


PAPER

Mobile Learning in Physics Education: Evaluating the Impact of Interactive Videos on Practical Work

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ABSTRACT

The emergence of multimedia has fostered the development of interactive videos, introducing an innovative approach to enhancing learner engagement. The rapid proliferation of mobile devices provides new learning opportunities, enhancing both information accessibility and immersion in various educational media, including interactive videos. In the context of practical work, these videos can serve as an effective teaching tool on mobile devices, facilitating the understanding and execution of experimental protocols. The aim of the present study was to evaluate the effect of using interactive videos on students' performance in physics practical work. It was carried out with 370 first-year students enrolled in the Bachelor of Education, Primary Specialization (BEPS) program at a Moroccan university. Participants were randomly divided into two equal groups: an experimental group using interactive videos on mobile devices and a control group using conventional methods. The results revealed that the experimental group completed the experimental set-ups in significantly less time and demonstrated better understanding and application of the protocols. The present findings underscore the efficacy of interactive videos in facilitating practical physics work, thereby emphasizing their potential to enhance student learning in this domain.

KEYWORDS

interactive video, mobile devices, physics practical work, higher education, performances

1 INTRODUCTION

Video is a dynamic visual medium that captures moving images and sound, allowing information, entertainment, or messages to be conveyed in an engaging and coherent way. It covers a wide range of content, from films and TV shows to online clips and educational materials. This ability to capture attention makes it an increasingly popular tool in various fields, including education [1], [2]. However, so-called "classic" videos limit active interaction by confining students to a passive spectator role, which does not always promote adaptation to individual needs [3], [4].

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In addition, these videos may sometimes lack dynamism, making the learning experience less engaging [5].

Technological evolution has given birth to interactive video, an educational tool that goes beyond traditional videos, allowing real-time interaction and personalization through elements such as quizzes, interactive cards, and interactive 3D objects [6]. This tool is defined as a digitally enriched form of the original raw video sequence, offering viewers attractive and powerful forms of interactivity and browsing possibilities [7], [8]. This form of video content allows users to make choices that influence the flow of the video, thus affecting their future viewing experience [9]. This approach, which goes beyond passive viewing, encourages active engagement by offering interactive elements that respond to user input, creating a more dynamic, enriching, and personalized learning experience [10], [11].

Interactive videos have proven to be a powerful educational tool for increasing student motivation in higher education, offering more dynamic engagement than traditional methods [12]. Integrating interactive video into teaching methods significantly improves motivation and learning outcomes, creating a more interactive and stimulating learning environment [13], [14]. These videos also show a positive impact on intrinsic motivation, resulting in better engagement and performance in physics classes [15]. Students using e-learning environments with interactive videos performed better and were more satisfied than those in non-interactive or traditional environments [16]. Interactive physics tutorials show a significant impact on academic motivation and performance [17], [18]. In addition, interactive videos have proven effective in preparing students for physics laboratory work, on a par with traditional lecture courses [19]. This suggests that interactive videos can effectively replace traditional lectures to prepare for practical physics work.

The implementation of interactive videos requires a significant technological infrastructure, which can be a major barrier for many educational institutions, especially in developing regions or under-funded institutions. Although desktop and laptop computers can stream these videos, their limited accessibility and lack of mobility may limit the student's learning experience, especially during practical work. Mobile devices such as smartphones and tablets, however, due to their portability and affordability compared to traditional computers, provide greater flexibility and transform the educational landscape by facilitating dynamic and interactive learning [20], [21], [22], [23], [24].

Mobile learning, defined as the educational process conducted via mobile devices such as smartphones and tablets [25], has become a viable alternative with several advantages [26]. These devices offer widespread accessibility, portability, and increasingly powerful processing and connectivity capabilities [27], [28]. They meet many challenges related to the implementation of interactive videos. In addition to affordability and accessibility, mobile devices incorporate interactive features such as touch screens, cameras, and sensors that enhance the interactivity and engagement of educational videos [29]. In science education, these devices can serve as portable laboratories by providing remote measurement and analysis tools. They also facilitate access to a wide range of educational resources, allowing the integration of interactive content and diverse teaching materials, including interactive videos [30], [31], [32].

In the specific context of physics education, the use of interactive videos via mobile devices can potentially bring significant benefits, such as improved student performance over conventional methods, a better understanding of concepts, and optimal preparation for practical experience [33], [34], [35]. Many studies have explored the impact of interactive video on mobile devices in practical physics work.

Hochberg et al. [36] demonstrated that these videos have a positive cognitive effect in the laboratory, thus improving learning of concepts. P. Ramírez-Leal et al. [37] assessed their effectiveness as teaching tools, revealing that they enhance students' understanding during practical work. Furthermore, Rolstad and Andersen [38] observed that the use of these videos in physics practical works improves understanding of physical phenomena, thus contributing to a better assimilation of concepts.

Despite the value of these studies, several shortcomings have been identified in the use of interactive videos via mobile devices in practical physics work. Firstly, the current research is often characterized by the use of small sample sizes, which limits the extent to which the results can be generalized. Furthermore, the assessment methods utilized are insufficient for accurately measuring students' practical abilities. Secondly, although there is evidence that interactive videos can enhance theoretical learning, their integration into laboratory experiments remains an understudied area. Furthermore, the majority of studies focus on student engagement or immediate satisfaction without fully evaluating the impact of interactive videos on students' understanding of experimental protocols and improvement of experimental skills. Finally, pedagogical strategies that fully exploit the potential of interactive videos in practical physics work remain largely understudied [36], [39], [40].

In order to address some of the identified gaps, particularly those related to methods for evaluating the impact of interactive videos in physics laboratories and issues with sample sizes, this study aims to investigate the effect of using interactive videos on students' understanding of experimental protocols and the development of practical skills. By employing a large sample size, the study aims to enhance the validity of the results. Furthermore, the study aims to compare the efficacy of interactive videos with that of conventional methods commonly employed in practical physics work. Conducted during the second semester at the Higher Normal School (HNS) of Abdelmalek Essaadi University in Morocco, this study focuses on three main criteria and targets first-year students enrolled in the Bachelor of Education, specializing in Primary Education (BEPS). The objective is to determine whether the integration of interactive videos via mobile devices can enhance students' performance in practical physics work in comparison to conventional teaching methods. Consequently, the central question of this study is: What is the impact of interactive videos on mobile devices on student performance in practical physics work in comparison to conventional approaches?

2 MATERIALS AND METHODS

This study used an experimental design to evaluate the effectiveness of two teaching methods during practical physics sessions. Specifically, the aim was to compare student performance in a conventional hands-on environment with one enhanced by the use of interactive videos on mobile devices. By comparing these teaching modalities, this study sought to determine whether the use of interactive videos on mobile devices could improve students' practical performance in physics compared with traditional methodology.

2.1 Population and sampling

A total of 370 first-year BEPS students from the HNS at Abdelmalek Essaadi University participated in this study. Participants were randomly assigned to

two equal groups of 185 students each: an experimental group and a control group. The randomization process was conducted using SPSS software, which facilitated an unbiased allocation of participants across the two groups, thereby enhancing the internal validity of the results.

The study was conducted in accordance with the ethical standards outlined in the Declaration of Helsinki and in compliance with national regulations on research ethics. Confidentiality and anonymity were ensured for all participants, as no identifying information was collected. Moreover, informed consent was obtained from all participants after they had been fully briefed on the study's objectives, procedures, and their rights, including the voluntary nature of their participation. These measures were implemented to safeguard participants' privacy and to uphold the integrity and ethical rigor of the research process.

To establish baseline equivalence between the experimental and control groups, a pretest was administered, assessing initial levels of knowledge, motivation, and technical skills. The results of this pre-test confirmed that both groups were comparable prior to the intervention, indicating no significant differences in key variables at the outset. This established equivalence strengthens the validity of the study's findings by ensuring that any observed differences in outcomes can be attributed to the intervention rather than pre-existing disparities.

In addition, to mitigate potential experimental bias, specific details related to the study's objectives and intervention were deliberately withheld from participants during the data collection phase. This methodological approach was designed to reduce expectancy effects and enhance the reliability of the results. After the study concluded, all participants were fully debriefed, with a comprehensive explanation of the rationale behind this procedure.

2.2 Preparatory training

A training session was organized for all participating students to enable them to acquire the necessary skills for the optimal use of the Moodle platform and interactive videos. This training was conducted using their personal mobile devices, ensuring a uniform experience for each participant and reflecting real-world usage conditions. Notably, these are the same devices that students in the experimental group would later use during the actual experiment, ensuring continuity and consistency in the technological environment. This methodological decision was guided by the principle of eliminating potential biases associated with disparities in technological aptitude, particularly within the experimental group. The objective was to ensure equitable access to digital tools and to enhance the reliability of the study's outcomes.

2.3 Study groups and teaching methods

The experiments were conducted under controlled conditions, with impartial and consistent supervision for both the experimental and control groups, thereby ensuring the validity and fairness of the results. In the experimental group, students participated in practical work sessions using interactive videos accessible via their personal mobile devices through a dedicated platform. These videos provided dynamic instructional content designed to enhance student engagement and support autonomous learning. Conversely, the control group engaged in conventional laboratory

sessions, relying on traditional teaching methods such as verbal instructions, face-to-face demonstrations, and direct interaction with laboratory equipment under the teacher's supervision. A Moodle LMS platform, adapted for use on mobile devices, was established. The H5P plugin was integrated to create interactive videos presenting the equipment used and the experimental protocols for the installations to be carried out. These videos incorporated interactive questions concerning the equipment, the steps involved in carrying out the experimental protocols, and the measurements to be made. In the event of an incorrect answer, detailed feedback was provided, enabling students to return to the previous sequence to review the necessary information before attempting a new answer.

In this study, the design of the interactive videos aimed at optimizing the learning conditions by reducing the cognitive load of the students. This approach was based on the principles of Mayer's cognitive theory of multimedia learning (CTML) [41], particularly respecting the principle of multimodality, limiting divided attention, reducing redundancy, and considering the transitory nature of verbal information. By meticulously structuring the content to minimize cognitive interference, the interactive videos employed in this study sought to reduce cognitive load and promote the concurrent processing of visual and auditory information, thus facilitating the integration of knowledge and the students' understanding of the experimental protocols.

2.4 Performance evaluation

In this study, the performance of the students was assessed based on three main criteria. The first criterion, practical performance, focused on evaluating the students' ability to correctly use laboratory instruments, handle experimental equipment with precision, and ensure strict compliance with safety standards during the practical sessions. Practical performance was graded on a scale of 20. The second criterion, understanding of experimental protocols, assessed the students' ability to identify the key procedural steps, justify the techniques applied, and accurately analyze the experimental data obtained from the experiments. This understanding was also graded on a scale of 20. Finally, completion time was measured in minutes for each task outlined in the experimental protocol, providing an objective measure of the students' efficiency in executing laboratory activities. Following the completion of the experiments, a comparative analysis was conducted to evaluate the performance of students in both the control group and the experimental group based on these three criteria. This analysis aimed to determine the extent to which the intervention influenced students' practical skills, protocol comprehension, and task efficiency.

3 RESULTS

This study employed an experimental approach to assess the impact of interactive video on students' performance in practical physics work. Students in the experimental group utilized interactive video via their mobile devices, while students in the control group performed practical work using conventional methods. The performance of students in both groups was compared based on practical performance, understanding of experimental protocols, and time taken to carry out experimental set-ups. A comparative analysis between the two groups was conducted using SPSS

version 21 software, as illustrated in Table 1. The Mann-Whitney test was employed due to the non-parametric distribution of the data.

To assess the statistical significance of observed differences, the p-value associated with each criterion was interpreted, with a p-value below 0.05 considered statistically significant [42]. At the same time, the interpretation of the size of the effect r has allowed us to measure the practical extent of these differences. A small r (about 0.2 to 0.3) indicates a small difference or association between groups or variables, a medium r (about 0.4 to 0.7) suggests a moderate difference or association, and a large r (0.8 and above) reflects a substantial difference or association between groups or variables. [43].

Table 1. Results of Mann-Whitney tests comparing the performance of the control and experimental groups in practical work

Evaluation Criteria	Control Group (n = 185)		Experimental Group (n = 185)		Mann-Whitney Test			
	M	SD	M	SD	U	z	p	r
Time required	25.36	1.860	15.16	1.839	5209.000	-12.001	0.000*	0.61 ^b
Experimental protocol understanding	14.00	1.373	16.00	0.924	4078.00	-1.38	0.000*	0.68 ^b
Practical performance	12.84	1.71	16.87	1.27	932.00	-16.09	0.000*	0.82 ^a

Note: ^alarge r , ^bmedium r , ^csmall r , * $p < .001$.

The results of the study reveal significant differences between the control group and the experimental group on the three criteria assessed. In terms of the time required to perform the experimental set-ups, the experimental group completed the task in less time on average than the control group, with a moderate r (see Figure 1). This significant reduction in time is attributed to the use of interactive videos, which enabled the students in the experimental group to familiarize themselves with the protocols and equipment more independently and at an earlier stage. Although the difference is significant, the moderate effect indicates that the completion times of the two groups, although different, are not completely distinct. This suggests that other factors could also influence the speed of the task, but the videos clearly offered an advantage in terms of reducing preparation time.

Regarding understanding of the experimental protocols, the experimental group showed a more thorough mastery of the experimental steps, with a higher score compared to the control group and a large r (see Figure 2). This result demonstrates that the interactive videos had a substantial impact on the students' ability to understand the experimental protocols as a whole. As well as explaining the steps in the protocol, the students in the experimental group were able to link these steps to theoretical concepts, justify the use of certain techniques and instruments, and anticipate results based on physical laws. This improvement in the theoretical understanding of the protocols demonstrates the effectiveness of the video method in conveying complex knowledge.

Finally, in terms of practical performance, the students in the experimental group obtained significantly better results than those in the control group, with a very large r (as shown in the graph in Figure 2). This significant difference reflects a better mastery of practical skills, such as using laboratory instruments, wiring circuits, and handling measuring equipment. In addition, the experimental group showed better compliance with safety standards, greater ability to solve problems during the

experiment, and more consistent production of reliable results. This underlines the significant impact of interactive videos not only on the speed of task completion but also on the quality of the execution of manipulations in the laboratory.

In conclusion, the analysis reveals that the use of interactive videos had a significant positive impact on students' performance across all three criteria assessed. The experimental group demonstrated greater efficiency, with reduced completion times, enhanced understanding of experimental protocols, and superior practical performance, supported by moderate to very large r . These findings highlight the effectiveness of interactive videos in improving both the speed and quality of laboratory tasks, as well as in fostering a deeper understanding of experimental procedures and the development of practical skills in physics education.

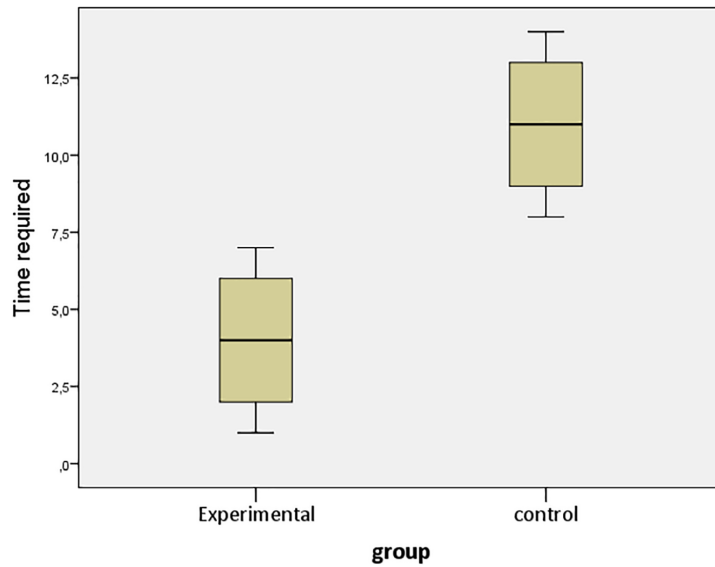


Fig. 1. Comparison of the time required to carry out the experiments between the experimental and control group

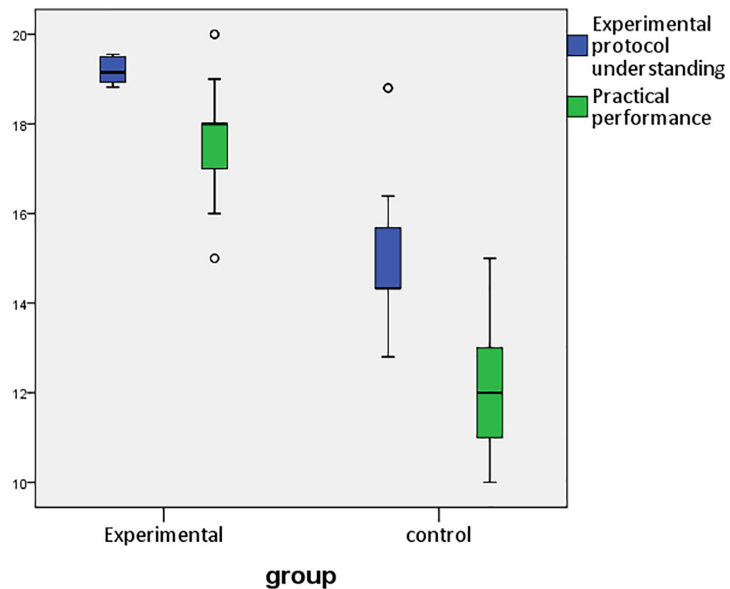


Fig. 2. Distribution of notes on the understanding of the experimental protocol and practical performance for each group

4 DISCUSSION

The results of this study confirm the effectiveness of interactive videos accessible via mobile devices in learning practical physics work. The main benefits observed are a reduction in the time needed to carry out experimental set-ups, an improvement in the understanding of protocols, and a strengthening of students' practical skills. These benefits are enhanced by the specific functionalities offered by smartphones and tablets, which promote a flexible, interactive, and adaptive learning experience.

Firstly, in terms of the time required to set up the experimental devices, our results show that students using interactive videos on mobile devices carried out their manipulations more quickly than those in the control group. These results are in line with the findings of several previous studies [44], [45], [6], emphasizing that interactivity in audiovisual media facilitates task completion by reducing errors and hesitations. The combination of video interactivity and the tactile interface enables learners to manipulate experimental elements virtually and to anticipate the steps to follow. This learning method saves time and increases autonomy in the preparation of experiments. In addition, interactive video mobilizes both the visual and verbal systems. According to multimedia learning theory, this has major pedagogical advantages. It makes learning more effective by preventing the student from being exposed to too much information at once on the same channel, thus reducing the risk of cognitive overload caused by saturation of processing capacity [41].

Secondly, in terms of understanding the experimental protocols, the study revealed significant progress in the students in the experimental group. These results corroborate previous studies [36], [40], [34], [46], [47], [48], [49], which highlight the importance of interactive visual aids in the assimilation of complex procedures. Interactivity, particularly through the integration of quizzes and interactive breaks, encourages active learning by regularly prompting reflection and checking knowledge [50]. These quizzes are designed to appear at key moments in the video, forcing the student to process the information immediately after viewing it, which reinforces memory retention [51]. In the event of a wrong answer, immediate feedback is offered, accompanied, depending on the case, by additional explanations or references to specific segments of the video [52]. In addition, the system uses interactive tree structures, enabling learners to be directed towards different paths depending on their responses. This type of conditional navigation paves the way for personalized teaching scenarios in which learners explore various ramifications of the content according to their level of understanding. This mechanism is similar to the non-linear scripting logic used in adaptive learning systems, in which the content is modulated according to the learner's choices and performance [53]. In addition, the use of the Moodle platform in our system made it possible to implement adaptive learning functionalities: the content of the videos was dynamically adjusted according to the students' responses, offering additional explanations in the event of error or more in-depth questions in the event of success [54]. This progressive support system helps to lighten the cognitive load by guiding learners in a targeted way through the complexity of the information to be processed. Furthermore, the consideration of the principles of Mayer's CTML [41] in the design of interactive videos has improved the understanding of the experimental protocols. The integration of principles such as multimodality, redundancy reduction, limitation of attention splitting, and the use of explicit signals has helped to optimize information processing. The structuring of the content, mobilizing the visual and auditory channels simultaneously, facilitated the mental organization of the steps presented

and supported the transfer of information to long-term memory, thus creating favorable conditions for a better understanding of the experimental procedures [55].

In addition, by integrating content and interactive elements, interactive video fosters constructive learning by creating a learning environment where the learner becomes an actor in their learning. Learners mobilize their prior knowledge, manipulate information, make choices, receive feedback, and actively develop their understanding of experimental protocols [56]. With this in mind, the integration of interactive quizzes and tree diagrams into interactive videos makes it possible to structure learning paths, offer immediate feedback, and guide the learner's choices. These features enhance cognitive engagement and illustrate the evolution of educational technologies towards more interactive, adaptive, and learner-centric devices. Indeed, interactive videos can take advantage of the mechanisms used in adaptive learning systems based on artificial intelligence, dynamically adjusting the content presented according to the learner's responses or choices. The integration of functionalities derived from intelligent agent systems thus makes it possible to personalize the learning path and adapt video sequences to target specific difficulties encountered. These technological advances help to individualize learning and enhance understanding of experimental protocols by providing more precise and responsive support for students' needs.

Thirdly, with regard to practical performance, our results highlight a significant improvement in experimental skills in students who benefited from interactive videos on mobile devices. These observations are in line with the results of previous work [7], [57], [58], [50], [59], showing that the ability to review detailed demonstrations at will and progress at one's own pace improves the accuracy and quality of manipulative execution. In addition, the integration of push notifications and real-time feedback into mobile platforms makes it possible to analyze and stimulate student engagement. These devices enable continuous monitoring and encourage the completion of learning sequences. In this context, analysis of connection data and user behavior, such as viewing time, number of views, and responses to questionnaires, provides valuable indicators of learner engagement and understanding. These measures help to personalize teaching and target pedagogical interventions more effectively, particularly in the context of using interactive video in hands-on activities [60].

The integration of mobile interactive video in practical physics work is not limited to an immediate impact on performance. It opens up prospects for a structural evolution in experimental teaching towards hybrid formats combining autonomous learning and face-to-face sessions. In this context, interactive videos can be used as an upstream preparation aid, optimizing time spent in the lab by focusing on application and deepening. This approach is particularly relevant in low-resource environments, where access to equipment is limited. Interactive videos can then serve as a partial substitute, preparing students for manipulations before they have access to the physics equipment [49], [57], [50], [59].

Finally, the perspectives of this study are based on three complementary axes. Firstly, the extension of mobile interactive video to other STEM disciplines and to hybrid or fully remote devices. Secondly, the integration of artificial intelligence into educational platforms would enable the deployment of more sophisticated adaptive learning systems [61], [62], [63], [64], capable of dynamically adjusting pedagogical content and exercise difficulty according to individual performance, engagement patterns (e.g., response time, concept review), and learning preferences. However, these technological advances require careful thought about their scalability and institutional adoption. To maximize the impact of mobile interactive videos in STEM programs, it is essential to accompany their deployment with:

- Teacher training programs in the use of digital tools, including the creation of appropriate pedagogical tools and the analysis of engagement data;
- Institutional strategies favoring the integration of these resources into curricula, notably through partnerships between educational institutions and technology players;
- Educational policies targeting low-resource contexts, where these tools could fill material gaps while guaranteeing equitable access to learning by doing.

5 CONCLUSION

The results of this study highlight the benefits of integrating interactive videos via mobile devices into physics laboratory work. These digital resources not only enable students to better understand experimental protocols but also improve their overall performance and reduce the time needed to carry out experiments. As a result, students become more autonomous, promoting more effective and independent learning during laboratory sessions. This increased autonomy also lightens the teaching load on teachers, making practical sessions smoother and less dependent on direct supervision.

The adoption of interactive video in experimental teaching can be scaled up without major investment, given that most academic institutions already have digital platforms and students have widespread access to mobile devices. However, to ensure effective implementation, it is essential that teachers take into account several best practices. Firstly, videos must be adapted to the screens of mobile devices, which are mostly smartphones, to ensure an optimal visual experience and ergonomic navigation. Secondly, their duration needs to be optimized to maximize student engagement and enhance pedagogical effectiveness, with a preference for concise, dynamic formats [65]. The integration of targeted interactive questions and supplementary materials can also promote independent learning and deepen understanding of experimental protocols. Finally, training teachers in the design and use of these digital resources would help improve their impact on student learning and facilitate their integration into existing teaching practices.

However, these results must be interpreted with caution, as the study was conducted in a specific context, which may limit their transferability to other disciplines or levels of teaching. To validate these results, it is essential that further research be carried out in a variety of contexts, including academic contexts at different levels. In addition, the analysis should be broadened by incorporating longitudinal data to assess the long-term effects of interactive videos on learning. This would provide a better understanding of whether the observed benefits are maintained over time.

It is also recommended to explore the impact of subjective variables, such as students' attitudes and perceived feedback, to get a more complete picture of their engagement and the value they attach to these interactive videos. Other factors, such as students' background knowledge and level of motivation, would provide a better understanding of the conditions under which interactive videos can maximize learning outcomes. These practical recommendations aim to guide teachers and institutions in the design and implementation of interactive videos in practical work while adapting to technological developments and students' pedagogical needs.

In addition, although this study focuses on the teaching of physics, its findings have the potential to be applied to other disciplines that require hands-on learning. They also offer avenues for enriching initial and in-service teacher training by integrating the use of interactive videos as a lever for developing digital pedagogical skills.

To encourage wider adoption, future research should explore the conditions for institutional integration of these technologies, assessing their scalability and economic viability, as well as the partnership arrangements between educational establishments, decision-makers, and designers of technological solutions. These elements are essential to ensure the sustainability and lasting impact of such innovations in educational systems.

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