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PAPER

Effectiveness of Real and Computer-Assisted Experimental Activities in Moroccan Secondary School Physics Education

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ABSTRACT

Experimental activities are widely recognized as an essential pedagogical tool in physics education that enables students to learn fundamental physical concepts. Experimentation sets physics apart from other disciplines by motivating learners to acquire knowledge, methods, scientific attitudes, and manipulative skills. Most current research focuses on the importance of conventional experimental work in the learning process or the contribution of new technologies to this process without pinpointing the experienced limitations hindering the two tools from achieving the pedagogical objectives for which they were originally designed. To gain a better understanding of what these issues are, we have performed the survey presented in this paper. First, the analysis investigated the challenges that impede the experimental approach from playing its vital role in the Moroccan education system and evaluated the efficiency of this approach in achieving its original pedagogical objectives. In doing so, the study indicates that the majority of Moroccan secondary physics teachers do not achieve the required rate of experimental activities due to several challenges, including the need for coaching and training, the lack of coordination between decision-makers and practitioners regarding the practical use of scientific laboratories, a shortage of necessary materials, and a lack of maintenance and repair of laboratory equipment. Thus, we conclude this paper by providing several solutions, implications, and limitations as potential directions for future research.

KEYWORDS

experimental approach, computer-assisted experimental activities, Moroccan secondary education, Physics learning

1 INTRODUCTION

The experimental approach can be defined as a method of preparing laws and scientific concepts that begins from observation to drafting laws and goes back to the event [1]. As for Develay, the experimental approach is thus imposed by the neutrality

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and objectivity of its users and subjects the ideas to the test of experimentation [2], which is confirmed by Claude Bernard, that is, based on the observed reality, the researcher proposes hypotheses submitted for examination and experiment, and after obtaining the results and interpreting them, concludes the validity of the hypothesis, or its rejection, and seeks another explanation [3]. Nevertheless, this approach, initially designed to build and facilitate the understanding of scientific concepts [4], could be one of the factors contributing to the challenges encountered by students in acquiring knowledge, especially in scientific disciplines, according to much of the research on learning and education [5], [6]. These troubles are due, in physics, for example, to the limitations of the implementation of experimental activities and the lack of scientific equipment in school laboratories [7]–[9]. This situation was also the subject of international reports that place Morocco in critical positions, as in the case of the International Association for the Evaluation of Educational Results (I.A.E.) of 2015 and the TIMSS of 2011, 2015, and 2019, where teacher's learning and training methods and teaching approaches were highlighted [10]–[12]. To overcome the challenges of the classical experimental approaches, several researchers have proposed solutions based on new information technologies, starting in 1982 with Bestougeff and Fargette [13], who introduced the concept of teaching and computers, through the definition of pedagogies using computer-assisted experimentation (CAEx) and advanced technologies such as virtual reality (VR) and augmented reality (AR) to illustrate a scientific concept [14]–[16].

This article, therefore, aims to:

1. Study the effectiveness of the classical and computer-assisted experimental approaches in achieving their original pedagogical objectives in Physics learning for Moroccan secondary schools;
2. Investigate the possible challenges that impede the experimental approach from playing its vital role education system;
3. Suggest solutions based on transforming challenges into opportunities to improve the rate of achieving these objectives.

This survey is based on a purely statistical approach through the collection of data relating to 80 teachers representing 40 Moroccan secondary schools in the regions of RABAT SALE KENITRA and FES MEKNES. A questionnaire is used for this subject, with detailed results presented and discussed in this document.

2 LITERATURE REVIEW

Since the beginning of the 20th century, practical exercises, that is, hands-on work, have been introduced at various levels of education [17]. Over the years, numerous studies have been carried out to compare the effectiveness of practical work and laboratory experiments with other teaching methods. Practical work and laboratory experiments have been demonstrated to offer several advantages. One of the fundamental advantages of experimentation in the physical sciences has been the ability to validate theories. This validation role involves the construction of experiments, most often artificially [17]–[19]. Similarly, Tala believes that observation and measurement are at the foundation of highlighting physical laws and that it is possible to create an artificial educational framework where, with proper guidance, students would be able to follow the same path in a shortened manner [20]. Indeed, in addition to being appealing to students [21], [22], experimental activities provide privileged moments for learners to practice the experimental approach, engage in critical thinking, generate hypotheses, design experiments, interpret results, and more [23]. However, while this approach was initially intended to enhance the comprehension of scientific concepts [4], it could potentially be one of the factors leading to challenges faced by students in acquiring knowledge, particularly in scientific disciplines. This observation aligns with a significant body of research in the field of learning and education [5], [6]. According to [24], many comprehension difficulties arise from the fact that teachers handle concepts without seeking to concretize them through practical activities, such as experimental tasks. The instruction remains purely theoretical, and students often lack an empirical reference point that could assist them in better conceptualizing the ideas.

With the advent of information and communications technology (ICT), various modes of experimentation in physics laboratories have emerged, including blended and virtual manipulatives, serving as alternatives to traditional physical experiments [4]. Some of the research discussed the advantages of virtual experiments and their manner of use [25]. Other researchers have found that students who engage in virtual experiments not only learn on par with those who perform physical experiments [26], [27], but in some cases, they may even learn more [28], [29]. Others presented innovative methods of learning using new technologies [30], [31]. Recently, authors have started focusing on VR and AR and their advantages for learning [32]–[35].

The literature review indicates a consensus regarding the significance of experiments in achieving learning objectives. However, the research findings regarding the effectiveness of physical, virtual, or blended labs in conducting these experiments remain inconclusive, highlighting the need for further investigations [36]. The challenges affecting this effectiveness and the opportunities for efficiency development are also subjects to be studied.

Therefore, this study aimed to assess the effectiveness of real-life and computer-assisted experimental activities in the context of physics education in Moroccan secondary schools. To address these concerns, the following research questions were formulated for this study:

1. Does the real and computer-assisted experimental approaches achieve their original pedagogical objectives in Physics learning for Moroccan secondary schools?
2. What are the possible challenges that impede the experimental approach from playing its vital role in the education system?
3. What are the possible solutions based on transforming those challenges into opportunities to improve the rate of achieving these objectives?

3 METHOD

3.1 Research procedure

This study is based on a questionnaire addressed in May 2021 to physics teachers as a social research method [37]. The research protocol and procedure were administered and validated by the Higher School of Education and Training. An electronic survey is used for data collection and the privacy of the respondents and their answers are guaranteed to minimize the Social Desirability effect as recommended by [38]–[41]. The survey is also based on teachers' answers and not students, considering their ethical engagement and their awareness that sincere answers are vital to resolving the problems they are experiencing.

This study focused on physics teachers in the regions of RABAT SALE KENITRA and FES MEKNES in Morocco. A total of 100 physics teachers were invited to participate in the study via an electronic survey distributed through email. 80 teachers representing 40 public secondary schools completed the survey, yielding a response rate of 80%.

3.2 Procedure of data collection

To collect data, an electronic questionnaire was designed and distributed to the physics teachers. The survey consisted of closed-ended and open-ended questions and was distributed via email. The questionnaire contains an introduction to the research project and 16 questions. Three items are devoted to gender, age, and affiliation information to study demographic factors. Three items focus on references used for general education, including practical experiences. Five items. Five questions are used to measure the rate of achievement of experimental activities and identify the factors and challenges contributing to the results. Two items are used to know the effect of handwork or its lack on learners, and the last three questions are oriented to the study of possible solutions.

The data collection process lasted for one month, during which participants were given sufficient time to respond to the questionnaire.

4 RESULTS

To answer the research questions, the results are presented according to the survey design logic as below:

- Demographic information (Figure 1)
- Study the effectiveness of the classical experimental approach in achieving its original pedagogical objectives in Physics learning for Moroccan secondary schools (Figures 2, 3, 4, 5).
- Investigate the possible challenges that impede the experimental approach from playing its vital role education system (Figures 6 and 7).
- Suggest solutions based on transforming challenges into opportunities to improve the rate of achieving these objectives (Figure 8).

The results are obtained from two regions of Morocco:

- The RABAT SALE KENITRA region, which contains the capital of the country. It is the most developed axis of Morocco, allowing it to cover the most developed and closely monitored secondary schools.
- The FES MEKNES region is a very large region, comprising cities, mountains, and part of the Eastern Sahara, covering rural areas and less developed schools.

This diversification takes into account all the specifications and differences between the regions of Morocco, which makes it possible to generalize the results at the national level. On the other hand, to take into account more factors that may affect the accuracy of the results, the extension of this study to other countries and regions with different levels of development should be considered.

4.1 Procedure of data analysis

The collected data was analyzed using Microsoft Excel software. Descriptive statistics were used to analyze the closed-ended questions, including frequencies, percentages, means, and standard deviations. The open-ended questions were analyzed using a thematic analysis approach, which involved identifying and categorizing the common themes that emerged from the responses. The analysis of the data aimed to evaluate the effectiveness of experimental activities in achieving pedagogical objectives and to identify the challenges and barriers that limit the effectiveness of this learning process. To ensure the quality and validity of the research outcome, the data were checked for accuracy, consistency, and reliability throughout the data analysis process.

4.2 Gender composition of the sample

To account for gender diversity, the questionnaires were originally sent to an equal number of male and female teachers. However, upon collecting the data, it was found that 87.5% of the responses came from male teachers, while only 12.5% were from female teachers. The teachers are of different ages (between 25 and 58 years), from two different regions of Morocco (RABAT SALE KENITRA and FES MEKNES), and represent urban and rural environments.

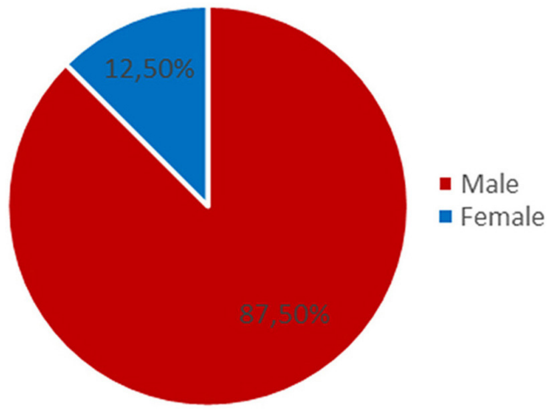

Fig. 1. Gender composition of the sample

4.3 Does your school have a physics laboratory, and is it equipped?

The results in Figure 2 evidently show that every school (100%) in the sample has a dedicated room or lab for physics experiments. However, only 19% of these labs are outfitted with the essential tools for experimental activities required in national pedagogical curricula, while the remaining 81% lack the necessary equipment, as shown in Figure 3.

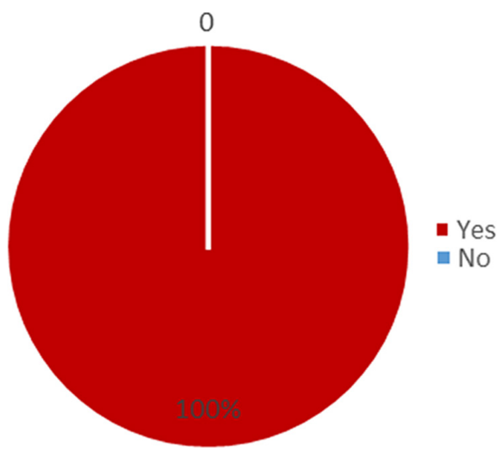

Fig. 2. Percentage of schools having a physics lab

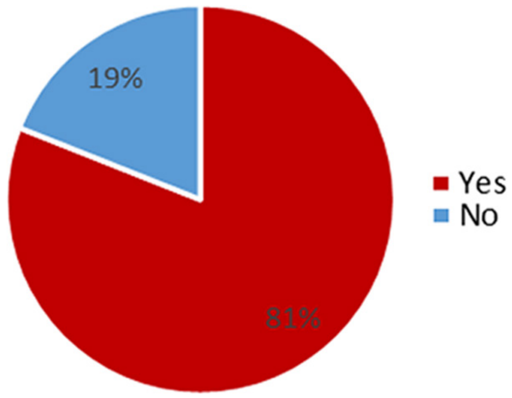

Fig. 3. Percent of equipped physics laboratories

4.4 Rate of achievement of requested experiments

The questionnaire results indicate that a mere 7.5% of teachers conduct over 80% of the experiments specified in official circulars and pedagogical guidelines, which is a notably low rate compared to the remaining 92.5%. Among this majority, 37.5% of teachers in the study perform less than 10% of the required experiments, followed by 30% who execute between 50 and 80% of the experiments, and finally, 25% of teachers who conduct between 10 and 50% of the prescribed experiments.

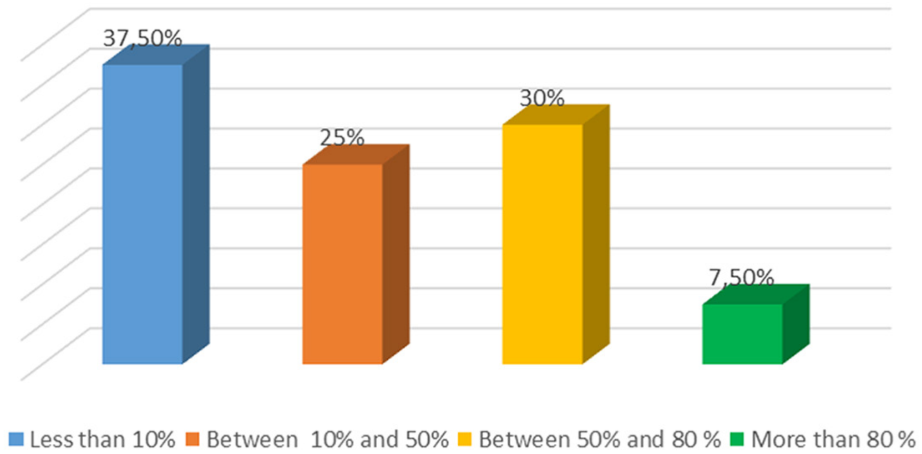

Fig. 4. Rate of achievement of requested experiments

4.5 Computer-assisted experiments CAEx adoption?

According to the findings, the majority (87.5%) of teachers believe that modern technology cannot fully replace traditional experimentation activities, but technologies can be a complement to achieve the requested educational goals. Which cannot be achieved based on conventional experiments given the issues already discussed above. While 12.5% believe that any way to reach the intended goals is desirable, this new type of experiment also presents challenges grouped in Figure 5.

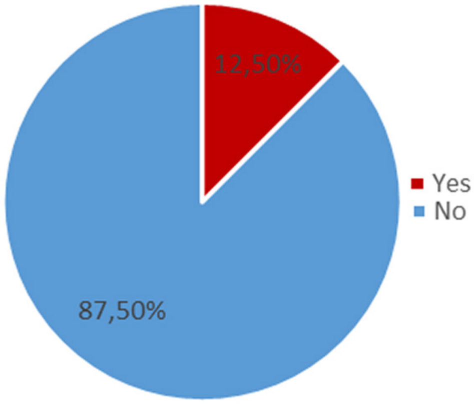

Fig. 5. CAEx adoption percentage

4.6 What are the challenges which limit the conduct of experimental activities?

According to Figure 6, 92,5% of teachers related the difficulty of conducting experimental activities to a lack of working resources and materials. 37.5% of professors think that the absence of a laboratory assistant is one of the main challenges, while the rest of the sample linked the difficulty of implementation to a variety of causes such as the training of professors, insufficient allocated time, or the mismatch of allocated time with the number of students in class knowing that the experimental activities require a reduced number.

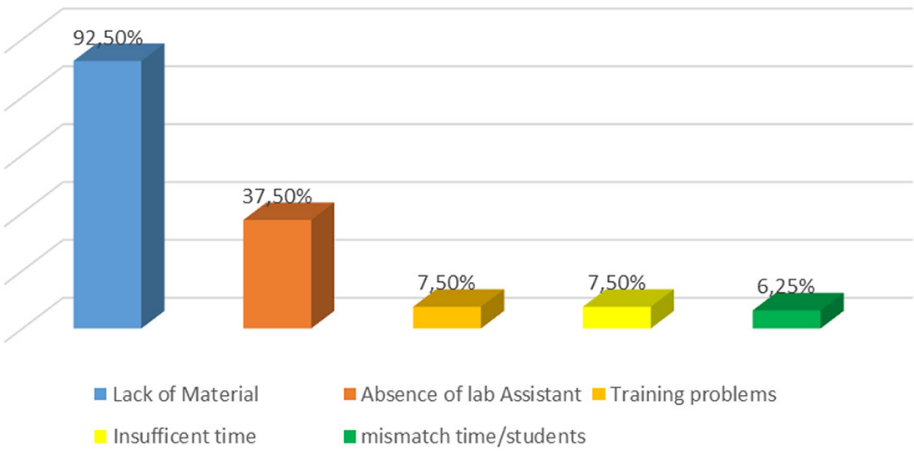

Fig. 6. Challenges that limit the conduct of experimental activities

Figure 7 shows that 62.5% of the professor's sample pointed out that the biggest challenges of computer-assisted experimental activities are the constraints of allocated time and activity organization due to large class sizes in secondary classes. On the other hand, 37.5 % of the sample liked the problem to the technical level of trainers who are not trained for this kind of experiment. The rest of the teachers think that the difficulty of handling high-technology materials such as sensors is one of the problems that limits the use of this type of experimental activity.

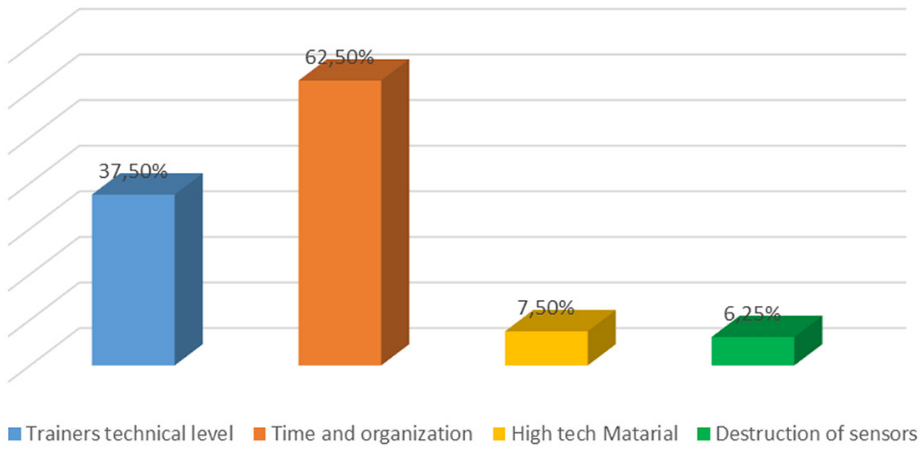

Fig. 7. Problems encountered while handling CAEx

4.7 What do you suggest to resolve this situation?

In logical correlation with the challenges that limit the performance of the experimental activities required in Moroccan secondary education, 82.5% of teachers suggest as a solution the training of teachers for the use of laboratory material. 43.75% believe that hiring a qualified assistant and the periodic allocation of the materials necessary for experiments and their monitoring can be effective solutions to overcome the obstacles of experimentation, while the rest of the teachers think that the effective solutions are material periodic control and maintenance, the allocation of experiment-specialized rooms, and good management of school curricula, taking into account the specification of experimental activities and the number of students.

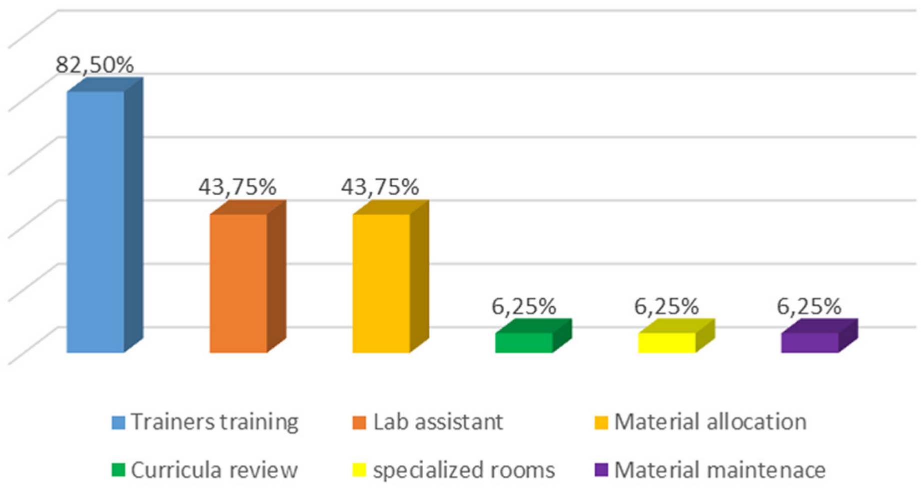

Fig. 8. Suggested solutions for overcoming challenges

5 DISCUSSION

This study evaluated the effectiveness of the classical experimental approach in achieving its original pedagogical objectives in Physics learning for Moroccan secondary schools and investigated the possible challenges that impede the experimental approach from playing its vital role in the education system. Most current research either focuses on the importance of conventional experimental work in the learning process or on the contribution of new technologies to this process without pinpointing the experienced limitations hindering the two tools from achieving the pedagogical objectives for which they were originally designed.

The results of this research clearly show that, under current conditions, the school laboratories in Moroccan secondary schools do not allow the achievement of the educational objectives for which they were initially designed. This leads to a very low efficiency of the classical experimental approach, severely limits the assimilation of most scientific concepts, especially in the physical sector, and hinders the learning and development of knowledge and skills in this area. Some of the reason behind the crucial educational challenges are listed below:

- The majority of these laboratories are not well equipped with the necessary experimental material for the required pedagogical objectives;
- In 90% of Moroccan secondary schools, there is an absence of a qualified laboratory assistant. This qualified person is the only one who can master the technical documentation for experiments and material maintenance;
- There is a mismatch of the time allocation and the number of students in secondary school classes
- ICT is often misused as an alternative or as a complement without a proper understanding of the concepts related to these technologies.
- There is a lack of trainers who receive continuing training in all fields, especially for experimental activities with ICT.

The situation is so worrying that it requires immediate intervention in the education and training sectors to remedy the cited obstacles. As medium-term solutions and to ensure the use of tools and materials for taking care of knowledge in general and especially for the conduct of practical experiments themselves to achieve the planned pedagogical objectives, the suggested solutions in the study are:

- To allocate the necessary and sufficient materials to the planned experiments, monitor and maintain them periodically
- To hire a qualified and trained laboratory assistant to handle the technical documentation and materials and to ensure the safety of the experiments requested, or to train the professors in this regard
- To plan periodic checks for the achievement rate of educational objectives in general and those related to experimental activities in a specific way
- To encourage the use of digital resources to teach physics and train teachers on an ongoing basis

As long-term solutions and to reactivate the role of scientific laboratories in the modern scientific renaissance 4.0, we suggest:

- To review the basic and in-service training of teachers so that they can innovate to overcome the difficulties of assimilating the concepts of their subjects, including experiments
- To prepare virtual labs based on VR and AR to avoid material destruction problems, and train the trainers on the subject

6 CONCLUSION

If the official Moroccan educational discourse is based mainly on the National Charter of Education and Training [42], which foresees the importance and crucial role of experimentation in the teaching of physics at the secondary level, the practical reality, as deduced from this study, shows a worrying insufficiency in the carrying out of the experimental activities. This severely limits the achievement of the educational objectives for which these activities were originally designed.

Several current research papers focus on the importance of conventional experimental work in the learning process or the contribution of new technologies to this process without pinpointing the experienced limitations hindering the two tools ability to achieve the pedagogical objectives for which they were originally designed. This study, as distinct from previous ones, allowed us to identify the problems and difficulties encountered by physics teachers when adopting experimentation to explain certain scientific concepts and to reveal their needs in the areas of coaching and training. It has also shown that there is an absence of coordination between management decision-makers and those involved in the practical use of scientific laboratories. This has resulted in a lack of necessary materials and a shortage in terms of maintenance and repair of laboratory educational equipment. These findings align closely with previous studies conducted in the same domain [43]–[45].

The challenges are also related to the absence of qualified laboratory assistants and the misuse of ICT as an alternative or as a complement without mastering the concepts related to these technologies. To solve these issues solutions are suggested as medium-term and long-term plans.

It should be noted that, despite measures taken to avoid the risk of socially desired responses, conducting the study through personal statements is a limitation to be noted [46]. In addition, the study is relative to the Moroccan context in a specific period, and the interest is to extend it to other countries and regions with different levels of development to better frame the obstacles and challenges affecting the efficiency of the use of experiences in secondary education.

Thus, this work cannot answer all aspects of the subject but rather allows the opening of new research paths by asking questions, problems, and hypotheses that could not be addressed by urgent circumstances such as the effectiveness of conventional experimental activities in hybrid education and the study of the use of advanced digital technologies such as VR and AR as a solution to increase such efficiency and overcome current obstacles to achieve the planned educational objectives for the experiments in physics for Moroccan secondary schools.

In summary, the current research results are highly consistent and comparable with the outcomes of prior research conducted in the same area [47]–[49]. These studies have investigated the same or similar research questions, used similar research methodologies, and reported similar findings. The convergence of findings across studies provides further evidence and strengthens the validity of the current research results. Additionally, it highlights the robustness and generalizability of the findings, as they are not isolated or unique to this particular study.

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