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ROBOTICS KITS FOR LEARNING IN MATHEMATICS

МАТЕМАТИКАНЫ ОКУТУУДА РОБОТОТЕХНИКАЛЫК КОМПЛЕКТТЕР

РОБОТОТЕХНИЧЕСКИЕ НАБОРЫ ДЛЯ ОБУЧЕНИЯ МАТЕМАТИКЕ

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ROBOTICS KITS FOR LEARNING IN MATHEMATICS

Abstract

There are numerous varieties of robotics construction kits employed for educational purposes in teaching mathematics. We studied 4 of them (LOGO, LEGO Mindstorms, Vex Robotics and Arduino), which can be used in teaching mathematics in engaging and interesting way. They're introduced mathematical concepts which can be learned with particular robotics kit such as: geometry, trigonometry, algebra, measurements, data analyses, proportions, patterns, coordinates etc. Overall, made a conclusion that robotics is a powerful tool for enhancing mathematics education and fostering a deeper understanding of mathematical concepts.
Keywords: robotics kits, mathematics, education, LOGO, LEGO Mindstorms, Vex Robotics, Arduino

Математиканы окутууда робототехникалык комплекттер

Аннотация

Математиканы окутууда билим берүү максатында колдонулган робототехникалык конструкторлордун көптөгөн түрлөрү бар. Биз алардын төртөөнү (LOGO, LEGO Mindstorms, Vex Robotics жана Arduino) карап чыктык, алар математиканы кызыктуу үйрөтүү үчүн колдонулушу мүмкүн. Алар белгилүү бир робототехника комплектинин жардамы менен үйрөнө турган математикалык түшүнүктөрдү киргизет, мисалы: геометрия, тригонометрия, алгебра, өлчөөлөр, маалыматтарды талдоо, пропорциялар, схемалар, координаттар ж.б. Жалпысынан, робототехника математикалык билимди жогорулатуу жана математикалык түшүнүктөрдү түшүнүү үчүн күчтүү курал деген тыянакка келди.

Ачкыч сөздөр: робототехникалык комплекттери, математика, окутуу, LOGO, LEGO Mindstorms, Vex Robotics, Arduino

Робототехнические наборы для обучения математике

Аннотация

Существует множество разновидностей робототехнических конструкторов, используемых в образовательных целях при обучении математике. Мы рассмотрели 4 из них (LOGO, LEGO Mindstorms, Vex Robotics и Arduino), которые могут быть использованы при обучении математике в увлекательной и интересной форме. В них представлены математические понятия, которые можно изучать с помощью конкретного робототехнического набора, такие как: геометрия, тригонометрия, алгебра, измерения, анализ данных, пропорции, закономерности, координаты и т.д. В целом был сделан вывод о том, что робототехника является мощным инструментом для повышения уровня математического образования и более глубокого понимания математических понятий.

Ключевые слова: робототехнические наборы, математика, обучение, LOGO, LEGO Mindstorms, Vex Robotics, Arduino

Introduction

The interaction with robots serves as a transformative bridge, guiding students from the realm of abstract mathematical theory into the practical domains of everyday existence. This transition is paramount, highlighting the importance of students establishing connections between their learning materials and their conventional school assignments (Karasyova, Dalinger & Smagulov, 2023). As students employ mathematical concepts to tackle real-world problems, harnessing the aid of robots in the process, they foster lasting hands-on experience while immersed in a social context. Consequently, this engagement leads to the cultivation of a more optimistic perspective on mathematics education, emphasizing its relevance and applicability in the world around them.

There are plenty types of robotics construction kit used for learning in STEM disciplines, especially in mathematics. In 1960s Seymour Papert, a mathematician, computer scientist, and educator, developed “Logo” - a programming language and educational tool. The use of robotics and programming has a long-standing history in mathematics education with tools such as “turtle” geometry or Logo explored in classrooms for almost 50 years. In Papert’s Logo, students programmed a robotic Logo turtle to turn and move, and a pen attached to it created geometric figures. Papert’s seminal work indicates that educational robotics is a useful tool to “externalize” learner’s ideas and to make mathematical concepts “more accessible to reflection” (Papert, 1980, p. 145).

Nowadays a lot of robotics kits can be used to teach mathematics in engaging and effective way, as they provide hands-on, real-world application of mathematical concepts. Some types of robotics kits that can be used for learning mathematics:

- LEGO Mindstorms;
- VEX Robotics;
- Arduino based kits and etc.

Taking the LEGO Mindstorms kit as an example, children both build and program LEGO-based robots to interact with their environment. Through the use of actuators (motors) and sensors (e.g., light, touch, motion, distance, and rotation sensors), students program the robotic device to measure a variable in the environment, which then triggers a specific programmed response from the robotic device. A typical robotics challenge activity will have students working in teams to build and program a robotic car to utilize a light sensor to follow a colored path on the floor. In actual STEM fields, prototypes and models are constructed to test ideas and designs (Zhong & Xia, 2018).

Discussion and results

Papert's Logo has a strong connection to mathematics, and this connection is one of the key reasons for its development and success as an educational tool. There are several ways in which Logo is closely related to mathematics:

1. Geometry and Spatial Reasoning: Logo's use of turtle graphics encourages users to explore geometric concepts. The turtle can move in various directions and angles, allowing students to experiment with concepts like lines, angles, shapes, and symmetry. This hands-on approach to geometry helps students develop spatial reasoning skills.

2. Coordinates and Cartesian Plane: Logo often involves specifying coordinates for the turtle's movements. For example, the command `SETXY` or `GOTO` allows users to position the turtle at specific (x, y) coordinates on the Cartesian plane. This introduces students to the concept of coordinates and how they relate to positions in two-dimensional space.

3. Mathematical Functions and Formulas: Logo supports mathematical operations, including addition, subtraction, multiplication, and division. Users can create mathematical formulas and equations within Logo programs. This allows students to practice and apply arithmetic skills while programming.

4. Procedural Mathematics: Logo encourages the use of procedures or functions. Students can define their procedures, which can involve mathematical calculations. This concept aligns with functions in mathematics, where one can create a reusable set of instructions to perform a specific task.

5. Patterns and Sequences: Logo's ability to repeat commands using loops (e.g., `REPEAT` or `FOR`) allows students to explore patterns and sequences. They can create programs to generate various numerical or geometric patterns, reinforcing mathematical concepts related to sequences and series.

6. Algorithms and Problem Solving: Writing Logo programs involves algorithmic thinking and problem-solving, which are fundamental mathematical skills. Students must break down tasks into smaller steps and logically sequence them to achieve a specific goal.

7. Variables and Variables Manipulation: Logo allows the use of variables, which can store and manipulate numerical values. This concept aligns with algebraic principles and reinforces the idea of using variables to represent unknowns in mathematical equations.

8. Trigonometry: Logo can be used to introduce basic trigonometric concepts, as students can control the turtle's movement by specifying angles. This can lead to discussions about sine, cosine, and tangent functions.

9. Measurement and Units: Logo can be used to teach units of measurement, such as distance, angles (degrees), and time. Students can explore how different units affect the turtle's movements and calculations.

Overall, Logo's integration of mathematics into programming makes it a powerful tool for teaching mathematical concepts in an interactive and engaging way. It helps students see the practical applications of mathematics and fosters a deeper understanding of mathematical principles through hands-on experimentation and problem-solving.

LEGO Mindstorms

Teaching mathematics with LEGO Mindstorms can be a fun and interactive way to engage students in mathematical concepts (Smagulov & Serikova, 2021). There are some steps and ideas on how to use LEGO Mindstorms to teach mathematics:

1. Basic Geometry and Measurement:

- Start with simple geometry lessons. Use LEGO pieces to create and discuss basic shapes like squares, rectangles, triangles, and circles.
- Teach concepts like perimeter, area, and volume by having students build three-dimensional shapes with LEGO pieces and calculate measurements.
- Explore angles and degrees by having students program their robots to move in specific angles, measuring the rotations of the motors.

2. Proportions and Ratios:

- Have students create robots with moving parts (e.g., arms, legs) and discuss the concept of proportions. They can explore how changing the length of one part affects the movement of the entire robot.

- Use sensors to measure distances, and then have students calculate ratios and proportions to navigate the robot to specific locations.

3. Graphing and Coordinate Systems:

- Introduce the Cartesian coordinate system by having students program their robots to move to specific (x, y) coordinates on a grid. They can then plot their robot's path on graph paper.
- Explore linear equations by having students program their robots to follow straight lines or perform specific tasks based on linear equations.

4. Patterns and Sequences:

- Use LEGO Mindstorms to teach patterns and sequences by having students create and program robots to follow repetitive patterns or execute sequences of commands.
- Discuss arithmetic and geometric progressions using robots that can repeat actions with different increments.

5. Data Analysis and Statistics:

- Integrate sensors to collect data (e.g., light intensity, temperature) and use this data to teach concepts related to data analysis and statistics. Students can record data, create graphs, and draw conclusions.
- Explore probability by programming robots to simulate random events or perform tasks with a probability element.

6. Problem Solving and Algebra:

- Encourage problem-solving skills by presenting students with challenges that require them to design and program robots to find solutions.
- Teach algebraic concepts by having students create and solve equations to determine how various inputs affect their robot's behavior.

7. Real-World Applications:

- Connect mathematical concepts to real-world applications. For example, you can have students design robots to simulate scenarios like calculating the trajectory of a projectile, modeling the behavior of a pendulum, or simulating traffic flow and optimization.

8. Collaborative Projects:

- Assign group projects that involve both robotics and mathematics. Have students work together to solve complex problems, which can include designing robots to work in tandem or achieve specific mathematical goals.

9. Assessment and Reflection:

- Assess students' understanding of mathematical concepts through their robot designs, programs, and problem-solving skills.
- Encourage students to reflect on their projects and discuss how mathematics played a role in their robot's design and functionality.

It’s essential that the key to effective teaching with LEGO Mindstorms is to make the learning experience hands-on, interactive, and engaging. We should encourage creativity and critical thinking while helping students see the practical applications of mathematics in robotics.

VEX Robotics

Teaching mathematics with VEX Robotics can be an exciting and hands-on approach to engage students in mathematical concepts (Serikova, 2022). There's a guide on how to use VEX Robotics to teach mathematics effectively:

1. Start with Basic Concepts:

- Begin by introducing fundamental mathematical concepts such as geometry, measurement, and angles. Explain how these concepts relate to building and programming VEX robots.

2. Geometry and Measurement:

- Use VEX parts to construct geometric shapes, emphasizing angles, lengths, and areas. Have students measure and calculate dimensions as they build.
- Challenge students to build robots that meet specific size constraints, encouraging them to use measurement skills.

3. Angles and Trigonometry:

- Explore angles and trigonometry by discussing how robot movements involve rotations and angles. Teach students about degrees and radians.
- Have students program robots to move in specific angles and calculate distance traveled or positions reached.

4. Coordinate Systems:

- Introduce the Cartesian coordinate system by having students program their robots to move to specific (x, y) coordinates on a grid.
- Challenge students to navigate a maze or draw geometric shapes using coordinate-based instructions.

5. Proportions and Ratios:

- Teach the concept of proportions by having students build robots with moving parts (e.g., arms, legs) and discussing how changes in one part affect the entire robot.
- Use sensors to measure distances, and then have students calculate ratios and proportions to control robot movements.

6. Patterns and Sequences:

- Explore patterns and sequences by having students program robots to follow repetitive patterns or execute sequences of commands.
- Discuss arithmetic and geometric progressions by having robots perform actions with different increments.

7. Data Analysis and Statistics:

- Integrate sensors to collect data (e.g., distance, speed, temperature) and teach data analysis and statistics. Students can record data, create graphs, and draw conclusions.
- Explore probability by having students program robots to simulate random events or perform tasks with a probability element.

8. Problem Solving and Algebra:

- Encourage problem-solving skills by presenting students with challenges that require them to design and program robots to find solutions.
- Teach algebraic concepts by having students create and solve equations to determine how various inputs affect robot behavior.

9. Real-World Applications:

- Connect mathematical concepts to real-world applications. For example, have students design robots to simulate scenarios like calculating projectile trajectories, modeling pendulum behavior, or optimizing tasks like sorting objects.

10. Collaborative Projects:

- Assign group projects that involve both robotics and mathematics. Encourage teamwork to solve complex problems or build robots that work together.

11. Assessment and Reflection:

- Assess students' understanding of mathematical concepts through their robot designs, programs, and problem-solving abilities.
- Encourage students to reflect on their projects and discuss how mathematics played a role in their robot's design and functionality.

The key to successful mathematics teaching with VEX Robotics is to make the learning experience hands-on, collaborative, and engaging. VEX provides a platform that allows students to see the practical applications of mathematics in robotics while fostering creativity and critical thinking.

Arduino based kits

Teaching mathematics with Arduino can be an engaging and practical way to help students understand mathematical concepts in a real-world context. Here's a guide on how to use Arduino to teach mathematics effectively:

1. Start with Basic Concepts:

- Begin by introducing fundamental mathematical concepts such as algebra, geometry, and basic arithmetic. Explain how these concepts relate to electronics and programming.

2. Algebra and Equations:

- Teach algebraic concepts by having students create and solve equations to control various components connected to Arduino.
- For example, students can design circuits and write code to vary the brightness of an LED based on algebraic equations.

3. Geometry and Trigonometry:

- Explore geometry by having students design circuits that involve angles, shapes, and measurements. Encourage them to calculate values like distances, areas, and angles.
- Teach trigonometric concepts by explaining how sensors like accelerometers and gyroscope modules can be used to measure angles and rotations.

4. Statistics and Data Analysis:

- Integrate sensors to collect data (e.g., temperature, humidity, light intensity) and use Arduino to process and analyze the data.
- Teach statistical concepts by having students record data, create graphs, and draw conclusions based on their experiments.

5. Arithmetic and Programming:

- Combine arithmetic with programming by creating projects where students write code to perform mathematical operations.
- For example, have students program an Arduino to act as a calculator or to solve math-related problems.

6. Geometry and Coordinates:

- Use Arduino to teach concepts related to coordinates and grids. Students can create projects that involve plotting points on a grid, calculating distances, or navigating robots using Cartesian coordinates.

7. Measurement and Units:

- Demonstrate measurement concepts using sensors and Arduino. Discuss units of measurement (e.g., inches, centimeters, volts) and conversions.

- For instance, students can use distance sensors to measure objects and convert readings between different units.

8. Real-World Applications:

- Connect mathematical concepts to practical applications. Challenge students to design Arduino-based projects that solve real-world problems.
- Examples include creating a weather station to collect and analyze climate data, building a digital thermometer, or developing a smart lighting system based on light intensity.

9. Problem Solving and Critical Thinking:

- Encourage problem-solving skills by presenting students with Arduino-related challenges that require mathematical thinking.
- Ask students to devise solutions to problems involving circuits, sensors, and data analysis.

10. Assessment and Reflection:

- Assess students' understanding of mathematical concepts through their Arduino projects, code, and problem-solving abilities.
- Encourage students to reflect on their projects and discuss how mathematics played a role in their Arduino designs and functionality.

The key to successful mathematics teaching with Arduino is to make the learning experience hands-on, project-based, and practical. Arduino provides a platform that allows students to see mathematics in action and understand its relevance in electronics and programming while fostering creativity and critical thinking.

There are three categories of integrating robotics with mathematics:

- learning by interacting with robots,
- learning by programming robots,
- learning by building and programming robots (Zhong, Xia, 2018).

In this paper half of the robotics kit is used for learning mathematics by programming and another half is used by building and programming (Table 1).

Table 1. Robotics kits by integrating way and what mathematical concepts can be achieved

Robotics kit	Integrating way	Mathematical concepts
Logo	learning by programming robots	geometric concepts, concept of coordinates, mathematical operations (such as multiplication, division and etc.), mathematical calculations, numerical or geometric patterns, problem-solving, variables, trigonometry, units of measurement;
LEGO Mindstorms	learning by building and programming robots	basic geometry and measurements, proportions and ratios, data analysis and statistics: patterns and sequences: graphing and coordinate systems, problem solving, algebra;
VEX Robotics	learning by programming robots	geometry, angles and trigonometry, statistics, data analyses, problem solving;
Arduino based kits	learning by building and programming robots	algebra and equations, geometry and trigonometry, statistics, arithmetic, measurements, coordinates, problem solving

Conclusions

The link between abstract mathematics and practical experiences in the real world is evident when teaching mathematics through robotics. Using robots as a learning tool enables students to grasp complex real-world applications and encourages various ways of approaching a problem. The interaction with robots facilitates a transition for students from the theoretical perfection of

mathematical concepts to the pragmatic aspects of everyday life. Therefore, it is crucial for students to connect their learning materials with their typical school tasks. As students apply mathematical concepts to address real-world challenges with the assistance of robots, they cultivate enduring hands-on experience within a social context and develop a more positive outlook on mathematics education. It is equally essential to ensure that every student has an equitable opportunity to engage in each hands-on activity, as this reinforces their understanding of the subject matter. Furthermore, all students should have the chance to practice repeatedly with the support of the robotics system, as this greatly aids in constructing their own mathematical knowledge.

In summary, teaching mathematics with robotics kits like LEGO Mindstorms, VEX Robotics, or Arduino shares many similarities that revolve around hands-on learning, problem solving, real-world applications, and interdisciplinary connections. These similarities make robotics a powerful tool for enhancing mathematics education and fostering a deeper understanding of mathematical concepts.

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