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Constraints, Challenges, and Innovation Issues for Integrating Virtual Lab Sessions in Life and Earth Sciences Education in Morocco

Information and Communication Technologies for Education play a central role in the Moroccan educational landscape. This article provides a comprehensive mapping of the constraints, challenges, and issues related to implementing virtual lab sessions in teaching Life and Earth Sciences in

Morocco. The methodological approach used in this study is based on two main axes. On the one hand, a series of surveys was conducted among teachers and students to assess their perceptions of virtual labs, identify major obstacles, and suggest potential solutions. On the other hand, a qualitative analysis of current practices was conducted to establish the current state of virtual labs in Moroccan educational institutions. The results reveal that the limited use of virtual labs is due to obstacles such as lack of access to technological resources, the need for teacher training, and logistical challenges. Additionally, teachers often express reluctance to adopt these methods due to a lack of awareness or confidence in their effectiveness. By highlighting these challenges, the article recommends the implementation of specific strategies to promote a more successful adoption of virtual labs, primarily through teacher training, improved access to technological resources, and the gradual integration of virtual labs into the Life and Earth Sciences curriculum.

Keywords: educational innovation, ICT in education, virtual lab sessions, Life and Earth Sciences, pedagogical integration.

Introduction

Practical work in Life and Earth Sciences (LES) represents a fundamental component of science education. According to Millar (s. d.), it is defined as "any science teaching and learning activity in which students, working individually or in small groups, observe and / or manipulate the objects or materials they are studying." This definition emphasizes the importance of direct observation and manipulation in practical sessions, enabling students to develop a deeper and more concrete understanding of scientific concepts.

Information and Communication Technologies for Education (ICTE) are opening up new opportunities for practical work in science. Simulations and virtual models can replicate laboratory experiments, granting students greater autonomy in their learning process while offering teachers innovative methods to enhance student engagement. These tools provide key advantages such as flexibility, safety, and personalized monitoring of student progress.

However, despite the rise of online learning platforms such as MOOCs, remote scientific experiments have not yet become widespread. The lack of appropriate equipment continues to pose a challenge to the implementation of practical activities. The integration of virtual labs (tele-practicals, e-labs), whether in-person or remote, therefore presents a complex technical and pedagogical issue that is currently the focus of numerous studies.

Previous research [*Mastafi*, 2014; *Madhi*, 2014] has highlighted the many challenges linked to the use of Information and Communication Technologies (ICT) in educational settings, particularly in scientific disciplines such as LES. Our study builds on these findings by focusing specifically on virtual practical work, an area that remains underexplored in the Moroccan context. Other studies [*El Kartouti, Juidette*, 2023; *Btissam, Aziz*, 2023; *Benali et al.*, 2021] have reported significant improvements in student learning outcomes through ICT, a result that aligns with the objectives of our research centered on virtual labs. Nevertheless, few investigations have directly examined the contribution of virtual practicals in LES, where the use of simulations and virtual environments shows great promise for boosting student engagement and comprehension.

The analysis by Nafidi and Alami (s. d.) on the adoption of ICT by science teachers highlights key barriers to integration. Our study distinguishes itself by specifically addressing virtual practical work in LES, offering a fresh perspective on how these tools can enrich science education for Moroccan learners. This same study also demonstrates the effectiveness of digital simulations in the teaching of Earth Sciences, providing valuable support to

our research. It illustrates the positive impact that digital technologies can have on student learning, reinforcing the case for deeper integration of such tools into pedagogical practices in Morocco, especially in the sciences.

In this context, our research question is as follows: What is the current state of integration of virtual practical work in LES education in Morocco, and what are the main challenges to be overcome for successful implementation?

This central question can be broken down into the following sub-questions.

1) To what extent are virtual practicals currently used in Moroccan educational institutions?
2) What are the main obstacles and innovation challenges related to the adoption of virtual practical work in LES education in Morocco?
3) What are the perceptions of teachers and students regarding virtual practicals, and how do they compare in effectiveness to traditional in-person practical sessions?

This study follows a three-phase analytical approach. First, we assess the material and pedagogical limitations of traditional practical work in Moroccan schools. Second, we examine the actual adoption of digital tools in LES education, with a particular focus on virtual practicals. Lastly, we analyze teachers' and students' perceptions of these new methods before presenting recommendations for their effective integration into the Moroccan educational system.

Methodology

This study is based on a descriptive and exploratory approach, using two anonymous questionnaires designed to survey LES teachers and secondary school students in Morocco. The aim was to compare the perceptions of these two key actors in order to analyze current practices related to practical work, the use of educational technologies, as well as the barriers and enablers associated with the integration of virtual practical work in science education.

The questionnaires specifically aimed to gather information on:

— the condition and use of school laboratories;
— student involvement in experimental activities;
— perceived obstacles to traditional practical work;
— the use of ICT in LES courses and practical sessions;
— perceptions of virtual practical work as an alternative or complementary solution.

The instruments were distributed online (via *Facebook*, *WhatsApp*, and email), with the support of educational inspectors, school principals, and teachers. The responses were analyzed to identify general trends, perception gaps, and possible avenues for improving the integration of digital technologies into LES teaching.

Analysis and Interpretation of Results

We conducted this study during the 2023—2024 school year. The survey was carried out across several provincial delegations of the National Education in Morocco. Our study targeted a sample of 4 000 teachers and 2 500 secondary school students, distributed as detailed in the table below.

Table 1. Target population of the study

Group	Questionners sent	Responses received
Teachers	4 000	720
Learners	2 500	575

Results related to the teacher questionnaire

Section 1. General Information

This first section aims to analyze the influence of several contextual factors on the implementation of practical work in schools. These factors include age, level of education, teaching experience, class size, weekly workload, as well as the geographical location and type of institution.

The data show that the majority of surveyed teachers are between 30 and 40 years old (40%), followed by those over 40 years old (34%), while teachers under the age of 30 represent 26% of the sample.

Regarding academic background, 45% of respondents hold a bachelor's degree, 30% a master's degree, 12% a diploma from a teacher training college (ENS), 7% a doctorate, and 6% a CPR diploma.
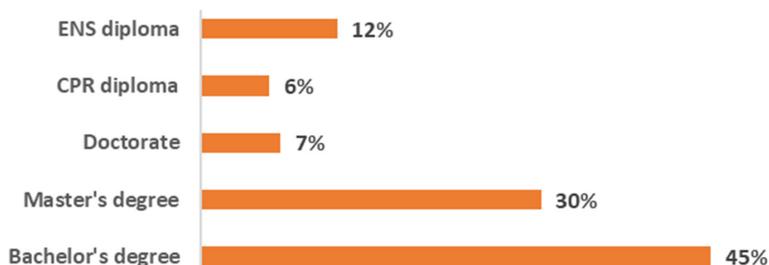
Fig. 1. Distribution of teachers by academic degree

The majority of teachers work in urban areas (75.4%), compared to 24.6% in rural settings. In terms of sector distribution, 97.7% of participants are employed in public schools, while only 2.3% work in the private sector. Concerning teaching experience, 30.8% report having between 5 and 10 years of experience, 26.3% more than 15 years, 21.7% between 10 and 15 years, and 21.14% less than 5 years.

Fig. 2. Distribution of teachers by teaching experience

Section 2. Teaching conditions and laboratories in institutions

The responses collected help to better understand the impact of teaching conditions on the implementation of practical work in schools.

With regard to weekly teaching hours, 45.7% of teachers report working 24 hours per week, while 44.5% report working 20 hours per week.
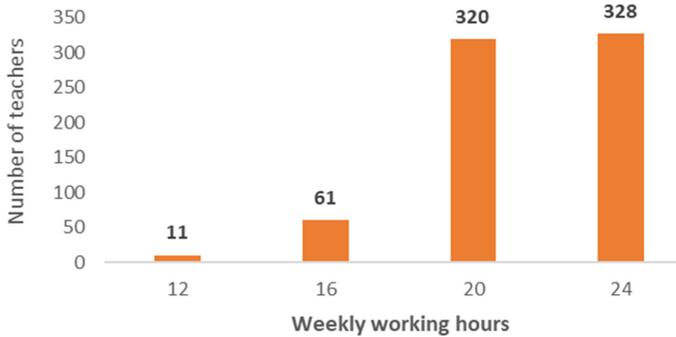
Fig. 3. Distribution of teachers by weekly teaching hours

In terms of class size, 86% of teachers supervise groups of 30 to 45 students, 9% work with fewer than 30 students, and 4% with more than 45 students.
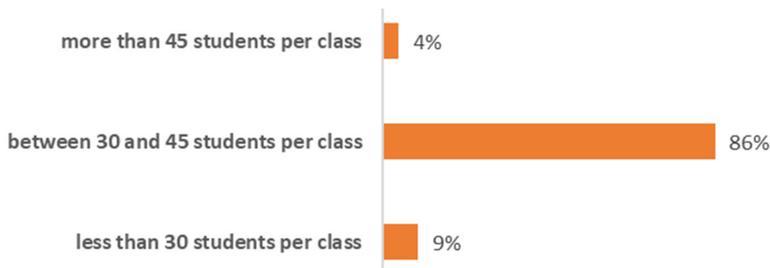
Fig. 4. Average class size as reported by teachers

Regarding the presence of a laboratory, all surveyed teachers report that their institution has a space dedicated to practical work. However, a large majority indicate that these laboratories are not always suitable for experimental activities.The frequency of practical sessions varies significantly: nearly 60% of teachers report organizing them rarely, while around 20% schedule them once a month.
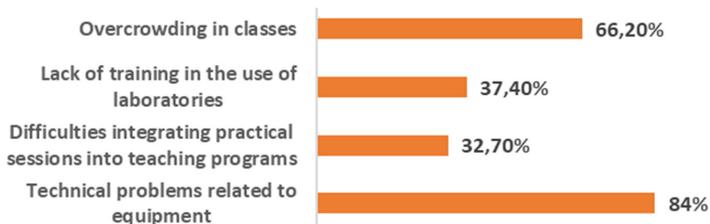
Fig. 5. Obstacles to implementing practical work as perceived by teachers

The main obstacles identified are technical in nature, mentioned by 84% of respondents (lack of equipment, expired materials). Oversized classes are reported by 66.2%, followed by insufficient training in the use of laboratory equipment (37.4%) and curriculum overload (32.7%).

Section 3. Use of ICTE in the teaching of LES

In this section, teachers were asked about the types of digital tools they use in LES classes, as well as their pedagogical purposes.

Regarding practical uses, 89.7% of teachers report using *PowerPoint* to present their lessons. *YouTube* videos are also widely used, with 72.9% of teachers indicating their use. Digital educational resources (software, animations, interactive modules) are used by 45%, while 35.5% rely on Internet searches to enhance their sessions. Digital encyclopedias are mentioned less frequently, at 10.3%.
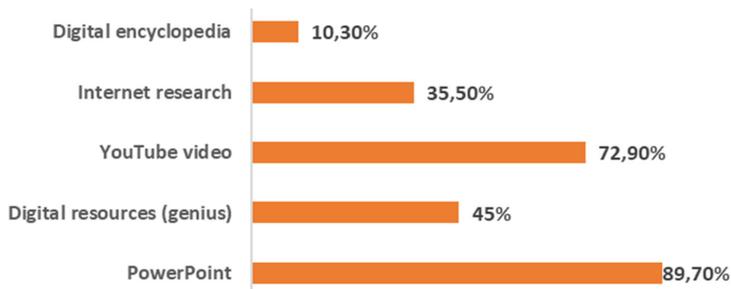
Fig. 6. Types of digital tools used by LES teachers

As for the pedagogical purposes of these uses, the majority of teachers (84.9%) report using ICT primarily to present visual content (slideshows, videos, images). Approximately 56.6% use them to carry out simulations of scientific phenomena. Just over a third (34.2%) employ them to support collaborative work, and 24.3% use them for formative or summative assessment.
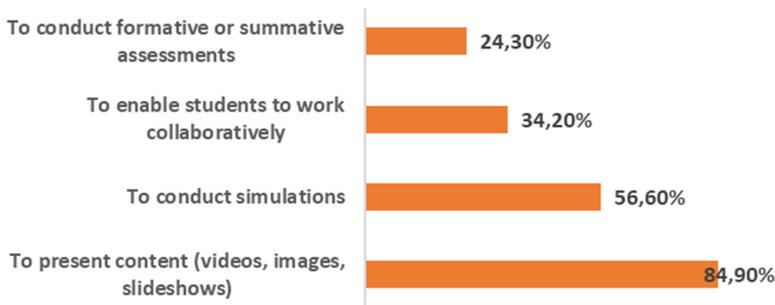
Fig. 7. Pedagogical purposes of ICT in LES according to teachers

Section 4. Use of Virtual Lab Sessions (Simulations)

This section aims to assess the use of ICT as an alternative to traditional practical work, through the analysis of their frequency of use, the resources involved, the perceived bene-

fits, and the limitations identified by teachers. Regarding laboratory equipment, 51.5% of teachers report having access to a computer and a projector, while 48.5% do not have either of these devices. On the question of replacing practical sessions with ICT tools, 80.5% of teachers report having already used digital tools to replace certain sessions, while 19.5% have never done so.

Among the main reasons mentioned are the lack of materials (87.9%), the complexity of carrying out certain practical activities in real conditions (49.3%), and time savings (47.1%). Other reasons include facilitating access to experiments outside class hours (22.9%), improving teaching effectiveness (22.1%), and reducing costs (15.7%).
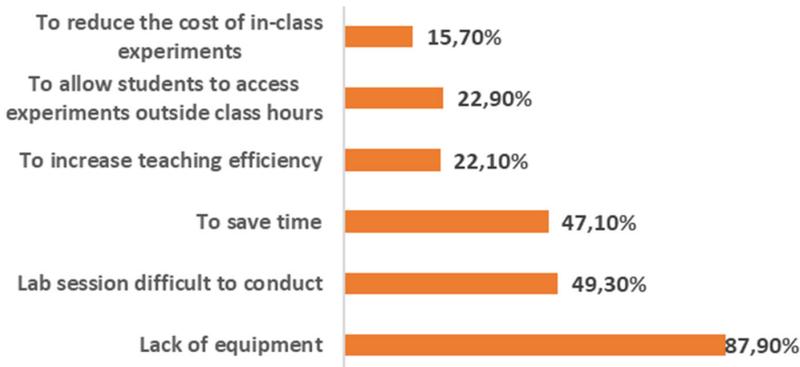
Fig. 8. Reasons for using ICT to replace certain practical sessions

The most commonly used tools during virtual practical sessions are animations (78.3%), digital resources (47.8%), simulation software (44.9%), and applications (29%).
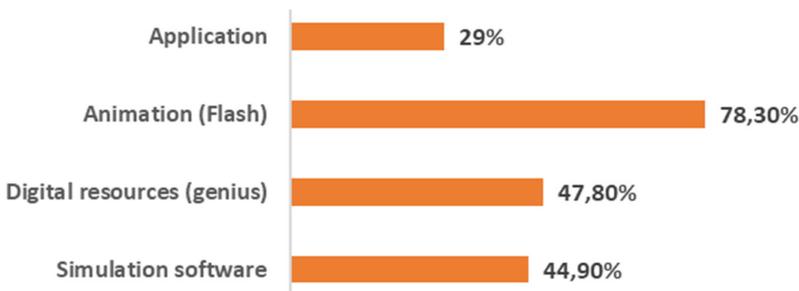
Fig. 9. Types of ICT use during the substitution of practical sessions

Regarding training, 42.9% of teachers report having received training in the use of ICT in LES, while 57.1% have never received such training. Skill acquisition was mainly achieved through self-training (60.3%), in-person training sessions (30.8%), online courses (17.8%), or collaboration with colleagues (26.7%).

Teachers identify several advantages of virtual practical work compared to traditional laboratory sessions. The most frequently cited benefits include reduced risks for students (58.5%), broader access to experimental activities (53.5%), ease of organization (52.4%), cost reduction (31.3%), and simplified preparation (45.6%).
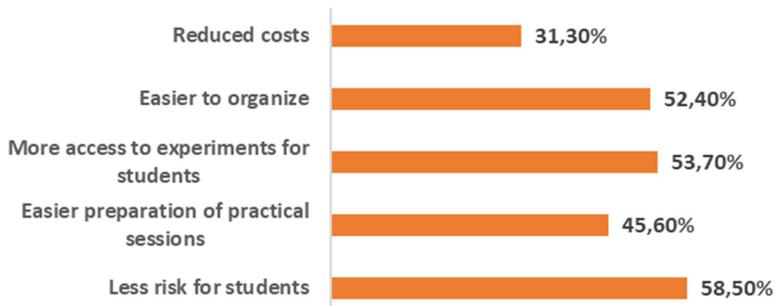
Fig. 10. Advantages of virtual practical work according to teachers

On the other hand, several limitations are also reported. The lack of physical contact with equipment is mentioned by 87.7% of respondents, followed by decreased student motivation (47.9%), difficulties in solving experimental problems (39%), and challenges in enforcing safety instructions (24.7%).
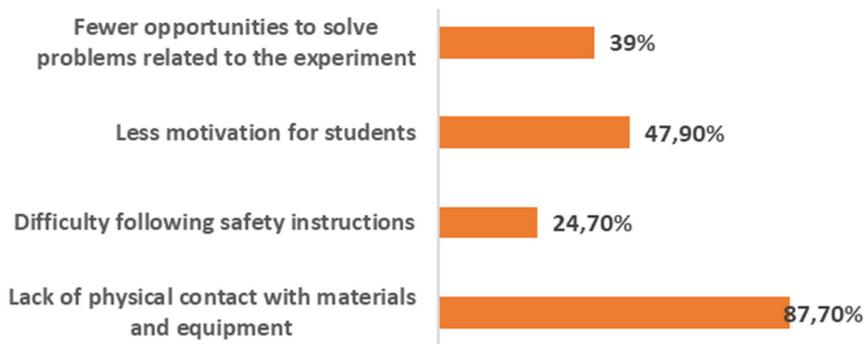

Fig. 11. Disadvantages of virtual practical work according to teachers

Finally, 74.8% of the teachers surveyed state that they would recommend the use of virtual practical work to their colleagues, while 25.2% would not.

Results Related to the Student Questionnaire

The analysis of responses to the questionnaire addressed to students provided significant information about the implementation and method of practical work in educational institutions.

Section 1. General Information

This section describes the general profile of the students who responded to the questionnaire. The variables collected relate to their level of education, the geographical location of their school, and other contextual information related to their learning environment.

The results show that the majority of participating students — 81.9% — are enrolled in upper secondary education, while 18.1% are in lower secondary education.
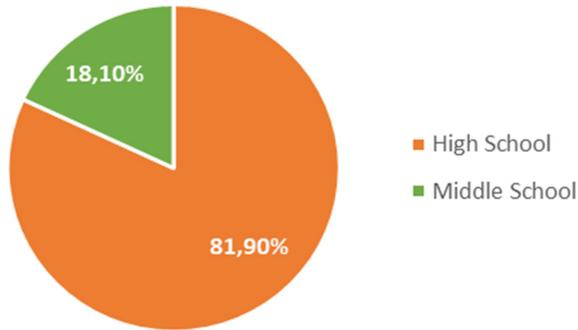

Fig. 12. Distribution of students by level of education

Next, students were asked to indicate whether their school was located in an urban or rural area. The results show that the vast majority of students (92.8%) attend school in an urban setting, while a minority (7.2%) are enrolled in rural schools.
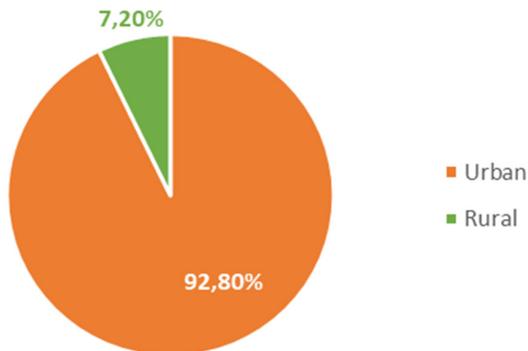

Fig. 13. Distribution of schools by geographical setting

Section 2. Use of ICT in the teaching of LES

In this section, students were asked about their experience with ICTE during LES classes, in terms of usage, accessibility, types of tools used, and their perceived impact on learning.

The results show that 76.8% of students report using ICT during LES sessions, while 23.2% state that they do not.
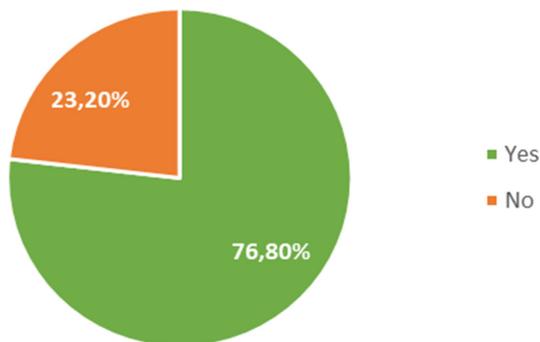
Fig. 14. Use of ICT in LES according to students

Regarding the most commonly used tools, 60.5% of students report watching *YouTube* videos, 58% conduct Internet searches, 55.6% use *PowerPoint* presentations, while 29.6% use digital resources and 7.4% rely on digital encyclopedias.
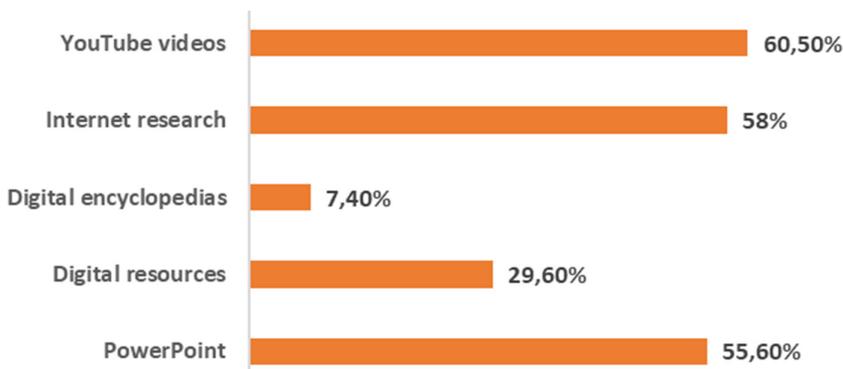

Fig. 15. Types of ICT tools used in LES according to students

In terms of access to ICT, 57.3% of students use school computers, 30.5% connect directly via the Internet, and 17.1% access ICT through applications installed on their personal devices.
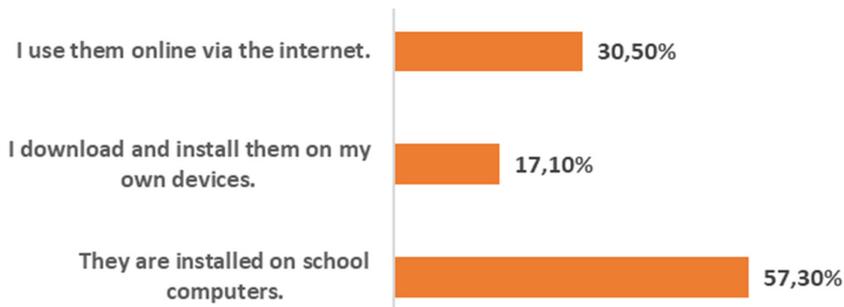

Fig. 16. Modes of access to ICT during LES sessions according to students

Regarding classroom motivation, 89% of students believe that the use of ICT makes LES lessons more engaging, while 11% do not share this view.

Finally, on the question of learning ease, 87.8% of students agree or strongly agree that ICT facilitates their learning, 9% disagree or strongly disagree, and 2.2% report being neutral.
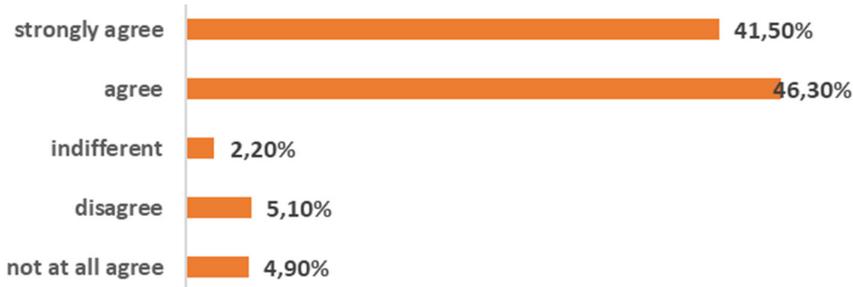
Fig. 17. Perceived impact of ICT on learning ease according to students

Section 3. Use of virtual labs (simulation)

In this section, students were asked about their use of ICT during practical work sessions, particularly as an alternative or complement to traditional laboratory activities. The results show that 59.3% of students report having used ICT to replace certain practical sessions, while 40.3% state that they have never done so in this context. When asked about the frequency of using digital resources to supplement practical work in class, 26.8% of students say they use them very often, 39% from time to time, 19.5% rarely, and 14.6% never.
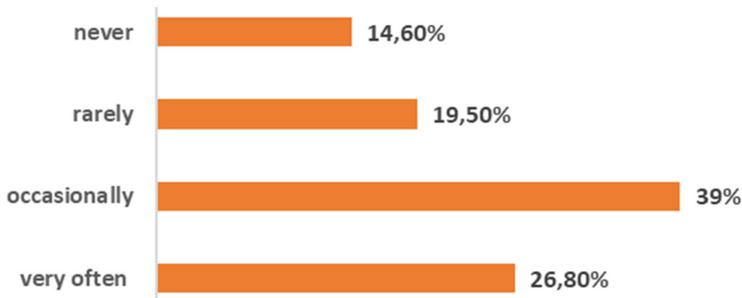
Fig. 18. Frequency of digital resource use to support practical work

Finally, students were asked to give their opinion on whether virtual practical work (simulators, interactive animations) could replace real-life experiments. The results reveal that 62.2% of students believe that ICT cannot replace hands-on experiences, while 37.8% think they can serve as a substitute.
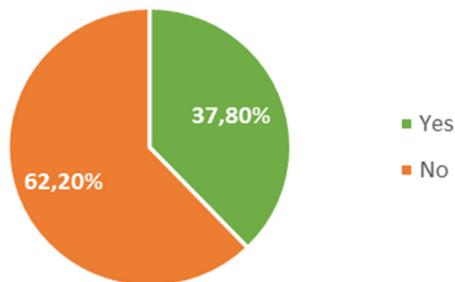
Fig. 19. Students' opinions on replacing real experiments with virtual practical work

Discussion of Results

The results obtained from both teachers and students provide valuable insight into the integration of virtual practical work in life and earth sciences education in Morocco. They highlight favorable perceptions, promising trends of adoption, as well as significant challenges that need to be addressed.

The analysis of life and earth sciences teachers' profiles reveals a predominantly young (30–40 years), qualified, and experienced workforce. This combination creates favorable conditions for the adoption of pedagogical innovations, provided that teachers are supported through targeted training programs. Disparities between urban and rural areas, particularly in terms of equipment, underscore the need for inclusive policies to ensure equitable access to digital resources.

On an organizational level, constraints related to teaching workload, class size, and inadequate laboratory facilities represent significant barriers to the implementation of traditional practical work. These findings reinforce the relevance of alternatives such as virtual practical work, which can help address certain structural limitations.

LES teachers already make extensive use of ICT in their teaching practices — *PowerPoint*, videos, simulations, and digital resources are commonly employed. This familiarity with digital tools provides a fertile ground for the gradual introduction of virtual practical work. However, the success of this transition depends on institutional support, access to quality resources, and ongoing professional development.

The results indicate a relatively widespread adoption of virtual practical activities (tele-TP). Their use is primarily driven by the lack of equipment, the complexity of conducting certain experiments, and the search for practical logistical solutions. Teachers recognize several benefits, including reduced risk, increased accessibility, and time efficiency. Nevertheless, important limitations remain: lack of direct contact with materials, reduced student motivation, and difficulty in replicating all dimensions of hands-on experimentation.

These findings advocate for the complementary integration of tele-TP alongside traditional practical work, rather than as a full replacement. The fact that most teachers recommend tele-TP to their peers reflects a generally positive attitude toward this approach.

From the students' perspective, ICT is generally perceived positively. It makes lessons more engaging and facilitates understanding. The variety of tools used reflects a diversity of digital learning practices. However, access to resources remains unequal, particularly

depending on school location or availability of personal devices. This highlights issues of digital equity that must be considered in any virtual practical work integration strategy.

Regarding tele-TP, while students acknowledge their usefulness, the majority believe they cannot fully replace real-life experiments. This perspective echoes that of the teachers and underlines the importance of combining virtual and hands-on approaches to provide a well-balanced and effective scientific learning experience.

Conclusion

Our study highlights the potentials and challenges associated with the integration of virtual labs in the teaching of life and earth sciences in Morocco. Through the analysis of perceptions and experiences of teachers and learners, it is evident that virtual labs offer significant opportunities to enrich LES education. They provide a flexible, safe, and interactive pedagogical approach, capable of overcoming some of the inherent limitations of traditional lab work. However, the results also emphasize major obstacles to their widespread adoption, including the lack of access to necessary technological equipment, variability in access to digital resources, and the increased need for teacher training in the use of these innovative technologies.

The general enthusiasm for virtual labs, as shown by the positive recommendation of their use by a majority of teachers, suggests a fertile ground for their further integration into the LES curriculum in Morocco. However, this study underscores the importance of a balanced approach that seeks not to replace, but rather to complement traditional labs with virtual practices. Combining both methods appears to be the most promising way to offer a complete and enriching learning experience to students.

To foster a broader and more effective adoption of virtual labs, it is crucial to invest in improving technological infrastructure within educational institutions, develop targeted training programs for teachers, and devise pedagogical strategies that fully leverage the benefits of virtual labs while addressing their limitations. The future of LES education in Morocco will largely depend on the educational system's ability to seamlessly integrate technological innovations into its pedagogical practices, in order to prepare students to navigate an increasingly digitalized world.

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Ограничения, вызовы и проблемы интеграции занятий в виртуальной лаборатории в процесс преподавания наук о земле и о жизни в Марокко

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Информационно-коммуникационные технологии в образовании (ICTE) играют главную роль в системе образования Марокко. Предлагаемая статья представляет комплексный анализ ограничений, вызовов и проблем, относящихся к проведению занятий в виртуальной лаборатории в процессе преподавания наук о земле и наук о жизни в Марокко. Методологический подход, использованный в этом исследовании, основан на двух основных осях. С одной стороны, была проведена серия опросов среди учителей и учащихся, чтобы оценить их восприятие виртуальных лабораторий, выявить основные препятствия и предложить возможные решения. С другой стороны, был проведен качественный анализ современных практик, чтобы установить текущее состояние виртуальных лабораторий в марокканских образовательных учреждениях. Результаты показывают, что препятствиями, ограничивающими использование виртуальных лабораторий, являются отсутствие доступа к технологическим ресурсам, необходимость подготовки учителей и логистические проблемы. Кроме того, учителя часто выражают нежелание использовать эти методы по причине недостаточной осведомленности или недостаточной уверенности в их эффективности. Подчеркивая эти проблемы, авторы статьи рекомендуют реализацию конкретных стратегий для продвижения более успешного внедрения виртуальных лабораторий, прежде всего —подготовку учителей,

улучшение доступа к технологическим ресурсам и постепенность в интеграции виртуальных лабораторий в программы наук о земле и о жизни.

Ключевые слова: инновации в образовании, ИКТ в образовании, занятия в виртуальной лаборатории, науки о жизни и о земле, педагогическая интеграция.