

A Virtual Laboratory for Pharmacology Education

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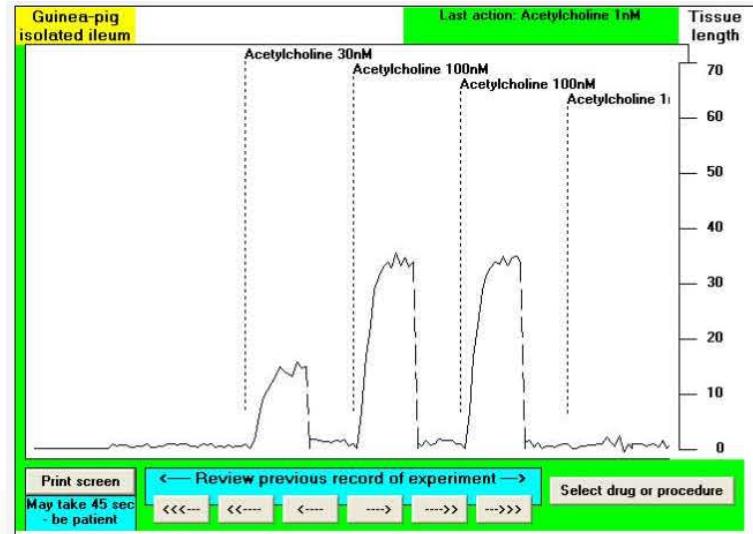
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INTRODUCTION

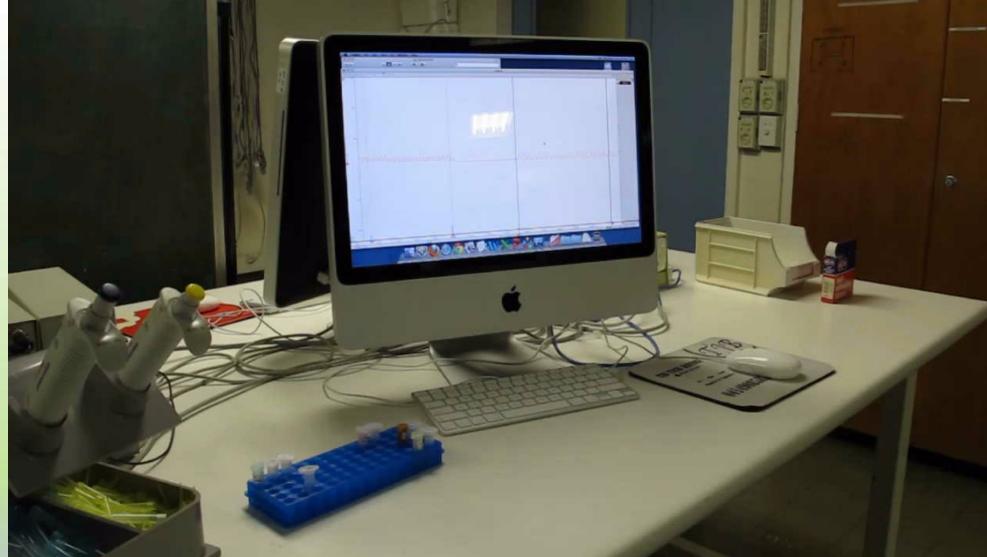
- Traditional CALs are outdated
 - poorly represent the real-life laboratory



- Increasing student enrolment numbers
 - significantly elevated student:staff ratios
 - Negative impacts on student ability to understand and complete laboratory practical classes

CONTEXT

- **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 image displays the VLPC (Virtual Laboratory Practical Class) interface. At the top, the acronym 'VLPC' is written in large, bold letters, with 'Virtual Laboratory Practical Class' in smaller text below it. A close-up photograph of a laboratory pipette is positioned in the top right corner. The main area features two side-by-side images: the left image shows a real laboratory desk with a computer monitor displaying a graph, various pieces of equipment, and supplies; the right image shows a virtual laboratory environment with a computer monitor displaying a graph, a keyboard, and a complex setup of glassware and sensors connected to a central unit. Below these images is a detailed diagram of the virtual lab setup, showing a computer monitor with a graph, a keyboard, a mouse, a yellow biohazard waste bin, and a complex arrangement of glassware, tubing, and electronic components. At the bottom, a box contains the text 'VLPC – Virtual Laboratory Practical Class' and 'Objectives:' followed by a list of learning goals.

VLPC – Virtual Laboratory Practical Class

Objectives:

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

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 EC₅₀

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



VLPC OVERVIEW 2

The image shows a screenshot of a virtual laboratory environment. On the left, there are icons for different pieces of equipment: a 10-100 µL pipette, a 100-1000 µL pipette, a two-stop pipette, a test tube, a 96-well plate, a 6-well plate, a rack of vials, and a beaker. In the center, a video player titled "Using pipettors" is open, showing a hand using a pipette to transfer liquid between wells of a 96-well plate. The video progress bar shows 00:47. To the right of the video player is a sidebar with options: "Select a video:" (highlighted), "Pipettors, tips and disposal", "Adjusting volumes and attaching tips" (highlighted), and "Two-stop pipettors and preparing solutions". Below the video player, there are small images of a pipette, a 96-well plate, and a disposal bin. On the far right, a computer monitor displays a graph of tension (mN) versus time (s). The graph shows a periodic oscillation between approximately 8.0 and 11.5 mN, with major ticks at 8.0, 8.5, 9.0, 9.5, and 11.5, and minor ticks every 5 seconds from 880 to 905.

THE VLPC TASK

uq.edu.au https://vlpc.ceit.uq.edu.au/index.html

my.UQ Staff Portal, T... School of Biomedical S... The University of Que... PubMed Home Faculty of Science - L... Home - British Journal ... Evolve | Faculty Home Online Forms - Financ... My MBBS Course Profiles, The U...

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 ileum with increasing concentrations of the drug
- Plot and analyse the concentration-response data

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

student login

START

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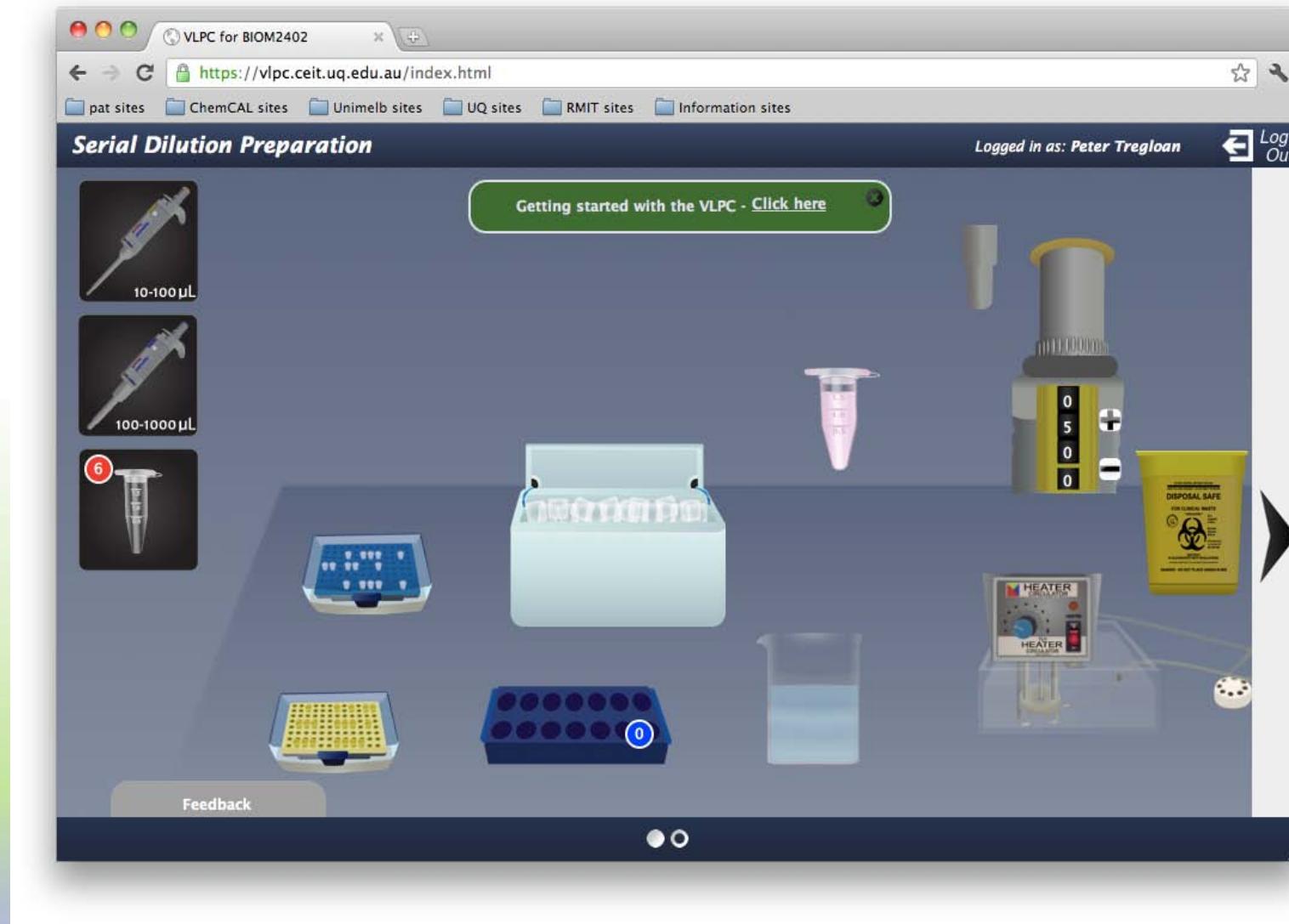
School of Biomedical Sciences
discovering your future now...

The University of Queensland

Research organisms stem cells function

Science discovery

VLPC - SCREEN 1



VLPC – SCREEN 2

Organ Bath Logged in as: Matthew Cheesman Log Out

The screenshot shows a virtual laboratory setup for an organ bath experiment. On the left, there's a detailed diagram of the experimental setup with various components labeled: a Heater, a Heated Stage, a Waste Container, a Test Tube Rack, and a Microscope. A central computer monitor displays a graph of Tension (mN) versus Time (s), showing a baseline with a sharp drop at approximately 1375 seconds. To the right of the graph is a table of experimental data for different Acetylcholine (ACh) concentrations.

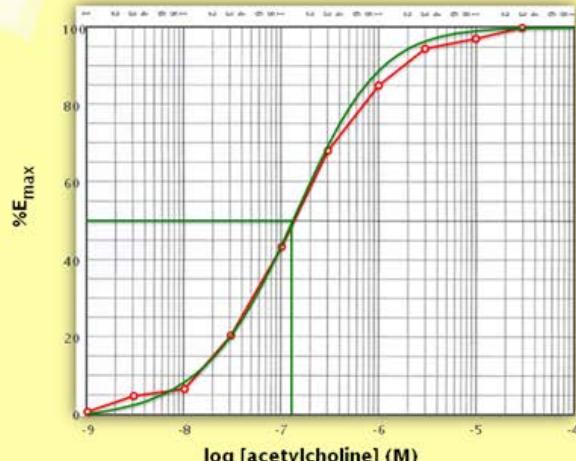
[ACh] (M)	Trial 1	Trial 2	Trial 3	Average	% Δ max
1×10^{-9}	0.1	0.2	0.2	0.2	0.5
3×10^{-9}	2.7	2	0.7	1.8	4.6
1×10^{-8}	2.8	2.9	1.9	2.5	6.4
3×10^{-8}	6.4	8.7	8.7	7.9	20.3
1×10^{-7}	17.8	14.7	18.3	16.9	43.3
3×10^{-7}	24.7	28.2	26.8	26.6	68.2
1×10^{-6}	34.6	32.7	32.2	33.2	85.1
3×10^{-6}	36	38.3	36.4	36.9	94.6
1×10^{-5}	36.9	39.4	37.5	37.9	97.2
3×10^{-5}	39.8	39.6	37.7	39	100

Feedback Plot & Finish Triplicate measurements for: 10 μ M ACh

VLPC – SCREEN 3

Data Analysis and Feedback

Logged in as: Matthew Cheesman [Log Out](#)



Theoretical EC₅₀ = 1.25×10^{-7} M

Enter Your EC₅₀: $\times 10^{-7}$ M

Estimated EC₅₀ is valid!

CHECK

Any comments about the VLPC?

Feedback

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



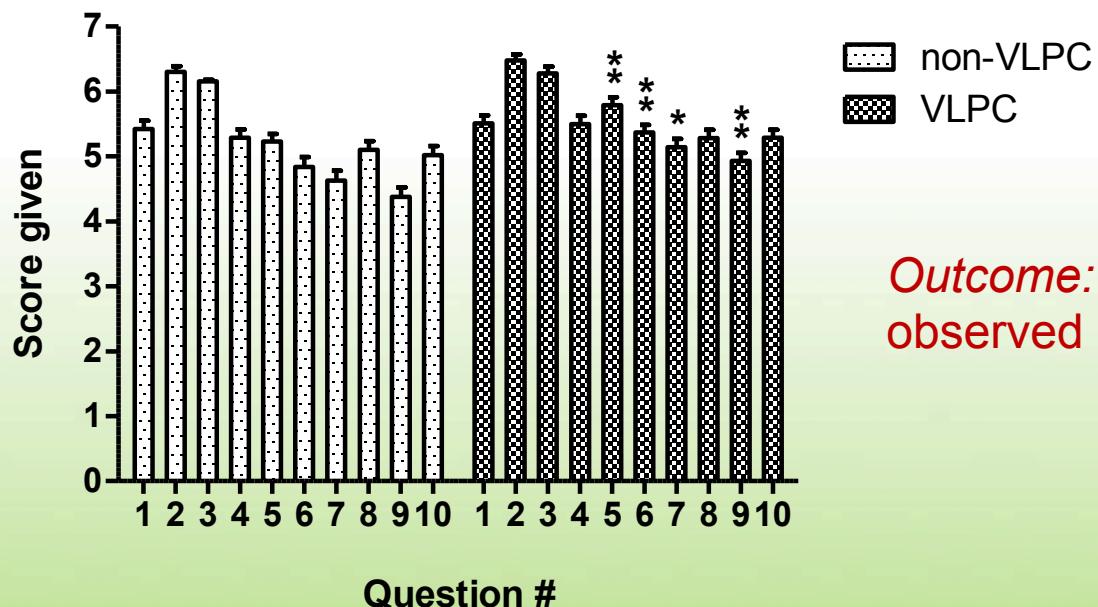
Data successfully submitted!
Please take a copy of the receipt code:
a5cb566a4c

Submitting this module will award 5% towards your BIOM2402 assessment.

Feedback

PRE-LAB SURVEYS

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

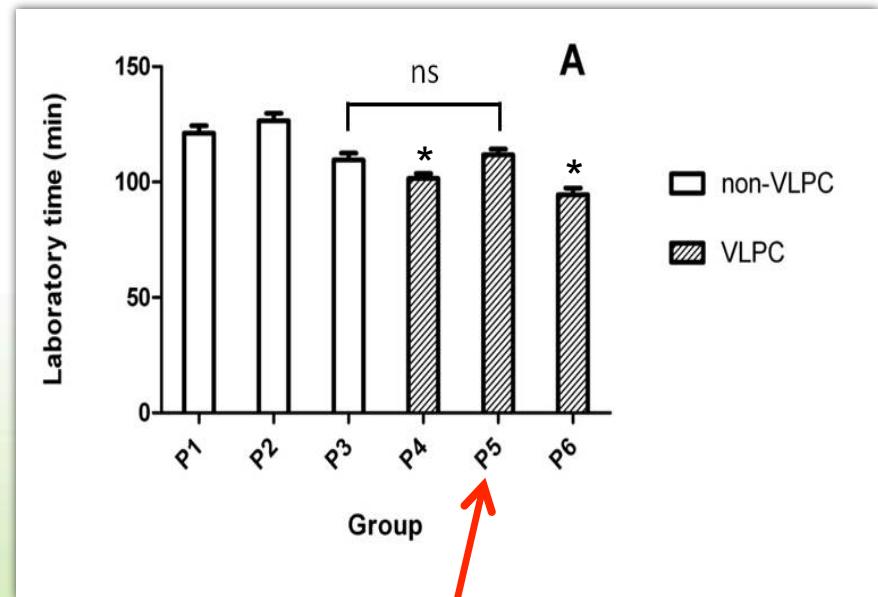
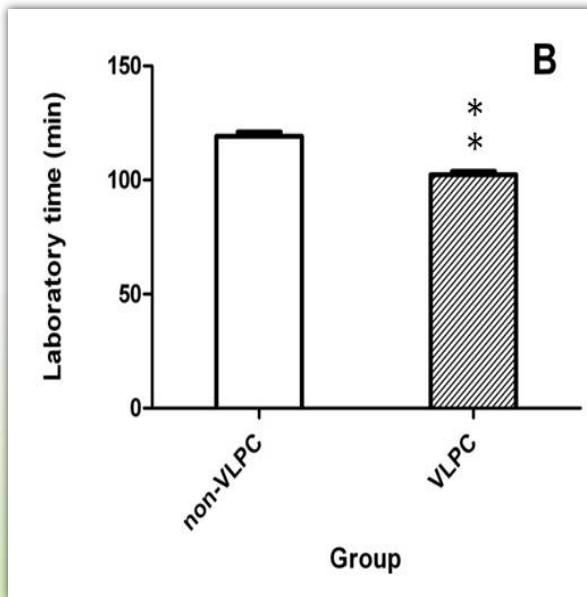


Outcome: Significant differences observed only for VLPC-specific tasks

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, $p = 0.005$.

LAB COMPLETION TIMES

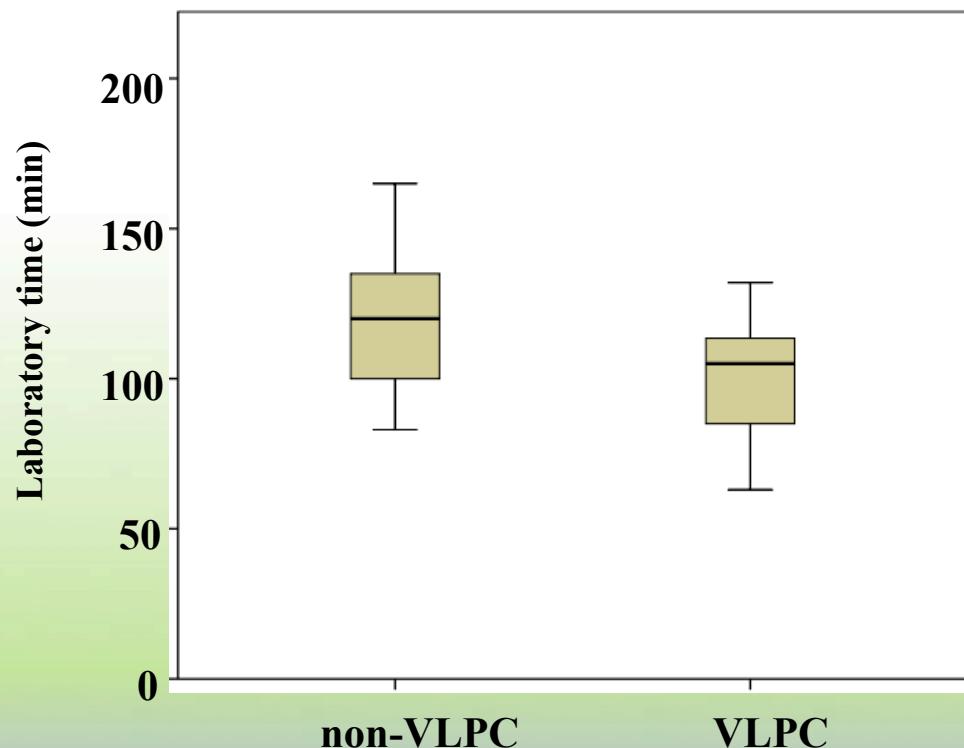
- Sign-on sheets were used to monitor student laboratory completion times



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

LAB COMPLETION TIMES - GROUPS

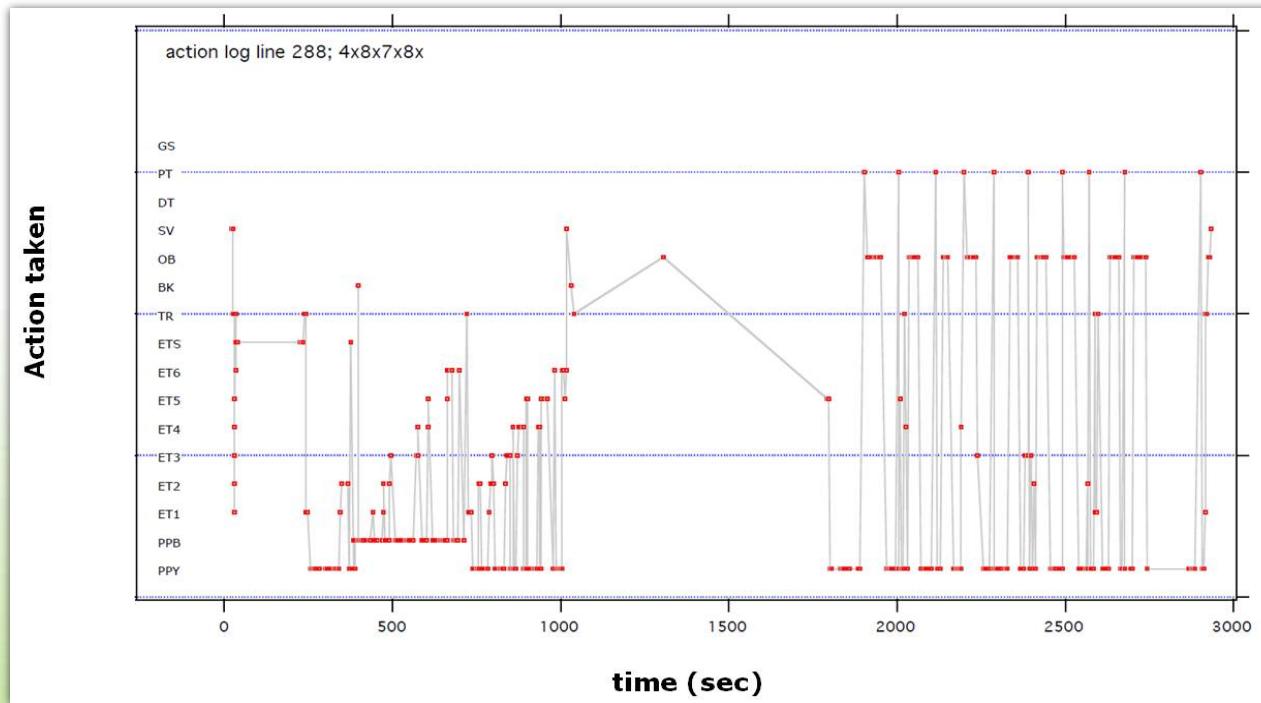
- Students work in groups of 3 (there were 45 groups in total)
 - Server data showed that 6 of these groups did NOT contain a member who completed the VLPC – **4 of these were from P5.**



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

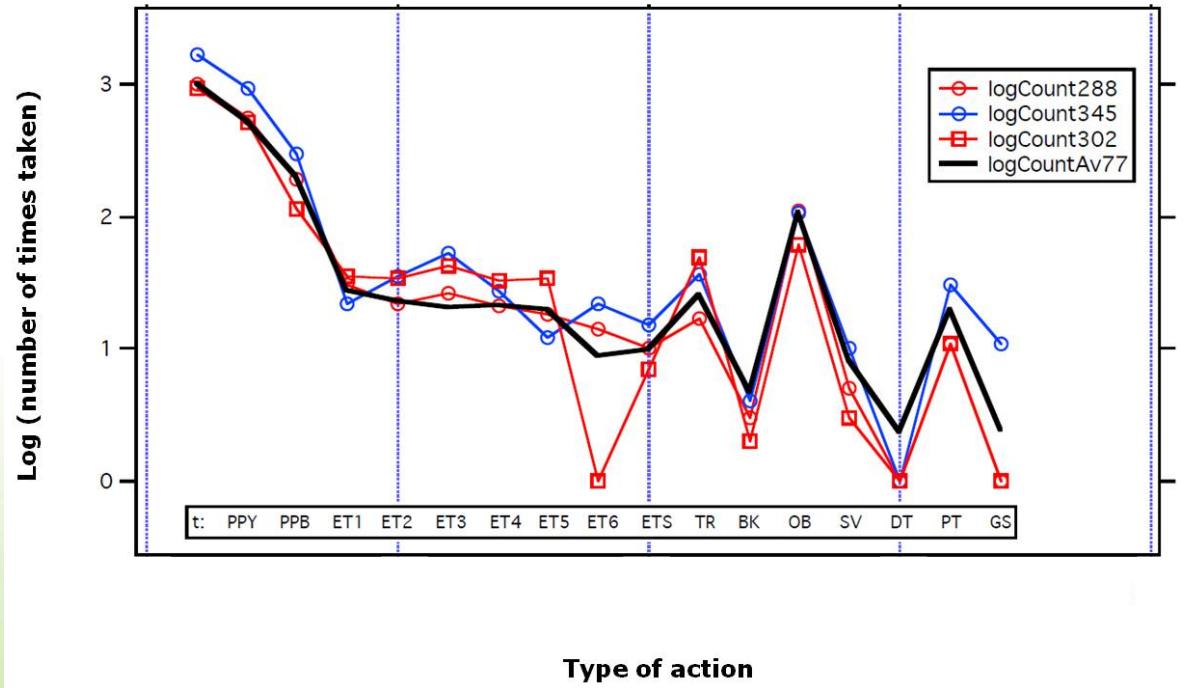
- Using the server data, we can track student use of the VLPC in real time



These student actions mirror precisely how the real experiment should be done in the laboratory

ACTION LOGS - FREQUENCIES

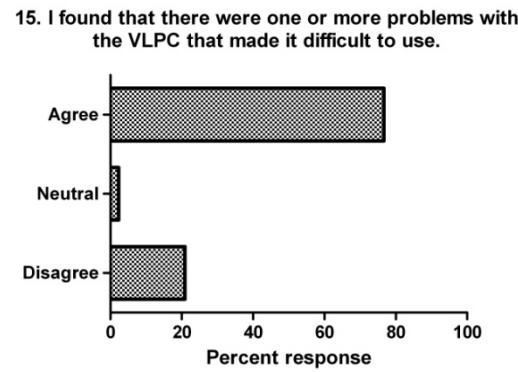
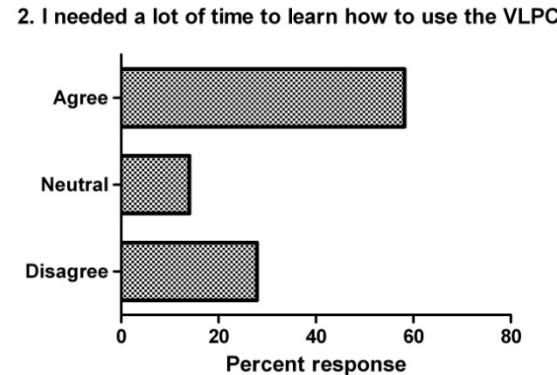
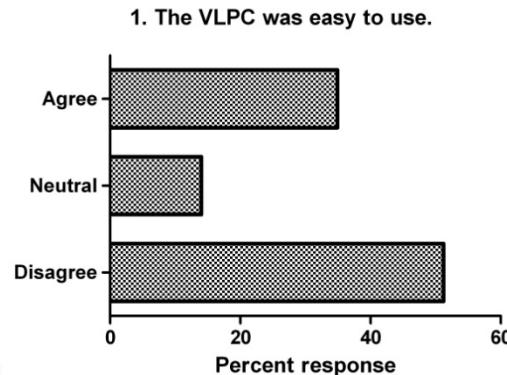
- We can also plot the frequency of the various actions



This powerfully demonstrates the remarkable consistency of frequencies of actions across many individual students.

FINAL SURVEY

- Use of, and engagement with, the VLPC - **Negative or neutral**



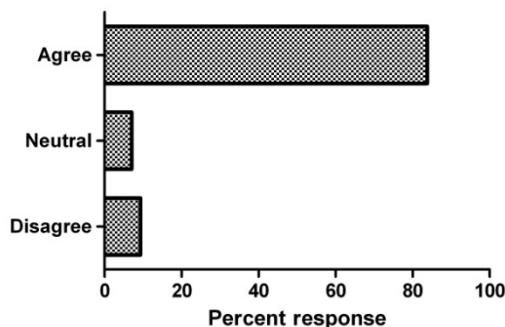
A number of reports of technical issues and interface problems may have accounted for some loss of engagement with the module.

FINAL SURVEY

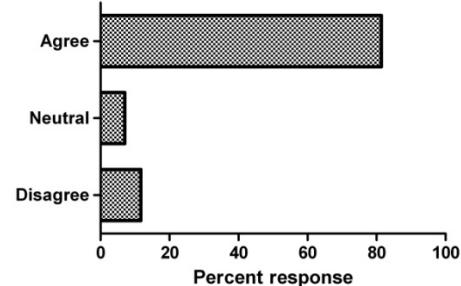
- Student preparation for the real laboratory task:

Positive or extremely positive

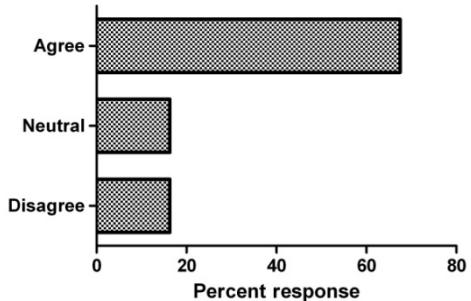
3. The VLPC helped me to understand how to prepare serial drug dilutions.



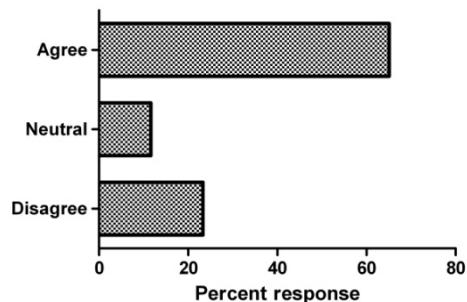
10. Practicing with the program helped me in the use of a real organ bath apparatus (adding drugs, washing).



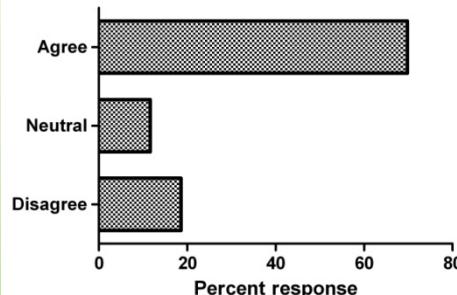
6. The VLPC helped me to identify lab equipment when I did the real laboratory exercise.



16. Making mistakes in the VLPC helped me to learn how to do the experiment.



19. The plot and data that I generated on the VLPC helped me learn how the real experiment should be done.



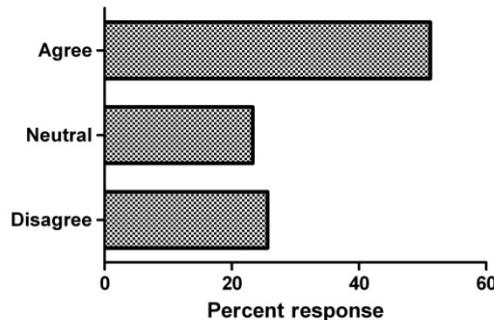
The VLPC helps students prepare for, and complete, the practical task.

FINAL SURVEY

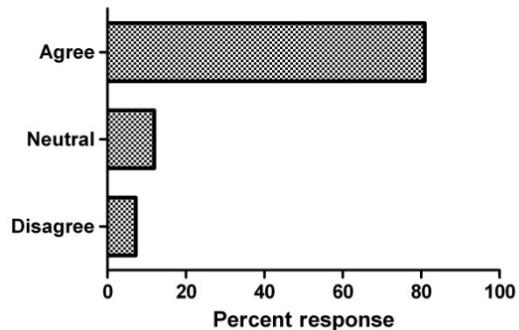
- Confidence and anxiety:

Positive or
extremely positive

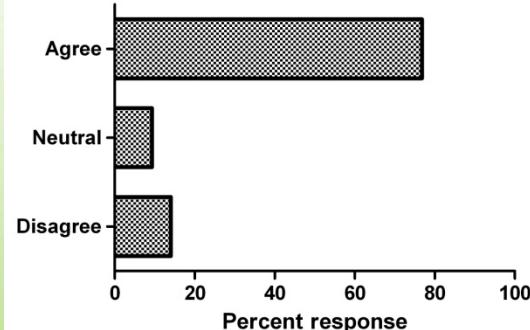
4. I felt confident in using and navigating around the VLPC program.



7. My confidence in the real lab was increased because I did the VLPC.



13. Doing the VLPC reduced my anxiety during the real laboratory task.

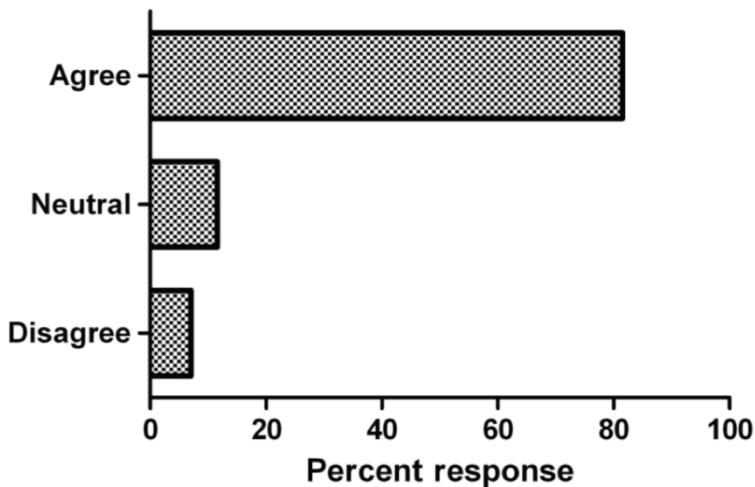


The VLPC decreased student in-lab anxiety while boosting confidence.

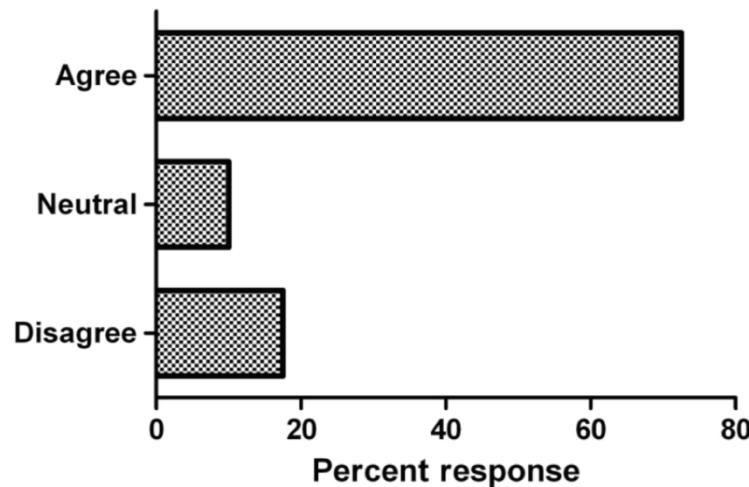
FINAL SURVEY

- Realism and future VLPC modules: **Extremely positive**

12. The VLPC was quite realistic and similar to the real laboratory.



20. I would like to see more of these VLPC programs in my future courses.



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.**

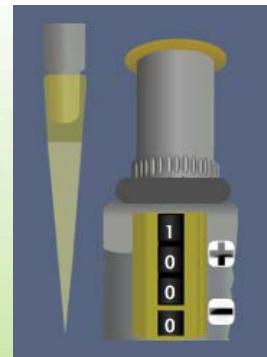
Question: how do students interact with the module, and are there any differences between science and pharmacy cohorts?

Preparation of the Ach serial dilutions

<i>To make a working stock solution of</i>	<i>pipette</i>	<i>of</i>	<i>& add Tyrode's buffer</i>	<i>to make a working stock volume of</i>
10 mM	100 µl	100 mM	900 µl	1000 µl
1 mM	100 µl	10 mM	900 µl	1000 µl
100 µM	100 µl	1 mM	900 µl	1000 µl
10 µM	100 µl	100 µM	900 µl	1000 µl
1 µM	100 µl	10 µM	900 µl	1000 µl



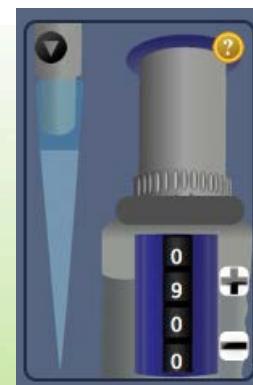
Select and label
an empty tube



Yellow pipettor



Concentrated Ach stock



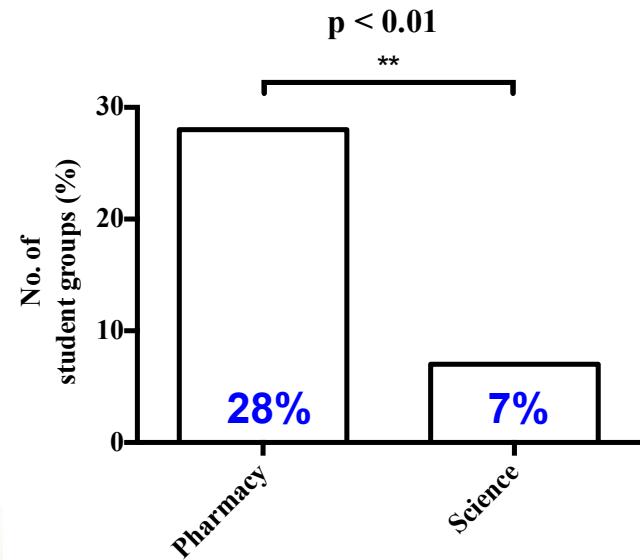
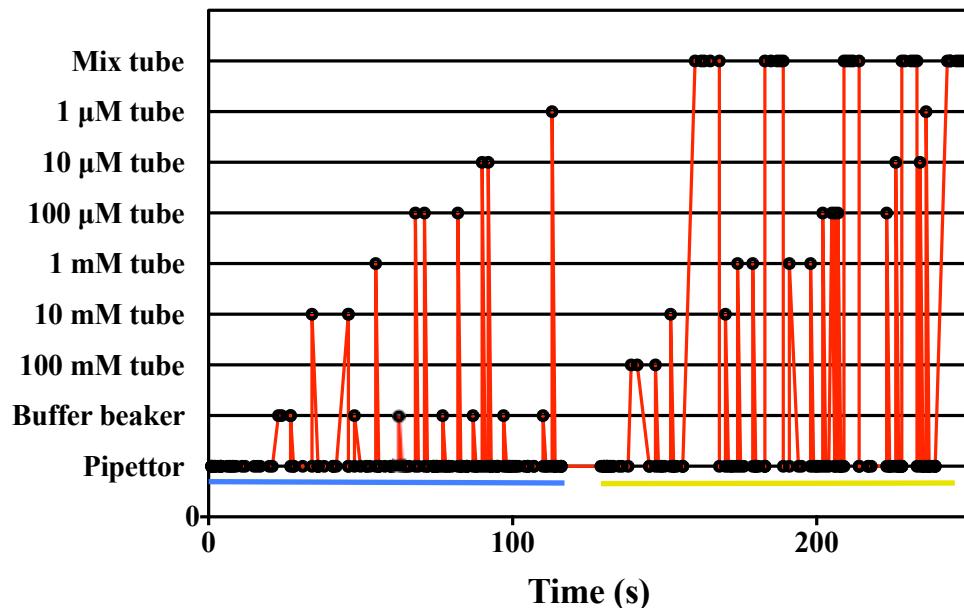
Blue pipettor



Mix the new stock

Results: CORRECT preparation of serial dilutions

Source



- 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.

Task	Time taken (s)		P value
	Pharmacy	Science	
Serial drug dilutions	723 \pm 54	603 \pm 24	0.35

Generating the concentration-response curve (i.e. acquiring the EC₅₀)

Table of organ bath final concentrations

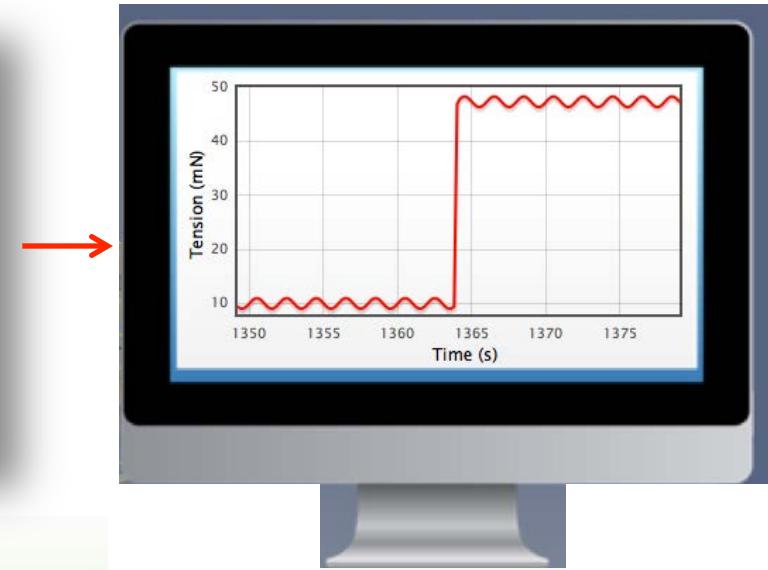
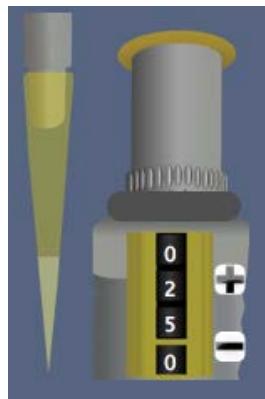
Serial dilution

1 |
2 |
3 |
4 |
5 |

<i>Use my working stock solution of:</i>	<i>pipette volume</i>	<i>into organ bath volume of</i>	<i>Final concentration in organ bath</i>
1 μM	25 μl	25 ml	1 nM
1 μM	75 μl	25 ml	3 nM
10 μM	25 μl	25 ml	10 nM
10 μM	75 μl	25 ml	30 nM
100 μM	25 μl	25 ml	100 nM
100 μM	75 μl	25 ml	300 nM
1 mM	25 μl	25 ml	1 μM
1 mM	75 μl	25 ml	3 μM
10 mM	25 μl	25 ml	10 μM
10 mM	75 μl	25 ml	30 μM

students complete this section before VLPC task

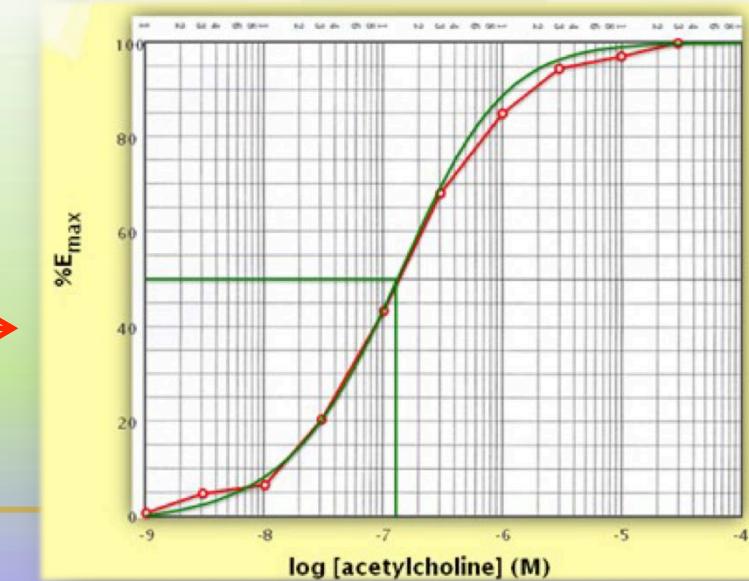
Protocol for generating the concentration-response curve



Net Contractile Force (mN)

[ACh] (M)	Trial 1	Trial 2	Trial 3	Average	%E _{max}
1×10^{-9}	0	0.2	0.1	0.1	100
3×10^{-9}					
1×10^{-8}					
3×10^{-8}					
1×10^{-7}					
3×10^{-7}					
1×10^{-6}					
3×10^{-6}					
1×10^{-5}					
3×10^{-5}					

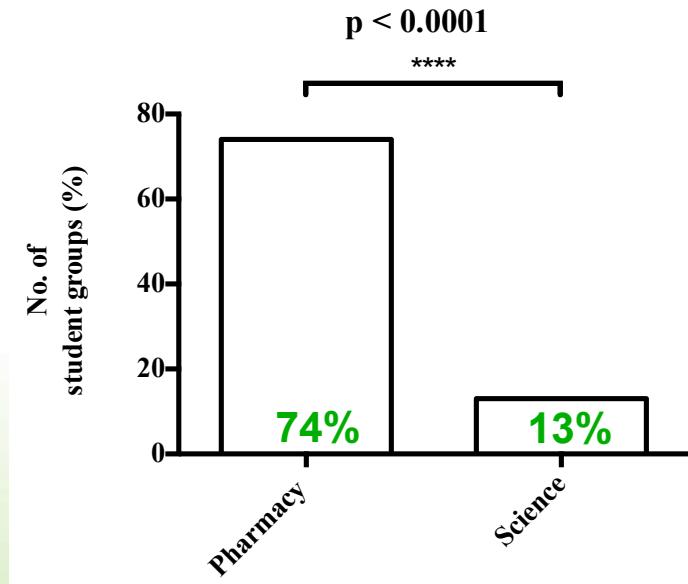
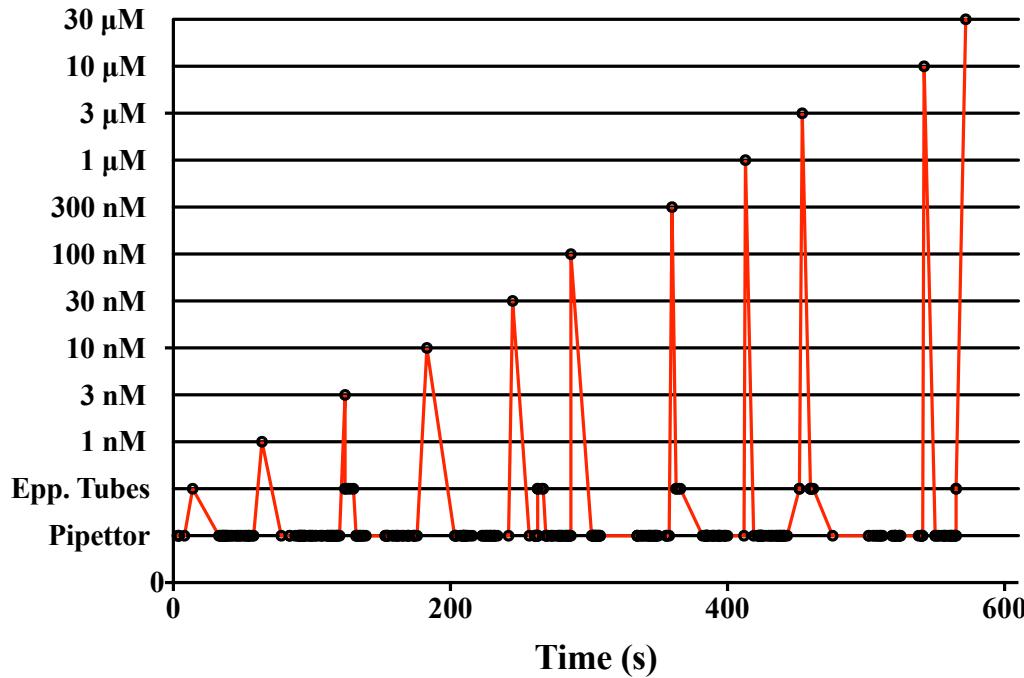
Triplicate measurements for: 1nM ACh Plot & Finish



Results: CORRECT generation of concentration-response curve?

Correctly

Source



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:

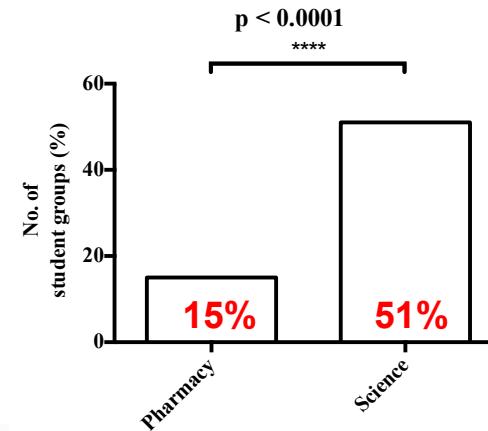
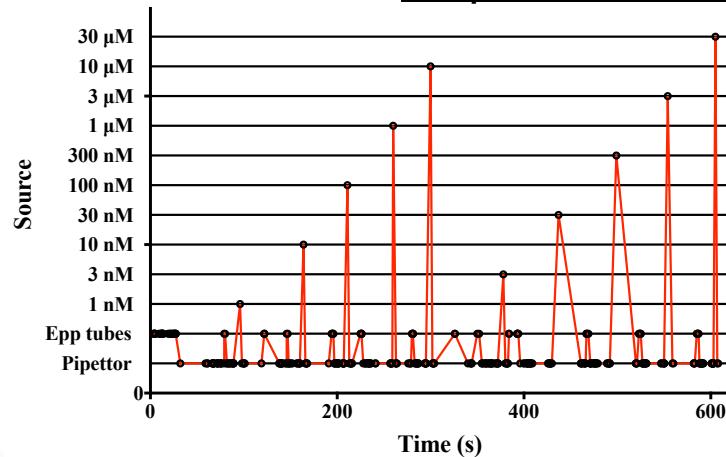
<i>Use my working stock solution of:</i>	<i>pipette volume</i>	<i>into organ bath volume of</i>	<i>Final concentration in organ bath</i>
$1 \mu M$	25 μl	25 ml	1 nM
$1 \mu M$	75 μl	25 ml	3 nM
$10 \mu M$	25 μl	25 ml	10 nM
$10 \mu M$	75 μl	25 ml	30 nM
$100 \mu M$	25 μl	25 ml	100 nM
$100 \mu M$	75 μl	25 ml	300 nM
$1 mM$	25 μl	25 ml	1 μM
$1 mM$	75 μl	25 ml	3 μM
$10 mM$	25 μl	25 ml	10 μM
$10 mM$	75 μl	25 ml	30 μM

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.

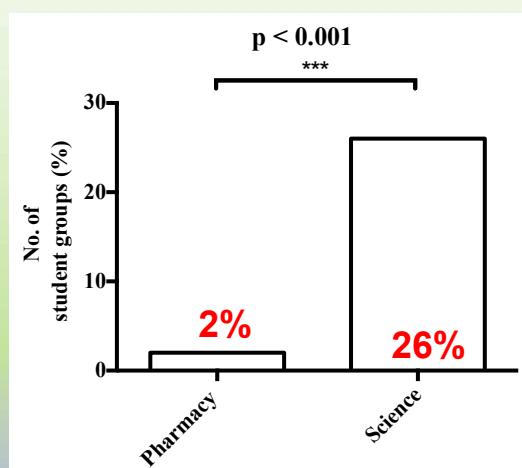
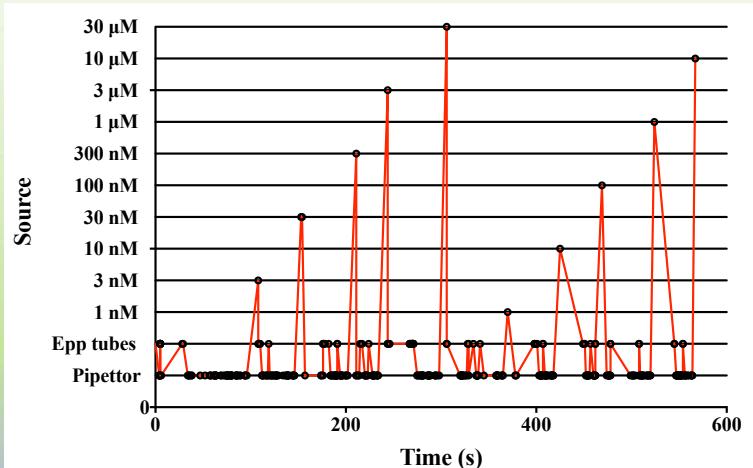
This was revealed by the action logs...

Results: INCORRECT generation of concentration-response curve

25 µl additions then 75 µl additions



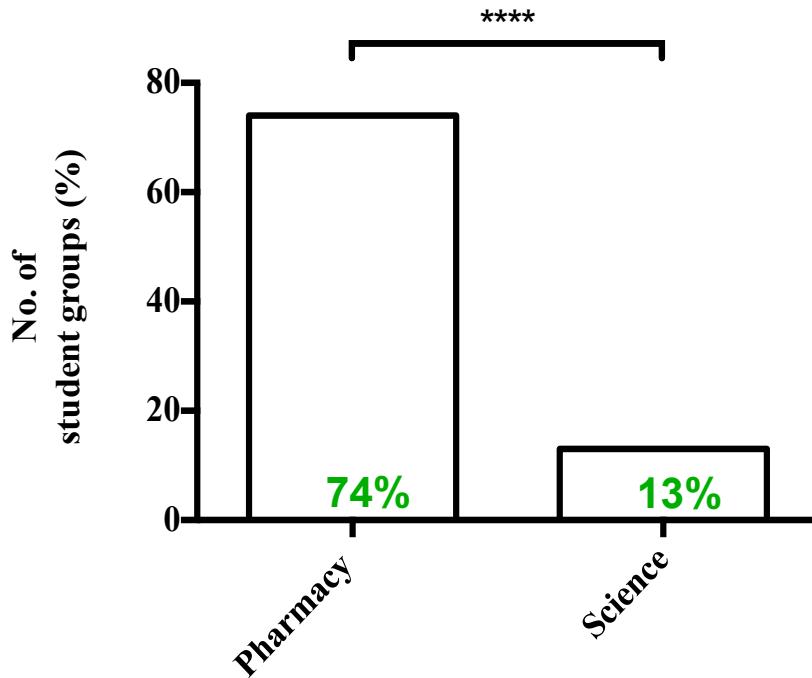
75 µl additions then 25 µl additions



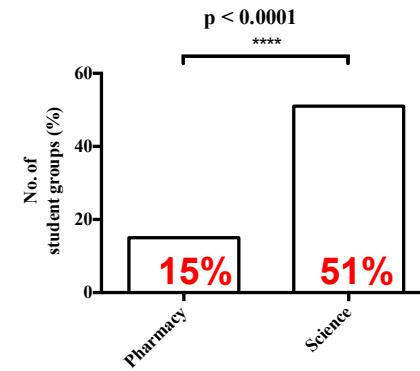
N.B. Therefore, 9% of pharmacy and 10% of science student groups completed the concentration-response curve via a process that does not follow any of these patterns.

Summary of correct & incorrect student approaches, and time taken

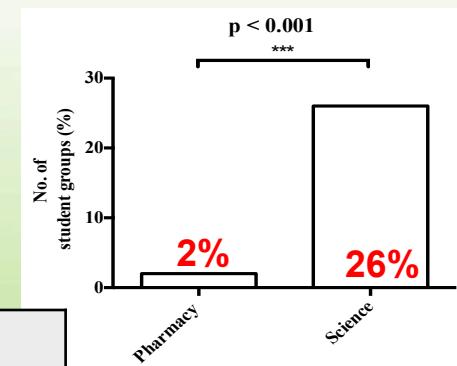
Recall: CORRECT $p < 0.0001$



INCORRECT: 25 µl then 75 µl



INCORRECT: 75 µl then 25 µl



Task	Time taken (s)		P value
	Pharmacy	Science	
Generating CR curve	1148 ± 53	872 ± 20	<0.001

Error types, and frequencies of these errors

Errors		% student groups	
		Pharmacy	Science
Serial dilutions	Failing to mix tubes	40	71
Generating CR curve	Failing to wash organ bath three times between steps	55	53
Pipetting errors	Incorrect pipetting technique by drawing from the second stop <ul style="list-style-type: none">• frequently• always	26 13	62 7
	Failing to change tips between use	6	16

Conclusions

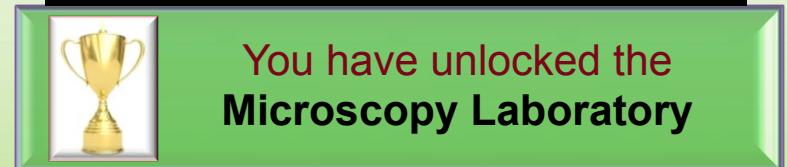
- Science student groups are willing to take shortcuts in completing the virtual laboratory task
- Pharmacy student groups appear more methodical and less likely to take risks in their approach
- Increased error frequencies committed by science students may be a result of exploitation of shortcuts in 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.

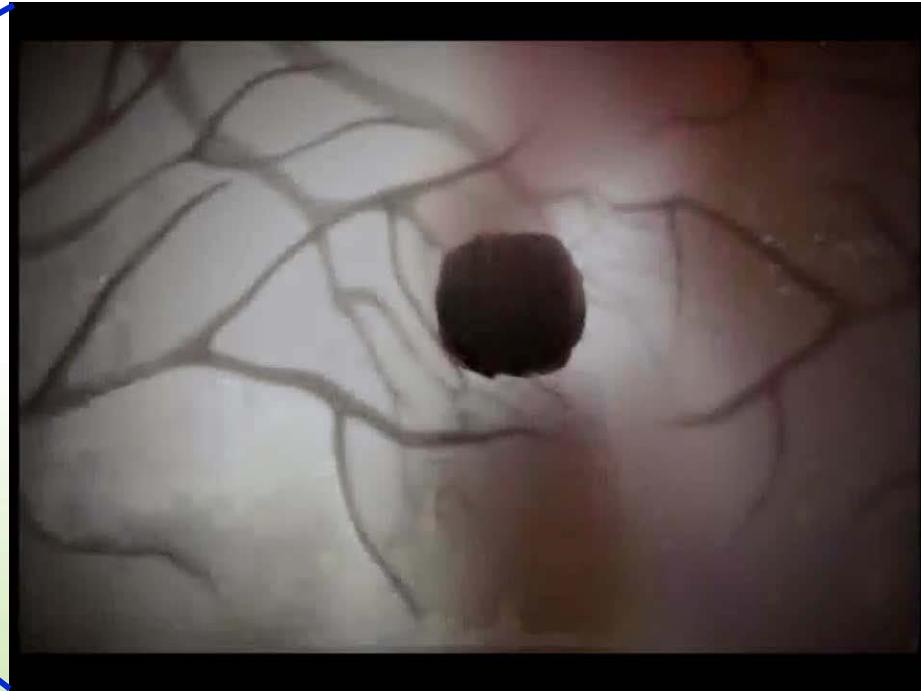
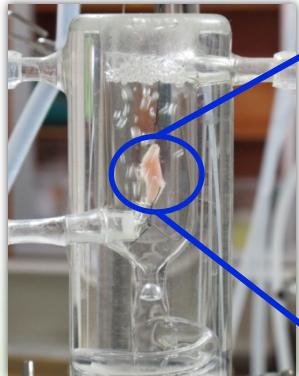
GAMIFIED Vlabs

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



-- Unlockable achievements --

SuperEye: From macro to micro





THE UNIVERSITY
OF QUEENSLAND
AUSTRALIA

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Dr Lucy Webster



University of Melbourne

Dr Kristine Elliott
Dr Terry Judd



University of Queensland

Dr Prasad Chunduri
Steven Chen
Prof Peter Tregloan
Prof Phil Long

