A Virtual Laboratory for Pharmacology Education

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INTRODUCTION

• Traditional CALs are outdated
  – poorly represent the real-life laboratory

• Increasing student enrolment numbers
  – significantly elevated student:staff ratios

→ Negative impacts on student ability to understand and complete laboratory practical classes
• **BIOM2402**
  - contains 233 students
  - Medicine (40%), Science (30%) and Biomed Sci (15%)
  - includes practical laboratory classes assessed by an assignment and examination questions
EDUCATIONAL QUESTION

• Interest in virtual reality technology. Funding acquired.

• Create a virtual lab that allows students to perform experiments and analyse data “pre-lab”.

Can students lab practical skills and understanding of experimental procedures be enhanced?
THE LABORATORY TASK

• Prepare a concentration-response curve for acetylcholine contraction of rat ileum smooth muscle

Students must:

1. Prepare 10-fold serial dilutions of the drug
2. Use an organ bath to add drugs to tissue and wash
3. Measure net contractions and record them in a data table
4. Plot the data on a logarithmic scale and determine EC$_{50}$
THE TWO GROUPS OF STUDENTS

- There were 6 practical (P) groups, 40 students per group:

- P1, P2 and P3 did not receive the VLPC before the real lab task (control group) — "non-VLPC" or "VLPC post-lab"

- P4, P5 and P6 were given access to the VLPC one week prior to their real lab sessions (test group) — "VLPC" or "VLPC pre-lab"

When the VLPC was released, all students were provided with access to the module.
VLPC OVERVIEW
THE VLPC TASK

Virtual Laboratory Practical Class (VLPC)
Concentration-Response Experiment

Objectives:
- Introduce the use of pipettors
- Use pipettors to prepare serial dilutions of an agonist drug
- Measure the contraction of rat Smooth muscle with increasing concentrations of the drug
- Plot and analyse the concentration-response data

Please have your BIOM2402 Laboratory Manual with you for this task.

START
VLPC - SCREEN 1
VLPC – SCREEN 2
Theoretical EC₅₀ = 1.25 x 10⁻⁷ M

Enter Your EC₅₀: 1.3 x 10⁻⁷ M

Estimated EC₅₀ is valid.

Any comments about the VLPC?

Feel free to go back and flip your appended tubes to check their volumes and concentrations.

Data successfully submitted!
Please take a copy of the receipt code: 324538434

Submitting this module will award 5% towards your BIOM2042 assessment.
PRE-LAB SURVEYS

- Pre-lab surveys at beginning of lab class
  - to examine student perception of their experience and confidence in laboratory tasks

The $p$ values for significant increases in scores for the VLPC students compared to non-VLPC students are as follows: Question 5, $p = 0.002$; Question 6, $p = 0.007$, Question 7, $p = 0.012$; Question 9, $p = 0.005$.

Outcome: Significant differences observed only for VLPC-specific tasks.
LAB COMPLETION TIMES

- Sign-on sheets were used to monitor student laboratory completion times

**Outcome:** P4 and P6 significantly lower than non-VLPC groups, but P5 is similar to P3 (alarm!)
LAB COMPLETION TIMES - GROUPS

- Students work in groups of 3 (there were 45 groups in total)
- Server data showed that 6 of these groups did NOT contain a member who completed the VLPC – **4 of these were from P5**.

**Outcome:** When only groups containing VLPC-experienced members were plotted alongside non-VLPC groups, statistically significant reduction in mean \( (p<0.001) \) and variance \( (p=0.042) \) times were observed.
ACTION LOGS

- Using the server data, we can track student use of the VLPC in real time.

These student actions mirror precisely how the real experiment should be done in the laboratory.
ACTION LOGS - FREQUENCIES

- We can also plot the frequency of the various actions

This powerfully demonstrates the remarkable consistency of frequencies of actions across many individual students.
• Use of, and engagement with, the VLPC - **Negative or neutral**

A number of reports of technical issues and interface problems may have accounted for some loss of engagement with the module.
• Student preparation for the real laboratory task: Positive or extremely positive

The VLPC helps students prepare for, and complete, the practical task.
The VLPC decreased student in-lab anxiety while boosting confidence.
FINAL SURVEY

• Realism and future VLPC modules: Extremely positive

Students considered the VLPC to be a realistic depiction of the laboratory, and would like to see more VLPC modules in their future courses.
New data

VLPC was then implemented within a practical class

• The VLPC was included as a pre-lab exercise with the BIOM2009 curriculum in semester 1, and in BIOM2402 in semester 2
• Due to large student enrolments, students were placed in groups of 3 and were required to complete the VLPC task
• Students received a brief introduction on the use of the program
• Data was collected by the internet server for the two semesters. This data included all mouse and keyboard interactions made by students throughout the duration of the VLPC.

• This stored online data was then analysed.

Question: how do students interact with the module, and are there any differences between science and pharmacy cohorts?
Preparation of the Ach serial dilutions

<table>
<thead>
<tr>
<th>To make a working stock solution of</th>
<th>pipette</th>
<th>of</th>
<th>&amp; add Tyrode’s buffer</th>
<th>to make a working stock volume of</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 mM</td>
<td>100 µl</td>
<td>100 mM</td>
<td>900 µl</td>
<td>1000 µl</td>
</tr>
<tr>
<td>1 mM</td>
<td>100 µl</td>
<td>10 mM</td>
<td>900 µl</td>
<td>1000 µl</td>
</tr>
<tr>
<td>100 µM</td>
<td>100 µl</td>
<td>1 mM</td>
<td>900 µl</td>
<td>1000 µl</td>
</tr>
<tr>
<td>10 µM</td>
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</tr>
<tr>
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<td>100 µl</td>
<td>10 µM</td>
<td>900 µl</td>
<td>1000 µl</td>
</tr>
</tbody>
</table>

Select and label an empty tube
Yellow pipettor
Concentrated Ach stock
Blue pipettor
Mix the new stock
Results: CORRECT preparation of serial dilutions

- Approx. one-quarter or fewer pharmacy or science student groups performed the serial dilutions using the correct approach (left panel).
- Of these student groups, significantly more pharmacy students used the correct approach compared to science students (right panel).
- An analysis of all other (incorrect) approaches revealed no distinct patterns.

<table>
<thead>
<tr>
<th>Task</th>
<th>Time taken (s)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pharmacy</td>
<td>Science</td>
<td></td>
</tr>
<tr>
<td>Serial drug dilutions</td>
<td>723 ± 54</td>
<td>603 ± 24</td>
</tr>
</tbody>
</table>
### Generating the concentration-response curve (i.e. acquiring the EC$_{50}$)

#### Table of organ bath final concentrations

<table>
<thead>
<tr>
<th>Serial dilution</th>
<th>Use my working stock solution of:</th>
<th>pipette volume</th>
<th>into organ bath volume of</th>
<th>Final concentration in organ bath</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 μM</td>
<td>25 μl</td>
<td>25 ml</td>
<td>1 nM</td>
</tr>
<tr>
<td>2</td>
<td>1 μM</td>
<td>75 μl</td>
<td>25 ml</td>
<td>3 nM</td>
</tr>
<tr>
<td>3</td>
<td>10 μM</td>
<td>25 μl</td>
<td>25 ml</td>
<td>10 nM</td>
</tr>
<tr>
<td>4</td>
<td>10 μM</td>
<td>75 μl</td>
<td>25 ml</td>
<td>30 nM</td>
</tr>
<tr>
<td>5</td>
<td>100 μM</td>
<td>25 μl</td>
<td>25 ml</td>
<td>100 nM</td>
</tr>
<tr>
<td>6</td>
<td>100 μM</td>
<td>75 μl</td>
<td>25 ml</td>
<td>300 nM</td>
</tr>
<tr>
<td>7</td>
<td>1 mM</td>
<td>25 μl</td>
<td>25 ml</td>
<td>1 μM</td>
</tr>
<tr>
<td>8</td>
<td>1 mM</td>
<td>75 μl</td>
<td>25 ml</td>
<td>3 μM</td>
</tr>
<tr>
<td>9</td>
<td>10 mM</td>
<td>25 μl</td>
<td>25 ml</td>
<td>10 μM</td>
</tr>
<tr>
<td>10</td>
<td>10 mM</td>
<td>75 μl</td>
<td>25 ml</td>
<td>30 μM</td>
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</table>

Students complete this section before VLPC task.
Protocol for generating the concentration-response curve
Results: **CORRECT** generation of concentration-response curve?

Three quarters of the pharmacy student groups performed the task as per the correct protocol, compared to less than 15% within the science counterpart. Within action logs of all remaining groups, **two distinct experimental patterns were observed.**
**INCORRECT** patterns for generating concentration-response curve

Recall:

<table>
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<th>Use my working stock solution of:</th>
<th>pipette volume</th>
<th>into organ bath volume of</th>
<th>Final concentration in organ bath</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 µM</td>
<td>25 µl</td>
<td>25 ml</td>
<td>1 nM</td>
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<td>1 µM</td>
<td>75 µl</td>
<td>25 ml</td>
<td>3 nM</td>
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<td>30 µM</td>
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</table>

Some student groups were generating their concentration-response curve by completing all of the 25 µl additions first and then completing the 75 µl additions; others were doing it the other way around.

This was revealed by the action logs…
Results: **INCORRECT** generation of concentration-response curve

N.B. Therefore, 9% of pharmacy and 10% of science student groups completed the concentration-response curve via a process that does not follow any of these patterns.
**Recall: CORRECT**  \( p < 0.0001 \)

<table>
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<tr>
<th>Task</th>
<th>Time taken (s)</th>
<th>( P ) value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pharmacy</td>
<td>1148 ± 53</td>
<td>872 ± 20</td>
</tr>
</tbody>
</table>

**INCORRECT:** 25 µl then 75 µl

**INCORRECT:** 75 µl then 25 µl
### Error types, and frequencies of these errors

<table>
<thead>
<tr>
<th>Errors</th>
<th>% student groups</th>
<th>Pharmacy</th>
<th>Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serial dilutions</td>
<td>Failing to mix tubes</td>
<td>40</td>
<td>71</td>
</tr>
<tr>
<td>Generating CR curve</td>
<td>Failing to wash organ bath three times between steps</td>
<td>55</td>
<td>53</td>
</tr>
</tbody>
</table>
| Pipetting errors              | Incorrect pipetting technique by drawing from the second stop  
  • frequently  
  • always | 26  
  13   | 62  
  7    |
|                               | Failing to change tips between use | 6        | 16      |
Conclusions

• Science student groups are willing to take shortcuts in completing the virtual laboratory task
• Pharmacy student groups appear more methodical and less likely to take risks in their approach
• Increased error frequencies committed by science students may be a result of exploitation of shortcuts in the software, although this should not be assumed for either cohort.
• Group effects must be considered

This has provided us with an informed teaching practice guide for future semesters to enhance the teaching of practical-based material.

Future work is directed at the design and evaluation of a new virtual lab with sufficient complexity to allow students to design their own experiments, with inbuilt consequences of their actions.
GAMIFIED Vlabs

- Harness the feedback power: students AND academics
- Student leaderboards, self and vs. other students

You have unlocked the Microscopy Laboratory

-- Unlockable achievements --
SuperEye: From macro to micro
ACKNOWLEDGEMENTS

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