

ANALYSIS OF COMPUTER SIMULATION USAGE IN MECHANICS EDUCATION IN THE DEMOCRATIC REPUBLIC OF CONGO: A CASE STUDY OF THE HIGHER INSTITUTE OF APPLIED TECHNIQUES IN KINSHASA

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Abstract

This study aims to assess the impact of using computer simulation, Specifically the «Interactive Physics» software, on teaching mechanics and its effect on the academic success of future engineers at the Higher Institute of Applied Techniques in Kinshasa, Democratic Republic of Congo. To achieve this, we employed a quasi-experimental design with pre-test and post-test assessments, involving 70 students divided into two groups: 40 in the experimental group (EG) and 30 in the control group (CG). The study addresses three research questions and tests two hypotheses at a significance level of 0.05. In addition to initial and final assessments, we gathered students' feedback on the software through questionnaires. We also closely observed the experiences of students using the simulator compared to those following traditional teaching methods, using a structured observation grid. To ensure validity, the research instruments were reviewed in two phases by physics experts, who provided feedback that refined the final versions of the materials. Additionally, we assessed the reliability and internal consistency of the data using Cronbach's Alpha, confirming the robustness of our instruments. For data analysis, we used mean statistics to address our research questions and applied the non-parametric Wilcoxon test to evaluate our hypotheses. The results showed a significant improvement in the cognitive performance of students in the experimental group compared to those in the control group. Moreover, 80% of the experimental group reported satisfaction with their learning experience using the software. Finally, a significant difference was observed in pre-test and post-test scores between the two groups. In conclusion, we strongly recommend integrating computer simulation into mechanics education to enhance academic performance and increase student engagement at the institute.

Keywords: Computer simulation, Learning, Mechanics, Performance, Teaching, Traditional method.

1. Introduction

In today's educational landscape, institutions are broadening their range of teaching resources, moving beyond traditional materials such as friction blocks, inclined planes, springs, balances, and free-fall tubes. These resources enrich learning experiences and seamlessly integrate technology. Teachers, who play a central role in the transmission of knowledge, must adapt and innovate to help students apply the knowledge they acquire to their daily lives. In an era of rapid educational advancements, new methods are emerging to enhance learning and retention.

However, in the Democratic Republic of Congo (DRC), the educational system faces specific challenges that limit the effectiveness of these new approaches. Despite efforts to integrate information and Communication Technologies (ICT) in teaching, in line with national education laws, there remains a lack of access to modern educational resources and a reluctance to adopt innovative pedagogical approaches.

These difficulties are particularly pronounced in the teaching of physical sciences, where traditional teaching methods struggle to engage students and enhance their understanding. Physics, a fundamental science essential for understanding the universe and our interaction with it, is often perceived as difficult due to the complex problems that students must solve.

In this context, it becomes crucial to adopt a learning approach that fosters deep conceptual understanding and actively engages students. Researchers advocate for pedagogical methods such as inquiry, discovery, simulation, and practical experiences, which encourage active learning and mastery of fundamental concepts. The integration of ICT, including computer simulations, plays a key role in improving teaching efficacy.

The software «Interactive Physics» offers a unique opportunity to bridge the gap between traditional pedagogical methods and modern technological approaches. By allowing students to directly engage with simulations, «Interactive Physics» facilitates a learning experience that mirrors the investigative processes of scientists. This approach not only supports the visualization of theoretical concepts but also creates an environment where teachers can effectively guide the active construction of knowledge among students.

Studies have demonstrated the effectiveness of computer simulations in improving teaching outcomes in physics [1-6]. The application of «Interactive Physics» in the context of the DRC aims to address the specific challenges faced by future engineers by integrating a technology-driven method that enhances both the understanding and application of scientific principles.

Furthermore, this research holds significant practical implications for educational policy and reform in the DRC. By demonstrating the effectiveness of computer simulations in physics education, it supports the broader integration of ICT in school curricula, which could guide policymakers in developing strategies to modernize science teaching methods, particularly in engineering training institutions. By strengthening the capacities of teachers and improving students' access to quality educational resources, this research contributes to an educational reform that addresses the specific needs of the Congolese context.

2. Research Problem

In the Democratic Republic of the Congo (DRC), the educational sector has yet to fully harness the potential of information and communication technologies (ICT), leading to detrimental effects on educational standards, especially in the teaching of physical sciences [7]. The instruction and understanding of these subjects in the DRC suffer from a significant shortage of experimental methodologies and inadequate textbooks tailored for educators in this field. Despite efforts to address this issue, such as the enactment of Framework Law No. 14/004 on national education by President Joseph Kabila on February 11, 2014, which aimed to integrate ICT into the national educational framework to empower instructors to innovate in their teaching methods, the challenge persists in Congolese schools and academic institutions [8-10].

This challenge is evident even within our affiliated institution, the Higher Institute of Applied Technologies (ISTA) / Kinshasa, where our research was conducted. Within ISTA/Kinshasa, a notable obstacle exists in conducting practical experiments in physical sciences, leading educators to heavily rely on theoretical instruction [11].

Nonetheless, However, the incorporation and utilization of ICT in the teaching of physical sciences, particularly in areas like electricity and mechanics, offer significant advantages in addressing these challenges [12]. ICT facilitates the transition to virtual laboratories, enabling students to simulate both simple and complex experiments discussed in class, with the added advantage of being able to repeat these experiments as needed. The adoption of ICT emerges as a pivotal approach to enhance the quality of teaching and learning in physical sciences, while also addressing the traditional scarcity of practical experiences [13].

In light of these circumstances, we propose the use of computer simulation software as an alternative to address this persistent issue. It is crucial to note that this alternative is not intended to replace real experiments. This viewpoint is supported by various authors [14, 15]. The proposed solution empowers students to simulate experiments that may be impractical to conduct in class due to equipment limitations. Moreover, adopting computer simulation within this context holds promise as a viable solution to enhance the quality of learning [16, 17].

It is within this framework that we initiated the present study. Our mission is to evaluate the impact of computer simulation software, specifically «Interactive Physics», on mechanics education. Specifically, this research aims to achieve the following objectives:

- Study and analyse the impact of using «Interactive Physics» software on the learning of mechanics by future engineers at ISTA/Kinshasa, based on the results of pre-tests and post-tests.
- Evaluate student engagement, analyse their interaction with the simulator, identify difficulties and strategies, and gather feedback on the experience using the observation grid during computer simulation sessions in mechanics.

In this study, we mainly aim to examine the impacts of using «Interactive Physics» simulation software on the learning experience and performance of ISTA/Kinshasa students during their simulation session. Specifically, we seek to answer the following questions:

- What is the level of performance in mechanics of students exposed to simulation activities using «Interactive Physics» software, assessed through pre-tests and post-tests?
- Is there a significant difference in pre-test and post-test scores between the experimental and control groups?

How do students in the experimental group perceive their experience using the «Interactive Physics» simulator in their learning of mechanics? Additionally, our research question is as follows: "What is the impact of using computer simulation on the understanding of mechanical concepts among future engineers at the Higher Institute of Applied Technologies (ISTA)?"

3. Methods

3.1. Research hypotheses

To answer this question, we have established the following hypotheses:

H0: The use of computer simulation software, such as «Interactive Physics», in teaching and learning mechanics does not lead to a better understanding of concepts compared to traditional approaches.

H1: The use of computer simulation software, such as «Interactive Physics», in teaching and learning mechanics could lead to a better understanding of concepts compared to traditional approaches.

3.2. Experimentation

To address our research question, we conducted a quasi-experimental study with students from the Institute of Applied Techniques (I.T.A.). Students were randomly assigned to two groups to avoid selection bias: an experimental group (EG) consisting of 40 students, who received computer simulation training using the «Interactive Physics» software, and a control group (CG) consisting of 30 students, who received traditional physics instruction.

In the experimental group, students engaged in problem-solving activities using the simulator under the supervision of the instructor, with technical support provided by the experimenters. The selection of topics covered in the experimental group was guided by their relevance to the mechanical concepts being taught, particularly those related to Newton's laws. This targeted selection was intended to fully leverage the capabilities of the «Interactive Physics» software to enhance students' understanding of these concepts.

Meanwhile, the control group received standard physics instruction without the use of the simulator. Both groups underwent a pre-test to assess their understanding of Newton's laws before the classes commenced.

The focus on specific topics within the experimental group allowed for the maximization of the software's educational effectiveness. This targeted approach led to a significant improvement in the performance of the experimental group compared to the control group, as evidenced by the post-test results, thereby underscoring the added value of integrating technology into the teaching of mechanical concepts. Figure 1 below illustrates the Overall Study Framework.

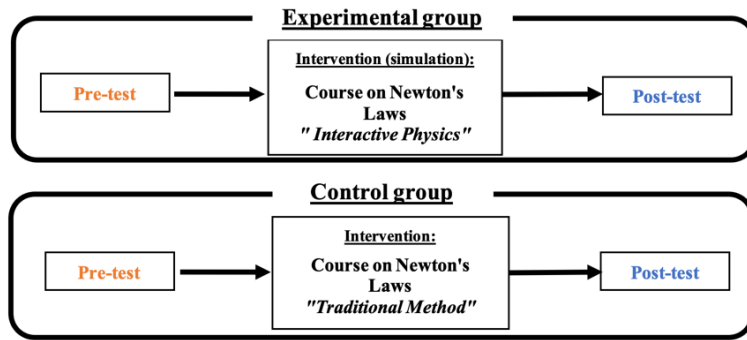


Fig. 1. Overall study framework.

For our simulation sessions aimed at learning the various laws of Newton, we chose to use the simulation software «Interactive Physics» to simulate mechanical phenomena. Figure 2 presents an example of a simulation interface on this software.

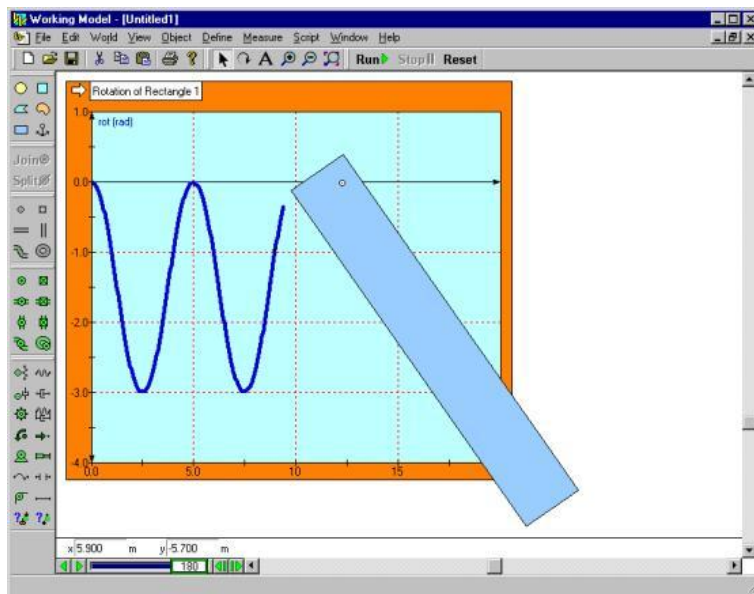


Fig. 2. Example of an interface of a simulation on the «Interactive Physics » software.

The «Interactive Physics» software offers a paid solution in mechanics education, enabling students to simulate physical concepts safely, thereby enhancing their understanding. Developed through a decade-long collaboration between physics educators, authors, publishers, and software engineers, it aligns seamlessly with national curriculum standards. The software provides students with an immersive learning experience, teaching fundamental motion tools used by scientists and engineers. [18].

In summary, «Interactive Physics» software actively involves learners in physical science study, promoting exploration of their environment through

interactive simulations and visualization of abstract concepts. It facilitates hypothesis testing and scenario examination while aiding in practical skill acquisition through motion tools simulating real-life situations.

3.3. Presentation of data collection tools

As mentioned earlier, we used two knowledge tests, the pre-test and the post-test, to collect data for this study. Additionally, an observation grid was used during the computer simulation session to teach mechanics concepts. This section of the study presents these tools in detail.

3.3.1. The pre-test

The pre-test, comprising fifteen questions with five answer choices, was administered to students in both the experimental and control groups. Covering Bloom's taxonomy levels one to three, the questions addressed fundamental physics concepts including Newton's laws, force units, effects of forces on object motion, dynamics principles, and interactions between force, mass, and acceleration as per Newton's second law. The aim was to assess students' understanding of basic Newtonian physics concepts and their application skills in various contexts.

3.3.2. The post-test

The post-test aimed to assess students' grasp of mechanical physics concepts through complex problem-solving tasks involving forces, inclines, and intricate interactions. To ensure fairness and objectivity, multiple-choice questions (MCQs) were utilized for comprehensive evaluation, with the test being identical for both experimental and control groups. This approach allowed for a thorough comparison of performance across the board.

3.3.3. Observation grid

The observation grid used in this study evaluates various aspects of students' experiences with the computer simulator compared to traditional teaching. It includes assessing student engagement, interaction with the simulator, identified difficulties, strategies for overcoming them, and collecting feedback. Structured into five main categories, each includes multiple-choice options to standardize evaluation and data collection.

3.3.4. Student impressions evaluation questionnaire

The post-use questionnaire for ISTA/Kinshasa students using « Interactive Physics » software gathers feedback on their experience, covering overall evaluation, engagement, interaction level, difficulties faced, strategies employed, and general feelings about the software. These responses complement the observation grid, offering a detailed perspective on the software's impact and effectiveness at ISTA/Kinshasa.

3.3.5. Validation of research instruments

To validate the content of the pre-test and post-test, we first developed initial versions by referring to the mechanics program taught at ISTA/Kinshasa. Then, we

submitted these assessments to a group of four specialists in educational physics from our research laboratory, who evaluated the relevance of each question in its respective domain. Their feedback allowed us to refine the documents to their final versions. Additionally, the reliability and internal consistency of the data were evaluated using Cronbach's Alpha, with alpha values exceeding 0.7 [19], indicating the reliability of the instruments. As shown in Table 1.

Table 1. Test reliability.

Tests	Cronbach's Alpha Coefficient
Pre-Test	0.80
Post-Test	0.82
Student Impressions Evaluation Questionnaire	0.78

3.4. Data analysis tools

We utilized IBM SPSS software for quantitative data analysis, essential for assessing data normality, accurately testing result significance, and exploring relationships between variables. This comprehensive approach ensured a rigorous analysis of our data.

4. Presentation and Analysis of Results

4.1. Pre-test and post-test results

To assess the impact of «Interactive Physics » software on mechanical concept understanding among future engineers, this study evaluated pre-test and post-test scores, conceptual test data pre- and post-intervention, and participants' attitude scores.

Table 2. Comparison of performance before and after the use of «Interactive Physics» in learning mechanics.

	Control Group		Experimental Group	
	Pre-test	Post-test	Pre-test	Post-test
N	30	30	40	40
Mean	8.6500	10.8667	8.2750	15.8875
Standard Deviation	2.29749	2.35962	1.99342	1.43441
Sum	259.50	326.00	331.00	635.50

In this study, the results from Table 2 underscore the remarkable effectiveness of using the software «Interactive Physics» in learning mechanics. The experimental group, comprising 40 participants, not only showed a significant improvement in average performance, increasing from 8.2750 to 15.8875 out of 20 after the intervention, but also a notable enhancement in the consistency of results.

The reduction in standard deviation from 1.99342 to 1.43441 highlights a more uniform learning outcome across the group, reflecting a homogenization of performance levels. Additionally, the total sum of performances in this group saw a significant increase, further demonstrating the robust impact of the «Interactive Physics» software as an effective learning tool. These findings suggest that the software not only boosts individual scores but also contributes to a more consistent level of understanding across different learners, thereby reinforcing its value in educational settings.

In this study, we evaluated the effectiveness of the «Interactive Physics» software in learning mechanical concepts by comparing the performances of two groups of students: a control group, which underwent instruction based on traditional pedagogical methods, and an experimental group, which used the «Interactive Physics» software as a learning tool. The post-test performance of the control group, as analysed in Tables 3 and 4, showed a slight decline after traditional teaching methods, with scores predominantly between 10 and 12. This suggests that traditional instruction may have had limited impact on enhancing students' understanding of mechanical concepts.

In contrast, the experimental group, analysed through Tables 5 and 6, exhibited a significant improvement after using the «Interactive Physics» software. Pre-test scores were already concentrated around higher scores above 10, but post-test results demonstrated even greater gains, with most scores exceeding 14. This substantial improvement can be attributed to the interactive nature of the software, which engages students more deeply in the learning process. Specifically, the software allows for dynamic visualization of mechanical concepts, enabling students to experiment and observe real-time changes, thereby reinforcing their comprehension.

The observed improvement in the experimental group's scores also suggests that the software addresses some of the limitations inherent in traditional pedagogical methods. While traditional methods may primarily focus on theoretical explanations, the «Interactive Physics» software provides a practical, hands-on approach that enhances conceptual understanding. The comparison between the two groups reveals a clear superiority of the experimental group, underscoring the software's effectiveness as a learning tool. The consistency of these results, further validated by statistical analyses, highlights the software's potential as a robust alternative to traditional teaching methods. Moreover, the normality test results, presented in Tables 7 and 8, confirm that the data include non-normally distributed elements, reinforcing the need for appropriate statistical methods to accurately assess the software's impact.

Table 3. Frequency of performance of students in the control group during the pre-test.

	Frequency	Percentage	Valid Percentage	Cumulative Percentage
	3.00	2	5.0	6.7
	5.50	2	5.0	6.7
	6.00	1	2.5	3.3
	7.00	2	5.0	6.7
	7.50	2	5.0	6.7
	8.00	2	5.0	6.7
Valid	8.50	1	2.5	3.3
	9.00	3	7.5	10.0
	9.50	2	5.0	6.7
	10.00	7	17.5	23.3
	11.00	5	12.5	16.7
	12.00	1	2.5	3.3
	Total	30	75.0	100.0
Missing System	10	25.0		
Total	40	100.0		

Table 4. Frequency of performance of students in the control group during the post-test.

	Frequency	Percentage	Valid Percentage	Cumulative Percentage
	5.00	1	2.5	3.3
	6.00	1	2.5	6.7
	8.00	2	5.0	13.3
	9.00	4	10.0	26.7
	10.00	3	7.5	36.7
Valid	11.00	8	20.0	63.3
	12.00	4	10.0	76.7
	13.00	2	5.0	83.3
	14.00	4	10.0	96.7
	15.00	1	2.5	100.0
	Total	30	75.0	100.0
Missing System		10	25.0	
Total		40	100.0	

Table 5. Frequency of performance of students in the experimental group during the pre-test, after using the «Interactive Physics» software.

	Frequency	Percentage	Valid Percentage	Cumulative Percentage
	4.00	2	5.0	5.0
	4.50	1	2.5	7.5
	5.00	2	5.0	12.5
	6.00	2	5.0	17.5
	7.00	6	15.0	32.5
Valid	8.00	3	7.5	40.0
	8.50	4	10.0	50.0
	9.00	8	20.0	70.0
	9.50	3	7.5	77.5
	10.00	3	7.5	85.0
	11.00	6	15.0	100.0
Total	40	100.0	100	

Table 6. Frequency of performance of students in the experimental group during the post-test, after using the «Interactive Physics» software.

	Frequency	Percentage	Valid Percentage	Cumulative Percentage
	13.00	1	2.5	2.5
	14.00	6	15.0	17.5
	14.50	4	10.0	27.5
	15.00	2	5.0	32.5
	15.50	3	7.5	40.0
Valid	16.00	9	22.5	62.5
	16.50	4	10.0	72.5
	17.00	5	12.5	85.0
	17.50	2	5.0	90.0
	18.00	1	2.5	92.5
	18.50	2	5.0	97.5
	19.00	1	2.5	100.0
Total	40	100.0	100.0	

Table 7. Normality tests for the control group.

	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistics	Ddl	Sig.	Statistics	Ddl	Sig.
Pre-test	,161	30	,047	,905	30	,011
Post-test	,156	30	,061	,958	30	,272
A. Lilliefors Significance Correction						

Table 8. Normality tests for the experimental group.

	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistics	Ddl	Sig.	Statistics	Ddl	Sig.
Pre-Test	,145	40	,034	,930	40	,016
Post-Test	,131	40	,080	,966	40	,262
A. Lilliefors Significance Correction						

The normality tests of the control and experimental groups, illustrated in Tables 7 and 8, reveal a lack of normal distribution of the data. The significance values of the pre-test (0.047) and post-test (0.061) for the control group, as well as those of the pre-test (0.034) and post-test (0.080) for the experimental group, are all less than 0.05, indicating the non-normality of the data. This finding underscores the necessity of employing non-parametric methods, such as the Wilcoxon test, to accurately interpret the effectiveness of the « Interactive Physics » simulator compared to the traditional methods used by the control group in teaching mechanics.

To further elucidate the factors contributing to the effectiveness of the « Interactive Physics » software, it is essential to examine the specific learning activities that utilized this tool. In the experimental group, the software was employed during practical sessions where students engaged in simulations of mechanical phenomena. These activities included interactive exercises that allowed students to visualize and manipulate mechanical concepts in real-time. The integration of the software involved tasks such as simulating forces, analysing motion, and exploring mechanical systems, which are crucial for understanding complex concepts.

The significant improvement in the experimental group's performance can be attributed to several factors related to these learning activities. First, the ability to interact with dynamic simulations enhanced students' comprehension of abstract concepts, making them more tangible and easier to grasp. Second, the immediate feedback provided by the simulator enabled students to correct misunderstandings promptly and refine their understanding of the material. Third, the software's visual and interactive nature likely increased engagement and motivation, contributing to better learning outcomes.

By addressing these specific learning activities and their impact, we provide a clearer understanding of how the « Interactive Physics » software contributes to enhanced learning. This detailed analysis reinforces the justification for using non-parametric statistical methods and highlights the importance of tailoring educational tools to effectively support the learning process.

To assess the effectiveness of «Interactive Physics» software versus traditional pedagogical methods in teaching mechanical concepts, a comparative analysis using the Wilcoxon test was conducted due to the nature of collected non-parametric data. Results are presented in Tables 9 and 10, showing mean ranks and

sums of ranks for differences between post-tests and pre-tests in both groups. Positive ranks in the experimental group indicate performance improvement after software use, supported by a significant Z value of -5.518 and asymptotic significance of 0.000. Similarly, the control group also exhibited performance enhancement, with a Z value of -3.359 and asymptotic significance of 0.001. This underscores the effectiveness of both approaches in enhancing students' understanding of mechanical concepts, with superior performance noted in the experimental group using the software, supporting the integration of technology in teaching for enhanced science learning.

Table 9. Wilcoxon test.

		N	Mean Rank	Sum Of Ranks
Post-test – Pre-test Experimental Group	Negative Ranks	0 ^a	0.00	0.00
	Positive Ranks	40 ^b	20.50	820.00
	Ties	0 ^c		
	Total	40		
Post-test – Pre-test Control Group	Negative Ranks	6 ^d	8.25	49.50
	Negative Ranks	21 ^e	15.64	328.50
	Ties	3 ^f		
	Total	30		

- a. *post-test experimental group < pre-test experimental group*
- b. *post-test experimental group > pre-test experimental group*
- c. *pre-test experimental group = pre-test experimental group*
- d. *post-test control group < pre-test control group*
- e. *post-test control group > pre-test control group*
- f. *post-test control group = pre-test control group*

Table 10. Comparison of differences between post-tests and pre-tests of experimental and control groups, according to the Wilcoxon rank-sum test.

	Statistical Tests^a	
	Post-test – Pre-test Experimental Group	Post-test – Pre-test Control Group
Z	-5.518 ^b	-3.359 ^b
Asymptotic Significance (Two-Tailed)	.000	0.001

b. *Based on Negative Ranks.*

4.2. Calculation of normalized conceptual learning gain

The Force Concept Inventory (FCI) is a conceptual test of mechanical physics originally designed by Hestenes and Wells [20]. This tool serves as a crucial assessment measure for evaluating teaching effectiveness and gauging students' conceptual understanding progression. It provides educators with objective data on learning outcomes. In our study, the FCI was employed to assess mechanical concept understanding among the experimental and control groups. Calculating the normalized gain for each group enabled us to determine differences in learning progression and identify the group showing the most significant advancement in understanding. Conceptual gain was calculated by comparing pre-test and post-test

scores, measuring understanding progression between assessment points. The normalized gain formula was utilized for each group.

$$g = (\bar{x} \text{ "Post-test"} - \bar{x} \text{ "Pre-test"}) / (20 - \bar{x} \text{ "Pre-test"})$$

where: g is the normalized gain; the pre-test mean is the average score obtained by students in one of the study groups in the pre-test, on a basis of twenty points; The post-test mean is the average score obtained by students in one of the study groups in the post-test, on a basis of twenty points.

The criteria for normalized gain, as defined by Hake [21], provide a precise framework for evaluating the performance of groups on pre-test and post-test tasks in the context of our study. A normalized gain less than 0.3 indicates marginal improvement in understanding between the two assessments. Groups with average normalized gains, ranging from 0.3 to 0.7, reveal substantial but not maximal improvement in learning. Finally, groups with a normalized gain greater than 0.7 indicate significant and effective improvement in understanding. These criteria allow for an objective evaluation of the effectiveness of teaching methods used in our study, and they play a crucial role in guiding pedagogical practices towards optimal learning outcomes. Results of normalized gain for each study group as shown in Table 11.

Table 11. Results of normalized gain for each study group.

Group Size	Group	Tasks		Normalized Gain
		Pre-test	Post-test	
30	Control	8.6500	10.8667	0.195
40	Experimental	8.2750	15.8875	0.649

In Table 10, we present the normalized gain results for both the control and experimental groups in our study. The control group, comprising 30 participants, achieved pre-test and post-test scores of 8.6500 and 10.8667, respectively, resulting in a normalized gain of 0.195. Conversely, the experimental group, consisting of 40 participants, obtained pre-test and post-test scores of 8.2750 and 15.8875, respectively, resulting in a normalized gain of 0.649. These findings underscore the effectiveness of the different teaching methods used.

Notably, the experimental group, which utilized « Interactive Physics » software, demonstrated a significantly higher normalized gain (0.649) compared to the control group (0.195), indicating substantial improvement in understanding. This reinforces the importance of integrating educational technologies like « Interactive Physics » to enhance learning outcomes in mechanics, supporting their adoption in educational programs, and promoting more effective teaching practices.

4.3. Evaluation results of the « Interactive Physics » software

In this section, we analyse student feedback on their experience with the « Interactive Physics » software (as shown in Fig. 3). The results indicate a high satisfaction rate, with 80% of students in the experimental group providing overall positive evaluations. Most students reported a high level of engagement during software use, with 75% indicating very high or rather high engagement. Regarding interaction, 70% of students actively engaged with the simulator, while 20% showed minimal interaction and 10% were hesitant.

Despite this positive feedback, challenges remain, particularly concerning interface understanding and tool manipulation. This explains why a significant minority (30%) is not favourable towards using the software, as these challenges limited their engagement and interaction with the simulator, despite their efforts to overcome them. Students adopted a proactive approach to address these issues, with 30% opting for independent exploration, 50% seeking instructor assistance, and 20% collaborating with peers. Responses ranged from positive to negative, reflecting diverse experiences with the interactive software.

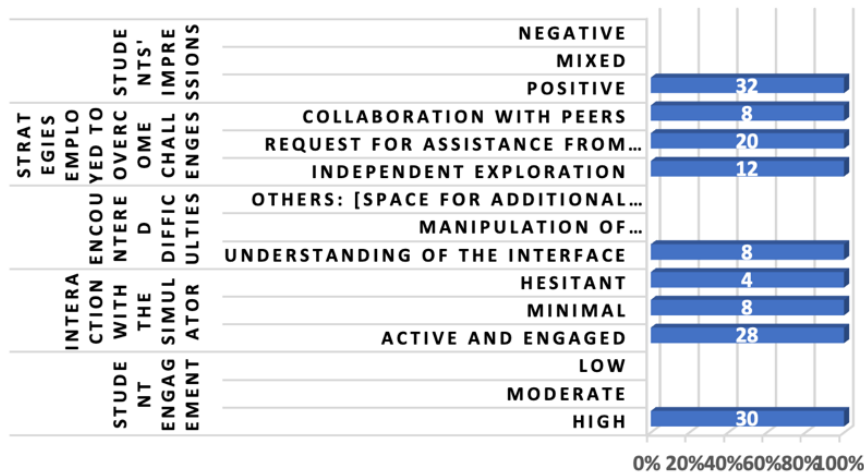


Fig. 3. Perception of students in the experimental group after using the «Interactive Physics » software.

5. Discussion

The results of this research shed light on the use and perception of computer simulation, particularly the « Interactive Physics » software, in teaching mechanical concepts to students, especially future mechanical engineers.

Firstly, our results confirm the hypothesis that the use of the « Interactive Physics » simulation software significantly improves students' performance in mechanics, as shown in Table 2. The experimental group exhibited a notable increase in average performance, rising from 8.2750 to 15.8875 after the intervention, indicating a consistent improvement within the group. This substantial gain underscores the software's effectiveness as a learning tool, aligning with active learning strategies that are crucial in mechanics education [22].

Our study stands out by integrating the « Interactive Physics » software into a hybrid methodology, allowing for overcoming the specific material limitations of the educational context in the Democratic Republic of Congo. For example, students were able to experiment with pendulum motion and test Newton's laws in a simulated environment-phenomena that would have been difficult to observe due to the lack of physical equipment. Unlike other studies that use simulations merely as substitutes, our study shows that the simulation does not simply replace physical experiments but enriches learning by allowing for an in-depth exploration of complex concepts. This hybrid approach maximized student engagement, with a

satisfaction rate of 80% in the experimental group, confirming the effectiveness of this model in a resource-limited educational context [23].

Our results also highlight the positive impact of the « Interactive Physics » software on students' learning experiences in mechanics. Indeed, 80% of the students in the experimental group expressed overall satisfaction with their experience with the simulator, demonstrating its effectiveness in capturing learners' attention while considering their diverse perspectives [23]. Regarding interaction with the simulator, our results reveal that the majority of students were actively engaged in its use, although a significant portion showed minimal interaction. This underscores the importance of tailoring educational technologies to the individual needs and preferences of learners.

Although similar approaches using computer simulations have been explored in other studies, our research stands out for the way it combines the modelling features of the « Interactive Physics » software with a hybrid pedagogical methodology. This combination not only enriches the students' learning experience but also addresses specific limitations related to the lack of physical equipment and the teaching context in the Democratic Republic of Congo.

The results of our study, consistent with other research, show that the use of computer simulation, particularly the « Interactive Physics » software, clearly improves the understanding of physical concepts. Indeed, this type of simulation simplifies the phenomena studied and enhances student motivation for the physical sciences, as highlighted by the study conducted at ISTA/Kinshasa [24].

While the use of simulation may be perceived as merely a substitute for traditional physical experimentation, it is important to emphasize that its role goes beyond this simple replacement. Beyond substitution, computer simulation introduces innovative dimensions that enrich the students' learning experience. It allows for the modelling and experimentation of complex phenomena interactively and visually, thus fostering deeper student engagement, which is difficult to achieve through traditional methods. This approach, offering unique opportunities for exploration and experimentation in a controlled environment, grants simulation an innovative character in the teaching of physical sciences.

To address the difficulties identified and the strategies implemented, as well as to collect feedback on the experience, it is necessary to explore in greater depth how these factors have influenced the observed outcomes. This will help justify the proposed computer simulation model, as discussed in Section 6. The integration of theories such as active learning theory and cognitive load theory helps to contextualize these improvements. Active learning theory supports the idea that interactive simulations can enhance understanding by actively engaging students in the learning process. Cognitive load theory explains how simulations can more effectively manage cognitive demands compared to traditional methods, providing immediate feedback and visual representations [25].

In summary, our findings confirm the significant role of the « Interactive Physics » software in improving students' learning experiences in mechanics. They advocate for the continued integration of innovative educational technologies into mechanical engineering programs, reinforcing the idea that computer simulations enhance concept comprehension, particularly when time and physical resources are limited. Furthermore, the use of simulation simplifies complex phenomena and

stimulates student motivation for physics, an essential aspect of teaching the physical sciences [26]. These results also align with previous studies, reinforcing the importance of integrating technology into engineering education [27].

6. Proposal of a Computer Simulation Integration Model

To enhance physical sciences teaching, particularly in mechanics, we propose an innovative model for integrating computer simulations (as shown in Fig. 4). Developed by researchers from the ERIPDS team and validated through intersubjectivity with experts, this model has been rigorously reviewed and approved to enrich students' learning experiences and modernize teaching methods.

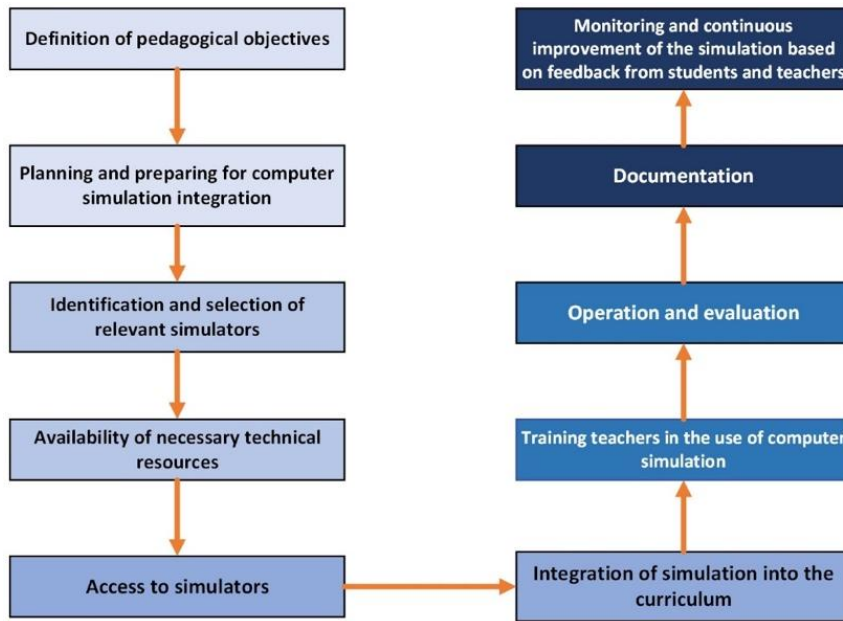


Fig. 4. Illustration of the proposed computer simulation integration model in this study.

With 10 strategic activities, each step is meticulously crafted for optimal efficiency. These include defining pedagogical objectives, planning simulation integration, selecting suitable simulators, arranging technical resources, facilitating access, curriculum integration, teacher training, rigorous exploitation and evaluation, documentation, and continuous improvement based on feedback. This model offers a robust structure for successful integration of Computer Simulation into physical sciences teaching, promoting modern and efficient educational practices applicable in various contexts, including at ISTA/Kinshasa.

7. Conclusion

In this study, we evaluated the impact of « Interactive Physics » computer simulation software on teaching and learning through pre-test and post-test assessments. Results indicate significant improvement in student performance with the software, highlighting its positive influence on subject understanding. This

study suggests that computer simulation is an effective solution for practical work limitations due to equipment scarcity, offering a credible alternative for deepening conceptual understanding. Training for teachers on « Interactive Physics » integration is recommended to optimize its effectiveness across various teaching contexts. Additionally, governments and educational organizations are encouraged to promote the integration of computer simulation into educational programs to enhance technological skills and scientific understanding. In conclusion, this study supports the effectiveness of computer simulation in science education, offering promising prospects for global teaching and learning enhancement.

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