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Impact of Low-Cost Robot EducThermoBot vs. EXAO on Students' Motivation and Learning in Physical Sciences in Morocco

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Abstract **– Teaching physical sciences presents a significant challenge in various countries, including Morocco, where student performance remains a subject of concern. This study aims to investigate the impact of introducing educational robotics as compared to computer-assisted experiments (EXAO) on students' motivation and learning in physical sciences. We divided a group of 120 middle-school students into two cohorts: one used the cost-effective educational robot, EducThermoBot, as an experimental group, while the other employed traditional EXAO as a control group. The findings demonstrate that the integration of educational robotics has a noteworthy and positive impact on students' motivation, whereas the overall academic performance exhibited no significant disparities between the two cohorts. Notwithstanding some limitations, this research offers valuable insights to enhance pedagogical practices by promoting the integration of educational robotics into the teaching of physical sciences in Morocco.**

Keywords **– Educational robot, physical sciences, student motivation, learning, EXAO.**

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1. Introduction

The teaching of physical sciences represents a significant challenge in many countries worldwide, with persistent concerns regarding student performance [1], [2], [3]. In a global investigation carried out by the International Association for the Assessment of Educational Achievement (IEA), Moroccan students were ranked among the five lowest-performing countries in the 2019 edition of the Trends in International Mathematics and Science Study (TIMSS), an assessment that evaluates students' proficiency in mathematics and science on a worldwide scale [4]. This situation is further echoed in national assessments, revealing that Moroccan students achieve mediocre scores in physical sciences across all educational levels [5], [6].

In Morocco, these challenges are further exacerbated by budgetary constraints that limit access to technological tools such as computer-assisted experiments (EXAO) in the teaching of physical sciences [7]. These constraints impact students' motivation and active engagement in the educational journey [8]. Consequently, it is of paramount importance to explore more affordable and effective alternative solutions to stimulate the interest and motivation of Moroccan students in physical sciences.

In order to elevate the educational standards in Morocco, the Strategic Vision for Educational Reform (2015-2030) was adopted in 2015, encouraging pedagogical innovations and the incorporation of information and communication technologies (ICT) in schools [9]. As part of this initiative, the educational robot (ER) has emerged as a modern and reliable ICT resource that can be effectively integrated into the teaching and learning of scientific concepts. Indeed, the ER plays a significant role in teaching scientific concepts across various disciplines, such as thermodynamics [10], mathematics [11], chemistry [12], programming [13], [14], industry [15], [16], and even language learning [17].

Moreover, leveraging educational robotics can significantly contribute to the advancement of skills related to the scientific process, such as evaluating possible solutions, formulating hypotheses, conducting systematic experiments, and controlling variables [18]. Numerous studies have also demonstrated that the integration of ER can amplify students' curiosity and active participation in STEM subjects [19]. As a powerful ICT tool, the ER fosters dynamic, enjoyable, and hands-on engagement of students in practical activities [20], [21]. Thus, the ER can serve as a powerful catalyst for student engagement in various learning activities [22], [23]. Despite its significance in education, the integration of ER into the Moroccan educational system remains absent.

In light of this, the current investigation seeks to explore the potential of the ER as a promising alternative to EXAO tools in Moroccan schools. By comparing the ER with EXAO, we aim to assess its financial accessibility while examining its impact on students' motivation and performance in physical sciences. The following research questions serve as the study's main focus:

- **RQ1:** What is the effect of integrating the affordable educational robot EducThermoBot compared to EXAO on students' motivation in physical sciences?
- **RQ2:** What is the impact of integrating the affordable educational robot EducThermoBot compared to EXAO on students' learning in physical sciences?

These research questions lead to the following hypotheses:

H0-1: There was no statistically significant difference in students' motivation for physical sciences between the experimental group utilizing the affordable educational robot EducThermoBot and the control group employing EXAO.

H0-2: When comparing the experimental group using the affordable educational robot EducThermoBot to the control group using EXAO, no noticeable distinction in the physical science learning of the students.

To address the research questions, we have adopted a comparative approach by assigning students to control and experimental groups. The students in the experimental group will use ER materials, while those in the control group will have access to EXAO materials. Data will be collected through knowledge tests and student satisfaction questionnaires. To analyze this data, we will employ the independent samples t-test, a suitable statistical method for a comprehensive comparison of students' performance and motivation in both groups.

The results of this investigation may have significant implications for improving the teaching of physical sciences in Morocco and overcoming budget constraints while fostering students' interest and motivation. Additionally, this research will contribute to the existing literature on the integration of ICT in the teaching of physical sciences. By providing valuable insights into the effectiveness of the educational robot compared to EXAO, this study could inform policymakers, educators, and teachers about best practices in utilizing educational technologies in the Moroccan context.

The subsequent sections of this paper are structured as follows: firstly, in Section 2, we will present a detailed description of the proposed educational robot. Next, we will delve into the methodology implemented in Section 3. The obtained results will be presented in Section 4, while the discussion of these findings will be explored in Section 5. In conclusion, the final section (Section 6) will provide the conclusions and offer insights into future prospects.

2. Descriptions of the proposed EducThermoBot

In this section, we delve into the detailed description of the proposed EducThermoBot, covering its prototype design and the fundamental components that constitute the 'EducThermoBot' system.

2.1. Prototype Design

The EducThermoBot [10] is an innovative ER that facilitates the learning of physical science concepts for middle school students. It allows students to assemble and program the robot. Figure 1 presents the comprehensive design of the EducThermoBot, consisting of four essential units, detailed as follows:

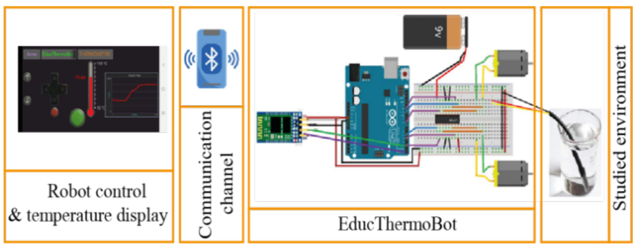


Figure 1. The overall design of the proposed EducThermoBot

- The environmental unit of the EducThermoBot allows for the observation and analysis of temperature variations in a given environment. With its integrated sensors, the robot can collect precise data on ambient temperature and display them in real-time.

- The central unit of the EducThermoBot brings together all the necessary hardware and software components for the robot's operation. It ensures the coordination of various functionalities and enables smooth and efficient use during the study of temperature and other physical concepts.

- The communication channel unit of the EducThermoBot utilizes Bluetooth technology to establish a wireless connection between the robot and the user. This feature offers freedom of movement during experiments and enables students to explore temperature and other physical aspects in different contexts.

- Finally, a user-friendly graphical interface (Figure 2) integrates the robot control unit and the temperature display unit. Students can thereby control the movements of the EducThermoBot and visualize real-time temperature measurements.

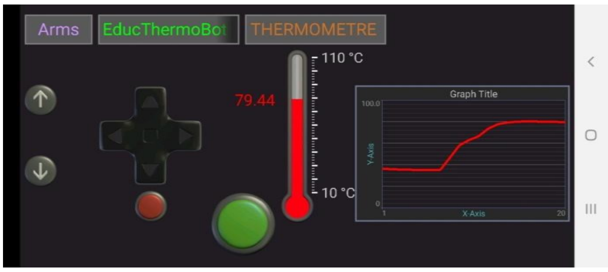


Figure 2. User interface of the Android application to control "EducThermoBot"

Although EducThermoBot can be used to study various physical concepts, yet our focus is on temperature. We believe that understanding this fundamental concept is crucial for students and provides a solid foundation for their future learning in scientific fields.

2.2. Basic Components of "EducThermoBot"

To understand the operation and capabilities of "EducThermoBot" (Figure 3), it is essential to know its basic components. Table 1 provides an overview of the main components used in the design of "EducThermoBot," along with their names, functions, and prices.

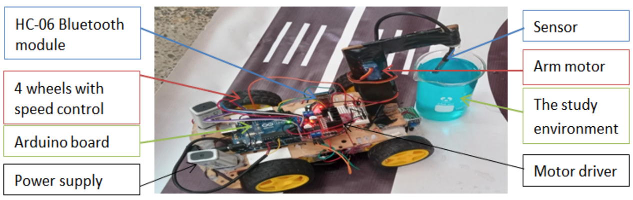
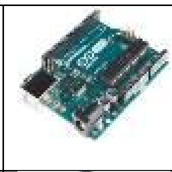
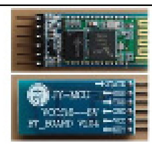
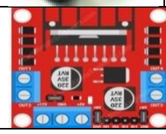


Figure 3. Prototype of the proposed "EducThermoBot"

Table 1. Basic components of "EducThermoBot"

Component		Role	Price ($)
ARDUINO UNO R3 board		Robot control unit	4.8
Digital temperature sensor with ds18b20 probe		Temperature sensor	1.2
Module Bluetooth HC-06		Wireless communicatio n module	1.66
4 DC motors		Robot propulsion and movement	1.6×4 = 6.4
Servomotor		Controls the movement of the arm carrying the temperature sensor	1.95
4 wheels		Robot motion support	2.00
L298N motor driver module		DC motor control	1.99

The robot was designed in a way that students can build it using low-cost components. The total cost to assemble the robot is estimated to be only 20 USD. This approach allows students to gain a thorough understanding of the components and construction of the robot while providing them with a practical and affordable experience in learning physical sciences.

3. Methodology

In this section, we delineate our research methodology encompassing various critical elements. We begin by providing an overview of the study participants, followed by a detailed exposition of the study procedure. Subsequently, we present the teaching scenario employed in our research, elucidate the research instrument utilized, discuss our approach to data analysis, and conclude with a brief outline of the ethical considerations that underscore our research framework.

3.1. Study Participants

Participants in this research project comprised 120 middle-school students who volunteered to take part, and their distribution is outlined in Table 2.

Table 2. Distribution of the study population according to groups and gender

Group	Total	Boys	Girls	% of boys	% of girls
Experimental group with EducThermoBot	60	26	34	43.3%	56.7%
Control Group with EXAO	60	28	32	46.7%	53.3%

Although the students followed the same physics learning program throughout the current academic year, we deemed it essential to control their initial learning level between the two groups. To achieve this, we used the performance index from the last completed physics stage by the students as a measure of their initial learning. Subsequently, we carried out an independent samples t-test to evaluate the initial performance in physics between the experimental group (M = 11.23 ; S.D = 4.704) and the control group (M = 11.78 ; S.D = 4.187). The results of the test indicate that initially, there is no statistically significant distinction between the two groups (T(118)=-0.645, P=0.897> 0.050).

The equitable distribution of gender and initial learning levels in both groups allows for a fair and unbiased comparison of the outcomes achieved through the utilization of EducThermoBot and EXAO.

3.2. Study Procedure

The middle-school students who took part in this research were selected from "Ibn Tofail," a public school located in Meknes, Morocco, during the academic year 2022-2023. The control group attended the temperature course using EXAO, whereas the experimental group engaged in the identical course with the integration of the proposed EducThermoBot.

The experimental procedure consisted of a two-hour practical session in which students from both groups conducted temperature measurement-related experiments. Following the session, the students underwent an evaluation test to gauge their knowledge acquisition and filled out a questionnaire employing a six-point Likert scale to gauge their motivational levels. Figure 4 provides an overview of the study procedure.

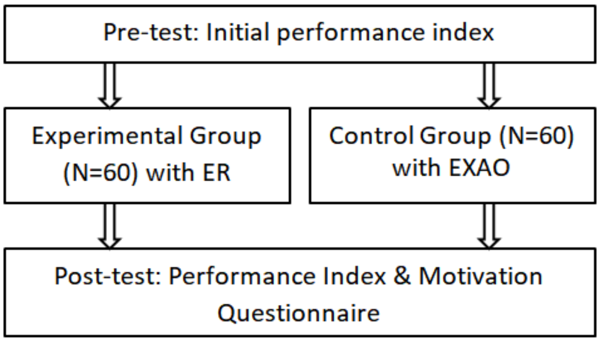


Figure 4. Study procedure

3.3. Teaching scenario

Educational scenario with EducThermoBot

In this scenario, students are responsible for directing the "EducThermoBot" to various environments to detect their temperatures (Figure 5).

Figure 5. Diagram illustrating the pedagogical scenario with the EducThermoBot

Once the EducThermoBot is positioned in a specific environment, the application's graphical interface prompts learners to establish the axes of the graph. This enables them to visualize real-time temperature variations in the studied environment. This step is crucial for observing and analyzing temperature changes over time.

Pedagogical scenario with EXAO

In the context of the pedagogical scenario based on EXAO, students are responsible for collecting temperature data in various environments using appropriate probes (Figure 6). These measurements are then displayed in real-time on the device's screen, allowing them to monitor temperature variations live.

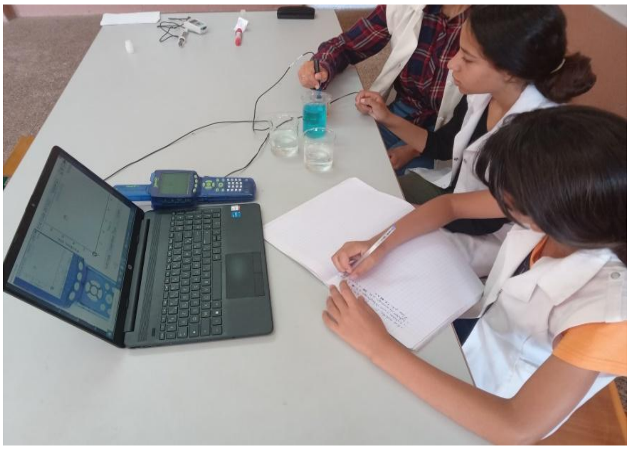


Figure 6. Diagram illustrating the pedagogical scenario with the EXAO

3.4. Research Instrument

To address the specific research objectives, two measurement instruments were used: a motivation questionnaire and a performance index derived from the evaluation test completed at the end of the practical work.

Motivation Questionnaire

Likert-scale questionnaires are widely recognized as an effective tool for assessing students' motivation [24]. Study [25] identified three major advantages of this method: the ease of constructing scales, direct evaluation by the respondent themselves, avoiding errors of judgment by an external observer, and the ability to obtain reliable measurements without requiring a large number of items. For these reasons, we chose to use a Likert-scale questionnaire to assess students' motivation.

In the context of our study, we designed a customized questionnaire to assess students' motivation. This questionnaire, inspired by the work of Rotgans and Schmidt [26] on motivation during collaborative learning, consists of 8 items rated on a Likert scale. The statements were adapted to specifically reflect our context, which involves physics practical work. Half of the statements are formulated positively, while the other half is formulated negatively. The complete questionnaire can be found in Appendix A.

Considering the significance of the motivation questionnaire in our research, we conducted an analysis to assess its reliability using Cronbach's alpha coefficient (α). This coefficient varies between 0 and 1, similar to the majority of other measures of internal consistency; the closer the value is to 1, the more reliable the instrument. We validated the questionnaire directly on the sample of 120 students divided into the two groups, as shown in Table 3.

We evaluated the internal consistency of the 8 items measuring motivation, which resulted in an excellent Cronbach-alpha-coefficient of 0.921. Since the high reliability of these 8 motivation items, we decided to include them into the results analysis, as illustrated in Table 4.

Table 3. Statistics on questionnaire reliability

Cronbach-Alpha	The quantity of items
0.921	8

Table 4. Statistics for each questionnaire item

Questions	The variance of the scale in case of deletion of an item	Alpha of Corrected Item-Total Correlation	Cronbah-Alpha with Item Deletion	Average Scale Score with Item Deletion
1	29.710	84.794	0.778	0.918
2	29.853	82.316	0.817	0.922
3	29.762	71.164	0.771	0.933
4	30.121	72.880	0.675	0.924
5	29.633	73.671	0.764	0.844
6	29.657	71.901	0.874	0.977
7	29.843	72.363	0.845	0.889
8	29.575	61.706	0.781	0.978

Student performance index for the physics experimental task

The students' performance index during the experimental task was determined based on the evaluation of a test devised by three teachers of physics (Appendix B). This test was administered at the conclusion of the session, with uniform marking criteria applied to all examination papers to ensure equitable assessment. Additionally, the same teacher graded all student responses to minimize variations in understanding. The test comprises 10 multiple-choice questions, designed to assess the students' knowledge. Prior to its implementation in the study, the test underwent a pilot phase involving 30 students to gauge its reliability, which was measured utilizing Cronbach-alpha and determined to be satisfactory (Cronbach's alpha = 0.82). Table 5 presents the objectives and cognitive levels corresponding to each question.

Table 5. Objectives and cognitive levels of the assessment test

Questions	Objective	Target cognitive level
1	Understanding the concept of temperature	Knowledge
2	Understanding the notion of change of state	Knowledge
3	Understanding of changes of state with temperature variation	Understanding
4	Application of knowledge of changes of state	Application
5	Understanding mixtures and changes of state	Understanding
6	Applying knowledge of mixtures and changes of state	Application
7	Analyzing and solving problems involving changes of state	Analysis and Application
8	Analysis of changes of state in everyday life	Analysis
9	Synthesis of knowledge on changes of state	Synthesis
10	Critical evaluation of change-of-state phenomena	Evaluation

3.5. Data Analysis

Two independent samples t-tests were conducted to evaluate any significant differences in motivation and performance between students who participated in a practical work with the EducThermoBot compared to those who used the EXAO. Before conducting these tests, we will check if our data meets the basic assumptions necessary for the use of the t-test, as recommended by Field [27]. If not, we will opt for the Mann-Whitney-Wilcoxon comparison test, which is more suitable for non-parametric data [27].

3.6. Ethical Considerations

We have taken into account essential ethical considerations to ensure the well-being and respect of the participants. Necessary permissions were obtained from the schools and parents of the participating students. Detailed information was provided, and their informed consent was obtained. The data was processed anonymously and stored securely. Safety measures were implemented during the experimental activities. All voluntary students had the opportunity to participate in the study, regardless of gender, ethnicity, or aptitude level. In summary, our study was conducted in accordance with ethical standards, ensuring reliable and ethically responsible results.

4. Results

In this section, we present the outcomes of our study, focusing on the analysis of data derived from the motivation questionnaire and the learning outcomes observed. The findings shed light on the impact of the educational interventions on students' motivation and academic performance.

4.1. Analysis of Data from the Motivation Questionnaire

The primary goal of this section is to evaluate the impact of utilizing EducThermoBot on students' motivation during practical work in physical sciences, in comparison to activities performed with EXAO.

In pursuit of this objective, we performed an independent samples t-test to investigate whether there exist any notable distinction in students' motivation between the two cohorts, specifically the group engaged with the Educational Robot (ER) and the group involved with EXAO.

Prior to conducting the t-test, we ensured that the six fundamental assumptions associated with this parametric analysis [27] were met. Firstly, our dependent variable, motivation, was measured on a continuous scale using a digital Likert scale spanning from 1 to 6. Secondly, our dependent variable comprised two independent groups: practical work in physics with and without robotics. Thirdly, we assumed the independence of observations, as no student participated in both groups, and each student was distinct. Fourthly, we confirmed that the data distribution did not exhibit any significant extreme outliers, as depicted in Figure 7.

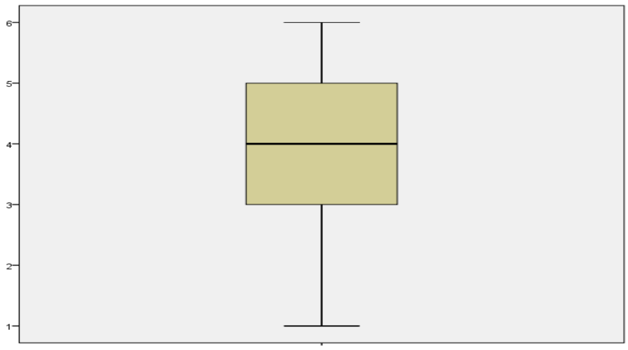


Figure 7. Distribution and outliers of motivation

Fifthly, we assessed the distribution of our dependent variable to ensure it followed a normal distribution. After conducting the normality tests, we observed that the skewness and kurtosis values were non-problematic, both below 1, as indicated in Table 6. Moreover, the Kolmogorov-Smirnov test yielded a non-significant P-value ($P = 0.161$), suggesting that the data is adequately normally distributed, as depicted in Table 7.

Table 6. Summary of motivation descriptive statistics

		Statistics
motivation	Average	4.05
	Median	4.00
	Variance	1.863
	Standard deviation	1.365
	skewness	-0.495
	Kurtosis	-0.612

Table 7. Assessment of motivation normality using Kolmogorov-Smirnov test

	Statistics	Df	Sig.
Motivation	0.05	120	0.161

Finally, the Levene's test was employed to assess the equality of variances, and the results indicated non-significance, as shown in Table 8. This suggests that the variances are equal, and no adjustments to degrees of freedom were necessary.

Table 8. Independent samples t-test for motivation

		Levene-test		t-test		
		f	sig.	t	df	sig.
The motivation	Equal variances assumed	1.304	0.673	5.344	118	0.000

After conducting the necessary checks, the results of the independent samples t-test are presented in Table 8. This test reveals a significant difference between the group that participated in robotics activities (M=4.65, SD = 1.287) and the group that did not participate in robotics activities (M=3.45, SD = 1.171) (t(118)=5.344, p<0.001). The Cohen's d effect size (d=0.88) associated with this test indicates a large effect size (Cohen, 1988). Thus, Hypothesis 1 is rejected.

4.2. Learning Outcome

Our specific objective 2 was to compare the impact of learning through hands-on practice using an ER on students' learning performance during a physics task, in comparison to the same task conducted with the utilization of EXAO.

To assess this difference, we conducted an independent samples t-test to compare students' learning performance between the two conditions.

Before conducting the t-test, we assessed the fulfillment of the six fundamental assumptions associated with this parametric analysis. Firstly, our dependent variable, learning performance, was measured on a scale ranging from 0 to 20. Secondly, our dependent variable consisted of two independent groups: one group conducted the practical work using the ER, while the other group performed the task without robotics.

Thirdly, we ensured the independence of observations by ensuring that no student participated in both conditions, and that each student was unique. Fourthly, we verified that the data distribution did not include significant extreme values, as illustrated in Figure 8.

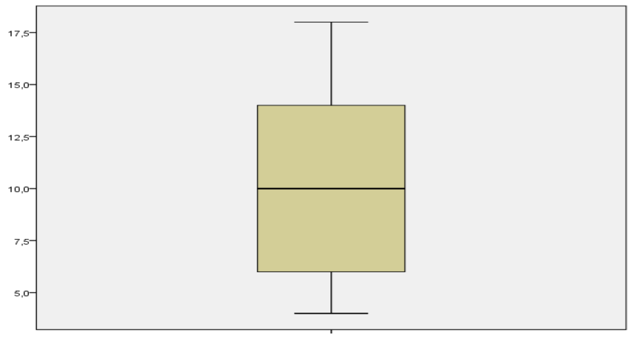


Figure 8. Learning distribution and extreme data

Fifth, we assessed the distribution of our dependent variable to check if it follows a normal distribution. To do this, we conducted tests of normality by examining the skewness and kurtosis of the data, as presented in Table 9. The values obtained for skewness and kurtosis are below 1, indicating that there are no major issues of non-normality.

Additionally, we performed the Kolmogorov-Smirnov test to confirm the normality of the data. The result of this test is non-significant (p=0.198), suggesting that the data sufficiently adhere to a normal distribution. The details of these tests and results are reported in Table 10.

Table 9. Learning descriptive statistics

		Statistics
Performance index	Average	13.43
	Median	12.00
	Variance	4.325
	Standard deviation	2.079
	skewness	-0.139
	Kurtosis	-0.365

Table 10. Analysis of Learning Performance Using Kolmogorov-Smirnov Test

	Statistics	df	Sig.
Performance index	0.05	120	0.198

We assessed the equality of variances using Levene's test (F = 0.735; p = 0.128 > 0.05), as presented in Table 11.

Table 11. T-test for independent samples on learning performance

		Levene-test		t-test		
		f	sig.	t	df	sig.
Performance index	Equal variances assumed	0.735	0.128	−0.531	118	0.599

After conducting the required examinations, the t-test presented in Table 11 demonstrates that there is no significant difference between the group that participated in robotics activities (M=13.50, SD=2.73) and the group that did not participate in robotics activities (M=13.37, SD=2.06) (t(118)=0.531, p=0.599>0.05). Therefore, Hypothesis 2 is confirmed.

5. Discussion

In this discussion section, we compare the results of our study to relevant scientific literature. We evaluated student motivation using a Likert scale. The results of the independent samples t-test revealed a significant difference in motivation between the group that participated in robotics activities (M=4.65, SD=1.287) and the group without robotics activities (M=3.45, SD=1.171) (t(118)=5.344, p<0.001) with a large effect size (d=0.88).

These findings are consistent with previous studies showing that the use of educational robotics stimulates students' interest and motivation [19], [28], [29]. For instance, Wahono *et al* [30] observed an increase in students' motivation to participate in learning activities through the use of robotics in the classroom. Similarly, Zhong and Xia [31] found a positive impact on motivation and engagement when integrating robotics into mathematics education.

The increase in students' motivation can be explained by several factors highlighted in the literature:

- The practical and immersive experience of educational robotics allows students to feel involved and accomplished, enhancing their self-esteem and intrinsic motivation [32].
- The use of educational robotics facilitates the connection between theory and practice, generating increased interest in physical sciences [33].
- Working in teams with robots encourages collaboration and teamwork, thereby contributing to students' motivation and engagement [34], [35].
- The playful nature of educational robotics makes learning more appealing to students, encouraging them to become more invested [36], [37].
- The ability to personalize learning based on the needs and skill levels of each student through robot programming can promote their success and motivation [38].

Regarding our second objective, we evaluated students' performance in the physics practical work using the evaluation test. The results of the independent samples t-test did not show any significant difference between the group that participated in robotics activities (M=13.50, SD=2.73) and the group without robotics (M=13.37, SD=2.06) (t(118)=0.531, p=0.599>0.05).

These results are consistent with previous studies that have found similar conclusions about the impact of educational robotics on students' performance. For example, a meta-analysis conducted by Talan [39] examined the effects of educational robotics in STEM fields and found that it improves students' problem-solving and critical thinking skills but does not have a significant effect on academic scores. Similarly, another study by Ferrarelli and Iocchi [40] on the integration of educational robotics in a science course showed that while students improved their understanding of physical concepts through robotics, this improvement was not significantly different from the control group. These findings suggest that educational robotics can be beneficial for certain cognitive skills, but its direct impact on academic outcomes is still a subject of debate.

In conclusion, our study suggests that the integration of educational robotics can improve students' motivation in physical sciences, but did not show a significant difference in overall academic performance. It is essential to consider various factors such as pedagogical design and student engagement when integrating educational robotics in the classroom. Further research is needed to deepen our understanding of the underlying mechanisms of the impact of educational robotics on students' learning in physical sciences and to identify best pedagogical practices for its optimal use in the school environment.

6. Conclusion

This research aimed to assess the influence of educational robotics on students' motivation and learning in physical sciences, with a particular focus on the concept of temperature.

The study's participants included 120 middle school students, evenly distributed into an experimental group of 60 students and a control group of 60 students. Two measures were collected: a performance index assessing the learning of the temperature concept and a Likert scale questionnaire assessing motivation towards physical sciences. Statistical analyses, including t-tests, were used to compare the results between the two groups.

The results of this study revealed that the integration of educational robotics had a positive effect on students' motivation in physical sciences. The students in the experimental group showed a significantly higher level of motivation than those in the control group. Regarding learning, no significant difference was observed in overall academic performance between the two groups.

However, this research has some limitations. Firstly, the sample consisted of students from a single school, which limits the generalizability of the results to other school populations. Additionally, the pedagogical design and student engagement may have influenced the results, highlighting the need for further studies to deepen our understanding of these factors. Another limitation is the relatively short duration of the educational robotics intervention. A longitudinal approach could provide better insights into the longer-term effects of integrating educational robotics in students' learning.

Despite these limitations, the findings of this research offer valuable insights for educators and educational program designers. The integration of educational robotics can be an effective way to stimulate students' motivation in physical sciences, promoting their active engagement and interest in learning activities. These conclusions provide a solid foundation for improving educational practices and fostering students' interest in scientific disciplines. Based on the results of this study it is advisable for physical science educators to integrate a greater number of educational robots into their teaching methods. This can significantly contribute to boosting students' motivation and facilitating their learning experiences. Researchers are also encouraged to conduct further studies on the integration of educational robots at different educational levels and in various school contexts. Finally, education authorities may consider offering continuous training to teachers to familiarize them with the use of educational robots in their pedagogical practices. These actions could contribute to improving the effectiveness of physical science education and sparking students' interest in science from an early age.

Appendix A: Motivation questionnaire

	Strongly Disagree	disagree	Slightly disagree	Slightly agree	Agree	Strongly Agree
1-I was very focused during this activity.	☐	☐	☐	☐	☐	☐
2-I was not interested in the activity we just did.	☐	☐	☐	☐	☐	☐
3-I liked everything about this activity.	☐	☐	☐	☐	☐	☐
4-The activity caught my attention.	☐	☐	☐	☐	☐	☐
5-I would like to experience more activities like this.	☐	☐	☐	☐	☐	☐
6-I think my friends did not like the activity.	☐	☐	☐	☐	☐	☐
7-The activity we have just experienced has captivated me.	☐	☐	☐	☐	☐	☐
8-This activity was boring.	☐	☐	☐	☐	☐	☐

Appendix B: Evaluation Test

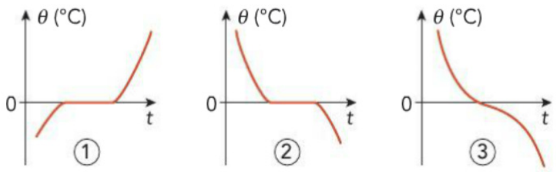
Question 1: What does temperature measure?

A) The amount of matter in an object
B) The speed at which an object moves
C) The thermal energy of an object
D) The mass of an object

Question 2: Which change of state corresponds to the transformation of liquid water into ice?
Melting; Evaporation ; Condensation ; Solidification

Question 3: When ice is heated, it melts to become water. At what temperature does this normally occur?
0°C. ; 100°C. ; -10°C. ; 50°C

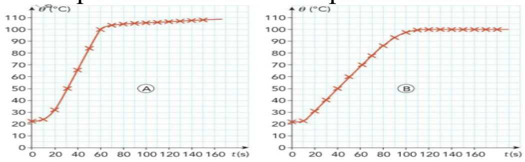
Question 4: Which of these three temperature curves represents the solidification of pure water?



Curve: 1 ; 2 ; 3 ; No curve

Question 5: What happens to the temperatures when we mix ice with hot water?
A) The temperature increases because the hot water heats the ice.
B) The temperature decreases because the ice cools down the hot water.
C) The temperature remains constant because there is a thermal equilibrium.
D) The temperature becomes unstable without a clear change.

Question 6: The curves represent the evaporation of two liquids. Which one is a pure substance?



A) Curve A B) Curve B C) No curve D) Both curves

Question 7: If you want to quickly cool a carbonated beverage, is it more effective to put it in the refrigerator or immerse it in an ice bucket? Why?

A) The refrigerator is more effective because the cold air cools the beverage quickly.

B) The ice bucket is more effective because ice absorbs heat rapidly.

C) Both methods are effective, but the ice bucket is faster.

D) Both methods are ineffective for cooling a carbonated beverage.

Question 8: Identify the states of matter involved in the melting of an ice cube exposed to heat.

A) Solid state (ice) to liquid state (water)

B) Liquid state (water) to gaseous state (water vapor)

C) Solid state (ice) to gaseous state (water vapor)

D) Gaseous state (water vapor) to liquid state (water)

Question 9:

A) Summarize the different changes of state possible for water and their characteristic temperatures.

B) Create a diagram representing the different stages of the water cycle.

C) Formulate a simple model to explain how temperature affects the density of substances.

D) Compare the changes of state of water with those of alcohol.

Question 10:

A) Analyze the advantages and disadvantages of using evaporation to cool a hot surface.

B) Discuss the implications of changes of state of water for life on Earth.

C) Evaluate the potential hazards associated with the use of liquid nitrogen.

D) Make an argument on whether changes of state are reversible or irreversible.

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