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ORIGINAL ARTICLE

Boosting Student Motivation in Chemistry: A Study on the Integration of Educational Robotics and Mobile Technology for pH Instruction

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ABSTRACT

To address the challenge of improving the understanding of chemistry concepts, particularly pH, this study explored the impact of integrating educational robotics on students' motivation and learning outcomes. A total of 160 3rd-year middle school students from a public school in Meknes, Morocco, participated in the study, which was divided into an experimental group (n = 82) and a control group (n = 78). Student performance was evaluated through standardized tests, while motivation levels were gauged using a questionnaire. The findings indicated a significant increase in motivation among students in the experimental group compared to those in the control group. However, no significant differences in overall academic performance were detected between the two groups. These findings provide valuable insights for educators and curriculum developers, underscoring the importance of integrating innovative pedagogical approaches with traditional methods to enhance science education.

KEY WORDS: Arduino; educational robotics; motivation; pH; science learning

INTRODUCTION

Improving science education, particularly in chemistry, is a critical challenge within numerous global education systems. In Morocco, this concern is amplified by various factors, including unsatisfactory results in international and national assessments, as well as budgetary constraints. Notably, in the 2019 edition of the Trends in International Mathematics and Science Study, conducted by the International Association for the Evaluation of Educational Achievement, Moroccan students were ranked among the bottom five countries in terms of mathematics and science knowledge (Mullis et al., 2020). Simultaneously, national assessments consistently revealed underwhelming performance in chemistry among Moroccan students across all levels of education (Bourqia et al., 2022).

Furthermore, these concerns are intensified by financial limitations that restrict access to technological tools in science education in Morocco. The use of computer-assisted experiments remains limited due to budgetary restrictions (Lahlali et al., 2023).

Among modern and reliable information and communications technology (ICT) resources that can be integrated into scientific learning, the educational robot (ER) emerges as a promising choice. Recent studies have demonstrated that ER plays a significant role in understanding complex concepts (Omari et al., 2024), encompassing thermodynamics (Omari et al., 2023), programming (Hamash and Mohamed, 2021; Hamiti et al., 2021), mathematics (Suárez-Gómez and Pérez-Holguín, 2020), and languages (Chuah and Kabilan, 2021; Huang, 2021; Youssef et al., 2023). Furthermore, the use of the ER has been conducive to the development of skills related to the scientific process, such as hypothesis formulation, methodical experimentation, and variable management (Jamal et al., 2021; Jawawi et al., 2022). Abundant evidence also supports the positive effect of integrating the ER on students' interest and engagement in STEM fields (Akış, 2024; Darmawansah et al., 2023; Houghton et al., 2022). As an ICT tool, the ER encourages active and playful participation of students in their learning experiences (Wang et al., 2023). These elements underscore the potential of the ER to address challenges encountered in science education, particularly in chemistry, and to enhance students' interest and engagement in their scientific learning.

In addition, using an ER to teach the concept of pH offers significant safety advantages for middle school students. Unlike direct manual experiments, which often involve handling potentially hazardous chemicals, the integration of the ER helps minimize the risks associated with these activities. The robot can be programmed to perform critical tasks such as measuring and mixing solutions, thereby reducing the need for students to handle chemicals directly. Furthermore, the robot allows for precise control of experimental procedures, which decreases the risk of human error and accidents. Thus, the use of the ER not only facilitates the learning of chemistry concepts such as pH but also ensures a safer learning environment for students.

In this context, this study aims to explore the effect of interaction with an ER and an Android application on students' motivation and learning during the teaching of the pH concept in chemistry. Mastering this concept in middle school is crucial, as it forms an essential foundation for addressing more advanced concepts in chemistry and other related scientific fields. Moreover, a solid understanding of pH is relevant in everyday life, from managing drinking water to biological processes. By examining how technological tools can positively influence students' motivation and comprehension of pH in chemistry, this study aspires to provide relevant insights for decision-makers, educators, and researchers striving to enhance science education. The research questions that will guide this study are as follows:

1. How does the interaction with an ER and the use of an Android application influence students' motivation in learning the pH concept compared to the traditional approach?
2. How does the interaction with an ER and the use of an Android application affect students' learning regarding the comprehension of the pH concept compared to the traditional approach?

These research questions necessitate the formulation of the following null hypotheses:

H01: There is no significant difference in students' motivation between the traditional method of teaching pH and the method that incorporates an ER and an Android application.

H02: There is no significant difference in students' understanding of the pH concept between the traditional approach and the approach using an ER and an Android application.

To test these hypotheses, a comparative approach was adopted by assigning students to either an experimental group using educational robotics materials or a control group using conventional materials. Data collection involved administering knowledge tests and motivation questionnaires. An independent samples t-test was then employed to analyze the results.

The outcomes of this study could have significant implications for enhancing chemistry education, addressing budgetary constraints, and fostering students' interest and motivation.

The remainder of this paper is organized as follows: Section 2 provides an in-depth description of the proposed ER. Section 3 details the research methodology employed in the study. In Section 4, we present the results, followed by a discussion in Section 5. Finally, Section 6 concludes the paper with key findings and suggests potential directions for future research.

DESCRIPTIONS OF THE PROPOSED ER

Prototype Design

The ER we named EduChemBot was designed to provide middle school students with an interactive and engaging learning experience in the field of chemistry, specifically focusing on understanding the pH concept. EduChemBot (Figure 1) consists of four main components that synergize harmoniously to offer an enriching and playful learning experience.

1. Android application: The Android application (Figure 2) associated with EduChemBot plays a crucial role in facilitating interaction and communication between students and the robot. It enables students to remotely guide the robot while displaying real-time pH values as well as a graphical representation of the pH variation over time
2. Communication channel unit: The seamless communication between the robot and the Android application is facilitated by a communication channel unit that employs Bluetooth technology. This feature enables students to remotely control EduChemBot, thus generating an immersive and real-time interaction. Through this functionality, students can remotely observe and analyze pH changes, eliminating physical limitations
3. EduChemBot unit: This unit serves as the core of the robot, housing the essential components that enable the robot to carry out its educational tasks. It incorporates an Arduino board, functioning as the brain of the robot, executing instructions for movements and actions. Motors and wheels ensure the robot's mobility, while the arm and pH sensor enable it to conduct measurements and experiments within the study environment
4. Studied environment unit: The studied environment unit is where the robot conducts its pH measurements. This specific environment, representing a real experimental setup, enables students to observe and comprehend pH variations in various solutions over time. Direct interaction with this environment provides students with a hands-on experience that enhances their understanding of the pH concept and its implications.

The EduChemBot represents an innovative pedagogical tool that combines educational technology with scientific exploration. By integrating a user-friendly Android application, efficient Bluetooth communication, ingenious design, and interaction with the study environment, the EduChemBot provides students with a stimulating and immersive learning opportunity in the field of chemistry.

Parts of the "EduChemBot"

To fully grasp the operation and capabilities of EduChemBot (Figure 3), it is crucial to understand its core components. Table 1 outlines the key components integrated into EduChemBot's design, detailing their functions, roles, and associated costs. This comprehensive breakdown provides insight into how each component contributes to the robot's overall functionality and cost-effectiveness.

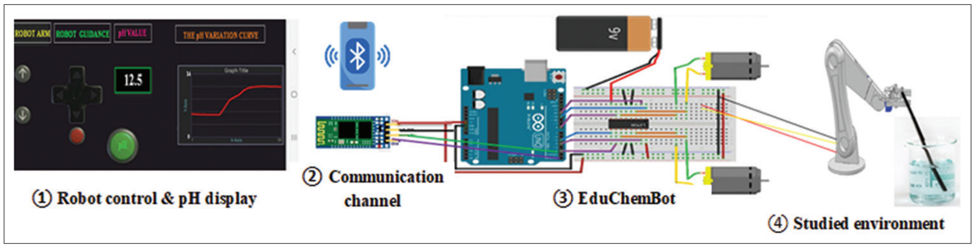

Figure 1: Design of "EduChemBot"

Figure 2: The Android application associated with EduChemBot

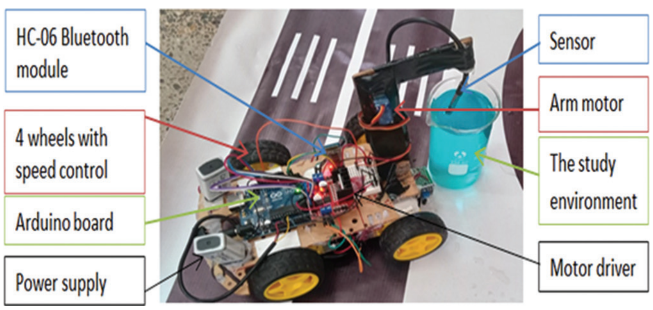

Figure 3: Components of "EduChemBot"

Table 1: Basic components of "EduChemBot"

Component	Designation	Role	Cost (USD)
Microcontroller	Arduino Uno	Central processing unit	4.8
Sensor	pH Sensor	Data collection and measurement	15
Actuators	Servo motors	Movement and interaction	1.95
Power supply	Battery pack	Energy source	1
Chassis	Custom-built Frame	Structural support	1
Communication	Bluetooth Module	Wireless connectivity	1.66
Software	Custom Android App	User interface and control	0 (developed in-house)

Our design approach for the EduChemBot robot was focused on accessibility, allowing students to build this tool from affordable components. The overall cost of assembling the robot is estimated to be a modest sum of 36 USD. This economical approach not only makes EduChemBot pedagogically beneficial but also financially viable for educational institutions. To put this in perspective, the Lego Mindstorm Ev3 product (Çavaş et al., 2020), a common commercial alternative, is typically sold at a significantly higher price. In fact, the average price of this product ranges between 350 USD and 700 USD. The significant cost difference between EduChemBot and commercial alternatives underscores our commitment to providing a cost-effective educational solution without compromising quality.

METHODOLOGY

Participants in the Study

The research sample was composed using a convenience sampling method. This approach was adopted due to logistical constraints that made forming another type of sample challenging (Gaudreau, 2011). These operational challenges guided our method choice. The selection criteria for the sample were as follows: Participants needed to be enrolled in the 3rd year of middle school and belong to the class of a willing teacher. All students meeting these criteria were invited to participate in our research project. With a focus on inclusivity and diversity, recruitment was conducted ensuring a balanced representation of both female and male students, without distinction of origin or socioeconomic background. The study population comprises 160 voluntary middle school students, distributed as shown in Table 2.

To ensure comparability between the two groups, despite the uniformity of the chemistry curriculum, we controlled for their initial levels of learning. This was achieved by assessing their performance on the most recently completed stage in chemistry as an indicator of their baseline knowledge.

Study Procedure

Participants were selected from Ibn Tofail Public Middle School in Meknes, Morocco, during the 2023–2024 academic year. The study compared two methods for teaching the concept of pH. In the control group, students used a traditional pH meter to measure the pH of various solutions. They recorded these measurements in a table and subsequently graphed the data to observe how pH varied with dilution for both acidic and basic solutions. This approach allowed students to engage directly with the pH measurement process and understand the relationship between pH and concentration through practical, hands-on experience. The traditional method helped students achieve key curriculum outcomes, including accurate pH measurement, data recording, and the ability to analyze and interpret graphical data on pH changes. In contrast, the experimental group used the EduChemBot, an ER designed to provide a more interactive and real-time visualization of pH values, thereby enhancing the learning experience with advanced technological support.

To evaluate the impact of EduChemBot on students' motivation and learning, a structured procedure was followed (Figure 4). Initially, a pre-test assessed the baseline knowledge of learners in both groups. The control group, consisting of 78 students, received a conventional pH course with traditional pedagogical methods. In contrast, the experimental group, with 82 students, engaged in the same course using EduChemBot.

After 3 h of practical work, all participants completed an evaluation test to measure the skills gained from their respective teaching methods. In addition, they filled out a Likert-scale questionnaire to gauge their motivation regarding the pH concept. The evaluation test and questionnaire were developed with input from three experienced chemistry teachers to ensure their validity and relevance.

Teaching Scenario

Scenario based on the "EduChemBot"

Problem situation: "The lost elixir of the pH world"

In the heart of a mysterious forest, the pH Elixir has been lost, leaving behind a series of puzzles centered around pH values. Only the most curious minds and creative thinkers can decipher these mysteries and find the precious elixir. Groups of students, each consisting of three explorers, are called on to solve this scientific puzzle, leading them on a unique educational quest (Figure 5).

Mission 1: Introductory Puzzle

Objective: Understand the importance of pH.

Description: Students begin their quest by watching an educational video on an Android application. After the viewing, they must answer a multiple-choice quiz that will allow them to earn crucial clues for the rest of the adventure.

Table 2: Descriptive statistics of the sample

	Control group with traditional pH meter	Experimental group with EduChemBot
Number	78	82
Mean age	14.64 years	14.87 years
Gender	51% female and 49% male	52% female and 48% male

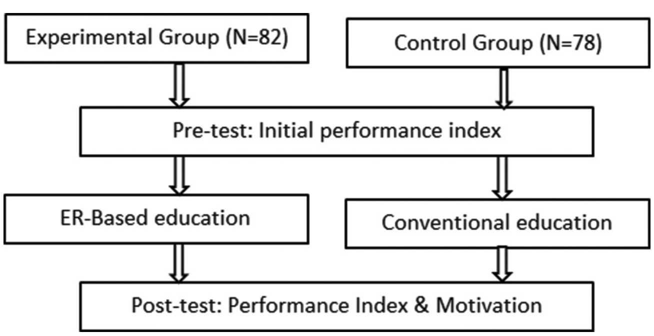

Figure 4: Study procedure

Mission 2: Equipment Preparation

Objective: Prepare EduChemBot for the adventure.

Description: Before embarking on the exploration, students must prepare EduChemBot, their robotic assistant. They need to equip it with the necessary sensors and configure the Android application to ensure smooth communication throughout the mission.

Mission 3: Erupting Volcano

Objective: Guide EduChemBot to the erupting volcano.

Description: Students must program EduChemBot to follow a specific trajectory leading to an erupting volcano. This step is crucial for approaching the study site safely.

Mission 4: Volcanic Data Collection

Objective: Measure the pH of simulated volcanic eruptions.

Description: Once at the foot of the volcano, students use EduChemBot to measure the pH of solutions contained in beakers placed around the volcano. These data are essential for understanding the nature of the eruptions.

Mission 5: Real-Time Visualization

Objective: Observe pH variations during eruptions.

Description: Using the Android application, students can observe real-time graphs showing pH variations during volcanic eruptions. This visualization helps analyze the dynamic changes in pH.

Mission 6: Discovery of Magmatic Solutions

Objective: Associate pH values with volcanic solutions.

Description: The collected data allows students to analyze the solutions and determine whether they are acidic, basic, or neutral. This step requires deep reflection to connect observations with theoretical knowledge.

Mission 7: Elementary Names

Objective: Name the solutions based on their pH.

Description: Using the knowledge gained, students must associate pH values with the correct names of the solutions, further reinforcing their understanding of scientific concepts.

Mission 8: The pH Elixir

Objective: Discover the pH Elixir by solving the mystery.

Figure 5: Pedagogical scenario with EduChemBot

Description: Armed with the information and clues gathered in the previous missions, students must now decipher the final puzzle. This step will lead them to discover the properties of the much-sought-after pH Elixir.

Mission 9: Knowledge Sharing

Objective: Present findings and discuss results.

Description: Students compare their conclusions with the correct answers and explain the connections between pH values and solution properties. This sharing of information allows for a consolidation of learning and a collective discussion of the results obtained.

Mission 10: Celebration of Success

Objective: Celebrate team achievements.

Description: To conclude the adventure, students share their experiences and the lessons learned from the pH quest. This celebration strengthens collective understanding and marks the end of a mission successfully accomplished.

The adventure "Mission pH Quest: In Search of the pH Elixir" takes students on an exciting journey where teamwork, playful learning, and solving scientific puzzles come together. Guided by EduChemBot and the Android application, groups of explorers unite their minds to uncover the secrets of pH, revealing the hidden mysteries of science at the heart of an erupting volcano.

Teaching scenario with the pH meter

In the teaching scenario involving the pH meter, students are tasked with gathering pH data from various environments using the device (Figure 6). The measurements are instantly displayed on the screen, allowing students to observe pH fluctuations in real-time.

Data Collection Tool

To achieve the study's objectives, two assessment tools were used: A motivation questionnaire and a performance index derived from the evaluation test administered following the practical activities.

Figure 6: Teaching scenario with the pH meter

Questionnaire on motivation

Questionnaires using Likert scales are well-regarded for their effectiveness in assessing students' motivation due to their ease of construction, direct self-assessment by respondents, and reliability even with a limited number of items (Potvin and Hasni, 2014; Likert, 1932). In this study, we developed a tailored questionnaire (Appendix A) to gauge students' motivation, drawing on the framework established by Rotgans and Schmidt (2011) for collaborative learning. The questionnaire includes eight items assessed using a Likert scale, with half of the statements framed positively and the other half negatively to capture a comprehensive view of motivation during chemistry practical work.

The reliability of the motivation questionnaire was assessed using Cronbach's alpha coefficient (α), which ranges from 0 to 1, with values equal to or >0.6 deemed satisfactory. The analysis, conducted with the 160 students participating in the study, yielded a Cronbach's alpha coefficient of 0.835, indicating excellent reliability.

Performance index for the chemistry laboratory task

The performance index used to evaluate student performance during the chemistry laboratory task was based on a multiple-choice test consisting of 10 questions (Appendix B). Each correct response was awarded one point, whereas incorrect or omitted answers received no points. This objective scoring method ensured consistency in evaluating students' understanding of the pH concept. To further ensure reliability, the test was pre-tested with a sample of 35 students, yielding a Cronbach's alpha coefficient of 0.87, which indicates a high level of internal consistency.

Regarding validity, the test was developed in consultation with subject matter experts to ensure that the questions accurately aligned with the learning objectives of the chemistry curriculum. This process established the content validity of the test, ensuring that the questions were representative of the intended knowledge outcomes. Consequently, the Performance Index serves as a reliable and valid tool for assessing student knowledge during laboratory activity, with a clear and consistent scoring method.

Ethical Considerations

Throughout this study, we have diligently adhered to the fundamental ethical principles related to research involving participants. We obtained prior permission from school authorities and the parents of the involved students. Furthermore, we ensured the anonymity and confidentiality of collected data, ensuring that no personal information was disclosed. Participating students were informed of the study's purpose and their freedom to participate or withdraw without negative consequences. Our research aligns with the ethical standards established in the field of scientific research and contributes to the development of responsible and participant-respecting pedagogical practices.

RESULTS

Analysis of Motivation Questionnaire Data

This section aims to assess and compare the effects of using a robotic environment (RE) versus a traditional pH meter on student motivation during chemistry practical work.

To achieve this, we conducted an independent samples t-test to determine if there were significant differences in motivation between the two groups: Those using the RE and those using the traditional pH meter.

Before performing the t-test, we verified that the data met the essential assumptions for this parametric analysis as outlined by Field (2013). Specifically:

1. Measurement of the dependent variable: Motivation was measured using a continuous numeric Likert Scale from 1 to 6, where 1 indicates minimal motivation and 6 indicates maximal motivation
2. Group Independence: The analysis involves two independent groups: One that engaged in practical work with the RE and one that used the traditional pH meter
3. Independence of Observations: Each student was assigned to only one group, ensuring that observations were independent of each other
4. Data Distribution: We confirmed that there were no significant outliers in the data, as illustrated in Figure 7
5. Normality of Distribution: The distribution of the dependent variable was assessed for normality. Normality tests showed skewness and kurtosis values were <1, as shown in Table 3. In addition, the Kolmogorov–Smirnov test yielded a non-significant result ($p = 0.178$), indicating that the data sufficiently met the normality assumption, as shown in Table 4.

These checks ensure the validity of the t-test results in assessing the motivational differences between the two groups.

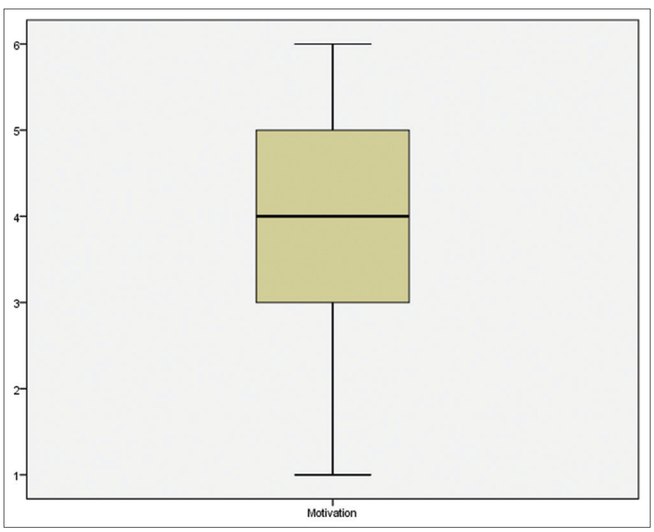

Figure 7: Distribution and outliers of motivation

Table 3: Descriptive statistics for motivation in the experimental group

Average	Median	Variance	Standard deviation	Skewness	Kurtosis
4.25	4.00	1.756	1.245	−0.478	−0.689

Finally, the equality of variances was assessed using Levene's test and found to be non-significant, as reported in Table 5, indicating equality of variances. Thus, no correction of degrees of freedom was applied.

The t-test shows a significant difference between the robotics group and the non-robotics group, with $t(158) = 5.655$, $p < 0.001$. As a result, hypothesis 1 is not supported.

Results of the Learning Test

Table 6 presents the performance results of students from two distinct groups. The control group, using a traditional pH meter, has an average score of 14.30 with a standard deviation of 2.49. The experimental group, using an ER, shows a slightly higher average of 14.96 with a standard deviation of 2.19. The difference between the two group averages is 0.66, suggesting a slight improvement in performance for the experimental group.

To determine if this difference is statistically significant and to reject the null hypothesis that the use of the ER did not influence student results, we employed the Mann–Whitney U test. As indicated in Table 7, the distribution of values does not follow a normal distribution, as the p-value from the Shapiro–Wilk test is below the selected alpha level of 0.05.

According to Table 8, the two-tailed asymptotic significance of the Mann–Whitney U test is higher than the chosen alpha level. A two-tailed asymptotic value of 0.258 does not allow for the rejection of the null hypothesis; therefore, it can be concluded that there is no significant difference between the tested groups. Thus, the use of the ER for studying pH appears to have a comparable effect on student performance to that of traditional laboratory learning.

Table 4: Evaluation of motivation normality with the Kolmogorov–Smirnov test

Alpha	0.05
Df	160
Sig.	0.178

Table 5: Independent samples t-test for motivation

		Levene's test		t-test		
		F	*Sig.*	*T*	*df*	*Sig.*
Motivation	Equal variances assumed	1.408	0.876	5.655	158	0.00

Table 6: Descriptive statistics of the learning test

	n	Minimum	Maximum	Mean	Standard deviation
Control group	78	9	17	14.30	2.49
Experimental group	82	11	18	14.96	2.19

Table 7: Normality tests

	Kolmogorov–Smirnov			Shapiro–Wilk		
	Statistics	ddl	Significant	Statistics	ddl	Significant
Control group	0.223	78	0.005	0.795	78	0.001
Experimental group	0.210	82	0.013	0.878	82	0.027

Table 8: Mann–Whitney *U*-test

	The groups
Mann–Whitney *U*	259.600
Wilcoxon W	539.500
Z	−0.899
Asymp. significant (two-tailed)	0.258

DISCUSSION

This extended discussion section will explore these findings in relation to a broader set of relevant studies, thereby strengthening the validity and applicability of our conclusions in the field of educational robotics.

Regarding the impact of EduChemBot on student motivation, our observations are in line with several studies that have highlighted the potential for improved motivation through the integration of educational robotics. Our findings resonate with a broader perspective, aligning with the findings of (Chalmers et al., 2022), who demonstrated that interactions with ERs can increase students' enthusiasm and engagement in scientific subjects. In addition, the study by (Gubenko et al., 2021) emphasized how carefully crafted pedagogical design can enhance student engagement in the context of learning with ERs.

The role of educational robotics in promoting student interest and engagement in science has also been highlighted by (Screpanti et al., 2021). Their study revealed that the use of educational robotics fosters greater enthusiasm for scientific subjects among students. In a similar vein, the work of (Nguyen et al., 2021) demonstrated that interaction with ERs can increase intrinsic motivation and engagement in learning activities among students. These findings, coupled with our significant results showing a difference in motivation between the groups using EduChemBot and the traditional pH meter, underscore the consistency of the positive effects of educational robotics on student motivation.

However, concerning learning performance, our results indicated no significant difference between the two groups. Learning performance related to the pH concept was similar, whether students utilized the ER or the traditional pH meter. This observation might stem from the conceptual nature of the pH concept in chemistry. Our conclusions align with the findings of (Ferrarelli and Iocchi, 2021), who suggested that fundamental and introductory concepts might not exhibit significant differences in learning performance between groups using traditional approaches and methods based on educational robotics.

Furthermore, insights from Talan's work (Talan, 2021) can shed light on the comparison of learning performances. Talan examined the impact of educational robotics on the learning of scientific concepts and proposed that the effectiveness of educational robotics depends on the complexity level of the concepts being addressed. In our case, learning the pH concept in chemistry primarily involves grasping the acidic and basic properties of solutions, as well as understanding the relationship between pH and the scale of values. These aspects were covered similarly in both groups, potentially explaining the observed similarity in learning performances.

It is important to note that the significance of the benefits related to student motivation and engagement cannot be underestimated. Our findings align with the work of (Afonso et al., 2021), who suggested that increased student motivation through the use of educational robotics could have positive effects on long-term learning and knowledge retention. In addition, our conclusions reinforce the perspective of (Mendoza et al., 2020) regarding the role of educational robotics in fostering essential cross-cutting skills in students, thereby promoting a holistic approach to learning.

In conclusion, our findings seamlessly align with the discourse in educational robotics research, highlighting the potential of this approach to enhance student motivation while emphasizing the need to consider specific context and content. This comprehensive discussion further deepens our understanding of the intricate interactions between educational robotics, motivation, and learning performance, while also providing avenues for future research to delve deeper into these dynamics.

CONCLUSION

This study evaluated the impact of educational robotics on student motivation and learning in chemistry, focusing on the pH concept. Involving 160 3rd-year students from a public middle school in Meknes, Morocco, the research compared an experimental group using educational robotics with a control group using traditional methods. Data were collected through an assessment test and a Likert-scale questionnaire. The findings revealed a significant increase in motivation among students in the experimental group, who used educational robotics. Despite this, there was no notable difference in overall academic performance between the two groups concerning their understanding of the pH concept. The study recognizes limitations such as logistical constraints and specific characteristics of the learning environment that may have affected the outcomes. It also notes that individual and contextual factors could influence motivation and performance. Future research should explore the specific elements of educational robotics, the mechanisms behind the observed motivational improvements, and the long-term impact on knowledge retention and skill development. Overall, this study highlights the potential of educational robotics to enhance student motivation in science education, underscoring the need for further investigation to optimize its effectiveness in educational contexts.

DECLARATION OF CONFLICTING INTERESTS

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APPENDIX

Appendix A: Motivational Survey

	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: Assessment Test

1. What scale is used to measure the acidity or basicity of a solution?
   a) Temperature scale
   b) pH scale
   c) Volume scale
   d) Pressure scale
2. A solution with a pH < 7 is considered.
   a) Neutral
   b) Acidic
   c) Basic
   d) Amphoteric
3. What is the pH value of a neutral solution?
   a) 0
   b) 7
   c) 14
   d) 10
4. What substance present in acidic solutions contributes to their acidic character?
   a) OH- ions
   b) Na+ ions
   c) H+ ions
   d) Cl- ions
5. If the pH of a solution increases, how will it affect its acidity level?
   a) It will become more acidic
   b) It will become more basic
   c) It will remain neutral
   d) It will become amphoteric
6. A solution with a pH of 9 is.
   a) Acidic
   b) Neutral
   c) Basic
   d) Amphoteric
7. How does the pH of an acidic solution compare to the pH of a basic solution?
   a) The pH of an acidic solution is higher than that of a basic solution
   b) The pH of an acidic solution is lower than that of a basic solution
   c) The pH of an acidic solution is equal to that of a basic solution
   d) The pH of an acidic solution is inversely proportional to that of a basic solution
8. What is the pH value of a highly acidic solution?
   a) 7
   b) 0
   c) 14
   d) 2
9. What is the pH of a solution where the concentration of H+ ions is equal to that of OH- ions?
   a) 0
   b) 7
   c) 14
   d) 10
10. How does the pH of a solution change when its concentration of H+ ions increases?
    a) The pH decreases
    b) The pH increases
    c) The pH remains constant
    d) The pH becomes neutral