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TEACHING MATHEMATICS WITH VIRTUAL ROBOTS TO STUDENTS

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Abstract. The study introduces the case of development of mathematics oriented 20-h robotics course for students (n=50) with educational program of “6B01501 - Mathematics”. The research aimed at exploring the impact of robotics on students’ motivation and engagement by learning math using robotics activities. These activities include controlling virtual robots while learning Algebra concepts. Overall, the aim of practicing math using robots is to investigate the effectiveness of this approach to teaching math, and to identify ways to improve math education using technology. During the study, the researchers examined the global application of robotics and conducted a review of academic databases to collect relevant literature. The findings revealed a dearth of knowledge in the academic literature concerning this particular subject. The study was carried out for three months on the basis of NJSC "Zhetysu University named after Ilyas Zhansugurov" (Taldykorgan), during which the training program "Learning Mathematics with the help of robotics" was developed and tested. Example of lessons at roboblocky.com implemented by students presented in this article. Roboblocky is an educational platform that integrates robotics and programming to facilitate the instruction of mathematical and scientific concepts to students. The platform employs a block-based programming approach, which enhances the accessibility and comprehension of these concepts among students. Based on the available research, it can be concluded that teaching math with Roboblocky is a promising approach. Studies on using robotics to teach mathematics have shown that it can improve student engagement, achievement, problem-solving skills, and spatial reasoning. Additionally, the use of virtual robots in the classroom can promote positive attitudes towards learning among students.

Keywords: mathematics, robotics, roboblocky, virtual robots, block-based programming, STEM education, educational platform, students’ engagement, problem-solving skills

Basic provisions

The field of mathematics education has witnessed a substantial transformation in recent years, largely driven by the integration of cutting-edge technologies into pedagogical practices. The integration of new technology in mathematics education has opened new avenues for engaging students and fostering a deeper understanding of mathematical concepts. One exciting innovation in this realm is the use of virtual robots as educational tools.

RoboBlocky is an excellent tool for forming math skills, for students. It combines programming and robotics with math concepts, making it a fun and engaging way to learn math.

Introduction

The integration of information technology in the learning process has become increasingly important in today's society, where technology is rapidly evolving and changing the way we live, work and learn. The use of technology in education has the potential to enhance the quality of teaching and learning, providing students with more personalized and engaging learning experiences.

The introduction of information technology in the learning process is an urgent aspect at the present time, as it requires a modern transformation of the content and methods of teaching disciplines. Even in the process of personal development in accordance with the characteristics and capabilities of the learner is carried out intensive process of implementation of information technology. Yesseikyzy A., and Smagulov E.Zh. [1] admitted in their study that full-fledged activities, daily life and professional activities of a person in modern society must have a change in the new approaches to the overall high level of development and general culture.

As the importance of future-oriented skills is recognized, there is a growing emphasis on defining and incorporating robotics in education, and particularly in mathematics. Mathematics is a fundamental subject that provides the foundation for many scientific, technological, and engineering fields. However, it is often viewed as a challenging subject by many students due to its abstract and theoretical nature. Research of Samuels, P., and Haapasalo, L. [2] has shown that teaching mathematics using robotics can be an effective way of improving student engagement, interest, and understanding of mathematical concepts. Robotics offers a hands-on and interactive approach to learning mathematics, allowing students to apply mathematical concepts in real-world scenarios, and develop problem-solving and critical thinking skills. The use of robotics can also enhance students' motivation and confidence in mathematics by providing a fun and engaging learning experience. This has led to an increased interest in the integration of robotics in mathematics education at all levels, from primary to tertiary education. However, to effectively implement robotics in mathematics education, there is a need for careful design and integration of robotics activities into the mathematics curriculum. Therefore, this paper aims to review the current research on teaching mathematics with robotics, exploring the benefits and challenges associated with this approach and providing recommendations for the effective integration of robotics in mathematics education using virtual robots.

Materials and methods

To pinpoint the difficulties linked to the use of robotics for teaching mathematics and exploring the impact of its on students, a review of relevant literature was carried out. Dependable peer-reviewed articles were selected from the Scopus and ScienceDirect databases as sources of information and employed steps that were relevant to the study's particular scope. The key searches implemented in the study given in the table 1.

Table 1 - The key words selected to search for materials

№	keywords	Additional keys	Number of found articles	Relevant to the topic
1	math AND lessons AND using AND robotics	-	43	12
2	robotics AND mathematics	TITLE-ABS-KEY (robotics AND mathematics) AND (LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2020) OR LIMIT-TO (PUBYEAR , 2019) OR LIMIT-TO (PUBYEAR , 2018)) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "MATH")) AND (LIMIT-TO (EXACTKEYWORD , "Robotics") OR LIMIT-TO (EXACTKEYWORD , "Educational Robotics"))	111	20
3	educational AND robot AND math AND lesson	-	12	7
4	roboblocky	-	1	1

In the course of this study, a total of 167 articles were gathered through keyword searches, and 40 of them were deemed relevant to the topic. Among these 40 articles, 11 were found to be duplicates, leaving 29 unique articles for analysis. Annotations from 19 of these articles were analyzed using theoretical research methods to examine indicators of student engagement and identify didactic conditions for integrating robotics into mathematics education. The remaining 10 articles were examined in full as part of this analysis of philosophical, psychological, pedagogical, and methodological literature.

Janika Leoste and Mati Heidmets (2020) [3] conducted a multi-stage research on the topic of “Bringing an Educational Robot into a Basic Education Math Lesson”in Estonia. The researchers propose that incorporating robot-assisted teaching as a supplementary element to the regular math curriculum for an extended period of time could be beneficial. In designing robot-supported lessons, it is essential to connect meaningful math content with robotics exercises and provide teachers with lesson scripting that incorporates modern teaching practices. Compared to traditional math lessons, robot-supported math lessons promote and encourage more independent work, collaboration, and peer tutoring among students. For students with special educational needs (SEN), robot-supported math lessons may prove to be more engaging and beneficial, provided that teachers allocate more time for these students. The researchers suggest that robot-supported teaching may initially require more effort and time from teachers and may be more demanding for students. However, once teachers and

students become familiar with this teaching method, it can support the professional development of teachers and the acquisition of math knowledge by students.

Moshe Barak and Muhammad Assal (2018) [4] developed a robotics course to teach students different aspects of mathematics, physics, and problem-solving, and evaluated the students' learning outcomes. The students in the experimental class varied in terms of their prior learning achievements and motivation, and as a result, some students only completed basic exercises, while others excelled in problem-solving tasks. Only a few students undertook complex projects. However, all the students showed a high level of motivation to learn robotics and STEM subjects. In summary, robotics provides an engaging and immersive learning environment for STEM education. Nevertheless, the success of the course depends largely on the design of the methodology and the students' assignments. The researchers suggest that only a small group of students are capable of learning a new subject on their own through project work, and these students need additional knowledge and skills before they can tackle complex projects.

Lopez-Caudana et al. (2020) [5] conducted a study to determine the conditions necessary for effective Mathematics learning using a robotic platform. Through case studies, they found that with proper use of the platform and appropriate teacher participation, hybrid classes of high quality can be given. This enhances student attention to the topics by changing the stimulus, leading to effective learning. The results showed numerical improvement in the scales used to assess specific behaviors and performance in all scenarios, indicating the potential usefulness of robotics in Mathematics teaching. The goal is to make learning more meaningful, leading to better grades and abilities for students. The study found a favorable impact on student attention and motivation and identified conditions necessary for an effective relationship between the teacher and the technological tool to increase the likelihood of better learning outcomes in Mathematics. Robotics is one of many technologies that can support the process of increasing mathematical learning, reinforcing critical thinking skills, digital skills, and teamwork skills through active learning.

Roboblocky is an educational platform that combines programming with robotics to teach students about math and science concepts. It uses block-based programming, which makes it easy for students to understand and learn.

Here are some ways RoboBlocky can help form math skills:

- Develop problem-solving skills: Programming robots with RoboBlocky requires students to think logically and solve problems. This helps them develop critical thinking and problem-solving skills that are essential for math.
- Learn math concepts visually: RoboBlocky uses a block-based interface that allows students to visually see the math concepts they are learning. For example, they can program a robot to move a certain distance, turn a specific angle, or measure objects.
- Engage in hands-on learning: Students can build and program robots with RoboBlocky, giving them a hands-on experience that helps them understand math concepts better.
- Personalized learning: RoboBlocky allows students to work at their own pace, making it easier for them to understand math concepts at their own speed.

- Practice math in a fun way: RoboBlocky's interactive and engaging platform makes learning math more fun and exciting for students. It motivates them to learn more and improves their retention of math concepts.

Overall, RoboBlocky is an excellent tool for forming math skills, as it combines programming, robotics, and math concepts in a fun and engaging way.

When studying math with Roboblocky, it's important to use scientific methods to ensure that learning is effective and accurate. Here are some scientific methods that can be useful when studying math with Roboblocky:

- Formulating hypotheses: When learning math concepts with Roboblocky, students can develop hypotheses about how certain mathematical rules and formulas work and then test those hypotheses by programming the robot to perform various tasks.
- Conducting experiments: Roboblocky provides a platform for students to conduct experiments that test different math concepts. Students can program the robot to solve math problems or perform certain operations and then observe the results of those experiments.
- Observing and recording data: Students should record their observations and data when using Roboblocky to study math. This helps them to keep track of what they've learned and to identify patterns and trends that can help them improve their understanding of math concepts.
- Analyzing data: After collecting data, students should analyze it to determine what it means and how it relates to the math concepts they are studying. This can involve looking for patterns, trends, or correlations in the data.
- Drawing conclusions: Based on the observations and data analysis, students can draw conclusions about the math concepts they are studying. They can then use this information to develop new hypotheses and continue to experiment with Roboblocky.

Using these methods can help students to better understand math concepts and to develop a more robust knowledge of the subject matter. It can also help to foster critical thinking skills and improve problem-solving abilities.

In order to solve the tasks, we set, we conducted a study which aimed: to investigate how students learn and engage in a robotics course about mathematics.

The objectives of the study were to identify patterns, achievements, and problems that students encountered during the course, and to determine how this experience influenced their motivation to learn technology.

The following research methods were used: questionnaire survey, observation, review and study of psychological and pedagogical literature on the topic of research, conversation, processing of survey results.

The study was carried out for three months on the basis of NJSC "Zhetysu University named after Ilyas Zhansugurov" (Taldykorgan), during which the training program "Learning Mathematics with the help of robotics" was developed and tested. 50 students took part in the study.

Results and Discussion

Fang et al. (2022) [6] and Grover et al. (2019) [7] identified four key computational thinking actions that students perform during the lesson: abstraction, coding, debugging, and iteration.

- Abstraction involves planning the necessary steps to move the robot from one location to another.
- Coding involves translating these steps into a set of instructions that can be coded into the robot.
- Debugging allows players to refine the code by adding, changing, or eliminating steps.
- In the iteration phase, the code is entered into the robot, and the players can evaluate the new iteration for the next turn.

The lesson itself has four steps.

1. Each student must solve a math problem.
2. Students use the solution of math problem code and debug the robot's movement.
3. Student manually enters the formula or solution into workspace (Figure 1), and running the program displays the movement of the virtual robot across the grid.
4. Student chooses the right answer from test or types it using keyboard.

There first and second steps could variate based on the task given.

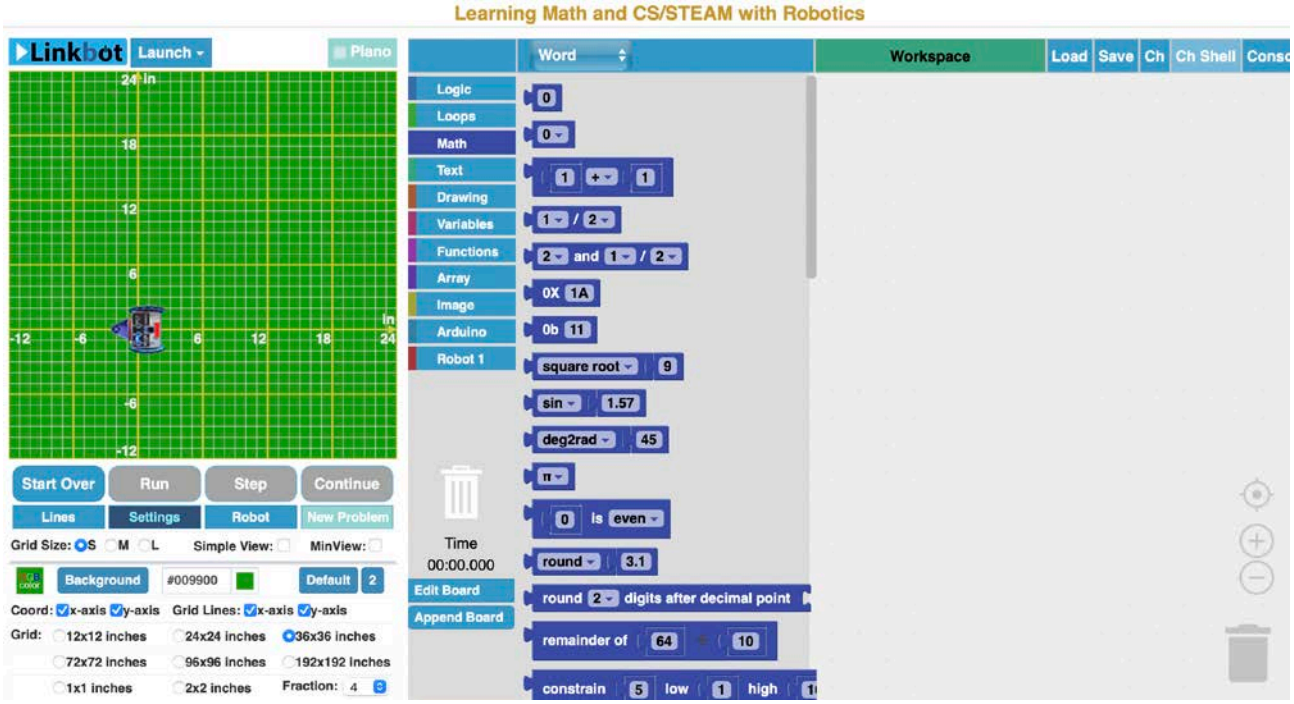

Figure 1 - Roboblocky's workspace

Example of lesson at roboblocky.com implemented by students is shown below.

Theme of the lesson: Graphing Systems of Linear Equations with Robots

Task: Solve 4(y - 5) = 3x and 2(y - 2) = 3x. First, convert both equations to slope-intercept form then edit the drivexyToExpr() blocks to move Robot 1 according to the

equation 4(y - 5) = 3x and move Robot 2 according to the equation 2(y - 2) = 3x. Then, find where these two lines intersect [8].

Solution:

1st step

In the workspace of platform the equations should be written into the blocks named driveToExpr(x0, xf, num, "(2)*x+1", where the form "(2)*x+1" – is slope-intercept form expressed by y:

- By converting the first linear equation we get: (0.75)*x+5;
- By converting the second linear equation we get: (1.5)*x+2 (Figure 2).

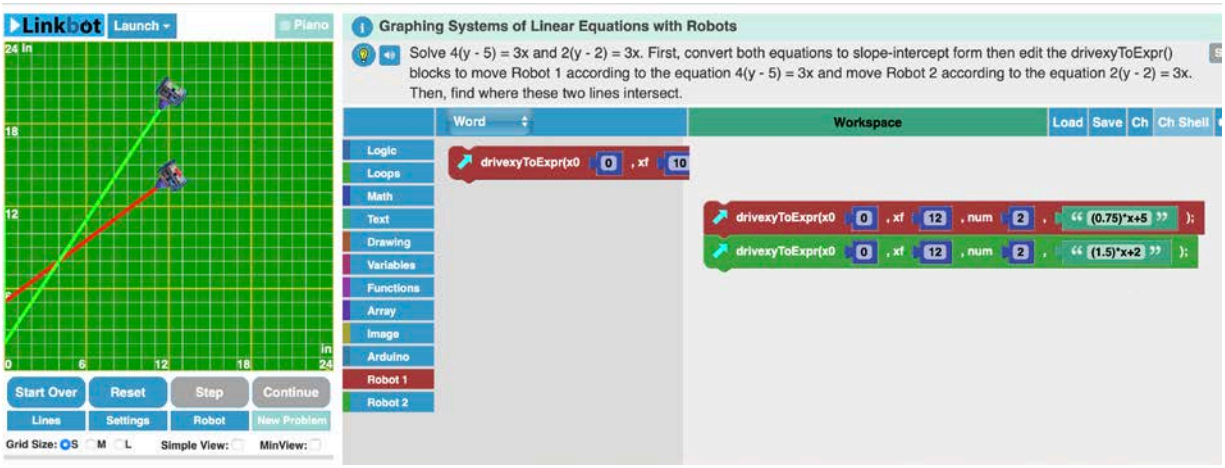

Figure 2 - Running the program

2d step

The system of linear equations can be solved with two methods: Cramer's rule and Gaussian elimination.

The Cramer's rule provides an explicit formula to solve a system of linear equations that has a unique solution and has the same number of equations as unknowns [9]. On the other hand, Gaussian elimination, also referred to as row reduction, is an algorithm used to solve systems of linear equations. It involves a series of operations performed on the coefficient matrix of the equations [10].

The first way to solve the problem given by Gaussian elimination.

A system of equations is given:

$$\begin{cases} 4(y - 5) = 3x \\ 2(y - 2) = 3x \end{cases}$$

Let us reduce the system of equations to the canonical form:

$$\begin{cases} -3x_1 + 4x_2 = 20 \\ -3x_1 + 2x_2 = 4 \end{cases}$$

Rewrite the system in matrix form and solve it by Gaussian Elimination (Gauss-Jordan elimination)

$$\left(\begin{array}{cc|c} -3 & 4 & 20 \\ -3 & 2 & 4 \end{array}\right)$$

R1 / -3 → R1 (divide the 1 row by -3):

$$\left(\begin{array}{cc|c} 1 & -\frac{4}{3} & -\frac{20}{3} \\ -3 & 2 & 4 \end{array}\right)$$

R2 + 3 R1 → R2 (multiply 1 row by 3 and add it to 2 row):

$$\left(\begin{array}{cc|c} 1 & -\frac{4}{3} & -\frac{20}{3} \\ 0 & -2 & -16 \end{array}\right)$$

R2 / -2 → R2 (divide the 2 row by -2):

$$\left(\begin{array}{cc|c} 1 & -\frac{4}{3} & -\frac{20}{3} \\ 0 & 1 & 8 \end{array}\right)$$

R1 + $\frac{4}{3}$ R2 → R1 (multiply 2 row by $\frac{4}{3}$ and add it to 1 row):

$$\left(\begin{array}{cc|c} 1 & 0 & 4 \\ 0 & 1 & 8 \end{array}\right)$$

The answer is:

$$\begin{cases} x_1 = 4 \\ x_2 = 8 \end{cases}$$

Now is the second way to solve the problem given by Cramer's rule.
A system of equations is given:

$$\begin{cases} 4(y - 5) = 3x \\ 2(y - 2) = 3x \end{cases}$$

Let us reduce the system of equations to the canonical form:

$$\begin{cases} -3x_1 + 4x_2 = 20 \\ -3x_1 + 2x_2 = 4 \end{cases}$$

Using the formula to calculate the determinant of matrix $\begin{vmatrix} -3 & 4 \\ -3 & 2 \end{vmatrix}$ we obtain:

$$\Delta = \begin{vmatrix} -3 & 4 \\ -3 & 2 \end{vmatrix} = (-3) \cdot 2 - (-3) \cdot 4 = -6 + 12 = 6$$

Using the formula to calculate the determinant of matrix$\begin{vmatrix} 20 & 4 \\ 4 & 2 \end{vmatrix}$ we obtain:

$$\Delta_1 = \begin{vmatrix} 20 & 4 \\ 4 & 2 \end{vmatrix} = 20 \cdot 2 - 4 \cdot 4 = 40 - 16 = 24$$

Using the formula to calculate the determinant of matrix $\begin{vmatrix} -3 & 20 \\ -3 & 4 \end{vmatrix}$ we obtain:

$$\Delta_2 = \begin{vmatrix} -3 & 20 \\ -3 & 4 \end{vmatrix} = (-3) \cdot 4 - (-3) \cdot 20 = -12 + 60 = 48$$

The answer for the second solution is:

$$x_1 = \frac{\Delta_1}{\Delta} = \frac{24}{6} = 4$$

$$x_2 = \frac{\Delta_2}{\Delta} = \frac{48}{6} = 8$$

or x=4, y=8.

Both answers from first and second ways of solution are correct and could be submitted in the window of submission.

3^d and 4th steps

After running the program in Figure 2 the submission of answer is needed as follows in Figure 3, where could be chosen the right answer (4,8).

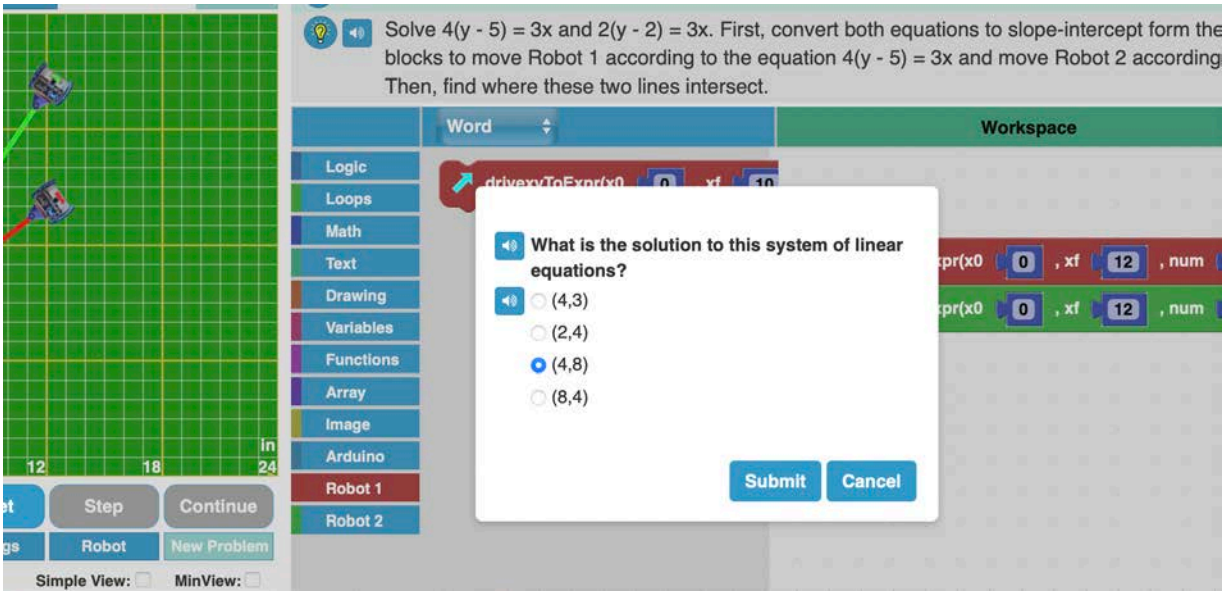

Figure 3 - Answer submission

A set of 13 survey items was analyzed from the Google Forms survey and classified into four dimensions: engagement, design, programming and overall result (Table 2).

Table 2 - Summary of user experience dimensions that are relevant to activities involving robotics

Dimension	*Survey item*	*N=50*		*Percentage (%)*	
		Positive	Negative	Positive	Negative
Engagement	Immersion	30	20	60%	40%
	time seems to pass quickly	37	13	74%	26%
	the surroundings are not noticed	28	22	56%	44%
	fun experience	35	15	70%	30%
Design	Attractive	45	5	90%	10%
	Ergonomic	44	6	88%	12%
	User-friendly	40	10	80%	20%
Programming	Ability to code	44	6	88%	12%
Overall result	General assessment	45	5	90%	10%
	Preference	35	15	70%	30%
	Would recommended to others	33	17	66%	34%

The survey was conducted among 50 participants and had four dimensions: engagement, design, programming, and overall result. For each survey item, there is a positive and negative rating. Based on the survey results engagement dimension's positive answers variates from 56% (the surroundings are not noticed) to 74% (times seems to pass quickly). The design dimension had overall results 80% and over for survey items such as attractiveness, ergonomic and user-friendly interface. Dimension of programming ability students felt confident since their answers gets positive 88%. The overall result dimension includes three survey items: general assessment made by

students (90%), preference (70%), and recommendation to others (66%). These survey items likely aimed to gather information about the participants' overall satisfaction and perception of the robotics activities they engaged in.

There have been several studies conducted on teaching math with robotics, and the results have generally been positive. Here are some examples of findings from studies on teaching math with robotics:

- Improved student engagement: One study found that using robotics to teach math led to increased engagement and interest in the subject among students. Students reported enjoying math more and feeling more motivated to learn.
- Higher math achievement: Another study found that students who learned math with robotics had higher achievement scores than students who learned math through traditional methods. The robotics group showed greater improvement in both basic math skills and more advanced concepts.
- Improved problem-solving skills: Teaching math with robotics has been shown to improve students' problem-solving skills, as they learn to program robots to perform tasks and solve problems.
- Increased spatial reasoning: Robotics-based math instruction has been shown to improve spatial reasoning skills, which are important for many math concepts.
- Positive attitudes towards technology: Using robotics to teach math has been found to promote positive attitudes towards technology among students. This can be important for future career opportunities in STEM fields.

Overall, the results of studies on teaching math with robotics suggest that it is a promising approach to improve student engagement, achievement, and problem-solving skills in math.

Conclusion

While there have been several studies on teaching math with robotics, there is limited research specifically on the effectiveness of using Roboblocky for teaching math. However, based on the available research, it can be concluded that teaching math with Roboblocky is a promising approach.

Studies on using robotics to teach math have shown that it can improve student engagement, achievement, problem-solving skills, and spatial reasoning. Additionally, the use of technology in the classroom can promote positive attitudes towards technology among students.

Roboblocky, with its block-based programming interface and focus on robotics, is well-suited to teaching math concepts in a hands-on and engaging way. Its visual programming language can help students understand abstract concepts and build problem-solving skills.

In conclusion, while more research is needed specifically on the use of Roboblocky for teaching math, the available evidence suggests that it is a promising approach to enhance student learning and engagement in math.

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ВИРТУАЛДЫ РОБОТТАР АРҚЫЛЫ СТУДЕНТТЕРГЕ МАТЕМАТИКАНЫ ОҚЫТУ

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Аңдатпа. Зерттеу "6В01501-Математика" білім беру бағдарламасы бойынша оқитын студенттерге (n=50) арналған математикаға бағытталған 20 сағаттық робототехника курсын әзірлеудің мысалын ұсынады. Зерттеудің мақсаты робототехниканың оқушылардың мотивациясына және робототехникалық шараларды қолдана отырып математиканы оқуға қатысуына әсерін зерттеу болды. Бұл әрекеттер алгебра ұғымдарын үйрену кезінде виртуалды роботтарды басқаруды қамтиды. Жалпы, роботтарды қолдана отырып жүргізілетін математика сабақтарының мақсаты математиканы оқытудың осы тәсілінің тиімділігін зерттеу

және технологияны қолдана отырып математикалық білім беруді жетілдіру жолдарын анықтау болып табылады. Зерттеу барысында робототехниканың әлемдік қолданылуы зерттеліп, тиісті әдебиеттерді жинау үшін академиялық мәліметтер базасына шолу жасалынды. Зерттеу үш ай бойы "Ілияс Жансүгіров атындағы Жетісу университеті" КЕАҚ (Талдықорған) базасында жүргізілді, оның барысында "робототехника көмегімен Математиканы зерттеу" оқу бағдарламасы әзірленіп, сынақтан өткізілді. Roboblocky.com сайтымен студенттермен орындалған сабақтар мысалдары берілген мақалада көрсетілді. Roboblockly-студенттерге математикалық және ғылыми тұжырымдамаларды оқытуды жеңілдету үшін робототехника мен бағдарламалауды біріктіретін білім беру платформасы болып саналады. Платформа бағдарламалауға блоктық тәсілді қолданады, бұл оқушылардың осы ұғымдарға қол жетімділігі мен түсінігін арттырады. Қолда бар зерттеулерге сүйене отырып, roboblocky көмегімен математиканы оқыту болашақтағы тәсіл деп қорытынды жасауға болады. Математиканы оқыту үшін робототехниканы қолдану бойынша зерттеулер оның студенттердің белсенділігін, оқу үлгерімін, проблемаларды шешу дағдыларын және кеңістіктік ойлауды жақсарта алатынын көрсетті. Сонымен қатар, мақалада виртуалды роботтарды қолдану студенттердің оқуға деген оң көзқарасын қалыптастыруға ықпал ететіндігі жайлы айтылған.

Тірек сөздер: математика, робототехника, roboblocky, виртуалды роботтар, блок арқылы программалау, STEM-білім беру, білім беру платформасы, студенттердің қатысуы, проблемаларды шешу дағдылары

ПРИМЕНЕНИЕ ВИРТУАЛЬНЫХ РОБОТОВ ПРИ ОБУЧЕНИИ МАТЕМАТИКЕ СТУДЕНТОВ

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Аннотация. В исследовании представлен пример разработки математико-ориентированного 20-часового курса робототехники для студентов (n=50) с образовательной программы "6B01501 - Математика". Цель исследования - изучить влияние робототехники на мотивацию и вовлеченность студентов при изучении математики с помощью робототехнических занятий. Эти занятия включают в себя управление виртуальными роботами во время изучения концепций алгебры. В целом, цель изучения математики с помощью роботов - исследовать эффективность такого подхода к преподаванию математики и определить пути улучшения математического образования с помощью технологий. В ходе исследования было изучено применение робототехники в мире и провели обзор академических баз данных для сбора соответствующей литературы. Результаты исследования показали, что в научной литературе недостаточно знаний по данному предмету. Исследование проводилось в течение трех месяцев на базе НАО "Жетысуский университет имени Ильяса Жансугурова" (г. Талдыкорган), в течение которых была разработана и апробирована учебная программа "Обучение математике с помощью робототехники". Примеры уроков на сайте roboblocky.com, выполненных студентами, представленными в данной статье. Roboblocky - это образовательная платформа, объединяющая робототехнику и программирование для

облегчения обучения школьников математическим и научным концепциям. В платформе используется блочный подход к программированию, что повышает доступность и понимание этих понятий студентами. На основании имеющихся исследований можно сделать вывод, что обучение математике с помощью Roboblocky является перспективным подходом. Исследования по использованию робототехники в преподавании математики показали, что она может повысить вовлеченность учащихся, их успеваемость, навыки решения задач и пространственное мышление. Кроме того, использование виртуальных роботов в аудитории может способствовать формированию у студентов позитивного отношения к обучению.

Ключевые слова: математика, робототехника, roboblocky, виртуальные роботы, блочное программирование, STEM-образование, образовательная платформа, вовлеченность студентов, навыки решения задач

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