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# Design,Development and Evaluation of Biochemistry Virtual Laboratory for Blended Learning

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***Abstract*— This paper examines students' reflection on the design and development of a prototype biochemistry virtual laboratory (vLab) at the University of Hong Kong. Second year students from the MBBS programme were divided into two groups. One group (non-vLab) took part in the original didactic lecture while the other group (vLab) joined in the trial blended virtual lab learning session. The learning outcomes were evaluated by a post-lab knowledge comprehension quiz and the class performances were analyzed. In addition, students' perceptions toward blended vLab learning experience were evaluated by questionnaires. The group with the vLab experience achieved higher quiz results. However, their evaluation and feedback with regard to the vLab learning experience were rather critical, which provided valuable insights for further improvements on the instructional design.**

***Keywords—blended learning; virtual lab;virtual learning;biochemistry education ; learning asessment***

## I. Introduction

Experiential learning is vitally important to biochemistry teaching and learning because laboratory exercises can facilitate the consolidation of concept learning. Unfortunately, real lab practice will not be cost effective due to higher cost of equipment, dedicated preparation by technical staff and unpredictability of time management. If students are not well instructed with lab safety measures, they could be more prone to danger. It is therefore essential for educators to innovate new tools to provide students with more satisfying lab-based learning activities while space and resources are limited.

Virtual simulation offers a possible solution to mimic real lab practice. Setting up a virtual lab can help students to gain more experimental practices at their convenience (Rohrig & Jochheim, 1999). With a click of mouse, students can repeat experiments many times over in risk-free environment without high cost of the real lab use (Cobb, Heaney, Corcoran, & Henderson-Begg, 2009). There have been many examples of virtual lab used for medical and health education. For example, The University of East London had developed a Virtual Biosciences Laboratory for practicing experimental techniques; The Texas Wesleyan University had set up interactive genetics lab (Gene Pool) to explore DNA and human chromosomes (Boulos, Hetherington, & Wheeler, 2007); The University of California had developed a virtual lab to educate people about schizophrenic hallucinations (Gorini, Gaggioli, Vigna, & Riva, 2008). However, the majority of virtual labs have not purposefully designed to be integrated in the wet lab curriculum for teaching and learning. How to construct wet lab biochemistry practical sessions with integration of these technologies demands more innovative instructional designs.

Currently, with the rapid development of technology, the world of education has shifted to a blended learning environment (Ellis, Steed, & Applebee, 2006). In the classroom, teachers are designing learning activities with the incorporation of the new educational technologies for more effective learning. Virtual technologies can prepare students to become more familiar with lab scenarios before taking real practices in a safe way. But virtually simulated lab cannot totally replace the real lab teaching and learning. Therefore, it is important for educators to design and implement virtual lab suitable for blended learning, which brings a lot of challenges for educators. On one hand, at the first encounter of teaching with virtual lab, many educators are not confident about how to design virtual lab and related learning task for classroom activities. On the other hand, educators would also be concerned about possible reservations from students for their willingness to use virtual technologies for education.

This research project aimed to design and implement a biochemistry virtual lab for blended learning purposes. Through evaluation of its implementation, we could assess whether or not virtual lab would enhance lab knowledge comprehension for students. We would also try to assess the degree of the acceptances of students toward blended virtual lab design for the biochemistry lab course. The students' perceptions of the virtual lab design would be able to inform the instructional designers to make further improvements in the second phase of the virtual lab development.

## II. METHODOLOGY

### *A. Students' academic background*

The development of the prototype biochemistry virtual laboratory was intended for the clinical biochemistry teaching of the year one to three undergraduate medical students. The students were enrolled in a six-year medical degree (MBBS) programmme. Approximately 75% of the intakes undertook the local public examination for the Diploma of Secondary Education (DSE), while the others studied either in the International Baccalaureate Diploma Program (IBDP) or the Advanced levels General Certificate of Education. A very small fraction was admitted as graduate students.

### *B. The medical program*

The teaching and learning at the University of Hong Kong (HKU)'s medical school adapts a holistic, discipline integrated system block approach. For example, the first year students study in an integrated art and science of medicine (IASM) block, while the second and third year students enter into human system blocks where disciplines of basic sciences as well as other humanity and basic clinical skill studies are carried out throughout the nine system blocks, such as the respiratory system block, cardiovascular system block, etc.

The medical programme also adapts a hybrid approach where Problem-Based Learning (PBL) and traditional classroom teaching co-exist. The cohort is divided into PBL groups of around 11 students per group. Teaching takes place in multiple of formats, including whole class lectures, practical sessions, clinical sessions and PBL sessions. The basic science teaching in Biochemistry is in part carried out as practical sessions. Typically, five PBL groups are together for a practical session of a three-hour duration. Therefore, such session is repeated four times to cover the entire cohort.

The development of the prototype biochemistry virtual laboratory was intended for use during the practical sessions, which means it was designed to blend in and complement the real-time practical sessions.

### *C. The Virtual Lab Design*

Second Life was chosen as the virtual design platform. At the beginning of the virtual lab construction, the instructional designer worked closely with the teachers to create a working flow chart. Based on the storyboards produced by the teachers and a working flow chart, initial architecture of the virtual lab was drawn. Next, according to the required list of virtual equipment, photographs of these items were taken from the real lab and send to the designers for the 3D virtual reconstruction. Simple equipment modeling work was done in Second Life while more complicated 3D virtual equipment construction was done with the 3D MAX software.

Following the storyboard instructions from the teachers, three learning space were created by the instructional designers; namely the virtual clinic, the virtual lab, and the virtual discussion area. Basically, the virtual learning space was designed to allow room for the teacher to tailor makes the appropriate amount of scaffolding to guide student's learning process.

Utilizing the virtual space provided, learning material was then installed in a certain sequence in the different virtual spaces to promote interactive, collaborative and problem-based learning. For example, a virtual patient with a relevant clinical problem would be installed in the virtual clinic as a lead-in stem to present a need to carry out a couple of clinical biochemistry tests; it thus take the students into the virtual lab to learn about the scientific principles behind the tests; eventually, with the test results from the virtual lab, the case can be discussed more comprehensively in the group discussion area.

To enhance more interactive teaching and learning, Google presentation suite and video clips were also integrated to supplement knowledge building. Furthermore, the instructional designers also helped to incorporate the video clips and Google presentation files into the virtual environment.

### *D. Blended Learning*

Traditionally, teachers instructed the class with a live synchronous and high fidelity face-to-face situation, where the student interactions and independent work would be minimum. With the advancement in technological developments, distance learning offered more self-paced learning in synchronous with low fidelity environment (Graham, 2006). Our model of blended learning takes advantages from both the face-to-face instruction and the virtual learning environment. (Graham, Allen, & Ure, 2003). As many online collaborative tools have been developed recently, teachers can apply constructivist learning into blended learning model, which make problem-based learning or project-based learning more organized in class. In this learning environment, people learn by active construction of ideas and building of skills through active exploration, experimentation, receiving immediate feedbacks, and then adapting their learning accordingly. Students would be performing authentic tasks in the online learning activities while still engaged in collaborative learning with their peers (Sharpe, Benfield, Roberts, & Francis, 2006).

Different to the typical model of this kind of blended learning, this biochemistry virtual lab was creatively designed to assist classroom teaching and learning rather than self-learning tool for asynchronous learning. It still requires tutor's face-to-face guide and students' in-class interaction. Using this strategy, virtual lab was served as a bridge to connect lecture contents and real wet-lab experiential learning, thus helping the students to be much more familiar with the abstract concepts, the equipment and lab procedures before doing real experiment. It could reduce the risk of inappropriate operations of the instruments and minimize the procedural errors.

During the implementation stages, the vLab group of students would be guided to complete different virtual learning activities step by step. Both the facilitators and the teacher would be closely standing by to deal with any hardware and software issues during the use of the virtual lab.

### *E. vLab Group versus Non-vLab Group*

A cohort of second year medical students was involved in our research study. 97 students were in the traditional teaching modality (non-vLab group) while 104 students were in the trial teaching modality with the integration of virtual lab (vLab group). Both groups finished lecture of the same lab contents and conducted real lab practice later. However, for the vLab group, prior to practicing the real lab exercises, they were asked to go through the virtual lab practice first. At the end of the session, two groups were asked to complete a short quiz to test their knowledge comprehension. In addition, the vLab group students were invited to complete a questionnaire designed to probe into their perceptions about the use of the vLab. Furthermore, two observers were invited to record the classroom performances for the two groups of students. Prior to the initiation of this study, we applied and obtained clearance from the human ethic committee. On the day of the study, consents were sought from all participating students.

### *F. Learning Assessment*

Formative evaluation was conducted after the classes. The observers would carefully follow both the vLab and the non-vLab group of students to record their class behavior in a standard observation form. The observation notes would be shared in Google Drive. The quiz results were exported to SPSS for statistical analysis. After the classes, the vLab groups of students were given one week to complete the questionnaires about their perceptions for the virtual lab. Their feedbacks were coded for analysis by the project team.

## III. RESULTS

### *A. The Virtual Clinic.*

For the medical students, one of the ideal contextualization to enhance the basic science learning is to use a clinical scenario. The virtual clinics were built as a replica to a real clinical environment.

The use of the patients in the virtual clinic was aligned with the use of the virtual lab. Students in one class formed five learning teams. Each team was assigned with one virtual patient for analysis. Virtual patients were placed in the clinic rooms with patient records displayed in the room. The surrounding pieces of equipment showed relevant examination results and index.

Figure 1. The Virtual Clinic

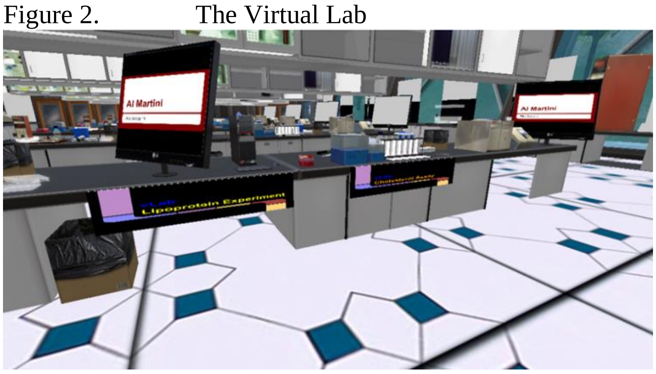
### *A. The Virtual Lab*

The purpose of the practical was to facilitate students understanding of the lipoproteins through interpreting the gel electrophoresis separation patterns of the plasma lipoproteins. The virtual display of the wet lab set-up prepared students to be much more perceptive of the real lab practice.

At the virtual lab bench, experimental specific equipment was displayed. In our particular setting, students would be required to carry out a procedure in the virtual setting by setting up a virtual gel electrophoresis for the plasma lipoproteins separation.

Two lab areas were designed to carry out virtual learning. One area is for audio tour where students would become familiar with the general lab equipment and instructions.

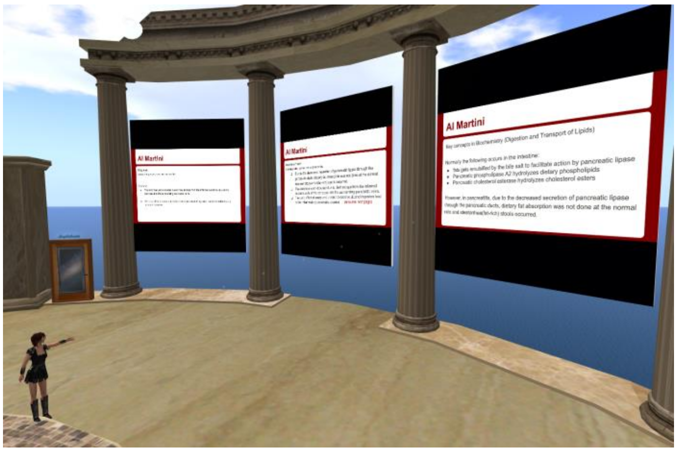
Figure 2. The Virtual Lab




### *B. The Virtual Discussion Area*

Virtual discussion room was designed to provide a virtual space where presentations of results obtained from the problem-based study could be displayed. It would be a place where post-lab discussions could take place either while towards the end of the class session, or after the class session.

Figure 3. The Virtual Discussion Area




**Learning outcomes**

The statistical analysis of the quiz results showed that the mean of non-vLab group is 6.51 (SD=1.56), while the mean of vLab group is 6.93 (SD= 1.37). There was a significant difference between the scores achieved by students in the two groups ($p<0.05$). vLab group students generally performed better in the quiz.

According to the class observation notes, students in the vLab group were more involved in PBL group discussions. They collaborated more with each other in controlling the virtual equipment, in the data collection and in conducting group presentations. Compared with the non-vLab group, students with blended virtual lab were more active, interactive and collaborative in the class activities. During the case study, the observers noticed that in the vLab group, students tried to incorporate a lot of vivid images from the virtual lab, making their presentation with much more abundant information. More group members contributed the opinions input in their final report. In contrast, for the non-vLab groups of students, the willingness for participation was relatively less, typically, only some representatives joined in the writing of the group work report.

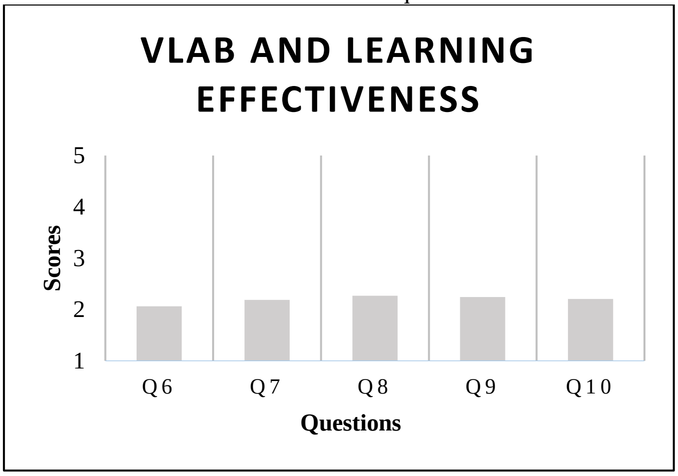
**Evaluation**

The vLab groups were also asked to complete questionnaires at the end of the teaching session.

Generally speaking, students could accept the virtual lab interface design (mean=2.87, SD=1.01). They appreciated highly of the virtual equipment design (mean= 2.96, SD=0.99) and thought the virtual lab closely mimicked the real lab, which was useful in helping them to get familiar with the real lab environment much more.

Although many students complained that they were confused and lost in the virtual clinic (mean=2.79, SD=0.96), they still thought the virtual clinical environment-based case study was more vivid than what was done in the traditional class. According to the responses from the open-ended questions, some students thought that the virtual lab interface was not user-friendly with low resolutions and imbalance of colours. On the other hand, some fantastic designs were actually not related to learning at all, and hence blurred the focus from the virtual lab. In their opinions, the interface should be much simpler, direct and meaningful for learning purpose. Furthermore, although the equipment in the virtual lab was similar to the real one, details of information on operation were missing. Moreover, there was a lack of interaction as there were only a very limited animation designs to support some virtual operation. In general, the avatar could only walk around viewing the equipment rather than being able to operate them in virtual. In fact, about 37% students regarded the system not interactive and 20% selected to give a neutral score. In additional, they were easily lost in the virtual island caused by the overtly complicated layout of the clinic as well of a lack of clear route instructions. They said that they had wasted a lot of time in dealing with the virtual navigations.

Figure 4 Summary of responses from the learning effectiveness evaluation questionnaire.




*The average response value obtained for each statement used on the questionnaire. 1 = strongly disagree; 5 = strongly agree.*

While the quiz indicated that the vLab group of students showed higher academic performance, they still indicated that their learning effectiveness were affected by this blended learning model. The overall satisfactions toward the learning experiences were relatively low. They did not think that the virtual lab could greatly facilitate their learning. They predicted that the knowledge comprehension would not be improved efficiently with the virtual lab. Some students even predicted negative influence toward their learning progress by the incorporation of such blended teaching and learning strategy.

## IV. DISCUSSIONS

Surprisingly, the vLab group of students obtained a higher score in the formative quiz ($p<0.05$). Although without any pre-test baseline, the quiz test might not strongly indicate the vLab group of students indeed performed better than the non-vLab group of students. However, at least, their learning gains were not reduced by the introduction of the virtual lab. This is a consistent findings with previous studies (Cobb et al., 2009). Even though students indicated that their learning effectiveness was slightly affected by virtual lab, the observers gained different findings from in-class record. First of all, their learning motivations were promoted with virtual lab. During the lab talk and case study, more students in the virtual lab group were active to raising in-depth questions during class time. They were more willing to share their opinions and conclusions. At the end of class, students in this group tended to stay longer to discuss experiment problems with peers and facilitators. Their learning passions to explore the virtual lab lasted for the entire class. Also, virtual lab extended their learning opportunities beyond the real lab. They could be more familiar with the lab equipment before they conduct the real experiments. Thus they showed more confidence during the real practice. After class, they were able to get access to the virtual lab to review the equipment and operation procedures. So their chances of learning were increased and their understandings of knowledge were enhanced. Finally, virtual lab blended learning offered a more open platform for social learning and group work. In real PBL sessions, due to personality differences, some students are reluctant to share their thought and opinions. The virtual setting could alleviate their pressure for face-to-face talk. Thus, more students could contribute to the knowledge building. Virtual lab actually had enhanced the active participations from different students in problem based learning.

There are many technical factors that hindered the learning effectiveness in this study. From the feedback, it was reflected that it was tough for some students, especially those using one computer in a team, to control and manage the virtual lab, which delayed their learning process. Some were caused by hardware problems like high CPU use and insufficient power supply issues. So their learning process was disrupted due to such computer issues, which would not happen to traditional class. Also, students complained about the unclear navigations in the virtual lab. The complex virtual layout with ambiguous navigation instructions had misled some students to incorrect places, hence wasted precious learning time and momentum in the class. Furthermore, due to the short development time and limited technical resources, the available vLab package and components were not enough to promote learning. Some designs were not able to fulfill the learning outcomes. It was not surprising that majority of the students felt that the virtual lab had very limited functionality in that it had a virtual display of equipment but lacked any functional and interactive learning components. Clearly, interactions during the learning process can help the students to become more active learners, independent thinkers and cultivate progressive reflections (Piccoli et al., 2001). Hence, it would be our immediate goals to input more interactive components into the virtual lab.

## V. CONCLUSIONS

In this report, we shared our experiences with the design and development of the virtual laboratory to facilitate medical students' learning. This study provides important information about the use and value of virtual lab in practical based science education at the university level. Use of the virtual lab help achieve the learning gain in comparison to traditional teaching methods. Although students indicated negative learning effectiveness in the questionnaires, our observers, however, observed some positive learning behaviours in the blended virtual lab approach, where there was enhanced interactive learning between students, improved involvement in the problem based learning.

In general, when deploying a blended learning solution with a virtual lab or any other virtual technologies, it is essential to consider how the virtual technology can help to achieve learning outcomes. The learner's reactions toward these virtual tools have to be carefully monitored. Students' feedback would provide meaningful insights for instructional designers to upgrade the systems. The reflective tips and feedback obtained from this study will be further tested in the second phase of the study.

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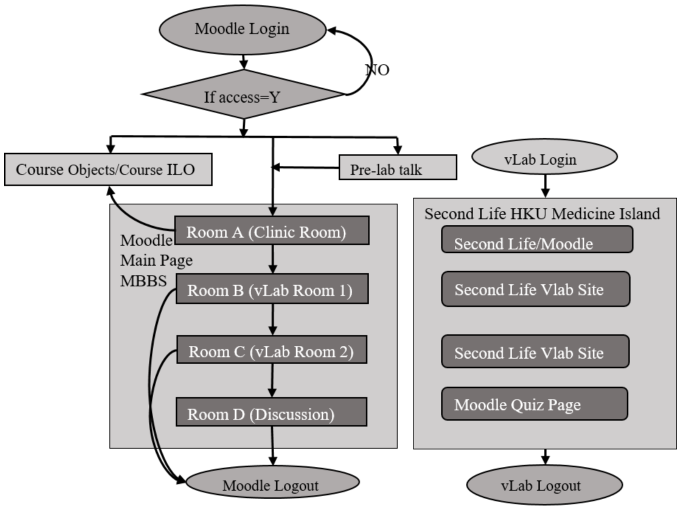
|---|---|---|
| Design | Q1 | The design of interface |
| | Q2 | The design of medical equipment |
| | Q3 | The design of virtual clinical room |
| | Q4 | The design of virtual lab |
| | Q5 | The design of discussion room |
| Learning effectiveness | Q6 | I find vlab make learning easier |
| | Q7 | Using vlab will be more convenient for me to acquire new skills |
| | Q8 | vlab provides me with more academic advantages |
| | Q9 | vlab helps me acquire new knowledge more quickly than before |
| | Q10 | vlab enables me learn new lesson more effectively |

Appendix 1 Statement of Evaluation Questionnaire




Appendix 2 Flow Chart Example