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Integrative STEM approach to enhance academic performance in physics among Spanish students

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Abstract

Physics is the discipline within the STEM fields (Science, Technology, Engineering, and Mathematics) with the lowest academic performance rates in secondary education and the most pronounced gender gap. This article examines the outcomes of implementing problem-solving activities using educational technologies within a STEM framework in physics education. The intervention was conducted in a secondary education setting (ages 14–16) with a group of 35 students (12 boys and 23 girls) over six sessions. Students completed a custom-designed questionnaire, administered both before and after the educational intervention, consisting of 20 multiple-choice questions on physics concepts. The results demonstrated an overall improvement in academic performance, with girls showing greater gains than boys.

Keywords: physics, secondary, educational technologies, smartphone, STEM approach

INTRODUCTION

The scientific literature highlights that physics is one of the disciplines with the lowest academic performance rates in secondary education (Barbero-García et al., 2007; Ministerio de Educación y Formación Profesional [MEFP], 2020; Sáiz-Manzanares & Bol, 2015). These challenges can be partly attributed to the high level of abstraction inherent in the subject matter (Suprapto, 2020). However, the integration of digital and technological tools within a STEM (Science, Technology, Engineering, and Mathematics) framework can enhance the teaching and learning processes in physics, facilitating students' conceptual understanding (Aldon et al., 2017; Queiruga-Dios et al., 2018, 2019a; Viloria et al., 2018). In traditional, lecture-based instruction, many students tend to memorize content and attempt to reproduce the teacher's words without fully grasping the underlying concepts or physical phenomena. In contrast, meaningful learning occurs when students actively connect new information with their prior knowledge (Queiruga-Dios, 2016). By integrating or assimilating new information into their existing cognitive frameworks, students are able to attribute meaning to the content. It is essential for students to actively make sense of the information received so that, through the modification of prior knowledge, new learning can emerge (Ausubel et al., 1976; Queiruga-Dios et al., 2016; Gravemeijer et al., 2017). Achieving this requires the implementation of active methodologies, such as problem-based learning, guided research, or inquiry-based approaches (Diez-Ojeda et al., 2021; Shongwe, 2024). All these methodological approaches have a common characteristic: intervenes in the zone of proximal development of the student (Vygotsky, 1979). In this approach, the student becomes the central figure in the teaching-learning process, taking responsibility for their own learning. They construct scientific knowledge and, in most cases, develop the ability to apply it to real-life situations. Integrative STEM approaches support this process (Martín-Páez et al., 2019; Shongwe, 2024). In these methodologies, the teacher acts as a guide, supporting the student through continuous feedback (Queiruga-Dios et al., 2019b). By employing a variety of methodologies and technologies, the teacher can tailor their interventions to reach all students, promoting inclusion in the classroom, increasing participation, and "reducing exclusion in and

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Contribution to literature

- The design of physics activities using an integrative STEM approach enhances students' academic performance.
- Physics programs that follow an integrative STEM approach help reduce the gender gap.
- The implementation of physics programs under an integrative STEM approach particularly benefits students with lower academic performance, leading to greater improvement

from education" (UNESCO, 2005, p. 13). This inclusion entails providing access to quality education without discrimination, and the transformation of the educational system must move in this direction (Queiruga-Dios et al., 2016).

This paper analyzes the impact of a teaching proposal centered on problem-solving and the integration of educational technologies within a STEM framework on students' academic performance in physics (Physics Activities Program). Additionally, it investigates potential gender differences in academic outcomes among students. This study involved two groups of students (A and B), and the following hypotheses were formulated:

Hypothesis 1 (Group Comparison)

Null hypothesis (H01): There is no significant difference in the gain scores between group A and group B.

Alternative hypothesis (H11): There is no significant difference in the gain scores between group A and group B.

Hypothesis 2 (Gender Comparison)

Null hypothesis (H02): There is no significant difference in gain scores according to the gender of the students.

Alternative hypothesis (H12): The gain scores present significant differences according to the gender of the students.

THEORETICAL FRAMEWORK

STEM Education, or education with a STEM approach, refers to the integrated and interconnected teaching of scientific and technological disciplines through real-world issues and contexts (Martín-Páez et al., 2019). This educational approach enables students to learn conceptual content while developing essential 21st century skills such as problem-solving, communication, critical thinking, creativity, and collaboration (Asrizal et al., 2023; MacDonald et al., 2019; Shongwe, 2024). Ideally, this prepares them to effectively integrate into the labor market and broader society, as it equips them to solve problems in a global and rapidly changing environment. Problem-solving requires comprehensive, interdisciplinary knowledge that allows for the transfer of understanding across subjects, helping students grasp the interconnectedness of these disciplines. As a result, various sectors are calling for an integrated STEM education approach that is applicable to real-world challenges and capable of addressing global issues (Bybee, 2010). Current educational curricula are aligned with this objective (European Council, 2018). It is often emphasized that science is fundamentally oriented towards problem-solving (Castro-Martínez, 2008; Varela-Nieto & Martínez-Aznar, 1997). Engaging students in solving real-life problems not only facilitates the acquisition of scientific knowledge but also stimulates the development of logical-mathematical thinking (Calvo-Ballestero, 2008; Díaz-Lozada & Díaz-Fuentes, 2018). Furthermore, problem-solving promotes significant conceptual change in students, particularly as they progress through phases such as problem analysis, hypothesis generation, and results evaluation. These processes are enhanced by metacognitive strategies, including the verbalization of thought processes, feedback, and discussion—interactions that involve both peers and the teacher (Castro-Martínez, 2008; Queiruga-Dios et al., 2016; Varela-Nieto & Martínez-Aznar, 1997). Therefore, it is crucial for teachers to consider the importance of each phase when designing activities. They should create spaces and allocate time for students to explain and justify the processes they followed in solving problems, as well as to analyze the solutions they found. This approach helps students understand which procedures led, or did not lead, to the correct answer (Calvo-Ballestero, 2008). In terms of academic performance, the instructional methods employed play a key role in the effective implementation of problem-solving in the classroom. Student attitudes are shaped by these methods, which, in turn, influence the development and improvement of problem-solving skills (Calvo-Ballestero, 2008; Gamboa-Araya & Moreira-Mora, 2016). In the context of science education in the classroom, it is essential to incorporate the strategies and processes employed by scientific teams to address real-world problems (Diez-Ojeda et al., 2021; Meneses-Villagrá, 2018). Over the past several decades, the existing literature has advocated for problem-based learning as an effective methodology (Gunderson & Gunderson, 1957; Leinhardt, 1988; Nufus & Mursalin, 2020). This perspective aligns with the international guidelines provided by the National Council of Teachers of Mathematics (NCTM, 2000), which emphasize the significance of problem solving. Such tasks have the potential to offer intellectual challenges that enhance students' understanding and logical-mathematical development, with applications across all curriculum disciplines. Indeed, problem solving is a fundamental component of mathematics learning, serving both as an objective in its own right and as a methodological axis for the construction of mathematical knowledge. In addition to the field of physics, it is imperative to pose and solve problems across all school subjects. The processes involved in problem solving encompass fundamental skills that are characteristic of various domains, including reading, reflection, planning the resolution process, establishing strategies and procedures, and reviewing and modifying the plan as necessary. Furthermore, these processes include verifying the solution and effectively communicating the results. These skills are integral to the competency frameworks outlined in contemporary educational standards (Queiruga-Dios et al., 2021a). This notion is echoed in the foundational works of Pólya (1945) and Schoenfeld (1985), which remain relevant to this day.

Indeed, the recognition of problem solving as a fundamental competence that students must acquire is evidenced by international assessments such as TIMSS (Trends in International Mathematics and Science Study), which evaluates student performance in problem solving (https://timssandpirls.bc.edu/timss-landing.html). These assessments aim to determine whether students possess the competencies associated with 21st century skills: Creativity, collaboration, communication, and critical thinking. These cognitive skills are essential for effective problem solving and are vital for lifelong learning (Queiruga-Dios et al., 2021a). Notably, the latest edition of TIMSS 2019 (Martin et al., 2020) introduced new specific problem-solving and inquiry tasks, referred to as PSI (Problem-Solving and Inquiry tasks). These mathematics and science tasks simulate real-world situations, enabling students to integrate and apply their skills and knowledge to solve mathematical problems and conduct small scientific investigations and experiments. Results from PISA (OECD, 2019) and TIMSS (Martin et al., 2020) reports underscore the necessity of enhancing and strategically developing broad and sophisticated thinking and reasoning skills. Such skills are crucial for improving the mathematical literacy of 21st century students in both primary and secondary education.

From this perspective, our research will concentrate on the task of solving school-related problems, both as a methodology and as content. This approach provides a unique environment for learning, where experiments and observations can be conducted, enhanced using technological tools.

Conversely, this educational approach is expected to contribute to addressing the decline in STEM vocations that society has been experiencing in recent years, a trend that is particularly pronounced among girls, who often exhibit limited interest in pursuing scientific and technological studies (Benavent et al., 2020; López-Iñesta et al., 2020a; Rocard et al., 2007). It is also important to recognize that approximately one-third of higher education students discontinue their studies in science and technology before completion. Moreover, academic performance during earlier educational stages correlates with retention rates, meaning that students' success in school is linked to their likelihood of persisting in university studies (Botella et al., 2019). Although this issue is not new, it remains a significant concern due to its implications for both national and transnational higher education programs (Larsen et al., 2013; Ulriksen et al., 2015).

In the field of physics, the existing gender gap in scientific and technological studies is more pronounced compared to other disciplines, both at the university level and in pre-university education. According to the UNESCO report Cracking the Code: Girls' and Women's Education in Science, Technology, Engineering, and Mathematics (STEM) (Bokova, 2018), engagement in STEM subjects among 10- to 11-year-olds is relatively balanced, with 75% of boys and 72% of girls expressing interest. However, by the age of 18, this interest declines significantly, with only 33% of boys and 19% of girls remaining engaged in STEM fields. This trend indicates a marked decrease in interest among females in pursuing studies in STEM disciplines. In higher education, the gap in enrollment in degrees related to engineering, technology, construction, and information technology widens for men while decreasing for women, with current figures indicating 72% for men compared to 28% for women. A review of the literature on the gender gap in STEM disciplines (Barone & Assirelli, 2020; Redmond & Gutke, 2020; Weeden et al., 2020) identifies several factors contributing to this disparity. One significant factor is the difference in academic performance between women and men in science and mathematics during the years leading up to university. The theory of rational choice (Stearns et al., 2020) posits that individuals are inclined to select educational paths that enhance their likelihood of success, which may explain why women often gravitate toward arts and humanities programs, where they tend to achieve higher grades. Nevertheless, this gender gap can be mitigated as the performance of both boys and girls improves through the implementation of interactive teaching and learning methods that promote collaboration and emphasize conceptual understanding (Labudde et al., 2000; Lorenzo et al., 2006).

Despite the lack of differences between boys and girls in terms of mathematical reasoning (Hutchison et al., 2019), a range of family and social factors contribute to the reinforcement of gender roles and stereotypes, which significantly affect self-perception and self-confidence in their abilities from the age of six (Bian et al., 2017). One possible explanation is that teachers, influenced by their own beliefs regarding gender differences in mathematics, may unconsciously make decisions that affect the participation of girls and boys in the classroom. This can result in differentiated instructional approaches based on gender (Espinoza & Taut, 2016; Keller, 2001). The lower participation rates of girls can lead to diminished expectations concerning their interest, motivation, and learning outcomes. Notably, this trend is consistent regardless of the students' age, ethnic background, socioeconomic status, the subject matter, or the country of study (Espinoza & Taut, 2016; Kelly, 1988).

Furthermore, OECD studies (2009, 2015) indicate that, on average, girls experience higher levels of anxiety and frustration in mathematical tasks compared to their male peers. They tend to exhibit lower perseverance, are less likely to solve mathematical problems, and often feel less motivated to learn mathematics (OECD, 2014). This situation of gender inequality adversely impacts the interests of girls and adolescents in scientific and technological subjects, including mathematics and science, as well as their choice of future studies in STEM fields. This phenomenon has been documented by various authors, including López-Iñesta et al. (2020a), Botella et al. (2019), Correll (2001), Eccles et al. (1983), Wigfield and Eccles (2000), and Sáiz-Manzanares et al. (2020). Furthermore, several studies have suggested that the higher levels of anxiety and frustration experienced by girls in mathematical contexts may not reflect a genuine lack of interest in science and mathematics. This may be due to a response to emotional and sociocultural factors that shape their academic self-concept. This emotional discomfort often leads girls to avoid situations that trigger stress or feelings of failure, such as tasks with a strong mathematical component. As a result, girls may orient their careers towards areas of science perceived as less mathematically demanding, such as life sciences and natural sciences. From this perspective, lower participation of girls in STEM fields should not be interpreted as a lack of interest in science, but rather as a consequence of affective factors and gender socialization processes that reinforce stereotypes about mathematical ability and success. Taking this situation into account is essential for designing educational strategies that reduce math anxiety and promote equitable participation in all scientific domains (Boateng et al., 2025; Eidlin-Levy et al., 2023; Lunardon et al., 2022).

Research Objectives

The objectives of this research are as follows:

1) To analyze the academic performance of Secondary Education students in the teaching-learning processes of physics through the implementation of a problem-solving program that employs technological tools within an integrative STEM approach.
2) To determine whether there are gender differences in the academic performance of students following their participation in the designed teaching-learning program.

METHODOLOGY

Participants

The study sample consisted of 35 students, including 12 boys and 23 girls, aged between 14 and 16 years, all in the third year of Secondary Education at an educational center located in the downtown area of a city in northern Spain. The families of these students were of medium-high socioeconomic status. The study was carried out in a course divided into two pre-established lines (A and B) defined by the school organization, so the group assignment was not random: The students were divided into two classrooms or groups: Group A, comprising 17 students (6 boys and 11 girls), and Group B, consisting of 18 students (6 boys and 12 girls). Group A exhibited better academic performance and more favorable behavior during classes compared to Group B. Each group participated in six identical educational interventions, delivered by the same instructor, over a period of three weeks Six educational interventions were conducted with each group.

Instruments

A quasi-experimental design was employed, incorporating pretest and posttest measures within the groups (Campbell & Stanley, 1995). To evaluate the academic performance of the students, a questionnaire comprising 20 multiple-choice questions on physics content was developed. This questionnaire was created by faculty members from the School's Science Department and subsequently reviewed by a panel of experts from the university. The questionnaire was designed based on well-established tools that assess students' mastery of specific concepts: The Test of Understanding Graphs in Kinematics for High School (Beichner, 1994), the Force Concept Inventory (Halloun et al., 1995), the Force and Motion Conceptual Evaluation (Thornton & Sokoloff, 1998), and the Energy Concept Assessment (Ding et al., 2013); and the pretest and posttest were administered three weeks apart to allow for assessment of academic performance.

A Physics Activities Program with a STEM focus was designed for instruction. The activities and problems that students engaged with were contextualized in real-world situations (see **Figure 1**). The physics and mathematics content covered included:

- Understanding the differences between position, trajectory, and displacement of a body.
- Distinguishing between average and instantaneous speed.
- Familiarity with the equations and graphs of rectilinear motion.

Figure 1. Students apply the physics activities program with a STEM approach in real contexts (Source: Field study)

- Analyzing and understanding rectilinear movements.
- Recognizing that forces are responsible for the movement of bodies.

Data Analysis

This research follows a quasi-experimental design. Data analysis for questions was conducted using the SPSS v.24 statistical package. The Alpha coefficient was .6431, indicating acceptable internal consistency for early-stage research or exploratory studies (Nunnally, 1975).

Process

Consent was obtained from the Management of the Educational Center where the study was conducted. Additionally, all participants and their families were informed about the objectives of the study, and their consent was sought. The selection of students for the sample was conducted using a convenience sampling method.

The physics content and teaching activities were structured to be addressed over six sessions. Some activities were designed for group work, while others were intended for individual tasks. A brief description of the activities conducted, and their objectives is provided in **Table 1**. In both the first and last sessions,

Table 1. Brief description of the activities

Activity	Brief activity description
1. *Kahoot!*	Questionnaire: This is a pre-assessment questionnaire designed to gauge students' prior knowledge of kinematics concepts and to identify their existing ideas. The students' responses will be analyzed and discussed.
2. Construction of graphs of movement	Construction of the Concepts of Velocity and Acceleration: This involves developing a comprehensive understanding of the definitions and differences between velocity and acceleration. Data Collection and Graph Representation and Analysis: Students will engage in gathering relevant data, followed by representing this data graphically and conducting a thorough analysis of the resulting graphs. Results Analysis: This step focuses on interpreting the findings derived from the data analysis to draw meaningful conclusions related to the concepts of velocity and acceleration.
3. Troubleshooting with the Smartphone	This activity is conducted in groups of four students who utilize the Physics Toolbox Sensor Suite app (https://bit.ly/3cXGhuY) and Video Tracker (https://physlets.org/tracker/). The students simulate various movements as follows: **Student 1:** a) Travels a distance of 40 meters in the yard at a constant speed, with markers placed every 5 meters. This experiment is repeated three times to ensure consistency. b) Attempts to cover the same distance while gradually increasing speed. **Students 2 and 3:** Measure the time it takes for Student 1 to travel the full 40 meters, as well as the times recorded at each 5-meter marker. Using this data, they will calculate the average speed for each interval, as well as the overall average speed for the entire distance. **Student 4:** Videotapes the movements of Student 1 during each experiment, ensuring the camera remains in a fixed position throughout the recordings.
4. Virtual Laboratory of educastur (García-González, 2020)	One of the objectives of this activity is to enable students to compare actual data collection (as outlined in Activity 2) with data obtained from simulations. Students will gather data and utilize Excel for analysis to identify differences between uniform and accelerated movements. This virtual laboratory can be accessed at: https://fisquiweb.es/Laboratorio/Cinematica/LabCinematica.htm.
5. Oral presentation using PowerPoint	Students will prepare and deliver an oral presentation utilizing PowerPoint to effectively communicate their findings from the physics activities. This presentation will require them to synthesize their understanding of kinematic concepts, demonstrate their analytical skills, and engage their audience. Emphasis will be placed on clarity, organization, and the effective use of visual aids to enhance comprehension. Students will also have the opportunity to answer questions from their peers and the teacher, fostering a collaborative learning environment.
6. QR codes	Reinforcement, extension, and additional activities designed to promote reading and transversal skills were created. Students could access these activities using their mobile devices. These tasks are intended for students to complete independently and then discuss with the teacher. Some activities include texts that contextualize kinematic concepts within real-world scenarios. These resources can be downloaded at the following link: http://bit.ly/2ROGo41.

Figure 2. Students employed various integrated technological tools to complete the activities, including Kahoot! and virtual laboratories (Source: Authors' own elaboration)

Table 2. Mean and standard deviations of the questionnaire (20-item test) score by group and gender

	Pre-test			Post-test		Difference	
	n	M	SD	M	SD	M	SD
A Group	17	10.59	4.66	12.64	4.33	2.06	2.93
Girls	11	9.36	4.97	11.64	4.57	2.27	3.20
Boys	6	12.83	3.31	14.50	3.45	1.67	2.58
B Group	18	9.17	2.87	12.77	3.52	3.61	3.52
Girls	12	9.0	3.25	12.50	2.35	3.50	2.88
Boys	6	9.5	2.17	13.33	5.43	3.83	4.88

students completed the pretest and posttest evaluation questionnaire to assess their understanding of the content through the resolution of problem-solving situations.

The students utilized the following integrated technologies during the teaching-learning activities:

- Smartphone: Used for recording videos of movements, capturing images for final report preparation, operating a stopwatch, reading QR codes, and utilizing Kahoot! (see **Figure 2**).
- Physics Toolbox Suite: A smartphone application that enables users to determine the acceleration and speed experienced by the device.
- Video Tracker: A program that facilitates data collection on the movement of an object based on video recordings.
- Virtual Laboratory: A platform for studying motion (García-González, 2020).
- Additional Equipment: Includes a PC, Excel, and QR codes.

RESULTS

Following the administration of the physics content questionnaire, a comparison of the pre-test and post-test results enables an analysis of student performance after the educational intervention. **Table 2** presents a brief descriptive analysis of the data, including the pre-test, post-test, and the differences between the two.

The results of the pre-test indicate that the initial conditions of the groups differ by more than one point, with Group A achieving a higher score than Group B. The post-test results indicate that both groups have demonstrated improved performance, with Group B showing a slight enhancement compared to Group A. However, it is noteworthy that Group B has improved its performance on the questionnaire by a mean of more than 3 points. **Figure 3** graphically illustrates several patterns identified in **Table 2**: It shows that, in Group B, boys and girls start with similar performance levels in the pre-test, whereas, in Group A, boys demonstrate superior performance compared to girls. Regarding the girls, Group B demonstrates a greater improvement compared to Group A.

An important aspect to consider is whether the initial levels of the participants regarding problem-solving abilities are truly comparable. To evaluate this, an independent samples t-test was conducted on the pre-test results, taking into account both gender and the students' group affiliation (A or B). Given the sample size, a non-parametric Wilcoxon test was conducted. The statistical analysis revealed no significant initial differences in participants' performance based on group affiliation ($W = 182$, $p = .3447$), nor were there statistically significant differences based on gender ($W = 180.5$, $p = .1426$).

Once the initial conditions were deemed comparable, the study assessed whether there was a gain between the post-test and pre-test scores. The analysis indicated that the gain scores for Group A were not significantly different from those of Group B ($W = 119.5$, $p = .272$). Consequently, it is not possible to reject the null hypothesis, which posits that training using the Physics

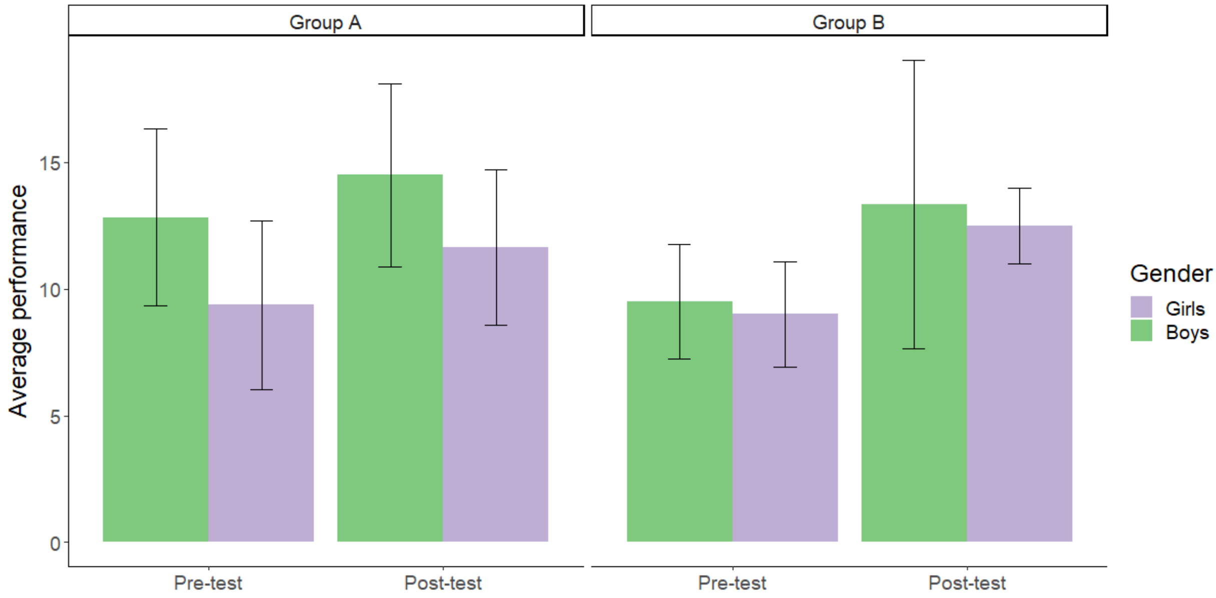

Figure 3. Mean performance on the questionnaire in pre-test and post-test by gender and group (Source: Authors' own elaboration)

Activities Program with a STEM approach does not lead to higher performance outcomes between the groups. Regarding the results related to the gender variable, the analysis yielded non-statistically significant results (W = 142.5, p = .8885).

When examining the gain scores for girls, Group A had a mean of M = 2.27 (SD = 3.20) and Group B had a mean of M = 3.50 (SD = 2.88); however, the results were not statistically significant (W = 56, p = .5551). For boys, Group A had a mean of M = 1.67 (SD = 2.58) and Group B had a mean of M = 3.83 (SD = 4.88), with similarly non-significant results (W = 12, p =.3717).

To complement the previous results, the students' responses to the questionnaire were analyzed. Based on the number of correct and incorrect answers in both the pre-test and post-test, a new classification of student performance was established: 80% of the students demonstrated improved academic performance following the educational intervention, while 14.29% experienced a decline, and 5.71% showed no change. By applying this new classification within each group, it was found that, although both groups exhibited noticeable improvement, Group B (88.89%) outperformed Group A (70.59%) by a margin of 18.3 points (**Figure 4**).

The performance analysis based on the gender variable is illustrated in **Figure 5**. The results indicate a significant improvement in academic performance for girls (81.8%) compared to boys (75%).

DISCUSSION

The limitations of this study include the sample size and its geographical constraints, which suggest that the conclusions should be regarded as exploratory. Nevertheless, the study could serve as a foundation for future research. Additionally, it may serve as a reference for other researchers and STEM educators.

Measuring academic performance through a questionnaire on physics content reveals that Group B begins with a disadvantage in this area. After instruction in physics using problem-solving techniques within a STEM framework, although Group B ultimately achieves a lower final performance than Group A, the difference in pre-test and post-test scores is greater for Group B. However, despite this notable difference, it was found not to be statistically significant. Furthermore, an analysis of the correct and incorrect responses indicates an 18.3-point difference in favor of Group B compared to Group A. Additionally, when examining the gender variable, there is an observable difference of nearly 7 points in favor of girls compared to boys based on the number of correct and incorrect answers.

Consistent with findings from previous studies (Madsen et al., 2013), the girls initially scored significantly lower than the boys. However, following the intervention, their performance levels were not significantly different from those of boys. This outcome aligns with other studies where science learning was enhanced through problem-solving approaches, utilizing diverse activities supported by technological tools or STEAM (Science, Technology, Engineering, Art, and Mathematics) methodologies. In these studies, students collaborated to solve problems through the integration of Technology and Art (Labudde et al., 2000; Queiruga-Dios et al., 2021a, 2021b; 2021c; Tveita, 1999). When the problems are further contextualized within real scenarios, student performance improves significantly.

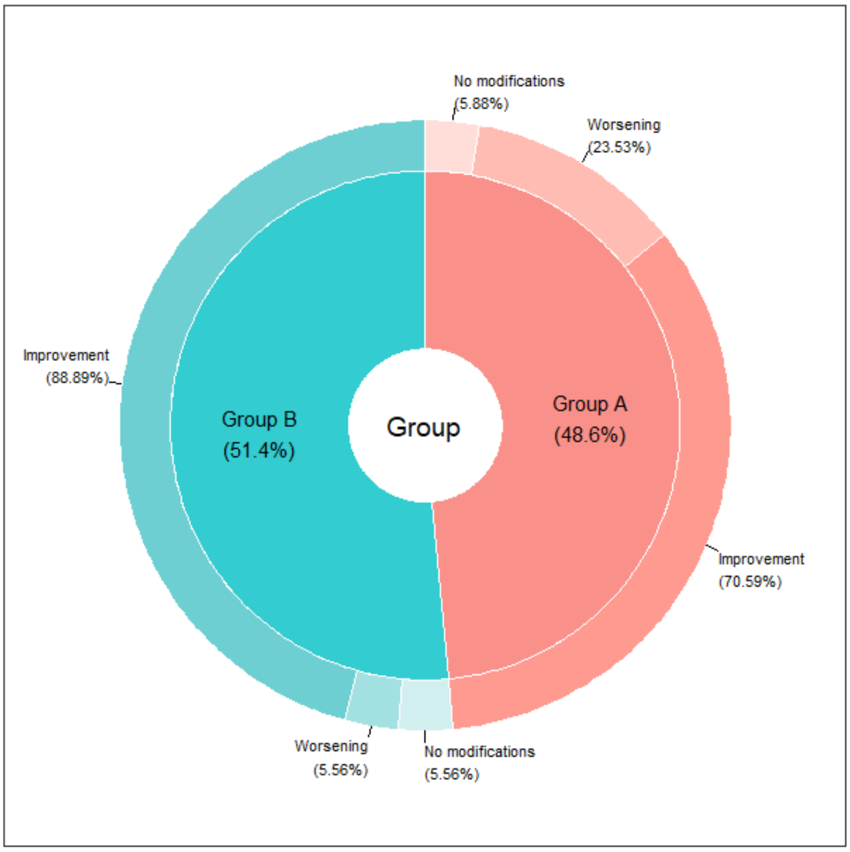

Figure 4. Performance classification based on the number of correct and incorrect answers (right: Group A, left: Group B) (Source: Authors' own elaboration)

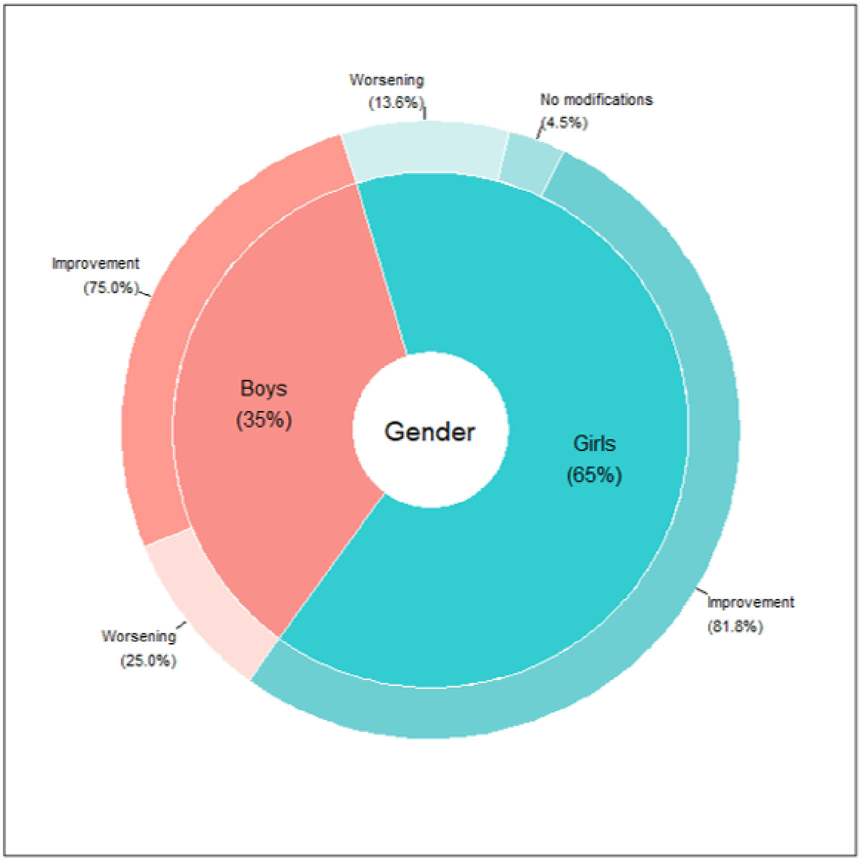

Figure 5. Student performance by gender (Source: Authors' own elaboration)

In PISA science assessment, girls outperform boys on average across OECD countries (by two score points). However, this pattern is reversed in Spain, where boys outperform girls by a similar margin, and the average science performance of both genders shows a downward trend compared to previous assessment cycles. Despite this decline, boys tend to be overrepresented at both the highest and lowest proficiency levels while girls are more concentrated at intermediate levels (MEFP, 2020; OECD, 2019). On the contrary, in the present study, carried out in a contextualized and integrative STEM framework, no significant differences were found between girls and boys in academic performance ($W = 142.5$, $p = .8885$). This suggests that with this instructional approach both genders achieved comparable learning outcomes, which differs from the general gender patterns reported in large-scale assessments such as PISA.

It can be summarized that the implementation of active methodologies, such as problem-solving (Castro-Martínez, 2008; Queiruga-Dios et al., 2016; Varela-Nieto & Martínez-Aznar, 1997), alongside the integration of digital and technological tools within a STEM framework (Aldon et al., 2017; Queiruga-Dios et al., 2018, 2019a, 2021b; Viloria et al., 2018), enhances the academic performance of all students in physics. This improvement is particularly notable among girls and students with lower academic achievement. Although gender is often viewed as an important factor influencing students' engagement in scientific and technological fields, research shows no inherent differences in ability between girls and boys. Women, however, remain the most under-represented group in STEM (particularly in physics, mathematics, computer science, and engineering) and this imbalance often begins in early schooling. In this study, no significant gender differences were found in students' post-test performance, suggesting that the contextualized STEM-based approach may contribute to fostering greater gender equity in science learning (Allegrini, 2015; Rodríguez-Mantilla et al., 2018; Botella et al., 2019).

In future investigations, it is recommended to increase the sample size and develop content specifically tailored to the physics curriculum. This would allow for systematic implementation across various educational levels, which is likely to enhance academic performance in the subject of physics.

CONCLUSIONS

The authors stress the need to re-evaluate didactic approaches in physics education, advocating for more accessible methods that align with the explicit recommendations of educational curricula. These approaches are crucial in addressing the diverse needs of students, including gender diversity, fostering a more inclusive learning environment. The integration of active methodologies and technologies in secondary-level physics education has been shown to enhance academic performance. In this research, the contextualized and comprehensive STEM approach enabled girls to achieve average scores comparable to those of boys, particularly benefiting students with lower academic levels. These reflections highlight the importance of designing STEM experiences that encourage cognitive participation but also address emotional aspects. Considering these dimensions in educational practice can contribute to reducing gender gaps and promoting more equitable participation in STEM disciplines. Thus, it is suggested that inclusive contexts be designed to foster confidence, perseverance, and interest in scientific and technological fields. The findings highlight the potential of inclusive, context-driven STEM learning environments to promote equity and engagement among all students, reinforcing the importance of teacher training initiatives that integrate gender-sensitive perspectives into science education.

Final Considerations

Both the literature reviewed and the results from TIMMS and PISA assessments indicate that gender differences exist in the patterns of solving verbal arithmetic problems and mathematical problems more broadly. These differences have significant implications for achieving academic objectives and may impact the long-term personal and professional futures of both girls and boys (Benavent et al., 2020; Botella et al., 2019; Duflo, 2012; López-Iñesta et al., 2020b). Furthermore, it is essential to recognize that the overarching goal of education is to cultivate a proactive, motivated, and independent citizenry capable of facing and overcoming ongoing challenges (Queiruga-Dios et al., 2021c). Problem-based teaching serves as an effective strategy for developing 21st century skills, offering students meaningful real-world, cross-curricular experiences. This approach enables students to navigate challenging situations that may impede their progress, requiring them to employ critical thinking in decision-making.

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