SWIFT-ly enhancing laboratory learning: genetics in the virtual world

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Undergraduate laboratory classes are constrained by time, resources and space, with limitations on the opportunities to acquire essential skills, such as, linking practical approaches with theoretical knowledge, team working, communication and development of experimental strategies.

The 3D Multi User Virtual Environment of Second Life® (SL) allows low-cost simulation of real-world spaces. As part of the SWIFT (Second World Immersive Future Teaching) project we have created a virtual genetics laboratory in SL to study the effectiveness of this medium for addressing limitations of practical laboratory classes. The aim is not to replace real laboratory teaching but to supplement it.

The first phase of the project was to develop an activity in SL to support real life laboratory induction. Thirteen Biological Sciences undergraduates volunteered, attending an SL training session and a taught class in the virtual lab with the aim of learning Health and Safety and the use of specific lab equipment.

The virtual lab classes ran successfully; the only technical difficulties encountered were with putting on and removing lab coats. The SL environment supported all activities well, except for detailed demonstrations of picking up and manipulating objects for which we suggest alternative approaches.

Participants were overwhelmingly positive about the virtual laboratory, finding it more realistic than expected. They reported a meaningful experience, but commented on the need for greater interaction with the virtual equipment. While learning gains were not directly measured, participants felt that they had either learnt new information or successfully revised existing knowledge.

Interactions between participants took place simultaneously in the physical room and in SL. This arrangement benefitted the SL socialisation process whereby participants gained a sense of reality and ability to work with others in the virtual environment.

Overall, we conclude that the virtual lab can provide both good preparation for the real lab and good revision afterwards. The virtual lab induction activity provides an excellent basis for subsequent phases of the SWIFT project.

Keywords: 3d worlds, collaboration, early announcement effectiveness, FE, genetics, immersive learning laboratory, learning, multi user virtual environment, MUVE productivity research risk, Second Life, undergraduate, Virtual Environment

1. Background

Effective practical science learning involves acquisition of skills including:

1. Understanding of the laboratory environment, equipment and issues.
2. The ability to carry out pre-designed experiments and evaluate data from a variety of technologies and equipment.
3. Linking of practical skills with theoretical knowledge.
4. Development of higher-level skills involved in strategic experimental design.
5. Development of team working and communication skills.
In laboratory-based classes there are constraints of time, resources and space, and limited opportunities for interaction between students and teachers. Research using problem based experimental design tutorials shows that group work improves students’ strategies for carrying out experiments but not factual knowledge, whereas students’ skills improve when working together online. There is a need for a different approach, combining the advantages of laboratory, group and on-line working.

1.1 Real-world genetics laboratories

At the University of Leicester, first year undergraduate genetics laboratory classes involve a combination of classical and molecular genetics experiments related to a range of organisms including bacteria, fungi, fruit flies and humans. A typical laboratory holds approximately 120 students and contains standard tools and equipment, such as PCR (Polymerase Chain Reaction) thermocyclers (to amplify DNA samples), equipment to visualise DNA, microscopes, micropipettes (for transferring small quantities of liquid) and Bunsen burners.

In genetics laboratory work, it is important to avoid contamination of the samples and to work very precisely. Laboratory users must understand how to behave in a lab, the wearing of appropriate clothing and how to use equipment safely.

1.2 Virtual worlds

The use of 3D Multi User Virtual Environments, or virtual worlds, alongside real laboratory teaching is one innovative approach to improving student laboratory learning. Virtual worlds are interactive computer-based environments that can be accessed by many people simultaneously through the internet. Each participant in the virtual world is represented by an avatar, a human-looking representation of him or herself. Other participants also appear as avatars in the virtual world. Avatars can explore the 3D space together in real time. Avatars can, for example, walk around buildings, talk to each other and interact with machinery and other objects. The world is persistent, and continues to exist and change whether an individual avatar is present or not.

Virtual land may be landscaped and buildings and objects may be created. Avatars can engage in social activities or work together in-world; learning spaces may be created and classes held.

1.3 The SWIFT project

SWIFT (Second World Immersive Future Teaching) is a three-year research project at the University of Leicester funded by the Higher Education Academy through the National Teaching Fellowship Scheme (NTFS). SWIFT is lead by NTF Prof. Annette Cashmore with NTF Prof. Gilly Salmon. The pedagogical limitations of practical teaching outlined above are relevant to many areas of science teaching but SWIFT focuses on the teaching of genetics within the biomedical sciences.

SWIFT has created a virtual genetics laboratory (Figure 1), to design activities in the virtual world in order to address some of the limitations of teaching in real laboratories, to develop learning situations whereby the activities are used alongside other modes of practical teaching, and to assess the effectiveness of the use of virtual worlds in this way on the students’ learning experience, providing exemplars for other sciences.

Many virtual worlds exist, with varying functionality and affordances. Second Life® (SL) was chosen for SWIFT because it is considered the most technically sophisticated and stable system available, and in use by other educational institutions. In addition, the University of Leicester’s Beyond Distance Research Alliance (BDRA) has had a presence in SL since January 2007, in the form of its Media Zoo.
In the SL laboratory students, as avatars, can explore, experiment and evaluate situations in a risk-free interactive way. Students can visit the laboratory in their own time, try out experiments unsupervised and take as long as they need, unlike a real laboratory which must be supervised for health and safety reasons.

In addition, since student interaction with the virtual laboratory is mediated by the computer, we are able to implement pedagogic models that are not practical in the real world. For example, virtual items of equipment can hand out usage notes, high-risk situations can be demonstrated and abstract concepts can be directly related to learners' actions.

SWIFT develops in stages to involve three types of activity:

i) Laboratory induction (pilot with first year Biological Sciences students).
ii) Investigation of case studies for genetic screening (first year medical students).
iii) Problem-solving, experimental design sessions in molecular genetics for trialling different experimental strategies, (second year Biological Sciences students).

We report here the first stage of SWIFT – induction into a genetics laboratory. In the real laboratory, students are given a printed sheet with relevant health and safety procedures; instructions on equipment use are given as and when required for each experiment. It is not cost- or time-efficient to use a real laboratory session solely for health and safety and equipment use issues.

The learning objectives for this part of SWIFT were identified as gaining an understanding of the laboratory dress code and health and safety in the laboratory, both generally and for specific items of equipment, as well as the basic operation of specific equipment.

This paper describes the process of preparing the virtual laboratory, preparing participants for the virtual world, and conducting virtual classes, along with our findings and observations.

1.4 Examples of other virtual world projects

The University of East London developed a virtual laboratory in SL that allowed students to use a PCR thermocycler. This experiment compared the learning gains of conducting an experiment in SL compared to watching a video of the experiment being conducted in a real laboratory. There was a high satisfaction...
with the virtual world experience. Although the learning gains were found to be similar in both cases, it was concluded that conducting the virtual experiment “makes students better prepared for the real thing”. SWIFT will look for evidence of the virtual lab as preparation for real-life labs.

The University of Bedfordshire asked 84 undergraduates studying IT Project Management to build showcases using SL. Initially, no assistance was given to the students in using SL, on the grounds that it is software intended for public use and students on a computer-related degree should be able to learn its use. However, this proved “overoptimistic”. It was found that a small introduction (15 minutes lecture time) greatly helped students begin building in SL. SWIFT will investigate ways to minimise time spent on SL training.

The University of Leicester’s MOOSE project (MOdelling Of Second life Environments) investigated the socialisation aspects of using SL. A small number of part-time mature students were recruited from a distance learning course in Archaeological Theory. MOOSE used SL activities to help the students “explore the social structure and spaces in traditional cultures”. In particular, the project looked at the way socialisation takes place through SL with reference to Salmon’s 5-stage model of on-line collaborative learning, finding “positive feelings about the nature of immersive environments and experience in it”. SWIFT uses experience from MOOSE in designing SL activities, such as helping participants identify with their avatar by including appearance and clothes changing in the SL training session.

2. The SWIFT virtual genetics laboratory

2.1 SL strengths and weaknesses

Virtual worlds use computer-based technology originally developed for games, allowing virtual worlds to benefit from the immersive sense of reality achieved by games and thus many affordances of the real world. A virtual world is fundamentally different to a Virtual Learning Environment (VLE) or classroom in being a world of experience, both cognitive and emotional. It is also a world that can be shared, experienced, discussed, and changed in a collaborative way with others.

The virtual world experience facilitates:

• Learning in context – field trips, learning in specialist spaces such as laboratories, experiencing an environment distant in time, space or accessibility.
• Learning procedural skills – a sequence of tasks, especially where tasks are spread out in space, or would take a long period of time, for example, doing lengthy laboratory work.
• Group-based learning – especially where learners are not able to be together in the real world, or cannot visit specific places together.

With game technology, and therefore with virtual worlds, one has limited control over details of an avatar’s movement. Therefore, today’s virtual worlds are not well suited to:

• Learning detailed practical tasks, such as manipulating objects.

2.2 Creating the virtual genetics laboratory

Based upon an analysis of the real labs at the University of Leicester, critical requirements for the SWIFT virtual lab were identified, such as protective clothing, safety notices, sinks and lab equipment. A number of objects needed to exhibit behaviours, for which SL scripts were written. For example, warnings are given when entering the lab without wearing a lab coat, alcohol catches fire when close to the Bunsen burner and avatars may pour liquid down the sink.

The SWIFT virtual lab was built inside a large dome-shaped building that already existed on the virtual land of the University’s Media Zoo Island. The lab was built in-house based upon the functional requirements. The more specialised task of scripting (to make objects perform actions) was outsourced.
3. **Method**

3.1 **Participants**

All 180 students from first year Biological Sciences were invited to a presentation on SWIFT. 46 attended, of whom 19 volunteered and 13 students ultimately took part — nine female and four male, all aged under 25. Eleven participants reported that they already knew at least one other participant by the first SL session and seven classed at least one of those as a friend. Participation involved a one hour SL training session and a one hour SL laboratory induction.

A paper questionnaire given before the first SL session to all Biological Sciences students indicates that the self-selected sample is representative of the cohort in use of computer games and SL (Figure 2).

![Figure 2. Comparison of computer game and SL use between SWIFT volunteers and non-volunteers (shown as percentages). Sample sizes 119 and 15.](image)

3.2 **Equipment**

As SL is not yet available across the University of Leicester campus, laptops meeting Linden Labs’ minimum requirements were set up using a private broadband connection.

Laptops were setup ready for each session, one for each participant. Version one of the SL software was used (“Viewer one”). Voice was enabled (to hear the Teaching Fellow – participants used text chat) and the start location was set to the University of Leicester island.

3.3 **SL training**

Volunteers were asked to register on the SL website to save time during the group session and because of Linden Labs’ restriction on registering multiple avatars from one broadband line. Participants were not asked or encouraged to use SL itself outside the group sessions.

SWIFT provided a SL training session for participants as research suggests SL training is important for participants to use SL successfully. The SL training session took place on a simple platform in the sky above the Media Zoo (Figure 3), with a small breakout room out of sight of the main platform giving separate areas for male and female avatar changing.

For the SL training session, the Teaching Fellow and participants (from three to six students) sat together in one room. The Teaching Fellow assisted participants directly, and was also present as an avatar to help in-world. The Researcher Associate was present only as an avatar to conduct the training. SL abilities necessary for the main lab class were taught: chat, walking, sitting, defining and returning to a home location, joining a group, changing clothes, moving the camera (viewpoint on-screen) and capturing an image. Flying was also covered as this was considered intrinsic to the virtual world experience.
3.4 Virtual laboratory lesson

For the virtual laboratory lesson the Research Associate and the participants sat together in one room. The Research Associate’s role was to assist participants in using SL if necessary and to observe. The Teaching Fellow was in a separate room.

In SL participants and the Teaching Fellow, as avatars, congregated in a social area comprising chairs and drinks machines. Firstly, the Teaching Fellow showed the participants around the virtual genetics laboratory (Figure 4) describing the main items of equipment, health and safety issues in general and such issues specific to each item of equipment.
Next, in groups of two or three, participants completed a worksheet. The worksheet was provided on paper in real life, but participants worked together as avatars in SL to complete their worksheets, communicating using group text chat. The work required participants' avatars to take photos of three lab objects and place them on an in-world notice board, answer 11 health and safety questions and collect all the in-world equipment notecards. (Notecards contain text that may be stored and reread; they were available for each piece of lab equipment by clicking on an adjacent label).

Finally, the Teaching Fellow led a discussion about the worksheet exercise in SL with all participants. The Teaching Fellow communicated using Voice within SL while participants used text chat.

3.5 The research study

All 180 students in the cohort (including SWIFT participants) were given a paper questionnaire to ascertain attitudes towards laboratory work, both before and after the SL sessions. SWIFT participants completed a short online questionnaire after each SL session about their experience, and returned for a 30 minute interview about three weeks later. Interviews began with 10 minutes of questions about their experience and views of the SL sessions. A further 20 minutes was spent investigating participants' views on learning in second or real life, which will be reported elsewhere.

4. Results

4.1 Students' experience of the SL training

Participants encountered three main types of technical difficulties during the SL training: understanding the SL user interface, disorientation when flying or teleporting, and difficulty putting on and removing clothing.

Eight of the 13 participants had used SL at least once before the SL training session (two of which had used SL several times). These eight participants reported not seeking help in learning SL, with the exception of one person who used YouTube.

In a questionnaire after the session, all 11 respondents agreed completely or somewhat with the statement “I enjoyed the session”. Only two of the 11 agreed with the statement “I didn’t need the [SL training] session”. Six of the 11 respondents agreed with the statement “I would have liked a second [SL training] session”, four neither agreed nor disagreed, and one disagreed.

However, when the respondents' rated their skills for walking, flying, sitting, changing clothes, moving the camera and taking photos almost all of the 11 respondents' six ratings were “Very confident” or “Fairly confident” (58/66 ratings) with no “Not confident” ratings.

4.2 Students' experience of the virtual laboratory

The virtual lab classes ran successfully. The only technical difficulties encountered were with putting on and removing lab coats. Participants' views on the virtual laboratory were overwhelmingly positive:

“it's a lot more realistic than you'd imagine” (Participant-2a)
“its really clean and very expensive looking” (Participant-4c)
“Cool! Really realistic and representative of a real lab in the university!” (Participant-4b)
“It looked very realistic; I didn’t think it would be quite that realistic, to be honest” (Participant-6b)

From observing participants in both the physical room and the virtual lab, and from later interviews, it is clear that all of them had fun taking part. In particular, all 13 participants returned for the second session and again for the interview, with several asking for further sessions in SL or volunteering to act as advocates for the next phase of SWIFT by giving video interviews.

“It was just like playing a video game, like the SIMs or something ... I do feel comfortable in it [SL]” (Participant-4d)
Overall, participants felt that they had a meaningful experience:

“Second Life gave me the opportunity to actually engage with what I’d be looking at. I know it’s not the real experience, but you still get that, sort of like a taste, you kind of get a general idea of what’s going to happen” (Participant-4e)

When asked what they would change, the general theme was for greater interaction with the virtual equipment:

“If possible, next time we could do an actually experiment?” (Participant-4b)

“I was hoping to use some of the equipment i had never actually used before but all we did was look at most of them” (Participant-6a)

We did not ask or encourage participants to use SL outside of the two taught sessions. However, by the first taught session, eight participants had already used SL. One participant found that the virtual world, like the real one, offers a great variety of experiences when outside the University’s defined area:

“When I did it at home and it didn’t have that sort of filter on it was a bit unusual because, obviously, there was, you know, inappropriate sort of content when I went to the welcome area when I tried it at home. But in the contained area it was really good.” (Participant-6b)

In addition, the reason given by one of the original volunteers for choosing not to participate was that they went into SL (presumably outside the University’s area) and did not like “the feel of it”.

4.3 Learning in the virtual laboratory

Later phases of SWIFT will assess learning gains through virtual lab use. For the pilot, participants were asked to assess their learning experience. Overall, this gave a positive response

“The uses of the equipment, like a lot of the equipment we haven’t actually been introduced to in real labs yet because we haven’t needed to use them, so I think learning about the equipment was important.” (Participant-4d)

“There were a lot of things, like distilled water taps, that I’d never heard of before ... more like a professional lab.” (Participant-4f)

In addition, the session was also a useful revision aid:

“And safety rules I think, that she ran over, which we do normally go over in labs, but I felt like I was learning it more.” (Participant-4d)

“For me I think it’s a better thing to have it now after I’ve already been to the real lab so I can connect it and see what I’ve missed” (Participant-5a)

If these virtual lab sessions were to be used as part of the curriculum, it would be worth considering the views of three participants who suggested running the SL induction on arrival at the University:

“When I first started labs in September I was really scared of going into the labs cause we did no [lab] work in biology in A-level ... and if we had of had this induction it would have really helped” (Participant-4f)

4.4 Tutor’s experience

The tutor reported that students took the taught lab session seriously and behaved well, making it an easy class to teach. There were a few instances of sitting on equipment, standing on benches, flying and so forth, but offenders would desist when asked. It seems likely that this was due to the novelty and affordances of the environment, rather than intentions to disrupt the lesson.
5. Discussion

5.1 SL session

We were impressed at how quickly and easily participants learned to use SL. Based on MOOSE, we intended teaching SL skills, whereas it was clear that around half of our participants had already used and learned SL successfully at home. Although participants were self-selecting, their computer games and SL use seems similar to the rest of the cohort. It is possible that undergraduates generally are now sufficiently familiar with game-style software to greatly reduce SL training needs in future projects.

Although one command was available for avatars to return to the training area if they became lost when flying or teleporting, several avatars left the training area and needed significant help to return. It is possible that the experience of being lost was interesting and the person did not wish to hurriedly return. We will investigate this further in the next phase of SWIFT.

We gave the avatars a clothes-changing task as wearing and removal of lab coats is necessary in the virtual lab, and to help users gain some identification with the avatar. We segregated avatars by gender for this task as one would in the real world. Despite the training, many participants had difficulty later putting on and removing the lab coat, with three avatars left wearing a lab coat but with hair or other clothes. However, we anticipate that recent releases of the SL software (known as “Viewer 2”) may address this (using improvements in how collections of clothing known as Outfits are handled).

In the virtual lab, there were scripted items which allowed the students to perform simple tasks such as pouring liquid down the sink. This proved less than simple for participants as the tasks involved several steps (take object, attach object, start animation, remove object), making the activity in SL far more complex than in real life.

As described earlier, the virtual world is not suited to learning detailed practical tasks, such as manipulating objects. The problems encountered here are further evidence of this weakness. Other similar projects have used the “click to see the bottle pour itself” approach, rather than showing the avatar holding the bottle and pouring. This is an important design consideration for learning spaces in virtual worlds which we shall take into account of in the next phase of SWIFT.

5.2 Lab session

Participants clearly believed that they had had a learning experience, either new learning, revision or both. Most participants believed that they had learned some useful health and safety information.

We were particularly interested in one participant’s comment that (s)he had not used a laboratory before arriving at University. The next phase of SWIFT will investigate this as a possible problem for first-year undergraduates and assess the potential of SWIFT to address such a problem.

Overall, we echo one of the main findings from that use of the virtual lab is good preparation for the real lab. We add that the virtual lab can also be good revision after the real lab.

Videos were not shown due to time constraints within the virtual lab. While physical laboratory time is limited, as are laboratory space and staff resources, in trying to circumvent these constraints we found that student time is also severely limited. Medical students in particular – who will be targeted in the next phase of SWIFT – have a very full schedule, and any virtual lab time must be used to maximum effect.

Finally, we note differences in the socialisation process from distance learning projects, such as MOOSE. SWIFT participants tended to arrive in pairs or groups, especially for their second session. Clearly, a real-world socialisation process was taking place in addition to their SL experience. Since participants were sitting together while their avatars were interacting, many interactions took place in the real world – often short comments or non-verbal communication (looks, smiles, sounds, etc.). Everyone knew whose avatar represented whom, and would refer to real or avatar names interchangeably. Questions about the task were asked in both the virtual and real worlds.
Thus socialisation for working together in the virtual world took place in both the real and virtual worlds. Just how participants divided and merged their experience across the real and virtual worlds is unclear. There may be a similarity with experiencing a movie as a group, where real world interaction is used to comment on and augment the technology-created joint experience. We intend to investigate this in future phases of SWIFT.

6. Conclusion

This study investigated the use of an innovative approach to expanding the student experience and learning opportunities of laboratory-based classes. Student participants were given time in a virtual laboratory to learn about the laboratory environment, equipment and health and safety issues, in addition to their regular lab classes.

Participants reported that they had had a learning experience, especially of health and safety information. Participants cited new learning, such as learning about a new piece of equipment, revision, such as the “safety rules”, or both new learning and revision. This suggests that virtual laboratories can provide effective learning experiences; future phases of SWIFT will seek to quantify learning gains from virtual lab use.

This study has shown that a virtual laboratory in SL is capable of providing an effective laboratory experience for the learning objectives set. The virtual lab itself supported the students’ activities very effectively, the only exception being the demonstrations of manipulating objects. The next phase of SWIFT will take more account of the strengths and weaknesses of the virtual environment.

Participants’ views on the virtual laboratory were overwhelmingly positive, with all participants really enjoying their SL sessions. This finding agrees with previous studies and suggests that a virtual laboratory would be accepted by students.

This study found that more than half the participants chose to learn how to use SL on their own prior to the taught SL session. This suggests that the amount of SL training offered to students could be less that the one hour offered in this study, something that the next phase of SWIFT will investigate.

For this study, participants worked together in one place in the real world while simultaneously working together in the virtual lab. Arranging work in this way appeared to help participants engage quickly with the virtual world through their avatar. This observation suggests that encouraging groups to work together in both the real labs and the virtual labs may help students to work together more effectively in the virtual lab, but requires further investigation.

The virtual lab induction activity used in this study provides an excellent basis for subsequent phases of the SWIFT project. The next phase of SWIFT will allow students to investigate case studies for genetic screening using the virtual lab, giving students additional experience of linking practical skills with theoretical knowledge. In the final phase of SWIFT students will use the virtual lab for experimental design sessions in molecular genetics, giving students additional experience using higher-level skills involved in problem-solving and strategic experimental design, and developing team working and communication skills.

7. Acknowledgements

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8. References


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