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# STEAM's approach to physics: The impact of using LEGO robotics elements on academic achievement in laboratory classes

Kazhymukan Kelesbayev[1], Sherzod Ramankulov[2], Makpal Nurizinova[3*], Bakytzhan Kurbanbekov[4], Amin Pattayev[5]

[1,2,4,5]*Khoja Akhmet Yassawi International Kazakh-Turkish University, Turkestan, Kazakhstan.*
[3]*Sarsen Amanzholov East Kazakhstan University, Ust-Kamenogorsk, Kazakhstan.*

Corresponding author: Makpal Nurizinova (*Email: makpal.nurizinova@gmail.com*)

## Abstract

Using robotics elements in physics laboratory classes is a method to implement the STEM (science, technology, engineering, and mathematics) approach. This study aims to identify the prerequisites and features of using the LEGO EV3 set (LEGO Mindstorms series from the robotics designer) in laboratory classes in teaching physics. Methods of system analysis using keywords and constructivist research methods were used for articles published in high-ranking journals during the study. A pedagogical study was also conducted in physics laboratories to assess the effectiveness of LEGO robotics elements in the implementation of interdisciplinary STEM projects. The pedagogical study involved 167 students (85 students in the control group and 82 students in the experimental group). During laboratory classes, students in the experimental group were taught using the LEGO EV3 set which allows them to create simple and complex mechanisms using a programming language. A written control work was used which was evaluated on a 10-point system as a means of collecting data. The effectiveness of LEGO robotics elements was assessed using a differential analysis of pre-and post-training scores based on the t-test. Scores after the educational process were in the experimental group ($x = 7.6$) while scores before were in the experimental group ($X = 5.004$). The results of the study showed that the use of LEGO robotics elements in STEM-based laboratory classes has a positive effect on the development of educational achievements.

**Keywords:** Elements of robotics, Interdisciplinary continuity, LEGO, Physics learning, STEM education, STEM project learning.

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## 1. Introduction

STEM education is critical to success in the realm of technology [1]. The modern world is rapidly changing as a result of scientific development and technological innovations. Education is critical in preparing the next generation of professionals capable of solving difficult problems and contributing to societal development in this dynamic environment where discoveries and ideas occur at unprecedented speed. STEM education (science, technology, engineering, and mathematics) is especially important in this context serving as a potent instrument for developing the abilities required for effective work in quickly changing environments. STEM education which includes natural sciences, technology, engineering, and mathematics helps students build essential abilities that are increasingly in demand in the modern labor market [2].

Future physics teachers play a critical role in the advancement of natural science and technology. It is essential for them to contribute to the development of competitive experts in their professional activities.

As a result, it is vital to establish conditions for future physics teachers to compete in the sphere of science and technology on a global scale by identifying and incorporating innovative technologies for mastering professional abilities into education. STEM education is one of the most advanced technologies, enabling future physics teachers to develop into persons capable of meeting the demands of the labor market, business and high-tech sectors.

STEM education (science, technology, engineering, and mathematics) is becoming an urgent problem in light of the world's rapid technological progress. The major objective of the STEM method is the main notion of the STEM approach which is still applicable today uniting disciplines such as natural science, technology and engineering in the context of student skill development. In this sense, the incorporation of robotics aspects into laboratory lessons is a relatively new strategy. The incorporation of robotics aspects into classrooms serves as an auxiliary tool for students to comprehend educational information. Similarly, this teaching method contributes to the development of practical skills.

The technology revolution provides new options for education. Today, robotics is one of the most advanced systems used in educational institutions. López-Belmonte et al. [3] previously conducted an examination of the stages of evolution of the term "robotics" in the field of education. The popularity of the LEGO robotics set can be attributed to its efficiency in incorporating robotics concepts into the instructional process. According to research, LEGO robotics improves students' comprehension of scientific and technical concepts, develops practical skills and boosts motivation. LEGO robots inspire students to experiment and apply theoretical information which promotes effective learning [3].

The importance of using LEGO robotic elements through the STEAM method in teaching physics is closely related to several key aspects in the educational process. The subject of physics can be complex and confusing for many students because this science is often based on abstract concepts. Students have the opportunity to see the laws and principles of physics through real experiments using LEGO robotic elements. This makes it easier to understand abstractions in the context of real-life applications, thereby increasing students ' interest in the subject. The use of LEGO robotics in physics lessons attracts students to the field of science and technology. In the future, the likelihood of choosing a profession in these areas increases. Since robotics and programming are the main components of modern scientific and technological achievements. An early interest in these areas opens the way for a successful future career for students.

## 2. Literature Review

Muchtar and Ding [4] analyze STEM education development as the primary route for altering curriculum, the forms that STEM education takes in different nations and the factors that influence international interest in STEM education. A crucial element that generates worries about STEM in schools is the potential of a rapidly changing world into which modern children will enter as well as the necessity to incorporate STEM competencies that educate students for a developed future [4].

According to Tomková's [5] research, STEM sees the approach as a successful teaching strategy that allows for the usage of interdisciplinary linkages. In recent years, this issue has been addressed in the educational field. STEM education has a unique role in the development of students' creative and technical thinking skills. Students' knowledge and skills in problem solving gained through STEM education are reinforced by experiments targeted at investigating the qualities of the materials with which they work.

Improving students' ability to incorporate multidisciplinary knowledge into problem solving is a significant and difficult global issue. As a result, STEM education (science, technology, engineering, and mathematics) is receiving special focus at all levels of school. Furthermore, the incorporation of robots contributes significantly to the advancement of STEM education [6].

Robotics is the design, modeling and use of robotic devices to perform previously human-made activities. In industries such as automotive, mining and aviation, robots are used to execute simple, uniformly repetitive operations. The application of robotics elements grows every year [7]. Robotics science is a discipline of science that plays a unique role in the development of autonomous technological systems. Robotics requires the usage of a wide range of technological devices [8].

LEGO education which combines a modular programming language and a modular assembly platform empowers students of all ages to actively participate in the learning process. Students can make a wide range of creations including robotic creatures and systems while playing the game. This allows each student to generate unique solutions for a single task resulting in a vibrant learning environment [9]. According to Damaševičius et al. [10] the education system should prioritize skill acquisition to align with globalization and sustainable development goals. Robotic learning can be used to engage students in STEM-related disciplines. Scientists will highlight the results of employing the quicker pedagogical platform to foster creativity in the classroom through group, project-based learning and educational robotics.

It is clear from the literature reviews that the assessment of students' achievements in physics is often based only on test results but it is often overlooked how working with robotics can develop students' engineering thinking, programming skills and teamwork achievements. Furthermore, ways to combine robotics with various pedagogical methods are not sufficiently considered in the teaching of physics. There is not enough full-fledged research on how LEGO robotics interacts with traditional teaching methods or other groundbreaking methods.

There are few investigations on specific physics topics to analyze their efficacy and pedagogical methodological aspects although the scientific literature has general methodological suggestions for the use of robotics elements in physics classes. Therefore, this work considers the following answers to such research questions as:

- What is the potential of LEGO robotics elements in explaining physical phenomena and laws?
- What is the effectiveness of the LEGO EV3 set in increasing academic achievement?
- What is the importance of using LEGO EV3 sets in mastering the subject when students perform interdisciplinary STEM projects?

The study examines the impact of using LEGO robotic elements on students ' success in physics lessons. We have developed the following research hypotheses in accordance with the research questions:

*$H_0$: The use of LEGO robotic elements does not affect the success of students in physics.*

*$H_1$: The use of LEGO robotic elements has a positive effect on students' progress in physics.*

## 3. Research Methodology

*3.1. Research Design*

This study uses a quasi-experimental design as participants will be assigned to groups based on study groups without complete randomization. The study aims to assess the impact of LEGO robotics on students' academic achievements in physics laboratory classes. The study will be conducted over one academic semester (15 weeks) during which students will participate in laboratory work using both traditional methods (control group) and LEGO robotics (experimental group).

*3.2. The Research Population*

Two universities in Kazakhstan (Akhmet Yassawi University and S. Amanzholov East Kazakhstan University) used LEGO EV3 robotics parts in their instructional processes. Pedagogical research was conducted while teaching the subject "Introduction to Academic Writing." The pedagogical study included 167 students from two courses (aged 17-19 years) in physics education programs. A random selection procedure was used to create the control and experimental groups. However, classes in the control group were structured traditionally in the experimental group. Some subjects were taught using LEGO EV3 elements in STEM projects.

*Inclusion Criteria:* First- and second-year students who study physics as part of the curriculum and have basic computer skills.

*Exclusion Criteria:* Students who have previously participated in robotics courses or have experience working with LEGO robotics outside the context of laboratory classes.

*3.3. Research Instrument, Validity and Reliability Tests*

The control work questions before and after teaching the discipline "Introduction to Academic Writing" were based on a similar level assessment using a 10-point system.

The use of the method of mathematical-statistical analysis requires some calculations. The arithmetic mean and standard deviation are the main parameters for the calculation of the t-test. The calculation of the arithmetic mean value is shown in equation 1.

$$\hat{X} = \frac{1}{n}\sum_{i=1}^{n} X_i \qquad (1)$$

Where

$\hat{X}$ is the arithmetic mean. $X_i$ is each element in the data set.

n is the number of elements (number of samples).

The next step is to determine the standard deviation. A parameter that shows how many times the results deviate from the standard deviation mean. The determination of the standard deviation is carried out according to equation 2.

$$S^2 = \frac{1}{n-1}\sum_{i=1}^{n}(X_i - \hat{X})^2 \qquad (2)$$

Where

$S$ is the standard deviation of the sample.

$X_i$ is each element in the sample.

$\hat{X}$ is sample mean.

n is the number of elements in the sample.

The result of determining two parameters allows determining the t-test. The t-test determination equation 3 is shown in the expression.

$$t = \frac{\widehat{X_1} - \widehat{X_2}}{\sqrt{\frac{{S_1}^2}{n_1} + \frac{{S_2}^2}{n_2}}} \qquad (3)$$

Where

$\widehat{X_1} - \widehat{X_2}$ are averages of the first and second groups.

$n_1$ and $n_2$ is the size of the samples of the first and second groups.
$S_1$ - $S_2$ is the standard deviation of the samples of the first and second groups.
In the calculation of the value of P, the value of the t-test and the degree of freedom (df) are used. As a result, the statistical significance of the difference between the two groups is determined.

Cohen's d is a statistical indicator for measuring the amount of exposure that shows the difference between the average values of the two groups in a standardized way. It is especially used to assess the practical significance of differences between groups.

$$d = \frac{\bar{X}_1 - \bar{X}_2}{S}$$

$$S = \sqrt{\frac{(n_1-1)S_1^2+(n_2-1)S_2^2}{n_1+n_2-2}} \quad (4)$$

Where
$S_1$ - $S_2$ is the standard deviation of the samples of the first and second groups.
$n_1$ and $n_2$ is the size of the samples of the first and second groups .

Students of the experimental group using LEGO robotics are expected to show higher academic achievements in physics compared to the control group. It is also assumed that the students of the experimental group will demonstrate greater involvement and interest in the subject as well as a deeper understanding of physical principles through the practical application of knowledge.

## 4. Research Results

The STEM method is the primary focus of global educational scholars. Previous research has shown that robots play an important role in teaching. There are relatively few works on the use of robotics aspects in physics education despite the amount of research in this field.

It is clear that parts of modern robotics such as educational robotics (ER) are fast developing in scientific educational institutions and research facilities. Educational organizations and teachers see learning as the primary form of activity, combining the STEM approach with robotics aspects. Researchers contend in their study that present educational curriculum do not provide adequate assistance to teachers and students. As a result, the development of instructional robotics is being hindered [11].

The scientific documentation for the study included a full investigation of the theoretical elements of using components such as LEGO robots in instructional activities (see Table 1).

**Table 1.**
Results of analysis of works in the Scopus and web of science database.

| Work | Title authors | Year, brief description and feature |
|---|---|---|
| Bringing robotics into classrooms | Eguchi [12] | Description of the various uses of educational robotics including LEGO for teaching STEM subjects [12]. |
| Educational robotics as learning tools within the teaching and learning practice | Eteokleous and Ktoridou [13] | Studying the impact of robotics on learning, successful experiments and examples of the use of LEGO for educational purposes [13]. |
| Teaching Newtonian physics with LEGO EV3 robots: An integrated STEM approach | Addido, et al. [14] | Considering the use of LEGO sets for teaching physics, including examples of laboratory tasks and projects [14]. |
| The effectiveness of integrating educational robotic activities into higher education computer science curricula: A case study in a developing country | Gyebi, et al. [15] | A case study on the integration of robotics into physics lessons showing the methods and results of using LEGO [15]. |
| Robotics as an educational tool: Impact of LEGO mindstorms | Afari and Khine [16] | Analysis of the impact of LEGO robotics on students' understanding of physical concepts, data on student motivation and skill enhancement [16]. |

Several skills are developed during laboratory work with LEGO robotics pieces for teaching physics. LEGO robotics provides some instructional objectives such as consolidating theoretical material obtained during laboratory lessons and developing subject concepts. Various benefits of using LEGO robotics elements in the instructional process were identified following the research review. Table 2 shows the benefits of using LEGO robotics parts in physics training.

**Table 2.**
Benefits of LEGO robotics elements in physics teaching.

| Types of training | Advantages of using LEGO |
|---|---|
| Technical skills | Working with LEGO elements helps students develop skills in designing and assembling mechanisms. They learn to understand how different components work and how they interact. Programs that use LEGO educational sets such as LEGO MINDSTORMS EV3 or SPIKE Prime and contribute to learning the basics of programming. These programs help students improve logical thinking. |
| Interdisciplinary communication | Integration of Knowledge LEGO EV3: Interdisciplinary communication is developed by incorporating robotics aspects into laboratory activity. Designing LEGO EV3 elements in the process of using them in laboratory work in physics lessons develops engineering skills, writing programming code covers the field of computer science, measuring and processing data obtained as a result of work requires mathematical knowledge. |
| Group work | They practice mutual discussion while completing laboratory work in groups of three or four students, expressing their own thoughts and perspectives. Communication abilities are developed. |
| Interest | The incorporation of robotics aspects into the educational process improves students' desire to learn new things. LEGO EV3 students will learn to integrate physical rules with life in an entertaining manner while using this set. |
| Critical thinking | Students determine the tasks set in the course of laboratory work and also provide an opportunity to set a scientific problem. The initial elements of critical thinking arise when performing laboratory work. |

A review of the scientific literature revealed that examples of the usage of LEGO robotics parts in physics classes had not been thoroughly investigated. In laboratory classes for the discipline "Introduction to Academic Writing", we have created options for using LEGO robotics parts in various topics.

For example, a methodological manual for laboratory work has been prepared on the topic "SunCar 1.0 and study of the principle of operation of a vehicle receiving a charge from solar energy using LEGO robotics pieces".

The laboratory work "SunCar 1.0" uses LEGO robotics to explore the functioning of a vehicle powered by solar energy. The project encompasses scientific, technological, engineering and mathematical issues. During this level, students blend theoretical knowledge with practical experience. Solar energy and robotics research is approached from an integrated perspective.

Classes are based on the theme "solar energy" and involve the usage of a robotic gadget, the Lego EV3. Participants will have the opportunity to design and program the Lego EV3 robot as well as learn how to operate it using various mobile devices. This method will allow students to have a greater understanding of the physical principles involved in the use of solar energy as well as becoming acquainted with the practical aspects of robotics. They use the LEGO EV3 device to build their technical skills, study modeling and program, all of which lead to a greater understanding of the issue. Students make the learning process more dynamic and exciting, increasing their understanding and active engagement in the assimilation of the content being studied by applying theoretical information to actual issues.

*Laboratory Work: The SunCar 1.0 study of the principle of operation of a vehicle receives a charge from solar energy.*

Solar panels (see Figure 1) convert solar energy into electricity which is an important and useful process. The abundance of sunlight makes them an excellent source of light and energy. You should be careful when using incandescent lamps as they generate a lot of heat. Therefore, it is recommended to use it only for a short time. If incandescent lamps have been running for a long time, they may fail. In addition, the lamps should be placed at a certain distance ($l \geq 8$ cm) from the solar battery to avoid overheating. If the temperature of the plate increases sharply, you should try placing it in a remote place. We recommend not using energy-saving lamps in this laboratory work. The reason for this is that energy-saving lamps cannot provide parameters that can be used in laboratory work. Energy-saving lamps emit infrared radiation exceeding $\lambda =$800 nm.

**Figure 1.**
Solar panel in Lego EV3.

*4.1. Necessary Equipment*

The solar panel consists of a solar battery and a diode. In the course of laboratory work, solar-powered batteries with a voltage of $U = 7$ V are used. Energy provides the necessary devices along the connecting wires.

*4.2. Technical Specifications*

The solar panel used in laboratory work provides a variety of working modes. You may regulate the amount of light that falls on the panel using a properly placed screw. This widens the scope of laboratory work.

The incandescent bulb plays a critical part in laboratory work, therefore, many types of operation must be considered. The physical properties of an incandescent lamp are as follows:

The sunlight that falls in the open is 6.5 V, 100 mA > 100 000 Lk.

The sunlight incident indoors is 6.5 V, 50 mA>50 000 Lk.

Incandescent lamp with power N=60 W from the solar panel l=0.025 M, U=5 V, 4 mA>2000 Lk.

Incandescent lamp with power N=60 W from the solar panel l=0.008 M, U=5 v, 20 mA>10 Lk.

*4.3. Security Measures*

1) Elements of the experimental installation should be used carefully.

2) It is necessary to calculate the distance at which the lamp will fall on the surface of the solar panel (($l \geq 8$ cm). In case of light attenuation, it is necessary to check the fixation of the lamps. If a malfunction is observed in the operation of the device, it is necessary to immediately disconnect it.

The purpose of the laboratory work is to study the principle of operation of the Suncar 1.0 vehicle receiving a charge from solar energy to determine the dependence of the vehicle on speed and acceleration by changing the structural components and to obtain a graphical representation of the results obtained using the "Vernier graphical analysis" program. Learning the basics of assembling and working with LEGO EV3 Robotech sets. The task "the influence of gear ratios on the speed of movement" requires students to study the speed of the SunCar 1.0 car on the experimental strip (see Figure 2) with different gears and the installation of two large rear wheels. Students consolidate their theoretical knowledge by making predictions and testing their predictions experimentally by completing this task.

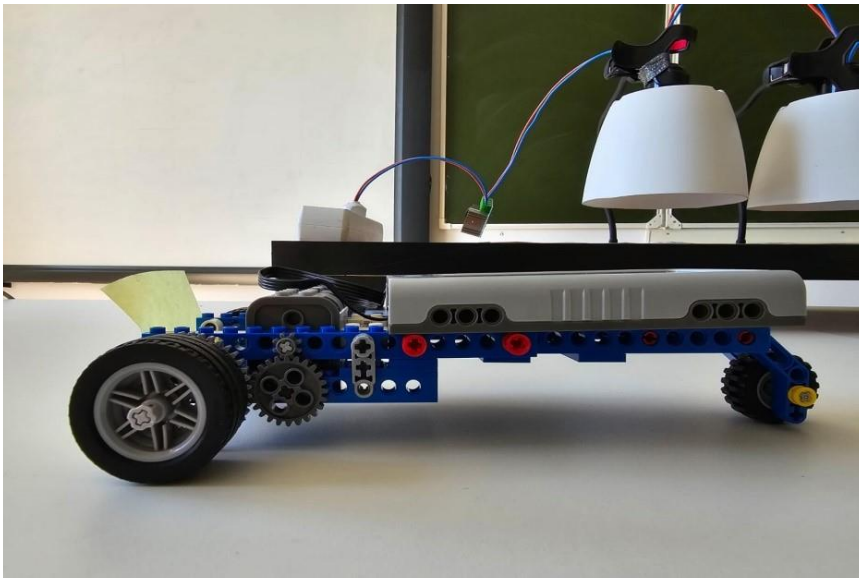


**Figure 2.**
The SunCar 1.0 solar energy charging vehicle.

The SunCar 1.0 is powered by $U = 9\ V$ electric motor with an internal gearbox. The option of using an electric motor as a generator is offered.

Structure of an electric motor:

- *Space on the Shaft.* The shaft plays a significant part in the installation. The camshaft rotates the vehicle's wheels to propel it forward.
- *Input and Output Pins.* The pin – electric motor transforms into gadgets that calculate the amount of energy generated by a solar panel.

If the idle speed is v=800 rp/m, the other parameters are as follows:

- Maximum torque: 4.5 n/cm.
- Motor with voltage $U = 9$ V.
- Gear ratio: 9.5 / 1.
- Length 20 cm-equal cable.

*4.4. Assembly*

1) The SunCar 1.0 builds a car that will charge from solar energy (see Figure 3).

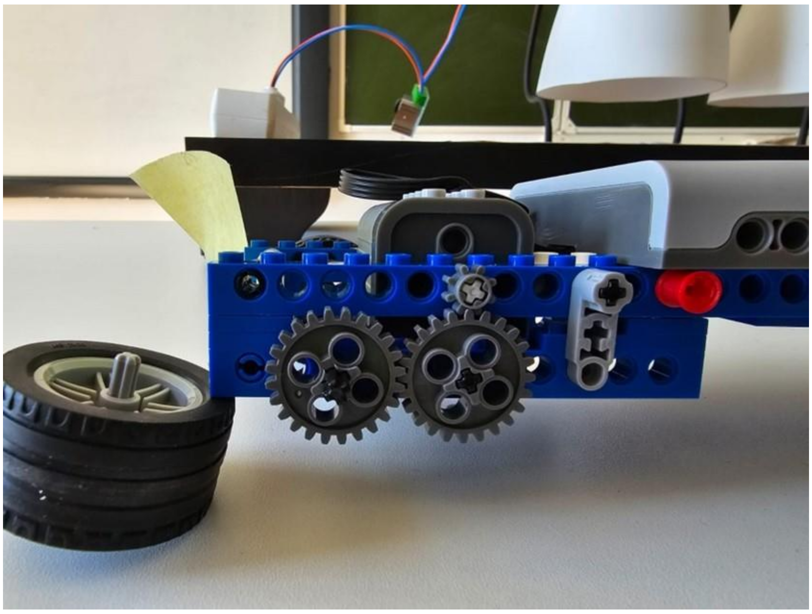


**Figure 3.**
Construction of the SunCar 1.0 vehicle.

2) After assembling the Suncar 1.0 solar energy charging vehicle, you can move on to the next step. Check the operation of the car for the absence of defects. If there is a need to reduce friction and increase speed during laboratory work, then loosen the bushing. Connect the plugs tightly.

*4.5. Test Installation*

1. Install the solar panels at a distance of $l \geq 8$ cm from the incandescent lamp equal to $U$ =60 W.
2. It is necessary to test the SunCar 1.0 vehicle for testing purposes before starting laboratory work. It is necessary to check the light of the lamps and change the height in cases where the car does not start moving or stops in some areas.
3. To control movement in the work area and enter the conditional designations "start" and "finish".
4. It is necessary to put the car at the "start" point and start moving. It is necessary to measure the time from the start to the end of the movement. We will need this in determining the speed (see Figure 4).

**Figure 4.**
Experimental installation.

After the students had observed how the experimental device worked. Their initial ideas about how the solar panel works begin to emerge. It is also acknowledged that brightness influences the speed of movement of the car. Table 3 shows that the rear wheels must be resized before being reassembled. It is required to repeat the laboratory work after replacing the rear wheels. Students should be asked to share their assumptions on how movement speed varies before proceeding with the activity. Forecasts are entered as shown in Table 4.

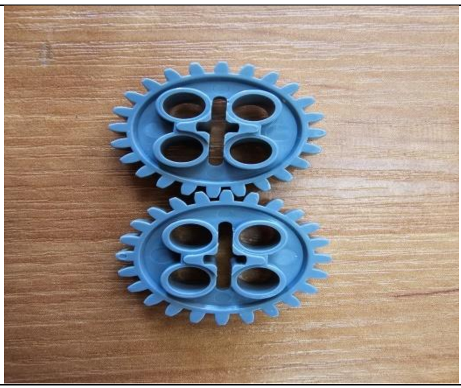
*4.6. Research*

1) To change the gear ratio of the SunCar 1.0 vehicle, you need to change different parameters. Change the ratio of the wheels to 5 by 1.

2) The speed at which a vehicle travels a distance of $S$ =100cm through a stopwatch is determined by the formula below. If necessary, repeat the experiment several times and get values (see Table 3).

Speed = (path traveled) / time

**Table 3.**
A form for entering laboratory results: A) the outcomes of the initial work?

| Elements of the experiment |  |  |
|---|---|---|
| Forecast | Seconds | Seconds |
| Research results | Seconds | Seconds |
| Calculation results | *m/s* | *m/s* |

*4.7. Replacing Wheel Settings*

1) To change the gear ratio of the SunCar 1.0 car, you must adjust several settings. Change the wheel ratio to three by one.

2) Re-measurements are performed in the same manner as in prior work with the distance changed (see Table 4).

**Table 4.**
A form for entering the results of laboratory work: the results of the first work?

| | | |
|---|---|---|
| Elements of the experiment |  |  |
| Forecast | Seconds | Seconds |
| Research results | Seconds | Seconds |
| Calculation results | m/s | m/s |

Students first make predictions in the course of laboratory work. Then, the time is determined using a stopwatch and the speed of travel is determined by putting the time and length of the track into the formula. After receiving the measurement results, the values are entered in Table 5 in the cell "Forecast". The next step is to use the Vernier product program "Vernier graphical analysis" to determine the parameters of any part of the movement. To do this, you need to follow the following steps.

1) Connect the "Vernier graphical analysis" program to your computer. You need to connect the Vernier movement recording device to a computer or mobile phone.

2) The motion sensor is then placed at the position where the vehicle begins to move. The Vernier motion recording sensor shows motion parameters on a computer screen (see Figure 5).

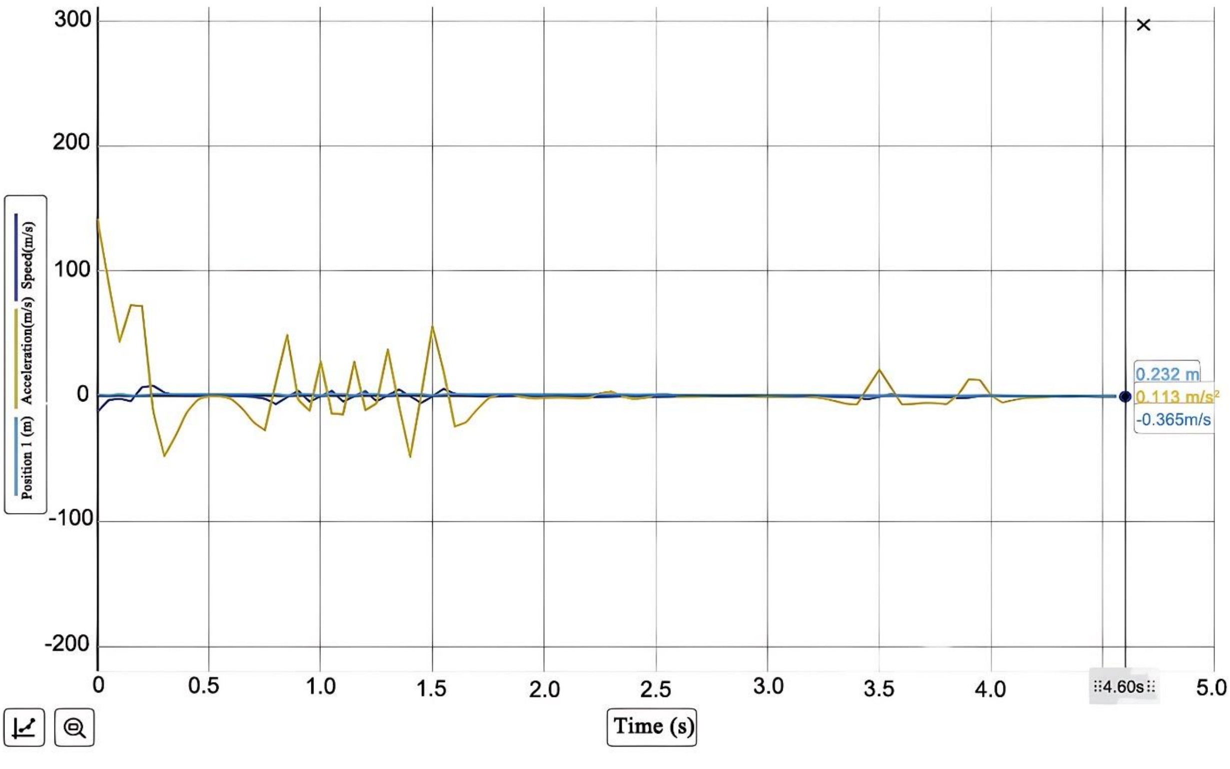



**Figure 5.**
The graphical interface of the Vernier graphical analysis program.

Carefully review and analyze the results of the study. Draw conclusions and write them down.

The following parameters affect the speed of movement:

a. **Gear ratio:** This is the ratio of the drive's teeth to its gears. The speed increases with a greater gear ratio. Nevertheless, the torque of the wheels is greatly reduced.

b. **Light Source Type:** Light intensity and properties such as brightness and luminance play an important role in the performance of solar panels. These factors directly affect the amount of energy emitted by solar panels which affects the speed and duration of operation of the electric motor.

c. **Wheels and their gear ratio:** The size of a vehicle's wheels affects its movement as discovered during laboratory study. For example, installing smaller wheels on your SunCar 1.0 can result in an improvement in speed.

*4.8. Analysis of Results*

1. It is necessary to compare the results obtained in the course of laboratory work in which case was the transport speed higher?
2. Answer control questions to determine the level of knowledge at the end of work.
3. Comparison of the obtained values (speed and acceleration) with the results obtained during the experiment using the "Vernier graphical analysis" software.

*4.9. Control Questions*

1) Did the predictions come true?
2) Explain the research results. What a pattern.
3) Is there a difference between the 3/1 and 5/1 gear ratio?

Their statistical significance was measured by calculating the t-test with the test results obtained from the study for the control and experimental groups. The difference between the two groups before the study is shown in Table 5.

**Table 5.**
Results of control work before the pedagogical study.

| Group (To) | n | X | Sd | df | T | P |
|---|---|---|---|---|---|---|
| CG | 85 | 5.1 | 2.1 | 165 | 0.2835 | 0.7769 |
| EG | 82 | 5.004 | 2.27 | | | |

**Note:** * n is the number of elements in the sample, X is the arithmetic mean value, Sd is the standard deviation, df is the degree of freedom, T is an independent t -test, the average difference is important at $p \leq 0.05$;

The results of the two pre-study groups: t (165) = 0.2835, P >.05. This indicates that there was no substantial difference between the students before the investigation.

The use of LEGO robotics parts for the experimental group in STEM-based laboratory classes helped to improve students' interest. It was discovered that there is a distinction between the control group which was trained using traditional methods and the experimental group which was trained using STEM learning. Table 6 shows the differences between students following the study.

**Table 6.**
Results of control work after pedagogical research.

| Group (After) | n | X | Sd | df | t | p |
|---|---|---|---|---|---|---|
| CG | 85 | 5.45 | 1.765 | 165 | 8.89 | 0.0001 |
| EG | 82 | 7.6 | 1.32 | | | |

The statistical significance of the test result on the level of students after the study was t (165) = 8.89. $p < 0.05$. It shows that there is enough evidence to reject the null hypothesis.

Cohen's d statistical indicator for measuring the amount of exposure that shows the difference between the average values of the two groups in a standardized form. While a value of d = 0.044 occurred before the study, a value of d= 1.375 after the study showed a high practical significance of the difference between the groups.

## 5. Discussion

Our previous work which tested interdisciplinary STEM projects through a pedagogical experiment [17, 18] allowed us to assess the research competencies of students. Our results from this study showed that the use of robotic LEGO elements in physics teaching has a positive effect on student academic performance. This conclusion is consistent with many previous studies. In addition, although the effectiveness of STEM practice among mathematics teachers was evaluated by pedagogical practice we focused on the effectiveness of multidisciplinary STEM projects in physics.

In a study, Chambers and Carbonaro [19] described the design, development and implementation of a course to train technology teachers based on LEGO robotics and discussed opportunities to enhance teachers' technological skills and innovate in the learning process [19]. This study examines the effectiveness of teaching physics in high school through the use of LEGO® MINDSTORMS® robots and shows that robotics can increase students ' interest and promote a deeper understanding of physics concepts [20].

A study by Stoppa and Carneiro [21] proposes the study of the Galileo plane using educational robotics and shows an effective way to explain the basic principles of physics to students through robotics [21].

A study by Alimisis and Boulougaris [22] analyzes that robotics contributes to the interpretation of the concepts of kinematics in physics lessons and the development of graphic abilities and shows that through the use of robots, students ' skills in displaying kinematic processes in the form of graphs are improved [22].

Based on the results, it was discovered that using LEGO robotics parts for the experimental group in STEM-based laboratory classes influences the growth of educational achievements. Finally, it should be mentioned that using of LEGO robotics parts for the experimental group in STEM-based laboratory sessions contributes significantly to students' interest in and mastery of the subject.

## 6. Conclusion

The usage of LEGO robot sets in laboratory physics classes is an effective way to achieve STEM educational objectives. This strategy improves learning outcomes, develops engineering and technological abilities, increases student enthusiasm and involvement and forms practical skills required in today's labor market. It is critical to continue to investigate and implement innovative teaching approaches to assist students in meeting future problems and possibilities in a rapidly changing world.

This study examined the operation of the "Suncar 1.0 solar energy charging vehicle fueled by solar energy and built of LEGO EV3 pieces. The laboratory work is distinguished by its ability to compare results with data gathered using the "Vernier graphical analysis" tool. This allows students to improve their prediction skills during laboratory classes. We also believe it is appropriate to incorporate motivating components into future study efforts to boost students' interest in the topics covered.

The study showed that the use of LEGO robotics using the STEAM method in physics lessons has a significant and positive impact on students' academic achievements. The students of the experimental group have made significant progress especially in understanding complex physical laws. By creating and programming LEGO robots, students were able to put physical concepts into practice which helped them connect their theoretical knowledge with real-world experience.

However, given the financial and technical limitations, the high cost of the necessary equipment for robotics and the need for special training for teachers can become an obstacle to the widespread use of this method in some educational institutions. The search for ways to solve this problem in the future will allow modernizing the education system and the widespread use of robotics.

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