Creation of Open-Access Virtual laboratories (VL) for teaching in STEM education: Biology across the Health Sciences

WP5 Task 5.5

IMPLEMENTATION REPORTS

CROSS-NATIONAL SYNTHESIS

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Executive summary

This cross-country synthesis consolidates the findings of the VHEalthLab implementation conducted in Spain, Cyprus, Greece, and Romania between May and September 2025. Drawing on pre- and post-questionnaire data, interviews, and focus groups, the evaluation assessed educators' digital readiness, perceptions of virtual laboratories (VLs), the usability of Module 1 and the pedagogical guidelines, and the learning experience in four virtual lab cases (Lab Safety, Light Microscopy, Cell Structure and Function, Cell Division–Mitosis).

Across all countries, pre-questionnaire data showed highly positive attitudes toward the pedagogical value of virtual labs and a strong consensus on the need for pedagogical guidelines and teacher training, although prior hands-on experience with VLs varied considerably. Teachers widely acknowledged virtual labs as complementary rather than replacements for physical laboratory work.

Post-questionnaire results indicated substantial increases in confidence, usability ratings, and intention to use the resources. Module 1 and the guidelines were perceived as clear, well-structured, and practical, and the platform was widely reported as easy to navigate. Challenges were mostly related to technical issues, assessment clarity, time constraints, and accessibility barriers (such as small text size, limited feedback, and missing accessibility features).

Qualitative findings consistently highlighted the pedagogical value, particularly in visualizing abstract processes, facilitating risk-free exploration, and structured inquiry-based scenarios. Teachers appreciated the authenticity of materials and multimedia but suggested enhancements in accessibility, interactive assessment, and curricular alignment.

Overall, the results show strong cross-country convergence: educators value the platform, perceive the VLs as pedagogically robust, and identify similar priorities for improvement. These insights will guide the next iteration of the platform, supporting the EU's broader efforts to strengthen inclusive, high-quality digital STEM learning.

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1. INTRODUCTION

The growing emphasis on digital transformation in education, particularly within science, technology, engineering, and mathematics (STEM), has positioned virtual laboratories (VLs) as innovative tools for enhancing teaching and learning. In response to this evolving landscape, the VHEalthLab project developed open-access VLs with a strong pedagogical foundation, aligned with contemporary inquiry-based learning (IBL) methodologies and with particular attention to inclusion. To support implementation, a pedagogical guide was created, along with three interactive training modules, providing clear guidance on deploying VLs in both secondary and higher-education classrooms. These digital tools enable educators to deliver engaging, student-centred science instruction that overcomes traditional barriers such as limited lab access, time constraints, and the complexity of experimental procedures.

This report compiles the qualitative and quantitative data collected in Cyprus, Spain, Greece, and Romania between May and September 2025, following the rollout of the pedagogical guide, Module 1 ("Introduction to Virtual Labs and IBL"), and four case-based virtual labs: Lab Safety, Light Microscopy, Cell Structure and Function, and Cell Division - Mitosis. The quantitative evaluation, via pre- and post-training questionnaires, examined teachers' initial digital readiness and measured changes in confidence, perceived usability, pedagogical value, and identification of technical challenges. The qualitative evaluation, through interviews and focus groups, added nuance by capturing participants' experiences, expectations, and suggestions for improvement.

These findings feed into the iterative refinement of the platform, highlighting which components perform best and where simplification or enhancement is needed. They also provide critical insights for European education policy on digitalization, teacher professional development, and equitable access to high-quality STEM resources. In doing so, the report not only assesses this specific training intervention but also contributes to the broader discussion on modernizing science education through inclusive, technology-enriched learning environments.

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2. METHODOLOGY

2.1. QUANTITATIVE DATA

2.1.1. Pre-questionnaires and post-questionnaires

Across all countries, a structured pre–post design was used to assess educators' baseline confidence, digital readiness, and expectations before interacting with the VHEalthLab materials, followed by their perceptions after completing Module 1, the pedagogical guidelines, and the virtual labs.

All countries used Likert-scale questionnaires, open-ended comments, and post-test reflection items. Data collection was carried out online in Romania and Greece, and mostly in person in Spain. Cyprus used both formats, as participants came from varied institutional settings.

2.1.2. Participant profile and data collection

Table 1. A combined overview across countries indicates:

Country	Pre (n)	Post (n)	Profile
Spain	30	30	Pre-service biology teachers (Master's programme)
Cyprus	18	17	Secondary teachers, HE lecturers, pre-service teachers
Greece	7	7	HE biology tutors + 1 secondary teacher
Romania	24	20	Secondary + HE biology teachers (mixed)

Across countries, most participants were biologists currently teaching or preparing to teach in secondary or higher education. All completed Module 1 and at least one virtual lab.

2.2. QUALITATIVE DATA

2.2.1. Interviews: Participant profile and data collection

Interviews were conducted in all four countries with:

- **Spain**: 7 interviews, all written, with biology graduates in a teacher-training master's programme; conducted remotely; structured in 15 questions.

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- **Romania**: 6 interviews; written format; following post-intervention; participants from secondary and higher education; explored pedagogical relevance, challenges, and curriculum alignment.
- **Cyprus**: 3 interviews; semi-structured, online, 30–40 minutes each; participants included an experienced teacher, a trainee teacher, and a lecturer.
- **Greece**: 5 written interviews; conducted remotely over several days; all participants involved in biology HE or secondary teaching.

2.2.2. Focus Groups: Participant profile and data collection

Focus groups were conducted in all countries:

- **Spain**: 7 participants, in person, 55 minutes, semi-structured, recorded and transcribed.
- **Romania**: 3 participants, online, after interviews; explored platform use and lab materials.
- **Cyprus**: 8 participants, online, 105 minutes; coded into five themes using thematic analysis.
- **Greece**: 7 participants, online, 45 minutes; HE and secondary tutors, recorded and transcribed.

Across all countries, focus groups were semi-structured and facilitated by project partners, ensuring cross-country comparability.

3. RESULTS

3.1. QUANTITATIVE DATA

3.1.1. Pre-Questionnaire Findings (combined cross-country summary)

Table 2 provides an overview of teachers' baseline perceptions and expectations before interacting with the VHEalthLab materials. The results show that although participants varied in their prior experience with virtual labs, they generally felt confident in using digital tools and strongly recognized the pedagogical value of virtual laboratories. Across countries, teachers consistently viewed VLs as complementary aids rather than substitutes for hands-on laboratory work. The table also highlights a clear consensus on the importance of pedagogical guidelines and teacher training, indicating that educators expect structured support when integrating virtual labs into teaching. Overall, the table reflects a positive starting point, with

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minor differences among countries related mainly to digital experience and familiarity with inquiry-based learning.

Table 2. Summary of Pre-Questionnaire Themes Across Countries.

Theme	Cross-Country Summary
Confidence with virtual labs and digital navigation	Mostly moderate to high confidence. Spain and Cyprus showed strong overall confidence; Greece showed moderate confidence with variation; Romanian participants reported strong digital readiness but limited VL experience.
Openness vs. hands-on experience	All countries saw VLs as useful **complements**, not replacements, for physical labs. Prior exposure varied: Spain and Cyprus reported limited hands-on VL experience; Greece mixed; Romania higher openness but doubtful about replacing hands-on labs.
Perceived pedagogical value	Universally high. VLs seen as effective for inquiry, visualisation, and safe experimentation. Spain showed the strongest agreement on pedagogical benefits; similar in Cyprus and Romania; Greece also positive but with more reservations.
Role of pedagogical guidelines	Extremely strong consensus across countries that guidelines are essential for implementation, inclusion, and addressing diverse needs.
Need for teacher training	Nearly unanimous agreement that VL implementation requires teacher training (strongest in Spain and Romania). Slight disagreement in Greece where 1 participant opposed training necessity.
Additional comments	Spain: accessibility concerns, need for clear guidance. Romania: emphasis on curricular integration and clarity of purpose. Cyprus: concerns about limited prior IBL experience. Greece: no comments submitted.

Across all four countries, participants valued the pedagogical potential of virtual labs, especially for inquiry and safe, visual exploration. Confidence in digital navigation varied, with Romania and Spain showing higher readiness and Greece showing more variation. Importantly, all countries agreed strongly that virtual labs should not replace physical labs but serve as complementary tools. Participants unanimously expected clear pedagogical guidelines and teacher training before implementation.

3.1.2. Post-Questionnaire Findings (combined cross-country summary)

Table 3 summarises educators' perceptions of Module 1 and the pedagogical guidelines after training. The results show high levels of agreement regarding the

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clarity of instructions, the ease of finding information, and the usefulness of the materials for teaching and learning. Participants reported that the modules were effective in introducing inquiry-based learning and clarifying how virtual labs can be implemented in different classroom contexts. While most educators responded positively, some variation appeared in areas such as strategies for inclusion, addressing the gender gap, and practical applicability across diverse teaching settings. Overall, the table demonstrates that Module 1 and the guidelines were well received and contributed meaningfully to increasing teachers' confidence and readiness to use the virtual labs.

Table 3. Evaluation of Module 1 & Pedagogical Guidelines.

Dimension	Cross-Country Summary
Clarity of instructions and language	Very high agreement in all countries; only minimal disagreement (Spain: 1 strongly disagree; Greece: 1 disagree).
Ease of locating information	Majority strongly agreed; Cyprus and Greece especially strong; small minority in Spain and Greece reported difficulty.
Usefulness for teaching and learning needs	High overall; Spain and Cyprus strongest; Romania positive but more varied due to wider teacher profile; Greece mixed but still positive.
Contextual understanding of VL implementation	Strong in Spain and Cyprus; moderate in Greece; Romania highlighted clearer alignment needed.
Practical IBL guidance	Strongly agreed across countries; Cyprus highest satisfaction (over 70% strongly agree) .
Strategies for inclusion and gender gap	Spain and Cyprus rated highly; Greece more divided; Romania positive but requested more concrete examples.
Intent to use in practice	Overall strong; Spain and Cyprus highest; Romania moderate; Greece mixed (1 strong disagreement).

Table 4 presents teachers' evaluations of the virtual lab platform and the four case studies. The results are consistently positive, showing that educators across all countries found the platform easy to navigate and the instructions clear and manageable. High task-completion rates indicate that users were able to follow the experimental steps without major difficulty. Minor issues reported, such as small font size or the occasional unclear button, did not significantly hinder usability. Overall, the table indicates that the platform functions reliably, supports learning effectively, and is accessible to users with varying levels of digital proficiency.

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Table 4. Evaluation of Platform & Case Studies.

Dimension	Cross-Country Summary
Ease of navigation	Very high in Spain, Cyprus, Romania; Greece slightly lower but still positive.
Clarity of case study instructions	Consistently strong across all countries; minor difficulties due to text size and interface issues.
Ability to complete tasks successfully	High across all contexts; Cyprus: 100% reported successful completion; small obstacles in Romania linked to assessment clarity.
Platform performance and functionality	Mostly smooth; occasional technical issues (slow loading, unclear buttons). Cyprus and Spain reported best overall performance.

Table 5 summarises the challenges teachers encountered during the implementation. The most frequent issues related to assessment clarity, including ambiguous quiz items and limited feedback for incorrect answers. Technical concerns such as slow loading or hidden navigation elements also appeared in several countries. Additional difficulties stemmed from differences in participants' familiarity with inquiry-based learning, time constraints, and accessibility barriers like small text or limited multimedia support. Despite these challenges, the issues were generally manageable, and they provide clear direction for improving the platform's design, accessibility, and instructional support.

Table 5. Reported Difficulties.

Type of Difficulty	Countries Mentioning	Summary
Assessment/quiz clarity	Cyprus, Spain, Romania	Ambiguous wording, lack of feedback, need for step-by-step checks.
Technical issues	Romania, Cyprus	Loading speed, navigation icons unclear, hidden buttons.
IBL familiarity	Cyprus, Romania	Some teachers lacked experience with inquiry-based teaching.
Time constraints	Cyprus	Managing module duration.
Multimedia clarity (fonts, labels, narration)	Spain, Cyprus, Greece	Need for larger text, voice-over, captions.

3.1.3. Reflections on learning and feedback for development

Key learning takeaways (all countries)

- Better understanding of microscopy, cell processes, and lab safety.

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- Appreciation of structured IBL sequences.
- Recognition of the value of virtual experimentation for student engagement.
- Understanding how virtual labs complement, not replace, hands-on labs.

Most useful features

- Step-by-step structure.
- Realistic videos and images.
- Scenario-based design.
- Immediate task completion and low-risk experimentation.
- Certificates (Spain, Cyprus, Romania).

Suggested improvements

- More detailed feedback in quizzes.
- More accessible multimedia (larger fonts, narration, captions).
- Better visibility of navigation buttons.
- Glossaries for terminology (Romania).
- Multiple versions for different educational levels.
- More formative checkpoints.

Additional comments
Participants consistently valued the potential for the VLs to reduce classroom risks, improve procedural understanding, and enhance student autonomy.

3.1.4. Interpretation and comparative insights

Across all four countries, the comparison of pre and post questionnaire results reveals a consistent pattern of improvement in teachers' perceptions and readiness to use virtual laboratories. Participants began with varying levels of confidence and prior exposure, yet the training led to clear gains in digital confidence, perceived clarity of the materials, and overall usability of the platform. Initial hesitation, often linked to limited experience with virtual labs or inquiry-based learning, shifted toward strong satisfaction and greater willingness to integrate the virtual labs into teaching practice.

The data also show that teachers across contexts consistently viewed the virtual labs as pedagogically valuable complements to physical laboratory work, rather than replacements. The most substantial positive changes occurred in teachers' confidence in using virtual labs, their understanding of inquiry-based learning

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implementation, and their perception of the clarity and accessibility of the instructional materials. Despite these improvements, several challenges persisted. Issues with assessment feedback, accessibility features such as text size and multimedia support, and occasional navigation difficulties remained evident across countries. These findings suggest that while the platform effectively strengthens teacher readiness and pedagogical understanding, targeted refinements in assessment design, accessibility, and interface navigation will further enhance its usability and impact.

3.2. QUALITATIVE DATA

3.2.1. Interviews: Combined Cross-Country Themes

Across all four countries, the interview findings reveal a coherent set of themes reflecting teachers' experiences with the VHEalthLab platform and materials. Participants consistently highlighted the intuitive structure and logical sequencing of the virtual labs, although several usability issues such as hidden buttons, small text, and the need for additional navigation functions were noted. The quality of multimedia resources emerged as another strong theme: educators praised the authenticity of real laboratory videos and visuals but expressed the need for enhanced accessibility features, including narration, captions, and more interactive or enlarged images.

Assessment design was a recurring concern, with teachers indicating that feedback within the virtual labs was often insufficient and that additional checkpoints or clearer explanations would strengthen learning. In contrast, the pedagogical value of the virtual labs was widely recognised, particularly their alignment with inquiry-based learning, their support for procedural understanding, and their capacity to visualise complex biological processes. Teachers also commented on curricular fit, noting the need for differentiated versions suited to different education levels and stronger alignment with national curriculum expectations.

The following diagram summarises the main themes that emerged from the interview analysis across all four countries, illustrating the key areas of teacher experience and perception identified in the qualitative data.

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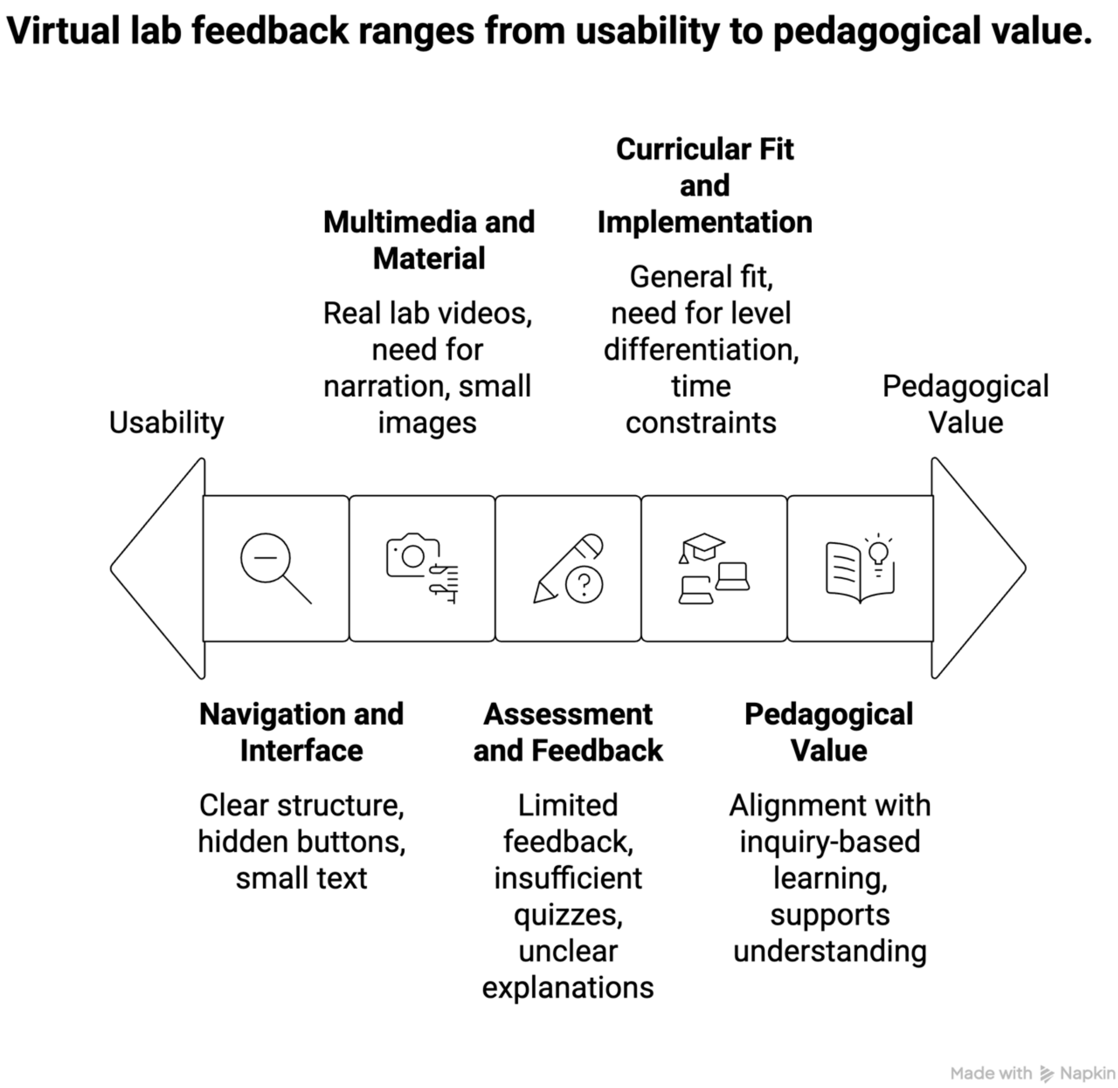

3.2.2. Focus Group: Combined Cross-Country Themes

The focus group findings closely mirror the patterns identified in the interviews. Participants generally found the VHEalthLab platform easy to use, reporting smooth overall navigation, though occasional difficulties with small icons or hidden controls persisted. Multimedia resources were again highlighted as a strong feature, with realistic images and videos contributing to learner engagement. At the same time, teachers noted challenges such as small visuals, static images, and the absence of audio narration, particularly for students needing additional support.

Assessment practices were a shared concern. While participants appreciated reflective questions and end-of-lab certificates, they consistently requested clearer explanations and more opportunities for formative interaction. Pedagogically, virtual labs were unanimously seen as valuable tools for inquiry, visualisation, and

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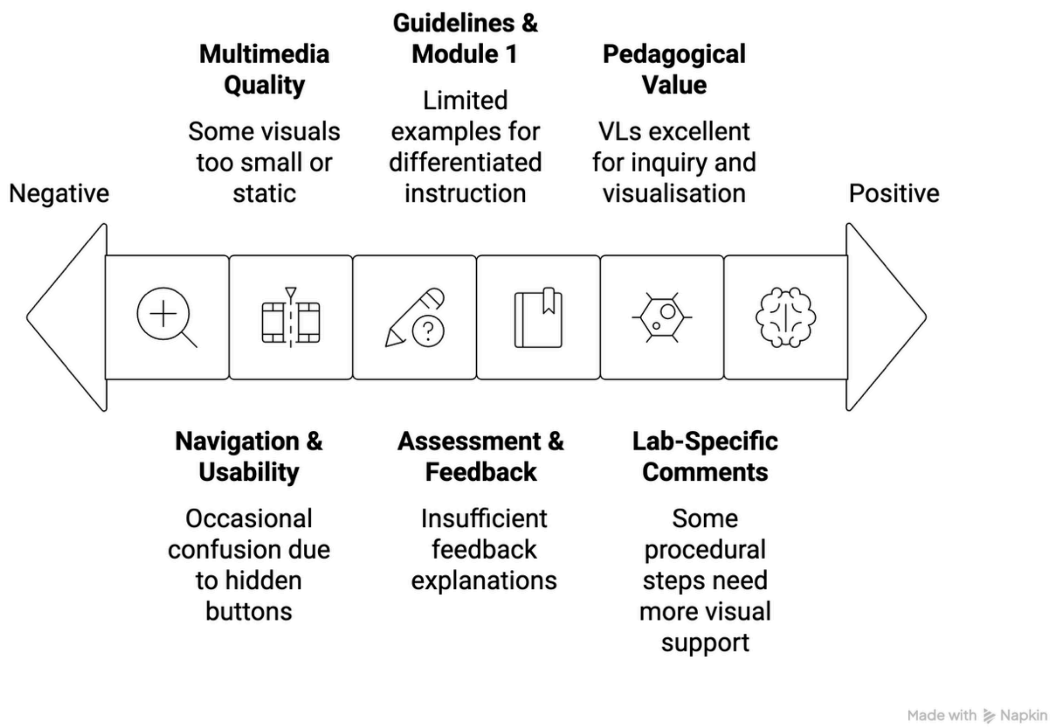
preparation for real laboratory experiences. Lab-specific feedback, especially on the Light Microscopy case, emphasised both its clarity and the need for more visual support in certain procedural steps. Participants also viewed Module 1 and the pedagogical guidelines as clear and practical, though they expressed interest in more concrete classroom examples and strategies for differentiated instruction.

The diagram below provides a visual overview of the themes derived from the cross-country focus group discussions, highlighting the shared strengths, concerns, and suggestions raised by participants.

Virtual lab themes ranked by positive to negative feedback



3.2.3. Overview of Qualitative Findings

Throughout all countries, educators viewed the VHealthLab platform as easy to use, with a clear, step-by-step structure that supported navigation and task completion. The pedagogical design, particularly its alignment with inquiry-based learning, was widely appreciated. Teachers found the multimedia elements helpful for visualising complex biological processes and engaging learners, noting that the realistic visuals increased student motivation and made abstract content more accessible. Many also highlighted that the structured scenarios supported learners who typically struggle with procedural tasks.

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Common challenges emerged consistently: limited assessment feedback, small text and image sizes, lack of captions or narration, and occasional navigation issues such as hidden buttons. Educators also noted the need for differentiated versions of the labs to suit various educational levels and for closer curricular alignment. Several participants added that these improvements would help streamline classroom implementation and reduce the need for additional teacher scaffolding.

Within countries, enhancement suggestions focused on improving accessibility, strengthening formative assessment, adding curriculum-linked guidance, and refining interface clarity.

Overall, qualitative findings show that educators regard the platform as pedagogically strong and highly usable, with clear opportunities for improvement in accessibility, assessment design, and curriculum integration. The overall sentiment across contexts indicates strong potential for the platform to become a widely adopted digital tool in STEM education with targeted refinements.

3.2.4. Overview of Quantitative Findings

Across all four countries, the quantitative data show a consistently positive response to the VHEalthLab resources. Participants expressed strong initial acceptance of virtual labs, and post-training results demonstrated clear improvements in confidence, usability, and readiness to use the virtual labs in teaching. Module 1 and the pedagogical guidelines received very positive ratings, especially in Spain and Cyprus, while Greece and Romania showed slightly more varied but still favorable responses. Teachers also found the platform easy to navigate, with high levels of task completion across all virtual lab activities.

At the same time, the data revealed recurring challenges. Participants identified issues with assessment feedback, noting that explanations for incorrect answers were sometimes unclear or missing. Accessibility concerns were reflected in the results as well, including small text, limited image clarity, and the absence of captions in multimedia elements. Minor technical issues, such as hidden buttons or occasional loading delays, also appeared across countries. Teachers additionally highlighted the need for differentiated versions of the virtual labs to suit different student levels and for stronger alignment with national curricula.

Overall, the quantitative findings indicate broad approval of the platform’s usability, structure, and pedagogical value, while also pointing to clear areas for improvement in accessibility, assessment design, and curriculum integration.

4. CONCLUSION

The combined results from Spain, Cyprus, Greece, and Romania demonstrate that VHEalthLab is a highly valued, pedagogically robust, and user-friendly digital platform for enhancing STEM education. The integration of inquiry-based learning,

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realistic multimedia, and structured virtual lab scenarios offers substantial benefits for both teacher training and classroom practice.

Quantitative data show clear gains in confidence and usability, while qualitative data reflect strong pedagogical appreciation and consistent identification of improvement needs. The broad convergence of results across diverse educational contexts underscores the platform's scalability and relevance across Europe.

The findings will guide the next iteration of VHEalthLab, ensuring that the platform evolves to meet teachers' needs in accessibility, assessment, and curricular integration, contributing meaningfully to the modernization of inclusive, inquiry-driven science education across the European Union.

5. Appendices

5.1. Appendix 1. Spain – National Implementation Report

(File: SPAIN_IMPLEMENTATION REPORT WP5.docx)

5.2. Appendix 2. Cyprus – National Implementation Report

(File: IMPLEMENTATION REPORT WP5_CYPRUS.docx)

5.3. Appendix 3. Greece – National Implementation Report

(File: GREECE_IMPLEMENTATION REPORT WP5.pdf)

5.4. Appendix 4. Romania – National Implementation Report

(File: ROMANIA_IMPLEMENTATION REPORT WP5.pdf)

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