International Journal of Engineering Education Vol. 40, No. 2, pp. 358–367, 2024
Printed in Great Britain

0949-149X/91 $3.00+0.00

Assessment of Engineering Undergraduates Active Learning Experience using Computer Simulations*

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This study explores the pedagogical approach in the first-year Applied Physics course of Engineering degrees at the University of A Coruña. Employing a comprehensive strategy, educators developed simulations to address student weaknesses identified in pre-tests. The research aims to bridge gaps by outlining objectives, elucidating methodology, and presenting tools used. Utilizing a quasi-experimental design over eight academic years, the investigation incorporates computer simulations, pre-tests, post-tests, and final exams. The primary objective is to improve engineering education through innovative methods, focusing on core principles like friction, thermodynamics, fluid rotation, and electromagnetic forces. Outcomes are showcased through various assessments, including general satisfaction surveys and specific questionnaires. Emphasizing distinctiveness, marked by inventive pedagogy, rigorous data analysis, and a sustained cohort study, the study contributes to ongoing discussions on engineering education enhancement. Ultimately, it empowers students for practical applications.

Keywords: active learning; engineering; easy Java simulations; computer simulations

1. Introduction

Applied Physics holds a paramount position in engineering education [1], providing indispensable tools for future engineers to tackle intricate challenges. Recognizing the practical nature of engineering, particularly for students entering without a physics background, instructors employed a constructivist approach, drawing from a review of pedagogical literature [2–6], and specifically adopting Ausubel's perspective [7] on meaningful learning. This approach emphasizes the integration of new concepts with existing mental structures. Active learning engages students in manipulating concepts through computer-based simulations, prioritizing comprehension over memorization [2–6]. Meaningful learning, facilitated by logical connections and practical application, enhances autonomy and problem-solving skills. Computer simulations play a pivotal role, enabling students to interact with abstract concepts visually and practically. The study assesses the method's validity by analyzing the pass percentage in the final exam, comparing a control group with traditional teaching to an experimental group using the new methodology in civil engineering degrees at the University of A Coruña. The evaluation spans cohorts from 2010–11 to 2017–18, acknowledging adjustments in the method due to teacher changes and the impact of COVID-19 from the 2017–18 cohort onward [2–8].

2. Literature Review

According to Senthamarai [9], active learning enables students to acquire scientific truths and applicable knowledge. This methodology fosters a critical stance towards the taught content during engineering training, providing future engineers with valuable skills. Active learning has demonstrated its effectiveness in promoting meaningful and enduring learning compared to traditional methods [10]. It enhances the ability to reflect on the studied phenomena, engaging students in the learning process and transforming them from passive recipients into active participants.

Numerous active learning techniques can be incorporated into the classroom setting, including the following ones [11]:

Project-based learning involves students applying their existing knowledge to develop a project.

Cooperative-based learning entails group activities with three or more students, utilizing various methods such as multiple-choice exercises, projects, and presentations.

Team-based learning begins with individual assessments, followed by collaborative problem-solving.

Competency-based learning focuses on students demonstrating mastery of knowledge and skills throughout their educational journey. Challenge-based learning engages students in real-

* Accepted 24 January 2024.

world scenarios, emphasizing knowledge acquisition and problem-solving.

Problem-based learning has students analyze real-world issues in small groups, drawing on existing knowledge, followed by individual responses and collaborative solutions.

Interesting teaching experiments in technological areas utilize active learning techniques. Olewe et al. [12] conducted a study comparing blended learning to face-to-face teaching in QBasic programming for university students in Nigeria. The research revealed that blended learning positively influenced academic knowledge retention. Another study in Nigeria assessed an innovative approach to teaching computer programming, combining context-based and problem-based learning with live online tools like Google Classroom and Google Meet. The results indicated significant improvement in academic achievement, programming skills, digital skills, and self-efficacy in the experimental group compared to the control group. This quasi-experimental study involved 152 second-year computer education students at Universities in South-Eastern Nigeria [13].

Encouraging students' active participation in the learning process is linked to increased study time, with a proven 40% improvement in grades for those who dedicate more time to study and reflection [14]. Ornek et al. [15] support a similar conclusion without specifying the percentage of extra study. Smigiel and Sonntag [16] attribute high failure rates in French engineering schools to a focus on mathematical formalism rather than the conceptual aspect of physics. Angell et al. [17] highlight students' interest in physics but suggest a need for greater emphasis on qualitative/conceptual approaches and student-centered instruction. Joel Michael [18] identifies misconceptions in Newtonian motion and supports Hestenes' force concept inventory [19] for evaluating the conceptual part of physics. Meltzer and Thornton [20] advocate for computer simulations in active learning, citing their advantage over real laboratory practices in eliminating discrepancies between expected and obtained results. Baser [21] uses open-source software for DC circuit simulations, reporting significant improvement in test results. Steinberg [22] notes the continued relevance of computer simulations in physics teaching, despite finding no significant difference in learning outcomes between simulation and traditional methods for studying air resistance. E-learning is identified as a means to enhance critical thinking [23]. Apkarian et al. [24] analyze factors influencing active learning adoption among STEM course instructors, revealing that class size, traditional fixed-seat classrooms, emphasis on evaluation over teaching effectiveness, and high research productivity can impede active learning use. Interestingly, an instructor's job security does not exhibit a clear relationship with active learning methodology adoption.

3. Methodology

3.1 Design of the Study

This research adopts a quasi-experimental design methodology due to the inability to select study groups of students. The University of A Corunna's civil engineering faculty offers two similar degrees: civil engineering technology and public works engineering, both with a 12 European Credit Transfer System (ECTS) in applied physics and identical academic programs. Students independently choose their degree without researcher intervention. The public works engineering degree serves as the control group, while the civil engineering technology degree serves as the experimental group. Gender was not a consideration in the study due to significantly lower female representation compared to males in each cohort.

3.2 Participants

Ethical statement: This study was carried out in accordance with our ethical policy.

Implemented over eight academic years in the subject of Applied Physics for the first year of the degree, this study constitutes a cohort study with a total of 1,411 participants, as indicated in Table 1. First-year engineering students are admitted from high school after completing the generic University entrance exam, which is not explicitly tailored for engineering or science students. The enrollment demand for civil engineering studies experienced a substantial decline due to the European construction crisis, notably impacting Spain. Consequently, the entry requirements for these studies were significantly reduced, particularly in the 2015–2016 academic year.

Table 1. Participants in each cohort

Cohort	Experimental Group	Control Group	Total Participants
2010–11	111	118	229
2011–12	135	137	272
2012–13	113	111	224
2013–14	101	104	205
2014–15	74	77	151
2015–16	61	60	121
2016–17	58	47	105
2017–18	50	54	104
			1,411

3.3 *Material and Procedure*

The study utilized computer simulations (CS), a pre-test (T0), post-test (Tf), final exam (FE), a general satisfaction survey (Gs), and a specific questionnaire (Sq). The method unfolded in the following steps: Step 1 involved conducting a pre-test (T0) to assess prior knowledge and pre-existing ideas. Step 2 consisted of implementing computer simulations (CS) in groups of two students. Step 3 encompassed administering a post-test (Tf) to gauge the knowledge acquired by the students. Step 4 involved a final exam (FE), identical for both control and experimental groups. Following Step 4, a general satisfaction survey on the subject was given to both groups, and an additional satisfaction questionnaire focusing on computer simulations was administered exclusively to the experimental group. Notably, this methodology did not replace hands-on laboratory practices. Both the control and experimental groups undertook the same laboratory exercises. Importantly, students in neither group were informed about their involvement in pedagogical research.

3.3.1 *Pre-test (P0) and Post-test (Pf)*

Both P0 and Pf comprised forty items with five options each, and participants were allotted an hour and a quarter for each test. These assessments aimed to evaluate the application and analysis of fundamental physics concepts for engineers, aligning with Bloom's taxonomy. The reliability of both P0 and Pf was assessed using Cronbach's alpha, resulting in values of 0.82 and 0.80, respectively. These values, in both cases, are deemed sufficient to affirm the reliability of the tests.

3.3.2 *General Satisfaction Survey (Gs) and a Specific Questionnaire (Sq).*

The researchers crafted surveys to assess student satisfaction with both the proposed methodology and the traditional approach. The Gs survey focused on three key teaching dimensions (didactic methodology, evaluation, and tutoring), incorporating similar items to compare the perspectives of the two groups. These questionnaires aimed to gather subjective perceptions and evaluations of various aspects of university teaching relevant to the study's objective. The survey scale ranges from 1 to 7, where 1 denotes complete disagreement and 7 signifies complete agreement. The "don't know" (DK) option is also provided. Specific questions, such as Question 14 evaluating the teacher's enthusiasm, Question 18 assessing clarity of expectations, Question 22 exploring alignment of assessments with course content, and Question 24 delving into overall teacher satisfaction, contribute to the comprehensive assessment. The remaining questions evaluated internal aspects of the institution and are not pertinent to the present study.

3.3.3 *Specific Questionnaire (Sq)*

To assess students' satisfaction with the four proposed simulations, a specific questionnaire was created using GoogleDocs, a tool developed by Google for free online word processing. Integrated with GoogleDrive since 2012, GoogleDocs enhances performance. The questionnaire utilized a 1 to 5 scale, with 1 indicating very difficult and 5 signifying very easy. Question 1 prompted students to identify their group based on the initial of their last name (group 1: A to L; group 2: M to Z). Subsequent questions evaluated the difficulty of using the simulation (question 2), the difficulty of the tests (question 3), the extent to which the simulation aided understanding of the studied phenomenon (question 4), and the overall rating for the simulation (question 5).

3.3.4 *Final Exam (FE)*

In both the civil engineering technology and public works degrees, students' grades are reliant on the final exam outcome. Consequently, the efficacy of the experimental teaching method will be assessed based on students' performance in this concluding examination. The exam, structured according to established guidelines, encompasses both theoretical questions and numerical problems spanning the entire subject program. Importantly, the exam content is uniform for both groups.

3.3.5 *Computer Simulations*

The Applied Physics course in Civil Engineering addresses identified student difficulties by incorporating four selected models into the curriculum. These models specifically target challenging subjects, serving as strategic tools to overcome obstacles and enhance learning in these areas. Moreover, the integration of these models with practical applications in civil engineering aims to strengthen the understanding of theoretical concepts for future professional use. To facilitate simulations for the experimental group, the faculty organized two subgroups based on the first letter of students' surnames – group 1 (A to L) and group 2 (M to Z). All simulations utilized Easy Java Simulations (EJS) software, known for its simplified conceptual framework and user-friendly visual tools. EJS's dynamic and interactive interface minimizes programming requirements [25]. The simulations covered frictional force on an inclined plane, an ideal thermodynamic cycle, fluid rotation, and the Lorentz force experienced by an electric charge.

3.3.6 Frictional Force in an Inclined Plane

The first-year engineering curriculum introduces challenges related to understanding Newton's laws, particularly in solving problems involving friction force and its dependence on the incline angle. To enhance learning, a simulation allows students to modify key parameters, including the inclination angle (ranging from 10° to 60°), materials for wheels and the plane (each with unique friction coefficients), and the initial position of the mobile. However, students cannot alter the mass of the mobile or the acceleration due to gravity.

This practical simulation offers students the opportunity to enhance their understanding of crucial concepts. They can explore the dependence of a body's speed and acceleration on the angle of an inclined plane in the absence of external forces. The minimum angles required for a body to commence descent, considering various coefficients of friction, can be studied. Additionally, students can calculate the final speed of a mobile by incorporating the inclination angle and the length of the inclined plane. A unique challenge involves identifying the constant parameter in the downward motion of a frictionless mobile, necessitating the placement of the mobile at different locations on the inclined plane.

The "Frictional force in an inclined plane" model provides a dynamic learning experience, allowing students to explore the impact of Newton's laws and friction in real-world scenarios. By altering parameters such as the incline angle and material coefficients, students gain insights into the effects on motion. It is crucial, however, to recognize certain limitations, including a fixed mass, simplified dimensions, and potential inaccuracies arising from omitted variables like air resistance. While the model serves as a valuable tool for conceptual exploration, its scope and precision are constrained by its simplified design and assumptions about prior foundational knowledge.

3.3.7 Ideal Thermodynamic Cycle (Carnot)

The Carnot cycle holds significance not only in engineering but also across various disciplines, serving as a foundational element for understanding entropy [26]. This simulation replicates the reversible processes inherent in a Carnot cycle, presenting a closed system with an adiabatic piston-cylinder device on the computer screen. Through manipulation of key variables such as gas type, cold bulb temperature, and temperature increase, the user can visualize the distinct stages of the cycle: reversible isothermal compression (A to B), reversible adiabatic compression (B to C), reversible isothermal expansion (C to D), and reversible adiabatic expansion (D to A). To ensure adherence to the Carnot cycle, the system alerts the user when introduced variables deviate from compatibility. The simulation prompts students with questions and tasks aimed at reinforcing their understanding of the Carnot cycle's principles. This set of tasks involves various aspects of the Carnot cycle, encompassing efficiency and area calculations, along with determining their respective units. The inquiry extends to whether the speed of a four-stroke engine correlates with the theoretical cycle, exploring the impact of the adiabatic coefficient on the formation of the Carnot cycle. Questions arise regarding the alteration of the "drawn" shape and reference states of the cycle. Further analysis delves into the Carnot cycle of both theoretical engines with very small and very large volumes, prompting reflection on the ease of identifying processes in each motor movement and the underlying reasons behind it.

The "Ideal thermodynamic cycle (Carnot)" model provides an interactive visualization of the reversible processes within the Carnot cycle, enhancing comprehension of thermodynamic concepts. Users can manipulate variables to observe the cycle's stages, aiding understanding of isothermal and adiabatic processes. However, the model's idealized assumptions might not fully represent real-world conditions, and its simplicity may limit in-depth exploration. While it offers valuable educational insights, its focus on the Carnot cycle's theoretical aspects could omit broader thermodynamic discussions.

3.3.8 Rotation of a Fluid

This activity aims to explore the relationship between the shape of a liquid's surface in a rotating container and its angular velocity. Developed in both 2D and 3D, the two-dimensional representation reveals the step-by-step generation of the curve based on initial conditions and fluid rotation. Additionally, it assesses whether, under specific conditions, the fluid exits the container. The cylindrical container rotates around its axis, with negligible consideration of surface tension effects. The resulting shape of the rotating liquid's surface is identified as a paraboloid of revolution, governed by equation (1).

$$z = z_0 + \frac{1}{2}\frac{wr^2}{g} \tag{1}$$

Where z_0 is the vertex of the paraboloid, w is the angular speed, g is the paraboloid radius and g the gravitational acceleration. Fig. 3 shows the conceptual scheme of the physical phenomenon to be simulated

Three possible cases can be studied depending on the sign of the vertex of the paraboloid: If $z_0 > 0$ the

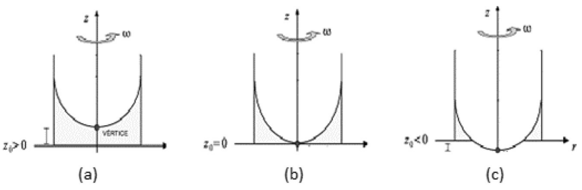

Fig. 1. Relative positions of the vertex of the paraboloid. (a) Vertex on the geometric axis of the container. (b) Vertex at the center of the base. (c) Vertex out of container.

vertex of the paraboloid is inside the container, this means that the entire base of the container is covered with liquid (Fig. 1a). If $z_0 = 0$ the vertex of the paraboloid is in the geometric center of the base, the rest of the container being covered with water (Fig. 1b) and finally, if $z_0 < 0$ the vertex of the paraboloid is located outside the paraboloid, therefore, part of the base of the container will not be covered with water (Fig. 1c).

In this exercise, students can modify key parameters including the radius (R) of the cylindrical container (ranging from 0 to 1 meter), the fluid height (h, ranging from 0 to 100%), and the angular speed of the container. This allows for an exploration of fluid dynamics under varying conditions within a rotating environment.

Through this practice, the student will be able to work on the following questions and asking the next questions:

Through this exercise, students engage with questions focusing on the behavior of a fluid in a rotating cylindrical container. They explore the maximum rotation speed to prevent overflow, draw the shapes of the paraboloid of revolution for specific container dimensions and rotation speed, and analyze forces acting on particles at the free surface. Questions delve into the fluid's surface shape during rotation, identifying points on the paraboloid unaffected by rotation speed. Additionally, students investigate variables influencing fluid overflow and the calculation of the paraboloid's vertex position under varying conditions.

The "Fluid Rotation" model visually demonstrates the impact of rotating parameters on the surface shape of a liquid within a container, providing students with an interactive learning experience. However, it simplifies the complexities of real-world fluid dynamics by omitting significant surface tension considerations and having a limited parameter range, compromising its accuracy for more realistic scenarios.

3.3.9 The Lorentz Force experienced by an Electric Charge

The Lorentz force, a fundamental concept in electromagnetism, is explored in this simulation, focusing on the movement of an electrically charged point particle (q) entering a space with a uniform magnetic field (B) at a velocity (v) [26]. The practice's design allows for adjustments in both the charge and mass of the particle, and the velocity vector's direction can be altered, offering insights into trajectory changes. The option to remove magnetic field lines between the N and S poles adds flexibility. This interactive exploration raises questions about the observed phenomena [26].

During the session, students delved into determining the radius of curvature for an electric charge with a known mass when its initial velocity is perpendicular to magnetic field lines. They were tasked with elucidating the movement of the electric charge based on the initial velocity and the angle it forms with the magnetic field lines.

The "Lorentz Force" model visually illustrates the impact of the Lorentz force on a charged particle navigating a magnetic field, facilitating the understanding of electromagnetism concepts. Students can manipulate particle charge, mass, and velocity direction to observe their effects on the particle's trajectory. However, the model's idealized conditions, simplified charge-mass interactions, limited dimensionality, and specific questioning may not fully capture real-world complexities or broader electromagnetism principles. While valuable for foundational understanding, its limitations should be considered when extrapolating insights to practical scenarios.

These four models are pivotal in engineering education, providing tangible insights into fundamental concepts. For example, the "Frictional force in an inclined plane" model explores friction and inclination effects on motion, relevant to surface engineering. The "Ideal thermodynamic cycle (Carnot)" model visualizes thermodynamic processes crucial in energy engineering. The "Rotation of a fluid" model examines parameters influencing fluid behavior in rotating machinery. The "Lorentz Force" model illustrates magnetic forces on moving charged particles, important for designing particle accelerators. These models enhance conceptual understanding and prepare students for practical challenges in engineering careers.

4. Results

4.1 Final Exam (FE)

Table 2 displays the pass percentages for the control and experimental groups in each academic year for the Applied Physics final exam. A preliminary examination reveals superior performance in the experimental group compared to the control group.

Table 3 reports the most representative statistics between both groups in the cohorts under study.

Table 2. Percentage of approved in Applied Physics per cohort

Percentage of students passing the course		
Academic year	**Control group**	**Experimental group**
2010–11	40.68	81.63
2011–12	36.94	77.88
2012–13	31.94	56.06
2013–14	39.53	61.40
2014–15	35.11	57.50
2015–16	38.89	52.78
2016–17	12.77	45.45
2017–18	29.03	42.31

These results were calculated using the SPSS program.

Fig. 2 depicts classic box and whisker plots, revealing significantly superior data obtained through the experimental method compared to the control group. The experimental group's median surpasses that of the control group by 20 percentage points. Additionally, the data in the control group exhibit lower dispersion than the experimental group, with interquartile ranges of 9.61 and 26.48, respectively. Notably, the control group's maximum value falls short at 41%, while the experimental group achieves a median close to 57%, reaching a maximum of 80% in the 2010–11 academic year.

To complete the statistical study a t-test has been carried out to evaluate whether the alternative hypothesis (the experimental method obtains better results than the control method) can be accepted. Considering the values shown in Table 4, where it is observed that the p-value is less than

Table 3. Comparative statistics between the control and experimental groups

		Group			
		Control		**Experimental**	
		Statistic	**Std Error**	**Statistic**	**Std Error**
Mean		33.111	3.2247	59.376	4.973
95% confidence interval for Mean	*Lower Bound*	25.486		47.6169	
	Upper Bound	40.736		71.1356	
5% Trimmed Mean		33.820		59.0881	
Median		36.025		56.7800	
Standard Deviation		9.12085		14.065	
Minimum		12.77		42.31	
Maximum		40.68		81.63	
Range		27.91		39.32	
Interquartile Range		9.61		26.48	
Skewness		–1.891	0.752	0.641	0.752
Kurtosis		3.909	1.481	–0.635	1.481

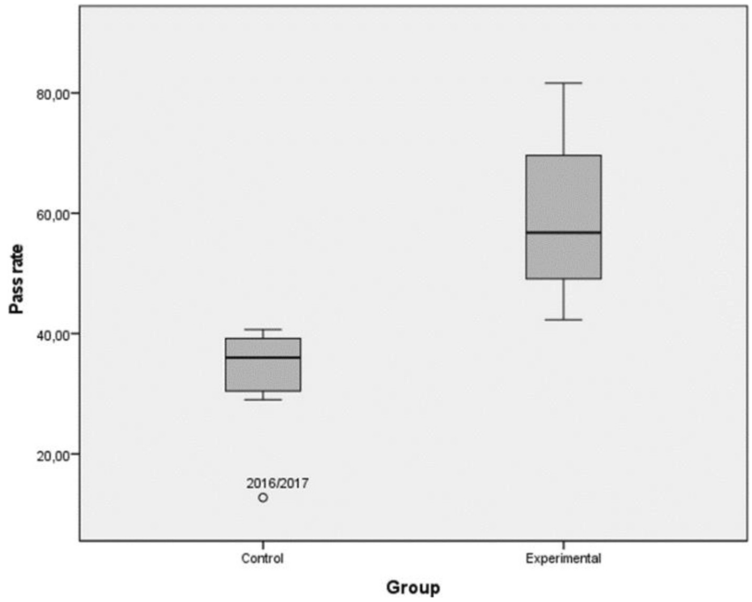

Fig. 2. box and whisker plots for the control and experimental groups.

Table 4. t-test results for the control and experimental group

		Levene's Test for Equality of Variances		**t-test for Equality of Means**						
									95% Confidence Interval of the Difference	
		F	***Sig.***	***t***	**Upper**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**	**Lower**	**Upper**
pass_rate	Equal variances assumed	1.427	0.252	–4.431	14	<0.001	–26.26500	5.92704	–38.97724	–13.552
	Equal variances not assumed			–4.431	12.002	<0.001	–26.26500	5.92704	–39.17864	–13.351

General Satisfaction Survey (GS).

0.001, the null hypothesis can be rejected and the alternative accepted

The efficacy of the method was evaluated by focusing on key questionnaire items, specifically questions 14, 18, 22, and 24. Question 14 gauges whether "The teacher appears enthusiastic and engaged in teaching," a factor deemed crucial for the method's success and its impact on student motivation. Question 18 assesses whether students have clarity on "What is expected of them in this subject?" Question 22 explores whether "The assessment aligns with the content covered in the course?" Lastly, question 24 delves into "What is the overall satisfaction with the teacher of this subject?" As depicted in Fig. 3, the results for these questions indicate satisfactory outcomes in both control and experimental groups, with a consistently positive trend in students' perception of the teacher's involvement. The lowest scores were noted in the 2012–13 cohort, where the control group scored 3.4 out of 7, and the experimental group scored 4.5 out of 7. It is essential to highlight that the remaining questions lack significance as they pertain to internal institutional matters.

Fig. 4 shows the results obtained for question 18 and 22 (*"Are you clear about what will be required of you in this subject?* "*Does the assessment adjust to the contents studied in the course*).

Fig. 5 shows the results of the global assessment (Q24) of teachers for both groups and cohorts

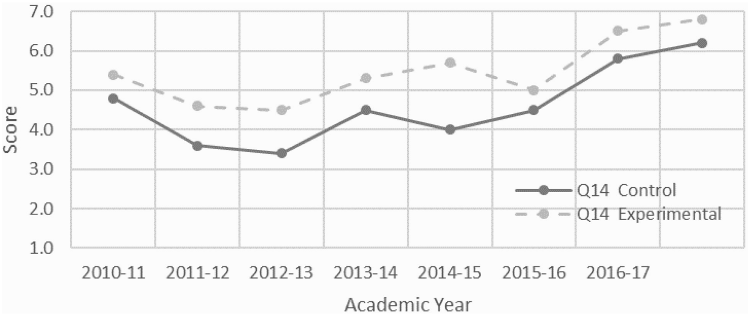

Fig. 3. Results of Q14 for the control and experimental group.

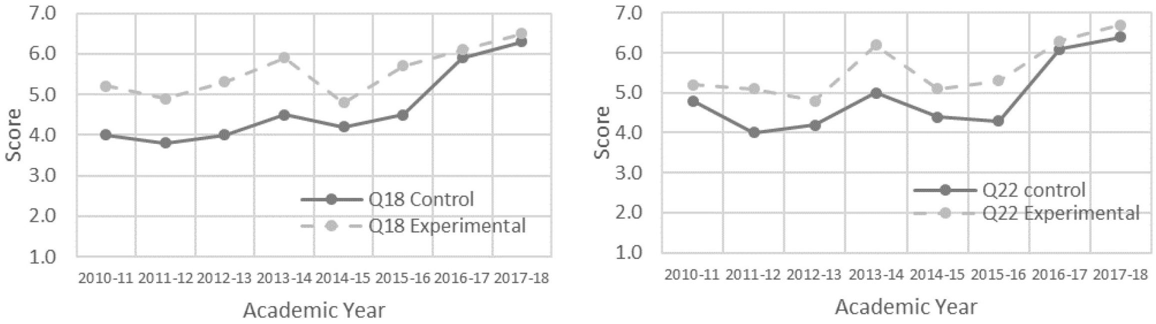

Fig. 4. Results of Q18 and Q22 for the control and experimental group.

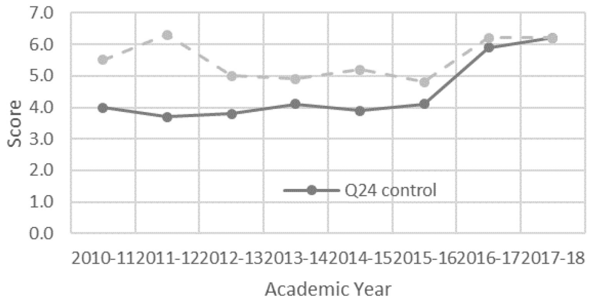

Fig. 5. Results of Q24 for the control and experimental group.

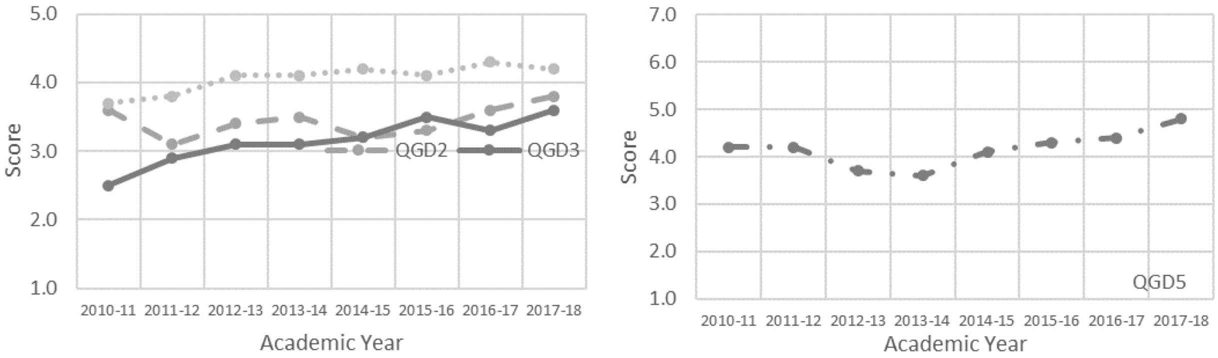

Fig. 6. Results of questions 2, 3 and 4 of the student survey on simulations and question 5.

studied. The results, as in the previous cases, are significantly higher in the experimental group than in the control group.

This is probably since more active learning by the student results in a better subjective impression of the teacher.

Regarding the percentage of participation in the general satisfaction survey (GS) across various cohorts, it is noteworthy that both the control and experimental groups consistently exhibit high participation rates. Analyzing the data, the control group's participation ranges from 59.3% in 2012–13 to a peak of 71.4% in 2014–15, while the experimental group demonstrates participation rates between 59.8% in 2017–18 and a high of 73.4% in 2014–15. These robust levels of participation underscore the reliability and relevance of the survey results over the specified cohorts, offering valuable insights into the dynamics of student satisfaction across different academic years.

4.2 Specific Questionnaire (Sq)

Question 2 (QGD2) assessed the difficulty of using the simulation, where 1 signifies very difficult and 5 signifies very easy. As observed, the scores hover around 3 out of 5. The last two academic years found them slightly easier than the preceding ones.

Question 3 (QGD3) pertains to the difficulty of the post-simulation test. Again, on a scale where 1 denotes very difficult and 5 very easy, an upward trend is evident across academic years. In essence, students perceive less difficulty in the exams. This trend is likely attributed to an improved adaptation to the teaching-learning method, both on the part of the teacher and the students. The results are shown in Fig. 6.

Question 4 (QGD4) asks about the help that the simulations have had in understanding the matter studied. In this case, 1 means "Strongly disagree" and 5 "Strongly Agree". As can be seen, in most of the academic courses the assessment exceeds 4. Therefore, most of the students consider the simulations useful in their teaching-learning process.

The participation rate in the specified survey has exhibited a consistent trend around 60% from the academic year 2010–2011 to 2017–2018. Notably, the highest level of engagement was recorded in the academic year 2014–2015, reaching 69.2%, while the lowest participation rate occurred in 2012–2013, registering 57.9%. These fluctuations indicate varying degrees of interest and responsiveness among students throughout different academic years, offering valuable insights into the dynamics of their survey participation over the specified period.

5. Discussion

The examination of Fig. 2 reveals a distinctive pattern in the control group, notably in the 2016–17 academic year, where the pass rate drops below

13%. Conversely, the experimental group faces its most challenging periods during the academic years 2016–17 and 2017–18. Despite both instances showing improved results compared to the control group, they are notably lower than those observed in other cohorts. The potential factors contributing to the subpar performance of these cohorts are intricate and not easily discernible. From our perspective, a plausible explanation could be the reduced admission standards for the academic years 2016–17 and 2017–18. The economic downturn during this period led to a significant decline in civil works contracts in Spain, subsequently diminishing the demand for studies related to construction and civil engineering. Consequently, the admission requirements for these programs were substantially lowered. Many students who enrolled in the civil engineering degree during this time had faced rejection from other programs with much higher admission standards. The lack of enthusiasm and motivation toward civil engineering studies was a prevalent observation among most instructors teaching this particular cohort. Fortunately, there are signs of a shift in this trend, though it is premature to draw definitive conclusions. Nonetheless, it is evident that the proposed methodology yields even more favorable results in such challenging situations.

The outcomes presented in Fig. 3 stem from the subjective perceptions of the students, making it challenging to pinpoint the exact reasons behind these results. Nevertheless, following a slight recalibration of our annual plans, with a heightened emphasis on the empathic aspects of our teaching approach, we observed notable improvements in both the control and experimental groups. Particularly in the 2016–17 and 2017–18 cohorts, significant advancements were noted in the performance of both groups. It is crucial to highlight that the experimental group consistently outperformed the control group across the entire spectrum of cohorts under examination. This superiority can likely be attributed more to the pedagogical dynamics intrinsic to the method itself than to the individual teacher's attitude.

In the context of question 22, it's noteworthy that the experimental group exhibits a more consistent and uniform trend, indicating a steady improvement over the years. Conversely, the control group displays a somewhat erratic trend, with fluctuations in performance. Despite this, it is crucial to underline that the control group's results are generally satisfactory. The lowest performance in the control group is observed in the 2011–12 cohort, scoring 4 out of 7, yet there is a notable improvement in the subsequent academic years.

The discernible difference in trends between the two groups can be unequivocally attributed to the instructional methodology implemented in the experimental group. The learning process in this group appears to be more impactful, contributing to the observed continuous improvement in performance. This divergence underscores the efficacy of the teaching approach in the experimental group, where lessons are structured to facilitate a more significant and enduring learning experience.

6. Conclusions

This quasi-experimental study compared the effectiveness of a computer simulation-based teaching approach with traditional methods in civil engineering education over eight academic years at the University of A Corunna. The research, focused on applied physics for civil engineering and public works engineering students, revealed that the experimental group consistently outperformed the control group in the final exam, indicating a positive impact on student performance. Additionally, students in the experimental group reported higher satisfaction levels, better clarity about subject requirements, and increased ease with computer simulations and tests over time. These positive outcomes were attributed to active learning and interaction with simulations, enhancing the understanding of physics concepts. Although gender differences were not explored due to low representation, variations in performance across academic years were noted, potentially influenced by external factors. In summary, the integration of computer simulations in teaching demonstrates improvements in student performance, satisfaction, and understanding of fundamental physics concepts in civil engineering education, emphasizing the benefits of an active learning approach with interactive technologies.

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