. It must start encouraging the creation of groups among the leading universities in research on robotics as the IPN, UNAM, IPN-CINVESTAV Tamaulipas and IPN-CINVESTAV Saltillo, Technological University of the Mixteca, University of Guanajuato and agricultural research institutions like INIFAP, COLPOS, and Antonio Narro Agrarian Autonomous University. So, the experience and capacity of research institutions on robotics and research institutions in agricultural sciences to advance the development of this discipline in Mexico would take advantage. The aim of this paper is to review the current status of robotics applications in Mexican agriculture, examine future prospects, and demonstrate that Mexico needs to make greater efforts, as research in agricultural robotics is significantly lagging. Negrete[25] many other tasks in agriculture in greenhouses can be made with robots. Past literature has reported many successful cases about crops in greenhouses. The main function of greenhouses is to recreate and keep adequate and controlled conditions of light, humidity, temperature, carbon dioxide, and pesticides, among others, in a confined space to grow plants for diverse purposes. However, those conditions can be potentially harmful to humans who work in greenhouses. An alternative to overcome this is the application of robotics in those agricultural sites, adequately applying Artificial Intelligence and mechanical subsystems that are part of a robot (Table 2).[26]

Table 2 Agricultural robots designed in Mexico

Author	Description	Year
Hernandez, et al.[27]	Redesign the irrigation robot BCC Cpmbi Boom, for which analyze the variables; measures overall working speed gear motor type, pump type, water consumption in nozzles, pressure waterpipes, transport system, etc. perform static, dynamic, hydraulic load, to obtain superior characteristics in actual robot operation	2007
Ramirez, et al.[28]	For the construction of the robot, a structure was design that could adapt easily to the trunk of the tree (inclination, height and diameter). The structure has a crank-connecting rod system that is capable of climbing the palm tree and carries at the same time a motor, a battery and a camera witch all together weighs 7 kg. The systems of artificial vision includes a camera IP that takes images to recognize the robot position. An algorithm that detects ellipses identifies the presence of coconut. The rod-crank mechanism used despite being very rustic, was effective for climb the robot on the palm. It also helps reduce the presence of motors on the robot, greatly reducing the amount of electronic devices on its control.	2013
Llamas, et al.[29]	Calculation of a two-degree-of-freedom robotic arm fitted with a video camera to capture images of plants, which will then be transmitted to a computer for analysis.	2014
Anonimous, et al.[30]	A group of students at the Technological Institute created the prototype of a robotic solar vehicle that improves the sowing and reforestation works through programming trajectories. The robotic car was designed with a mechanism that can plow the crop field and thus speed up the process. The vehicle is aligned with a dispenser, which enables to sow the seeds that are then covered by a shovel installed in the bottom of the device	2016
Salinas, et al.[31]	The development of an agricultural robot in Mexico for teachers and students at UACH is a multifunctional vehicle designed for agricultural tasks. It features an innovative suspension system, autonomous navigation between crop rows using computer vision, enabling crop monitoring, fertilizer application, pest and disease control, and the ability to plant various types of grains.	2023
Miranda, et al.[32]	Designed a prototype of an autonomous mobile robot to characterize crop soils and investigate the effects of radiation during the germination of corn seeds and seedlings.	2021
Cortez, et al.[33]	Proposed a sowing robot for application in agriculture in the region. Proposal for the design of a seeder robot, which was carried out in the CAD software SolidWorks 2018®. Likewise, the conditions and mechanical and electronic devices to be used were proposed. The latter proposes the use of microcontrollers from the XIDE platform and microprocessors from the Raspberry Pi platform, where they are the components to be physically implemented.	2019

Discussion

Agricultural Robotics and the teaching of mathematics can greatly contribute to the development of critical thinking and problem-solving skills in students.

I. **Hands-on Learning:** Robotics in agriculture involves practical applications and experiments. Students can engage in designing, building, and programming robotic systems for farming tasks. This hands-on learning approach encourages critical thinking and problem-solving as students analyze challenges, troubleshoot issues, and find innovative solutions.

II. **Analytical Thinking:** Mathematics education requires logical reasoning and analytical thinking. Solving mathematical problems involves breaking down complex situations into smaller, manageable components. Students learn to analyze, interpret data, and apply mathematical concepts to real-world scenarios, fostering critical thinking skills.

III. **Quantitative Decision Making:** Agriculture involves numerous variables and data points that need to be analyzed for optimized decision-making. Mathematics provides students with the necessary tools to collect, organize, and interpret data to make informed choices. This process enhances critical thinking by teaching students how to analyze various factors and their impact on decision outcomes.

IV. **Problem-Solving Strategies:** Both robotics and mathematics provide students with problem-solving strategies and methodologies. Students learn to identify problems, formulate hypotheses, explore different solution paths, and evaluate the effectiveness of their approaches. These processes develop critical thinking skills by teaching students systematic problem-solving frameworks.

V. **Collaboration and Communication:** Robotics and mathematics often involve collaborative projects, where students work together to solve problems and achieve common goals. Collaborative work enhances critical thinking as students engage in discussions, share ideas, evaluate alternate solutions, and communicate their reasoning. This exchange of perspectives develops analytical thinking and problem-solving skills.

Conclusions

Incorporating agricultural robotics education into mathematics can have several potential benefits:

1) **Experiential learning:** Robotics allow students to engage in hands-on activities, giving them practical experiences in applying math concepts. It enhances their understanding of mathematical principles through real-world applications in the agricultural context.

2) **Problem-solving skills:** Robotics encourage students to think critically and solve problems creatively. By programming and operating robots in agricultural tasks, students develop analytical and logical thinking abilities to solve mathematical challenges related to farming practices.

3) **Enhanced mathematical understanding:** Robotics can provide a concrete representation of abstract mathematical concepts. Students can see mathematical concepts, such as geometry, algebra, measurements, and data analysis, in action through programming and controlling robots, fostering a deeper understanding of these mathematical principles.

4) **Interdisciplinary connections:** Robotics integration promotes the connection between mathematics and other subjects like science, technology, engineering, and agriculture. It allows for a holistic and interdisciplinary approach, encouraging students to explore various facets of knowledge while using mathematics as a foundational skill.

5) **Career readiness:** Agriculture is becoming increasingly automated with the use of robotics and technology. By incorporating robotics education in mathematics instruction, students can develop skills and knowledge that are directly applicable to future careers in agricultural technology, precision farming, or robotics engineering.

6) **Engagement and motivation:** Robotics adds an element of excitement and engagement to mathematics instruction. Students often find the practical application of math concepts through robots to be fun and motivating, leading to increased interest in learning mathematics and improved overall engagement in the subject.

7) Inclusive, incorporating robotics education into mathematics instruction in the agriculture field can provide students with valuable skills, practical knowledge, and a deeper understanding of mathematical concepts, preparing them for future academic and career opportunities. In conclusion, robotics in agriculture and the teaching of mathematics provide students with opportunities to develop critical thinking and problem-solving skills through hands-on learning, analytical thinking, quantitative decision-making, problem-solving strategies, and collaborative work.

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Conflicts of interest

None

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