Flexible Learning

Pilots Completion Report

Document details

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Title of the Pilot	Evaluation of Bespoke Simulations for use in an Immersive Virtual Lab Simulator for delivery of Practical education at Undergraduate & Postgraduate Levels
Pilot ID Number	FLP-Pilot-ID33

Pilot Completion Report Template

Report Category	Report Requirement
Overall Rating ***Fully Delivered***	
Summary	**PLEASE SEE ANSWERS BELOW TABLES** *Please give a summary of what your pilot delivered. With a focus on progress toward the original aims. (Circa 1000 words)*
Deliverables	*Please list your pilot's deliverables*
Relevance	*Has the pilot topic and its activities met the information/experience needs of the intended stakeholder groups? To what extent are the completed pilot outcomes still in line with the needs and priorities of the Flexible Learning Programme?*
Efficiency	*To what extent did the methods/approaches used in this pilot lead to improvements in efficiency (financial/staffing/resourcing etc)? What other approaches could be considered in light of the pilot - would these be more or less efficient?*
Effectiveness	*To what extent did the methods/approaches used in this pilot lead to improvements in effectiveness (learning/outcomes/experience/flexibility etc)? What other approaches could be considered in light of the pilot - would these be more or less effective?*
Outcome	*To what extent was the pilot able to meet/exceed its objectives? To what extent has the pilot led to improved outcomes or behaviours in the stakeholder groups? Were there any other unintended positive or negative outcomes from the pilot?*
Sustainability	*To what extent has the pilot identified the potential for its activity to lead to the long-term behaviour/operational change? What would need to happen to make these changes happen?*
Financial	Completed financials.
Lessons Identified / Learned	*Please Consider enabler and inhibitors in the following areas:* • *Systems and process* • *Incentives and capacity* • *Policy and strategy* • *Student experience* • *Physical Estate* • *Culture*
Materials or publications	Bespoke simulation learning packages mapped to BIOL10401, BIOL10412, and BIOL21041 (please see video link for example of PCR simulation) Generic simulation-based learning package template for practical skills development (appendix) Pilot feedback summaries from student focus groups, surveys, and informal discussions (key sentiments in report – anonymised due to ethical approval)

	Draft academic publication (in preparation) on the use of digital twins in bioscience education, with contributions from the University of Manchester, UCL, University of Oxford, University of Aberdeen, University of Nottingham, and Columbia University Internal presentations shared with the Schools of Biological Sciences, School of Health Sciences & Medicine, School of Chemistry (PPs) Mapping of practical skills developed for SBS & SHS (Excel)
Report approval and comments	*To be completed by a delegated person agreed by the workstream governance group.*

Cost Type	Description	Costs and Total
Staff	*Insert staff name and grade, post, FTE in the quarter in this quarter and the post.*	*Please add the cost of each post and the total claim for staff, this can then be added to the retrospective costs in the forecast form.*
Non-Staff	*Please add in any actuals (received and receipted paid in the quarter).* *Non staff can include any other approved cost category including:* • *Goods* • *Services (inc. Consultancy)* • *Travel* • *Fees*	*Please add the cost of each post and the total claim for staff, this can then be added to the actuals in the forecast sheet.*
Adjustments	*Please add any adjustments from previous quarters. This will be added or subtracted from your quarterly request for payment.* *Please give details of the original cost and the reason for the adjustment.*	*Please give the adjustment amount.*
Final reconciliation	*Please calculate the total costs of the pilot and the total income to ensure the claim has covered all eligible costs.*	
Request for payment	*The payment in the next box should include all staff costs, non-staff costs and adjustments total.* *By submitting this form, you are a confirming that the figures are correct to the best of your knowledge and the correct processes for recruitment procurement and selection have been followed.*	*Please provide:* • *total staff costs* • *total non-staff costs* • *total adjustments* • *final reconciliation* • *Total request for payment*

Pilot study to evaluate the use of Immersive Virtual Labs to support undergraduate practicals

Summary

The Flexible Learning Pilot explored the development and use of immersive simulations to support the teaching of laboratory skills across undergraduate and postgraduate bioscience programmes. The aim of this pilot was to assess whether immersive, simulation-based learning, delivered through digital twin technology, can enhance student confidence, engagement and understanding of core laboratory techniques, while also providing a scalable and sustainable approach for practical teaching across the Biosciences.

The simulations were developed using a modular simulation platform capable of generating accurate digital twins* of laboratory equipment, offering students an interactive and realistic learning experience that closely mirrors real laboratory environments. A small number of simulations were produced and embedded within bespoke learning packages, mapped to undergraduate practicals at both first- and second-year levels [BIOL10401 (Introduction to Laboratory Sciences), BIOL10412 (Introduction to Experimental Biology), and BIOL21041 (Experimental Design)]. In addition, a generic learning package template was created, which can be adapted for any simulation requiring practical skills development. These practicals were selected because of their relevance to core lab skills and their suitability for virtual learning due to existing online components. Practical manuals developed by academic staff were used as the basis for simulation content, ensuring close alignment with existing course objectives and minimising the need for new content development. This helped streamline the process and reduced demands on academic time.

Each simulation followed a structured pedagogical framework, using scenario-based, decision-tree learning approaches to mirror authentic lab workflows. Students were guided through a series of procedural steps, with opportunities to make decisions, encounter realistic outcomes (including errors), and receive contextualised feedback. Adaptive learning was built into the system, allowing students to revisit and reflect on their actions. These features were informed by established educational research and tailored to student needs identified during early consultation.

The pilot developed simulations for a range of standard techniques including pipetting, PCR, gel electrophoresis, UV imaging, DNA ligation & cloning. These were delivered as part of bespoke learning packages, which included background information, embedded media and formative assessment questions. A generalised learning package template was created for future use, offering a flexible model that can be adapted to additional techniques and disciplines with minimal rework.

In terms of pedagogical impact, feedback gathered through surveys, focus groups and informal interviews showed that students found the simulations very useful for increasing confidence and reducing anxiety. Many students reported that they appreciated being able to explore techniques before attending in-person labs. They also highlighted the ability to repeat tasks and learn from mistakes in a low-risk setting, which is not always possible in traditional lab environments. Some students noted that the simulations helped them better understand the reasoning behind each

step, rather than simply following instructions. This aligns with the goal of supporting deeper engagement with core concepts and procedures.

Because the simulations were based on existing practical manuals, staff time can be mostly spent reviewing rather than creating new content. The use of a modular platform made development more efficient and reduced overheads.

Three key use-cases emerged during the pilot: pre-lab preparation, fully online alternatives for techniques and post-lab assessment. The strongest support was for using simulations as pre-lab tools, with both students and staff commenting on their usefulness for building familiarity with procedures. There was also interest in using simulations to teach techniques that are difficult to offer in physical labs due to cost, time, or safety concerns, such as flow cytometry or mass spectrometry. Some academic staff expressed interest in replacing or supplementing traditional post-lab assessments with simulation-based tasks, which may offer a more engaging and meaningful way to assess procedural understanding.

The pilot trialled the use of AI tools (GPT-4o) to generate scenarios and assessment questions. While these tools were not fully integrated into the simulation platform during the pilot, the initial tests showed promise. AI-generated content was used to create variability in questions and adapt feedback based on student actions, supporting personalised learning pathways. Full integration is expected in future phases, but the early results indicate that this approach may further improve the efficiency and adaptability of simulation-based teaching.

The pilot also enabled broader institutional engagement. Departments outside of the School of Biological Sciences expressed interest in adopting similar approaches. In Pharmacy, simulation mapping has begun for aseptic techniques and dosage calculations. The Department of Chemistry is exploring use cases for titration, chromatography and spectrophotometry. Engagement with external institutions, including UCL, Oxford, Columbia University, and Rothamsted Research, has also begun, and a joint publication is in progress to share insights into digital twin technologies and approaches.

The delivery model developed in the pilot has shown potential to support scalable implementation across disciplines. The core system can simulate a wide range of techniques using a base library of digital twin equipment, making it adaptable and resource-efficient. A single simulation design can be re-used or modified for different modules, disciplines, or levels of complexity, further improving efficiency.

In terms of institutional priorities, the pilot aligns well with the Flexible Learning Programme by promoting digitally supported, inclusive, and sustainable teaching approaches. The ability to offer flexible learning experiences without over-reliance on physical lab space or consumables supports wider university goals around accessibility, digital transformation and curriculum innovation. The work is also consistent with strategic aims to improve digital literacy and embed digital tools across the student learning journey.

While the pilot has made substantial progress, areas for further development have also been identified. These include expanding the library of simulations, improving user interface features (such as fast-forwarding through repeated steps) and providing additional training and support for staff who may wish to build their own simulations. Feedback has also indicated that some students would benefit from clearer explanations of the research context or practical applications of techniques, which can be addressed by embedding more links to real-world research and case studies.

In summary, the pilot delivered a functioning model of simulation-based lab education that uses pedagogically informed approaches, technically scalable and aligned with the practical realities of teaching in higher education. Student and staff feedback suggest that the approach is both usable and valuable and institutional interest indicates that further development is valuable. The pilot has built a strong foundation for future use and offers a pathway toward broader curricular integration of immersive digital learning in the biosciences and beyond.

Key Deliverables

As part of the pilot, a range of deliverables were produced to support the development, integration, and evaluation of simulation-based learning in bioscience education. These included the creation of bespoke immersive simulations mapped to existing undergraduate practicals, covering key techniques such as pipetting, PCR, gel electrophoresis and microscopy. A general simulation-based learning package template was developed to support future scalability and adaptation to additional modules. The project trialled the use of AI tools to generate adaptive assessment content, including scenario-driven feedback and branching questions. Student feedback was collected through surveys and focus groups to inform evaluation of the learning experience. The pilot identified three use-cases across practical teaching & the main teaching scenarios: pre-lab preparation, fully online alternatives and post-lab assessments demonstrating flexibility in their application. The pilot engaged colleagues from Pharmacy, Chemistry, and Health Sciences, where planning has begun for future use cases. A draft academic publication is in preparation with input from national and international partners and contributions to external events exploring the role of immersive digital twin tools in education have taken place.

Relevance

The pilot has addressed the information and experience needs of its primary stakeholder groups, including undergraduate students, academic staff and institutional teaching leads. For students, the simulations offered an accessible and engaging way to develop confidence with laboratory procedures prior to hands-on sessions, supporting their requests for more interactive and preparatory resources. Feedback indicated that the ability to practice techniques virtually contributed to reduced anxiety and a better understanding of procedural steps and their underlying rationale. For academic staff, the use of existing practical manuals meant that integration required minimal time investment, aligning with wider needs for efficient and sustainable teaching solutions. There is scope to build efficiencies in costs from reducing the number of demonstrators needed in practical classes, if students are better prepared in advance. From an institutional perspective, the pilot's outcomes remain closely aligned with the priorities of the Flexible Learning Programme, particularly in its emphasis on scalable, inclusive and digitally enabled approaches to practical education. This model supports flexibility in teaching delivery and allows for consistency across diverse student cohorts, while also reducing demand on physical lab spaces and consumables - further addressing long-term goals related to sustainability and resource management.

Efficiency

The simulation approach has the potential to improve teaching efficiency by reducing the need for staff to deliver all stages of practical instruction in person. By allowing students to engage with techniques and decision-making processes independently, simulations could reduce reliance on demonstrators for basic procedural support, particularly in large cohorts. This could lead to savings in staffing costs, where demonstrators are typically paid around £15+ per hour and multiple sessions are run across the semester. In addition to practical delivery, the use of simulations for assessment could also improve efficiency. For example, in units such as the Research Skills Modules (RSMs), post-lab assessments are marked manually and can require significant staff time across a large student group. A simulation-based assessment model, incorporating automated feedback and scenario-based questions, could offer a scalable alternative while still testing procedural knowledge and data interpretation skills. These efficiencies suggest that simulation-based learning can support both the delivery and evaluation of practical skills in a sustainable way.

Effectiveness

The methods trialled in this pilot suggest clear potential for improving the effectiveness of practical teaching across several dimensions, particularly in terms of student learning, engagement and flexibility. The simulations were designed to provide a structured, interactive learning experience that allowed students to practice procedures, make decisions and receive feedback in a way that traditional resources, such as written protocols or videos do not typically allow. Feedback gathered during the pilot indicates that students valued being able to learn at their own pace, make mistakes in a low-risk environment and revisit steps they found challenging. This contributed to greater confidence and understanding, especially in relation to equipment use and the rationale behind specific procedures. The scenario-based structure also encouraged critical thinking and contextual awareness, supporting deeper engagement with the material. Students stated in feedback that assessing practical core skills is currently not done in a lab environment and the use of a virtual laboratory would be a good alternative as it uses digital twin technology.

In terms of flexibility, the simulations offer multiple use-cases that can be tailored to different teaching contexts, whether as a preparatory tool before physical labs, as a substitute for techniques that are not feasible to run in person / to provide additional access to practical skills, or as an alternative format for post-lab assessment. This adaptability is particularly relevant for large or distributed student cohorts, or in courses with limited lab time or equipment access.

Compared to more static formats like pre-lab reading or recorded demonstrations, the interactive nature of the simulation, combined with adaptive learning & feedback, makes them a more engaging and potentially more effective approach for developing procedural skills. Other approaches, such as off-the-shelf simulation platforms, can also be effective for foundational instruction but may be less suited to teaching institution-specific protocols or equipment. In contrast, the modular and customisable structure used in this pilot allows for closer alignment with course objectives and lab manuals, potentially increasing relevance and learning impact. Further research in live teaching environments would be valuable to quantify the effect on learning outcomes, but initial responses suggest that the approach is a promising complement to traditional practical teaching.

Outcome

The pilot has demonstrated its ability to address the needs of key stakeholder groups by providing a flexible, scalable and interactive model for the development of practical skills. Students responded positively to the opportunity to practice procedures in a low-pressure environment, highlighting the potential of simulations to build confidence and familiarity with lab equipment ahead of in-person sessions. The format also supported greater independence, helping students better understand the purpose behind each step rather than relying solely on written protocols. For academic staff, the project introduced a practical way to enhance student readiness with minimal additional workload, aligning well with the Flexible Learning Programme's goals around scalable, inclusive and digitally supported teaching.

The project delivered a set of simulations mapped to core undergraduate modules and tested a reusable learning package template. These outcomes were achieved with limited academic time investment and prompted interest from colleagues in other departments. Student and staff feedback suggests that the simulations could meaningfully support both preparation and assessment activities and their adaptability offers scope for wider curriculum integration. The pilot also opened conversations about longer-term changes to assessment design, particularly in large modules where post-lab work currently requires significant manual marking. While further development is needed to embed the simulations into regular teaching and ensure alignment with assessment strategies, no negative outcomes were reported. The pilot has laid a solid foundation for continued exploration of simulation-based approaches within flexible teaching models.

Sustainability

The pilot has highlighted a number of ways in which simulation-based teaching could lead to long-term behavioural and operational change. In terms of teaching practice, one of the initial opportunities would be to transfer existing practicals into simulation format, allowing for pre-laboratory preparation that complements in-person practical teaching. Beyond replication, the platform also provides a chance to design entirely new virtual practicals, particularly for techniques that are currently not feasible to run due to equipment, safety, or time constraints. This flexibility opens up space for innovation in curriculum design and broadens access to complex or resource-intensive methods.

The simulations also offer the basis for developing a new type of assessment that focuses on procedural reasoning and decision-making. This format could provide a meaningful alternative to traditional post-lab reports, while also helping to mitigate concerns around the use of generative AI in written assessments. Because simulation-based tasks require students to make context-specific choices and interpret variable outcomes, they lend themselves to authentic, skills-focused assessment that is harder to replicate through AI tools.

At an operational level, the pilot draws attention to the need to embed flexible learning more systematically into practical teaching. While flexible and blended approaches have been widely adopted for lectures and seminars, practical classes have seen less change in this area across the institution. Moving towards greater integration of virtual practicals would require a coordinated effort, including curriculum review, technical support and cultural change within departments.

To enable this shift, the next steps could include a programme of workshops or demonstration sessions to showcase the simulations to teaching staff. These would serve both to raise awareness and to encourage academics to consider how virtual practicals could be applied or adapted within their own modules. In parallel, guidance and support materials should be developed to make the process of converting or designing new simulations more approachable for staff.

Further institutional support would also be beneficial, for example, by embedding simulation development into curriculum planning processes, recognising staff contributions to digital teaching in workload models and ensuring compatibility with digital infrastructure such as the VLE. Continued evaluation and sharing of best practice will be key to scaling the approach in a way that supports long-term, meaningful change across faculties.

Ethics

This study received ethical approval from The University of Manchester Proportionate UREC for the project "Evaluating the Use of an Immersive Virtual Lab Simulator to Support Undergraduate Practical Teaching." The approved document set included a participant information sheet, consent form (UK GDPR), recruitment materials, pre/post-simulation surveys, focus group/interview guides, and distress/debrief protocols. Data collection is authorised for up to five years from the approval date. Any amendments to methodology, documents, or timelines will be submitted for review and will not be implemented prior to written approval. All comments and feedback have been anonymised, with any personal identifiers removed to ensure that individual participants cannot be identified.

Module Selection and Content Development

The work was piloted using three practical course units in the School of Biological Sciences: BIOL10401 (Introduction to Laboratory Sciences), BIOL10412 (Introduction to Experimental Biology), and the 2nd year Experimental Design module (BIOL21041). These units encompass a broad range of laboratory techniques that lend themselves particularly well to simulation, including processes such as pipetting, PCR, gel electrophoresis and data interpretation. Further, these units already incorporated an online component, making them especially suitable for integration with virtual learning technologies. An additional advantage of the selected units was that they had well-established procedural documentation, including practical manuals authored by academic staff. Rather than requiring entirely new content to be developed, these existing resources were directly adapted into simulation-based learning packages. This approach ensured that the simulated activities were tightly aligned with the curriculum, as well as with current teaching methods and learning objectives.

By working from existing laboratory manuals, the development process placed minimal demands on academic time. Staff involvement could therefore be limited to reviewing and approving simulation drafts. While the simulation platform allows lecturers to independently develop procedures in a modular fashion, this would require initial training to ensure simulations are constructed effectively. In the early stages, it is recommended that simulations be developed by the platform provider in collaboration with academic leads, to streamline the process. This method significantly reduces development overhead and provides a sustainable model for expanding simulation-based learning across additional units in the future. A number of simulations were developed covering core biological techniques, including, but not limited to, PCR, pipetting, gel electrophoresis, UV imaging, DNA ligation and transformation, restriction enzyme digests and microscopy.

Pedagogical Rationale and Impact

The simulations were developed using a scenario-based, decision-tree learning approach to contextual learning, incorporating adaptive learning principles and aligned with ongoing research at the University of Manchester. This approach was informed by educational literature as well as feedback from both lecturers and students. By embedding technical content within realistic, research-aligned scenarios, students are encouraged to engage with both the procedural aspects and the underlying rationale of laboratory techniques - an area frequently identified as a gap in traditional lab preparation.

The pedagogical model draws on scenario-based learning (SBL), which is widely recognised for supporting critical thinking, problem-solving, and deeper conceptual understanding (Villanueva and Yap, 2020). Aligning simulated tasks with authentic research contexts is intended to enhance both the relevance of the material and student engagement, particularly in biomedical and biological science programmes.

Recent evidence supports the effectiveness of virtual laboratories in enhancing learning outcomes. A quasi-experimental study by Bazie et al. (2024) showed that chemistry students who used virtual labs achieved higher practical scores than those receiving lecture-only instruction and performed comparably to students in traditional labs. Similarly, Tatira and Mshanelo (2024) observed significant improvements in physics students' performance after using virtual labs to study impulse and momentum.

A 2024 meta-analysis in PLOS ONE found that virtual labs significantly improved academic performance and cognitive skills among engineering students, suggesting their applicability across a broad range of scientific domains (Li and Liang, 2024).

Kashaka (2024) highlighted the accessibility benefits of virtual laboratories, noting that they provide learners with the opportunity to practice techniques repeatedly in a low-risk environment.
This aligns with student feedback from our pilots, in which many expressed that virtual simulations alleviated anxiety and improved their confidence in using unfamiliar equipment.

"Provides more freedom to make mistakes and learn from them, which is nice."
"It is also stress-free, helping us become confident with the lab equipment before stepping into the real thing."
"A lot of the time I'm not sure why I'm doing something or what it's used for."
"Maybe giving more context as to why we are completing certain steps or processes."

Lessons Learned / Identified

In terms of systems and process, the modular design of the simulation platform was a key enabler, allowing content to be built directly from existing lab manuals and aligned with institutional workflows. However, integration with current digital systems (e.g. the VLE) remains limited, and further work is needed to streamline access and embed simulations within standard teaching platforms.

On incentives and capacity, the low time demand for initial implementation was helpful, as staff could review rather than build simulations from scratch. Nonetheless, sustained adoption would require formal recognition of simulation development in workload models, along with practical support and training to build internal capacity for content creation.

From a policy and strategy perspective, the pilot aligns closely with institutional goals around flexible and digital learning. However, practical teaching has not yet been widely targeted by flexible learning initiatives, so clearer strategic direction and resourcing will be needed to embed this work within broader curriculum planning processes.

Student experience was a strong enabler, with positive feedback highlighting the value of simulations for building confidence, reducing anxiety and supporting flexible engagement with core lab techniques. Usability could be further improved through interface refinements and more contextual support, but overall, the student response was highly encouraging.

In terms of physical estate, the simulations offer a scalable alternative or supplement to space-constrained labs, particularly for large cohorts. This flexibility could help reduce pressure on specialist facilities and create more options for hybrid delivery. However, institutional planning around lab capacity currently assumes primarily in-person delivery, which may limit opportunities unless virtual formats are actively considered in space planning.

Finally, culture remains mixed. While the pilot generated strong interest and support among early adopters, broader uptake will depend on shifting perceptions around the value of virtual practicals. Departmental-level engagement, peer examples and targeted workshops could help build confidence and normalise the use of simulations as a valid part of lab teaching.

Student Experience

Feedback gathered from structured surveys, post-pilot discussions and informal focus groups provided a rich and nuanced understanding of how students engaged with the immersive simulations. Responses were overwhelmingly positive, with students highlighting the value of the platform in improving confidence, reducing anxiety and building a deeper conceptual understanding of laboratory processes. The data also provided constructive recommendations for usability, accessibility, and pedagogical enhancements, offering a roadmap for iterative improvement and long-term scalability. Among second-year students who had recently completed their final mandatory practical unit, self-reported confidence in in-person laboratory skills was moderate, with many rating themselves at 6 out of 10. While most students felt comfortable following written protocols, fewer expressed confidence in understanding the underlying rationale for procedures or in independently operating laboratory equipment.

Usefulness and Confidence Building

A consistent theme in the feedback was that the simulations offered a low-pressure, exploratory environment in which students could practice core techniques repeatedly without the constraints of time, cost, or resource limitations. This freedom to experiment, make mistakes and correct errors at their own pace provided a unique opportunity to build both technical proficiency and confidence.

Students particularly valued the opportunity to practice with equipment and processes that are often considered “high stakes” in a physical lab setting, such as adjusting pipette volumes, setting up PCR reactions, or balancing centrifuges. Many noted that the ability to familiarise themselves with these techniques before entering the physical lab reduced feelings of anxiety and helped them feel more prepared to engage actively during in-person sessions.

“It helped me learn how to use the right measurements in a pipette… This way I will get the chance to try and explore more.”

“Being able to use some machines that we aren’t allowed to ourselves in labs is really good and brings a massive help into fully understanding it.”

“It’s a good software to let us practise core techniques or set up experiments anytime.”

"It most certainly is going to be useful for allowing the practice of laboratory skills… The freedom to experiment with mistakes is an interesting feature."

"It is also stress-free, helping us become confident with the lab equipment before stepping into the real thing."

This finding supports the use of the simulations as pre-lab preparation tools, particularly for large or mixed-confidence cohorts where levels of familiarity with lab equipment and protocols vary significantly.

Quantitative responses mirrored these qualitative insights. Across all groups, the usefulness of the simulations was rated between 8 and 10 out of 10, while quality was consistently scored between 9 and 10 out of 10.

Students particularly highlighted the high-fidelity design and the realism of the equipment models, noting that these elements contributed to a sense of immersion and authenticity that traditional resources (e.g., written protocols or video-based pre-labs) often fail to deliver.

"It was a really good simulation that replicated real lab environments… more stimulating than pre-labs with videos."

"Very useful, being able to use lab equipment you wouldn't normally have a chance with and perform your own PCR."

"I think it's pretty impressive and allows us to develop the necessary skills for the actual labs."

"Yes, I really liked it. It's gaining an experience in a fun way."

"Yeah, I would use it 100%."

"Want it for sure."

The visual and procedural accuracy of the digital twin models was also recognised as a major strength. Several students remarked that the realistic interfaces helped them feel confident using equivalent equipment during in-person practical sessions.

Suggestions for Improvement

While feedback was largely positive, students identified several areas for improvement to further enhance usability and accessibility. These suggestions, many of which are relatively straightforward to implement, offer clear opportunities for iterative improvement:

- Accessibility Enhancements
  - Increase font size, particularly for use on smaller devices such as iPads.
  - Provide background colour options (e.g., blue overlays) to support students with dyslexia or visual strain.

- User Interface and Controls
    - o Refine keyboard shortcuts and mouse interactions to make object manipulation more intuitive.
    - o Offer prompts or visual cues when completing certain steps (e.g., tip ejection from pipettes or identifying correct centrifuge slots).
    - o Introduce a fast-forward or skip option for wait times during repetitive steps, to balance realism with usability.
- Adaptive Learning Features
    - o Include contextual hints or "coaching pop-ups" when students make repeated mistakes, to provide immediate corrective guidance.
- Pedagogical Features
    - o Expand opportunities for reflective learning, such as integrated explanations of the scientific rationale behind key steps, or links to relevant research contexts.
    - o Introduce steps such as wearing PPE (e.g., lab coat and goggles) or correct waste disposal to emulate full real-world practices.

Representative comments include:

"Controls need to be adjusted to what would be naturally expected… Currently to pick up and rotate is shift then control, it doesn't feel natural to use both at the same time."

"When adjusting the pipette values, the bottom one is too slow… a function like Ctrl that is used for the above values could be implemented into the bottom one as well."

"I would increase the font size, as it strains my eyes to read… Maybe also adding a segment of PPE, wearing lab coat and goggles should also be part of the simulation."

"If the person makes the same mistake thrice, a pop-up screen pointing out their mistake and suggesting corrections would be good."

Engagement and Realism

Students frequently highlighted the engaging and immersive nature of the simulations as a significant benefit. The combination of photorealistic design and interactive elements created a sense of authenticity that made learning both enjoyable and meaningful. Several students compared the experience to playing a simulation game, emphasising that this level of engagement kept them more focused and motivated than traditional preparatory resources.

"I found it more stimulating than pre-labs, especially the ones with the videos, because sometimes I find myself zoning out."

“The design and whole idea is really incredibly impressive.”

“The design is going to be very useful in experimenting what might go wrong during an experiment and learn from it.”

“It has a great level of detail which will give such good hands-on experience… we will understand and pick up on things much quicker than just reading the protocol.”

“This would be really good to help understand what we do in the labs and why.”

Many students mentioned in informal focus groups that they do not fully understand what they do in practicals at both 1st and 2nd year.

The above positive responses underscores the importance of maintaining high-fidelity visuals and interactivity in future iterations, as these elements appear to significantly enhance the learning experience.

Potential for Assessment and Revision

Another recurring theme was the potential for simulations to support both formative and summative assessment, as well as structured revision. Students recognised that the interactive nature of the simulations provided a more authentic and skills-focused way to test procedural knowledge and decision-making skills compared to static assessments such as post-lab reports.

“I think using this as a post-lab assessment is a great idea.”

“It would be nice if it was this instead of traditional post-labs.”

“Would make excellent revision material and test material and be a great way to learn and get confidence, especially for any future lab roles.”

Students stated their confidence levels ahead of in-person practical classes and some comments related to exam revision for practicals:

“Confident when we have a set of instructions.”
“Quite confident with a protocol, otherwise not so much.”
“Somewhat confident.”

“I just went through the protocols.”
“Past papers and reading practicals.”

Summary and Implications

Overall, student feedback provides strong evidence that immersive simulations deliver significant educational value. They offer a scalable, flexible and engaging platform that not only supports technical skill development but also improves confidence, critical thinking and deeper conceptual understanding.

The feedback also highlights several practical recommendations - such as accessibility enhancements, user interface refinements and the integration of adaptive learning features, that would enhance the platform's usability and inclusivity in future iterations.

These findings strongly support the integration of simulation-based learning within the curriculum and point toward its potential as a cornerstone of flexible, digitally enhanced practical education in the University.

Technical Development and Institutional Engagement

Simulations were developed using a white-labelled platform (Virtual Scientia Ltd) that supports modular design, enabling academics to build procedures using digital twin representations of commonly used laboratory equipment. Existing teaching materials were used to produce learning packages, making the process time-efficient, scalable and sustainable. Separate AI tools (ChatGPT model 4o) were also trialled to support the generation of scenarios and assessments, providing variability in content (however, to note full integration of these tools into the simulation platform is not expected until December 2025).

The modular nature of the system allows lecturers to create their own procedures, offering a scalable solution. In principle, a broad catalogue of simulations could be developed using a core set of 20 - 30 laboratory equipment models. A single simulation format can therefore be adapted across multiple disciplines with only minor adjustments.

The approach has already attracted interest from other departments. In the Department of Pharmacy, mapping of practical sessions is underway, with potential use cases including aseptic technique, dilution calculations, and dose preparation. The Department of Chemistry is similarly identifying opportunities for simulation in techniques such as spectrophotometry, titration, and chromatography - particularly for large cohorts or where equipment access is limited.

A separate publication from the author (Dr S. Hyatt) exploring the role of digital twins in bioscience & healthcare education is currently in preparation, with contributions from collaborators at UCL, Columbia University, the University of Oxford, the University of Aberdeen, the University of Nottingham. Engagement has also extended to institutions such as Rothamsted Research, the University of Bristol, the University of Liverpool, the Macular Society, the European Bioinformatics Institute (EBI), and Loughborough University.

This project has further enabled outreach beyond the University of Manchester, including a recent invitation from Meta Academia (London) to discuss the potential transfer of these simulations from desktop delivery into a mixed reality environment. Many higher and further education institutions attended the conference too.

Through pilot testing and student feedback, we have identified three key use cases:

Each simulation has been structured according to established pedagogical principles, incorporating clear learning objectives, contextualised scenarios, step-by-step procedural guidance (supported by short video clips), and opportunities for data interpretation and analysis. The simulations are designed to be used flexibly across various stages of the learning cycle, as pre-lab tools, fully online alternatives for advanced techniques, or as post-lab assessment resources.

Pre-lab preparation:

Many students indicated that they would have preferred the opportunity to rehearse procedures in advance using an interactive tool. There was also strong interest in using simulations as an alternative to traditional post-lab assessments:

Students found that using simulations ahead of in-person practicals improved their readiness and reduced anxiety. They expressed a strong preference for being able to explore techniques in a virtual environment before encountering them in the physical lab. Staff also supported this use case, highlighting its value in building foundational understanding and familiarity with equipment.

"It would be nice if it was this instead of traditional post-labs."
"I would be excited to use it in units themselves. It would keep me engaged unlike current pre-labs."

"Pre-lab, or any case where I can get a preview of the practical… That would mean I will be less lost."
"As pre-labs, because it would allow us to understand the actual lab much better."

"If to replace pre-labs and be able to have more freedom in the lab... gives more confidence and independence."

"It is also stress-free, helping us become confident with the lab equipment before stepping into the real thing."

"I would be excited to use it. It would keep me engaged unlike current pre-labs."

Fully online practicals:

The platform supports the simulation of additional practical techniques or advanced techniques such as mass spectrometry and flow cytometry, which many students may not have the opportunity to perform hands-on due to cost, time, or resource limitations. In such cases, high-fidelity virtual simulations offer a viable substitute for skill development and conceptual understanding.

"This is going to be very useful in experimenting with what might go wrong during an experiment and learning from it."
"It's a good software to let us practise core techniques or set up experiments anytime."

Post-lab assessment:

Students valued the use of simulations as a more interactive and skills-focused alternative to traditional post-lab reports. Academic staff agreed that this could be a more meaningful and scalable way of evaluating student learning. The ability to revisit procedures and demonstrate understanding through scenario-based tasks was seen as a key factor.

"I think using this as a post-lab assessment is a great idea."
"It would be nice if it was this instead of traditional post-labs."
"Provides more freedom to make mistakes and learn from them."

Simulation Design and Impact:

The design of the simulations was a key area of focus during the pilot phase, with particular attention paid to realism, usability and pedagogical alignment. Student feedback consistently highlighted the importance of high-fidelity design in creating an engaging and meaningful learning experience. The detailed visual representation of equipment, clear procedural flow and opportunity for exploratory learning were all noted as strengths. The comments below illustrate how students responded to the look, feel, and educational potential of the simulations.

"The design is going to be very useful in experimenting what might go wrong during an experiment and learn from it. This has great potential in helping students learn and build very good experience and skills."

"It has a great level of detail which will give such good hands-on experience… Will understand and pick up on things much quicker than just reading the protocol."

"I think it's pretty impressive and allows us to develop the necessary skills for the actual labs."

"Yes, I really liked it. It's gaining an experience in a fun way."

"This would be really good to help understand what we do in the labs and why."

"I think it is well-designed and I agree with adding a fast-forward option."

"It's also good because there's no waste or expensive materials used."

These findings support the view that simulation-based learning can complement and, in some cases, replace traditional lab formats, particularly where accessibility, scalability, and engagement are priorities.

Biological Techniques Suitable for Simulation in Undergraduate Bioscience

A broad range of biological techniques can be effectively simulated for undergraduate learners, particularly when supported by high-fidelity digital twin environments. Fundamental skills such as microscopy (including brightfield, fluorescence, and phase contrast), spectrophotometry lend themselves well to virtual practice, allowing students to explore sample preparation, slide handling, and objective lens selection without the constraints of microscope availability. Molecular techniques such as DNA cloning, PCR, gel electrophoresis and restriction enzyme digests are especially suited to simulation, as they involve clear procedural stages and can be easily mapped to student decision-making paths. More advanced methods such as Western blotting, immunofluorescence, and immunohistochemistry - typically restricted due to time, cost, or safety constraints - can also be simulated to enable conceptual understanding and procedural exposure. Additionally, simulations offer a way to visualise otherwise inaccessible elements of practicals, such as mass-spectrometry, electron microscopy and flow cytometry, making them powerful tools for bridging the gap between theoretical knowledge and hands-on application.

Simulation-Based Learning Package Template

1. Simulation Overview

Title: [e.g. PCR and Gel Electrophoresis Simulation]
Discipline: [e.g. Molecular Biology]
Unit: [e.g. BIOL10412 – Introduction to Experimental Biology]
Unit Coordinator: [Staff name]

2. Aims and Intended Learning Outcomes (ILOs)

Aims

To familiarise students with the technical and conceptual steps involved in [e.g. polymerase chain reaction (PCR)] through an immersive, decision-based simulation using digital twin representations of real lab equipment.

ILOs

On completion of this learning package, students should be able to:

Identify and describe the core components and purpose of [technique].
Independently follow correct procedural steps using realistic lab interfaces.
Make informed decisions during experimental design and execution.
Interpret results generated based on procedural choices.
Reflect on procedural outcomes and understand how errors impact results.

3. Background

Provide a short research-aligned overview of the technique. This should explain:

What the technique is
Why it is used in research
How it fits within the context of the course/module
What real-world problem or research scenario it mimics
Include citations to relevant research or publications from the University.

4. Simulation Setup

Equipment Used (Digital Twins):

Pipetting Tool – Micropipette

Centrifuge

PCR Thermal Cycler

Gel Electrophoresis

UV Gel Imager

Sample tubes, buffers, reagents

Desktop/lab PC interface

Software Mechanics:

Drag-and-drop interactions

Mouse button operation mimicking physical locations

Data output generation based on decision paths

Timer controls and error injection (e.g. mis-pipetting, wrong temperature)

5. Learning Journey / Simulation Flow

The simulation should be divided into phases, each linked by branching decisions.

Phase 1 – Planning

User selects reagents and sets up the initial conditions.

Decision node: choose the type of DNA template and primers.

Phase 2 – Execution

Steps like mixing, pipetting, centrifuging, loading gels.

Each step has embedded short video clips (if needed fore real-world comparison) and tool tips.

Errors (if any) are reflected in later output.

Phase 3 – Results

Gel images or data tables are dynamically generated based on user choices.

Differences in band size, intensity, blur etc. based on input choices and accuracy.

Phase 4 – Interpretation and Reflection

Students are prompted to answer questions about their results.

Adaptive feedback is provided based on their input.

6. Embedded Formative Assessment

Use decision-tree logic to tailor questions based on simulation path.

Recommended question types include:

Multiple Choice Questions (MCQs)

e.g. "Which step should follow reagent mixing in PCR setup?"

Multiple Answer Questions (MAQs)

e.g. "Select all possible causes for faint or missing bands on a gel."

True or False

e.g. "The annealing temperature must be higher than the denaturation step in PCR."

Questions should branch depending on choices made in the simulation. Correct/incorrect paths provide immediate, targeted feedback.

7. Feedback and Adaptivity

Immediate, context-aware feedback

If errors are made, allow students to “rewind” and reattempt
Provide alternative paths for incorrect setups to continue learning

8. Reflection and Research Connection

Final reflective question: “How does this technique apply to current research in [topic]?”
Link to published university research using this method
Optional: short video from a researcher discussing real-world application

9. Exportable Summary

At the end, auto-generate a PDF summary for the student:

Path taken
Errors made and corrected
Results generated
Assessment scores
Personalised feedback

Virtual Laboratory Options

A few virtual lab platforms are currently sporadically used in higher education, each offering different pedagogical approaches and degrees of flexibility. Virtual Scientia (University startup) focuses on photorealistic digital twins (powered by Artificial Intelligence), allowing users to interact with equipment that mirrors real-life lab setups in both appearance and function. This approach facilitates procedural accuracy and helps students build confidence in handling complex techniques, particularly when mapped to real lab manuals and research-based learning scenarios. The modular design also enables the creation of bespoke simulations (by lecturers themselves) tailored to specific institutional curricula. The key learning tool is adaptive learning enabling students to produce bespoke results based on their choices e.g. DNA bands on a gel will be of the size chosen during pipetting materials, blur may be added if the voltage is run too high for gel electrophoresis.

Labster and PraxiLabs provide broader libraries of ready-made simulations, often delivered through stylised or animated formats. These platforms are well-suited for foundational instruction but may be less adaptable when departments require simulations to replicate particular equipment or align closely with local lab teaching practices. VR Lab Academy, which is primarily headset-based, focuses on immersive experiences and offers a library of simulations, though its reliance on VR hardware can limit ease of integration into standard university teaching workflows.

Digital twin-based approaches in life sciences offer the added benefit of familiarising students with the exact equipment and software interfaces used in real labs, for example, recreating the operation panel of a PCR machine (this is was available in the PCR simulation tested in this pilot). This not only supports technical accuracy but may also reduce the need for multiple demonstrators, as students arrive better prepared and more confident to carry out tasks independently, which in turns drives efficiencies in staff, resources and equipment.

Future Steps

In the Academic Year 2025–26, we will extend evaluation in 1st and 2nd year units BIOL10401, BIOL10412, the Experimental Design module (EDM: BIOL21041), as well as the postgraduate lab skills unit, gathering structured feedback. Student and staff input will be collected through brief pre/post-simulation surveys and optional in-class polls, complemented by in-simulation analytics on task completion, results, error patterns and time-on-task. Findings will feed into rapid revision cycles each teaching block (content tweaks, accessibility/UI refinements and assessment alignment), with a consolidated mid-year and end of year review. If this feedback confirms positive outcomes, the virtual lab will be further implemented into units in the Academic Year 2026–27, in a more integrated and curriculum-embedded manner to support consistent delivery across undergraduate and postgraduate teaching. Importantly, ongoing funding for this project is secured, with Virtual Scientia (the University start-up) successfully awarded Innovate UK funding and Dr Hyatt receiving Women TechEU funding. Together, these grants provide over £100,000 in resources to support continued development, expansion and creation of new simulations to enhance teaching and learning.

Academic Consultations

The development and piloting of the immersive simulations involved consultation across multiple academic departments, with discussions from key staff in the School of Biological Sciences (SBS), School of Medical Sciences (SMS), School of Health Sciences (SHS), the School of Chemistry, and the Institute of Teaching and Learning.

Within the School of Biological Sciences, Professor Nicky High, Director of Education and Professor Lisa Swanton, Deputy Director for Curriculum, provided strategic oversight. Dr Susan Taylor served as the unit coordinator for the postgraduate PGT Lab Skills unit. Dr Ruth Grady coordinates BIOL10401 (Introduction to Laboratory Sciences), while Dr Maggy Fostier leads BIOL10412 (Introduction to Experimental Biology). Dr Dave Boam, the practical coordinator for PCR and Clone analysis within the Experimental Design module, contributed detailed procedural content. Dr Helen Graham, SBS lead for flexible learning, Professor Michael Sherratt and Professor Paul Shore provided additional academic guidance at the start of the project.

In the School of Medical Sciences, Dr Tracey Speake the unit coordinator for BIOL21041 (Experimental Design), contributed to guidance of the pedagogical alignment within the unit. Professor Angela Davis, Director of Digital Transformation in Healthcare Education, provided valuable advice and support of integration within flexible learning strategies.

The School of Health Sciences is represented by Dr Christos Tapeinos and Dr Ruth Ledder, both of whom serve as unit coordinators for the undergraduate pharmacy practical skills modules. Dr Susan Cochran also supported the development of content mapped to SHS requirements.

From the School of Chemistry, Dr Carl Poree, practical lead for the school, provided input on adapting the simulation platform to Chemistry-based experiments and outlined future implementation use cases.

Finally, the Institute of Teaching and Learning team, in particular Holly Dewsnip, supported the project and will be invaluably involved in dissemination of project findings across institutional networks.

*Digital twins has been used in this context, however there are differing terminologies in published literature with regards to digital models, digital shadows and digital twins based on metrics such as data-flows (we have a paper pending to address these terms to give more clarity).

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