

# A Virtual Laboratory for Pharmacology Education

*Matthew J. Cheesman, PhD*

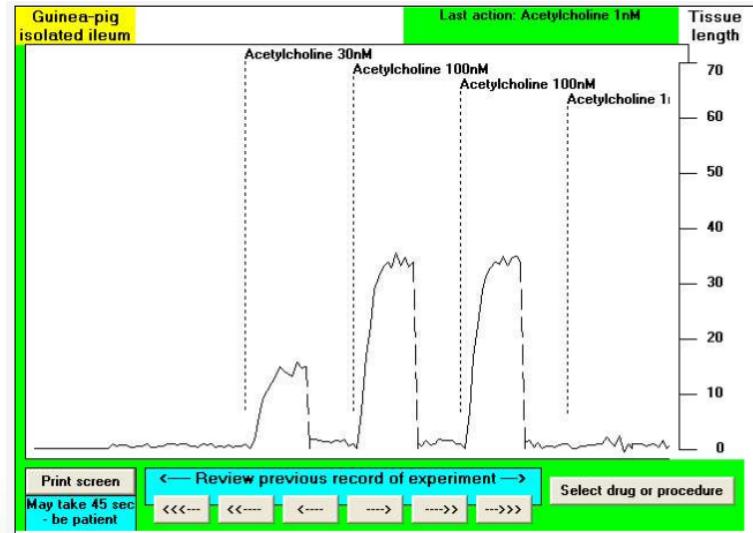


THE UNIVERSITY  
OF QUEENSLAND  
AUSTRALIA



# INTRODUCTION

- Traditional CALs are outdated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

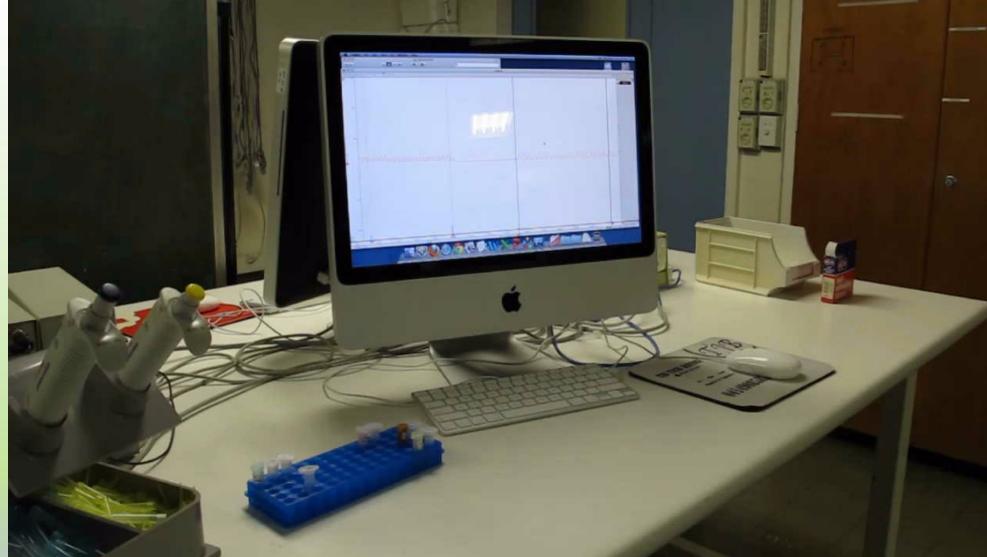


- Increasing student enrolment numbers
  - significantly elevated student:staff ratios
  - Negative impacts on student ability to understand and complete laboratory practical classes

# CONTEXT

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- **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

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- 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 prominently displayed next to a digital pipette icon. Below it, the text 'Virtual Laboratory Practical Class' is written. The interface is divided into several sections:

- A large photograph of a real laboratory setup, featuring a computer monitor displaying a graph, various pieces of laboratory equipment like shakers and flasks, and a complex glass apparatus with yellow tubing.
- A smaller, stylized illustration of a virtual laboratory setup, showing a computer monitor with a red waveform graph, a keyboard, a mouse, and various laboratory glassware and equipment.
- At the bottom, there is descriptive text: 'VLPC – Virtual Laboratory Practical Class' followed by 'Objectives:' and a bulleted 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

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



*Students must:*

- ❶ Prepare 10-fold serial dilutions of the drug
- ❷ Use an organ bath to add drugs to tissue and wash
- ❸ Measure net contractions and record them in a data table
- ❹ Plot the data on a logarithmic scale and determine EC<sub>50</sub>

# THE TWO GROUPS OF STUDENTS

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- 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.

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# VLPC OVERVIEW

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# VLPC OVERVIEW 2

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The image shows 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 rack of test tubes, a beaker, and a 12-well plate. In the center, a video player titled "Using pipettors" is open, showing a close-up of a hand holding a pipette and dispensing liquid into a well of a 96-well plate. The video player has a progress bar at 00:47. To the right of the video player is a sidebar with the heading "\* Select a video:" and three options: "Pipettors, tips and disposal", "Adjusting volumes and attaching tips" (which is highlighted in yellow), and "Two-stop pipettors and preparing solutions". Below the video player is a graph on a computer monitor showing "Tension (mV)" on the y-axis (ranging from 8.0 to 11.5) versus "Time (s)" on the x-axis (ranging from 880 to 905). The graph displays a periodic oscillation between approximately 8.5 mV and 11.0 mV.

# 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.

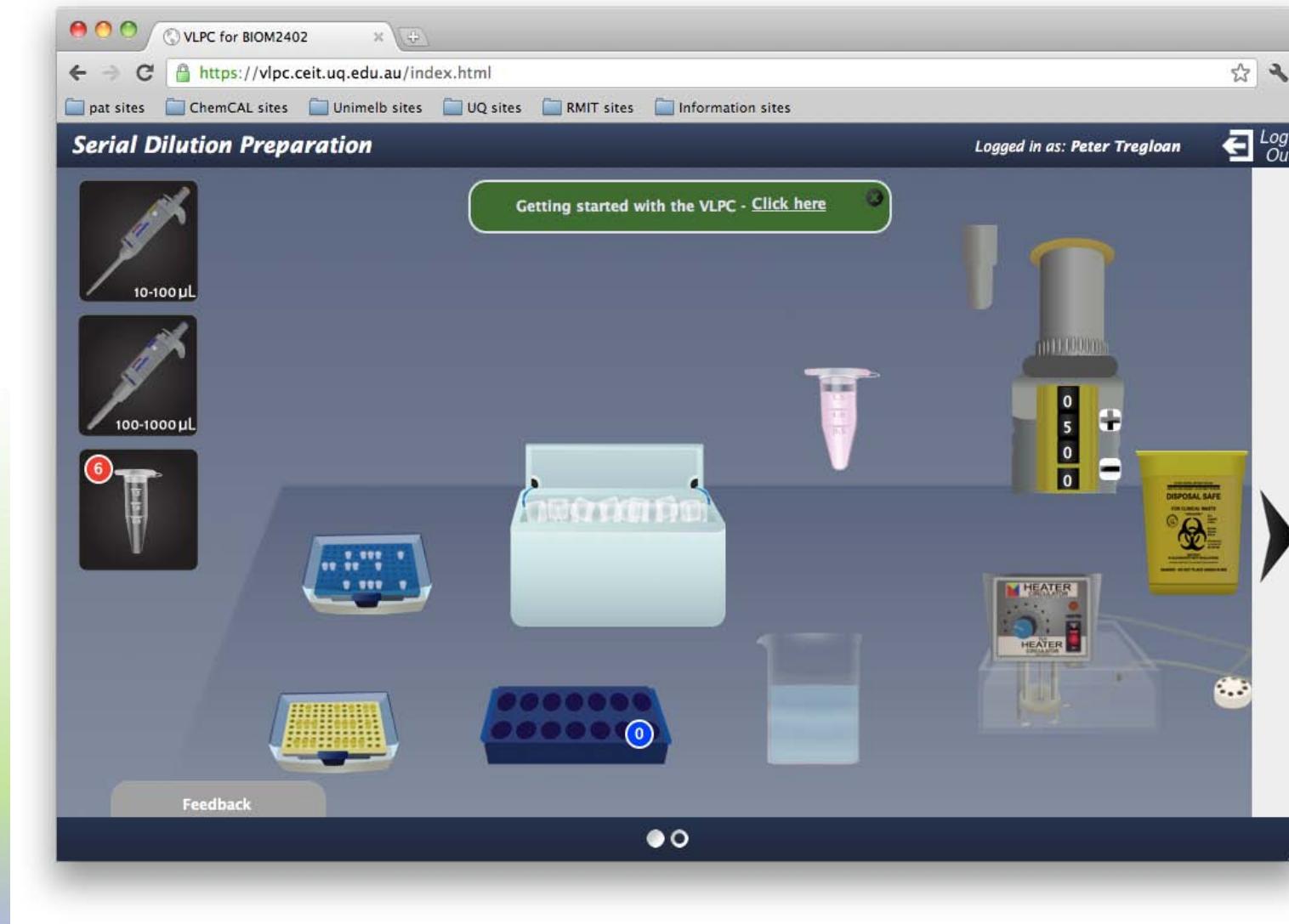
  
Research discovery  
molecular organisms stem cells function

Powered By 

School of Biomedical Sciences  
discovering your future now...



# VLPC - SCREEN 1



# VLPC – SCREEN 2

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

The interface features a 3D model of the experimental setup on the left, showing a tissue sample in a bath, a heater, and various reagent containers. On the right, there's a real-time graph of 'Tension (mN)' vs 'Time (s)', a data table for 'Net Contractile Force (mN)', and icons for reagents and a pipette.

**Tension (mN)**

Time (s)

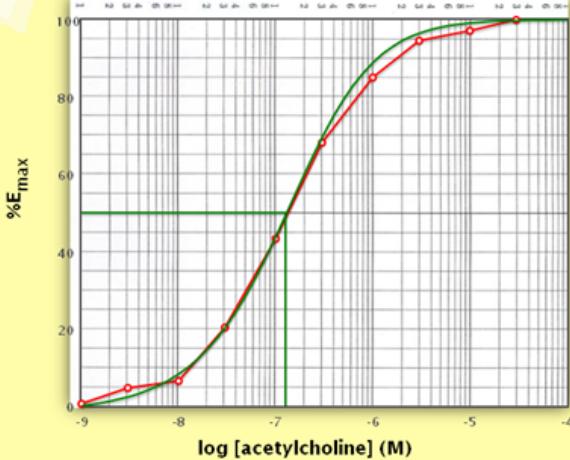
[ACh] (M)	Trial 1	Trial 2	Trial 3	Average	%E <sub>max</sub>
$1 \times 10^{-9}$	0.1	0.2	0.2	0.2	0.5
$3 \times 10^{-9}$	2.7	2	0.7	1.8	4.6
$1 \times 10^{-8}$	2.8	2.9	1.9	2.5	6.4
$3 \times 10^{-8}$	6.4	8.7	8.7	7.9	20.3
$1 \times 10^{-7}$	17.8	14.7	18.3	16.9	43.3
$3 \times 10^{-7}$	24.7	28.2	26.8	26.6	68.2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

Feedback      Triplicate measurements for: 10µM ACh      [Plot & Finish](#)

# VLPC – SCREEN 3

Data Analysis and Feedback

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



Theoretical EC<sub>50</sub> = 1.25 × 10<sup>-7</sup> M

Enter Your EC<sub>50</sub>: 1.3 × 10<sup>-7</sup> M

Estimated EC<sub>50</sub> 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

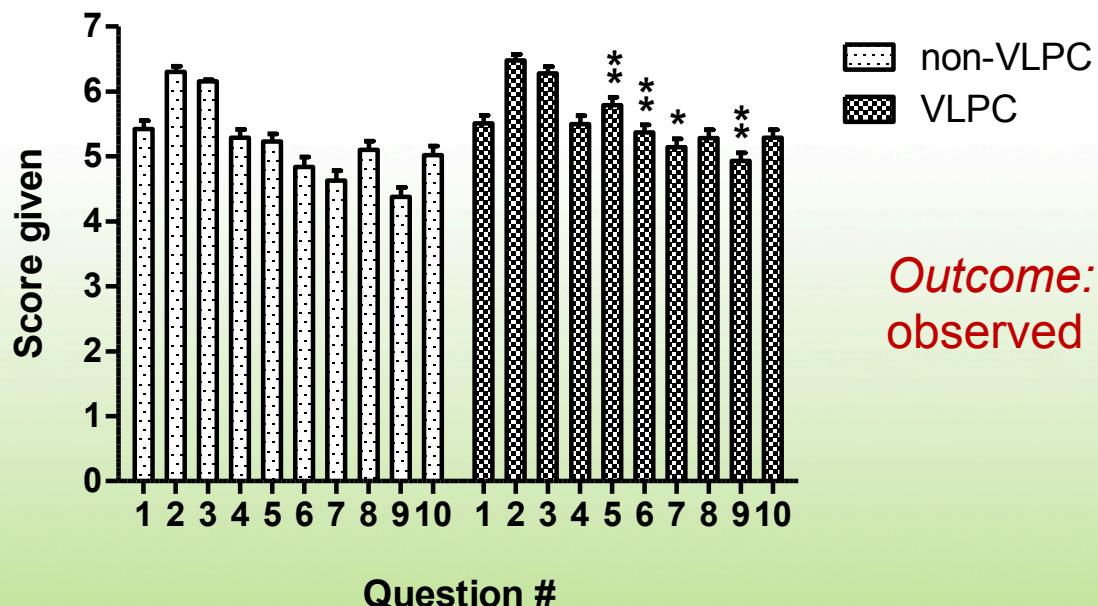
Submitting this module will award 5% towards your BIOM2402 assessment.

Feedback

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# PRE-LAB SURVEYS

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

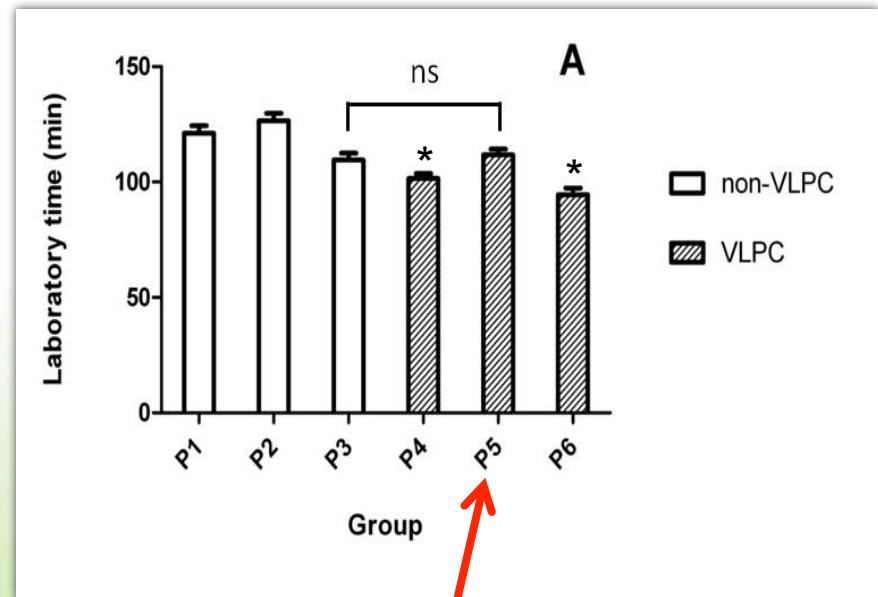
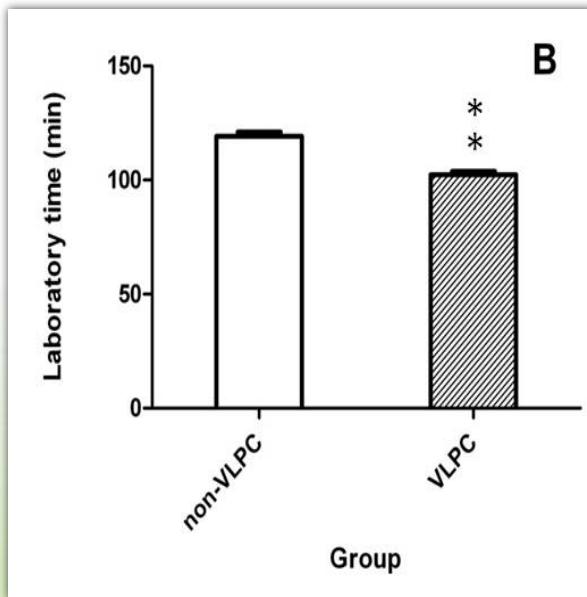


*Outcome:* Significant differences observed only for VLPC-specific tasks

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

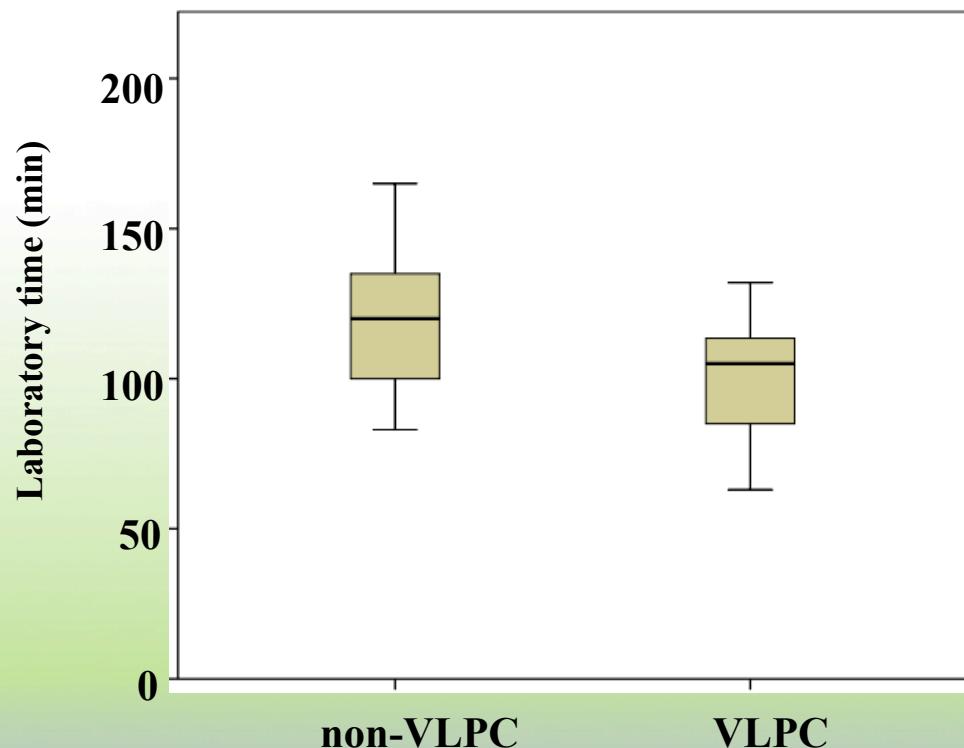
- Sign-on sheets were used to monitor student laboratory completion times



*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.**

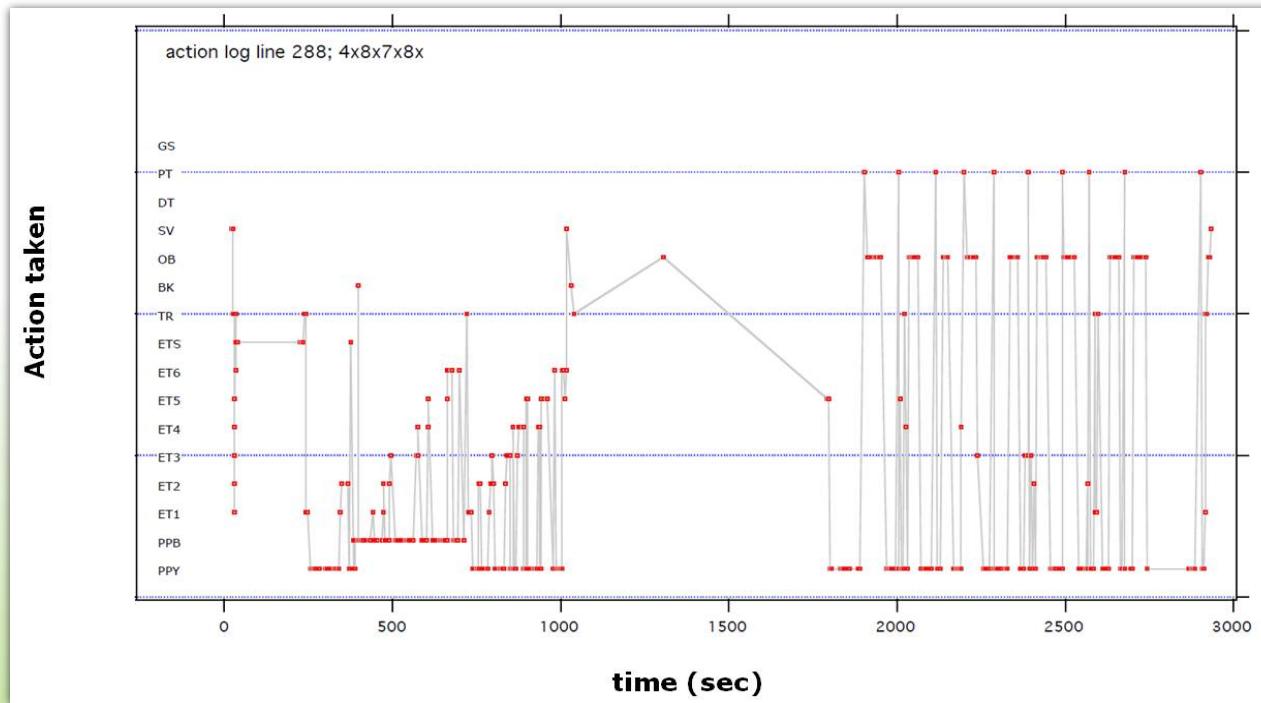


*Outcome:* When only groups containing VLPC-experienced members were plotted alongside non-VLPC groups, statistically significant reduction in **mean** ( $p<0.001$ ) and **variance** ( $p=0.042$ ) times were observed.

# ACTION LOGS

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

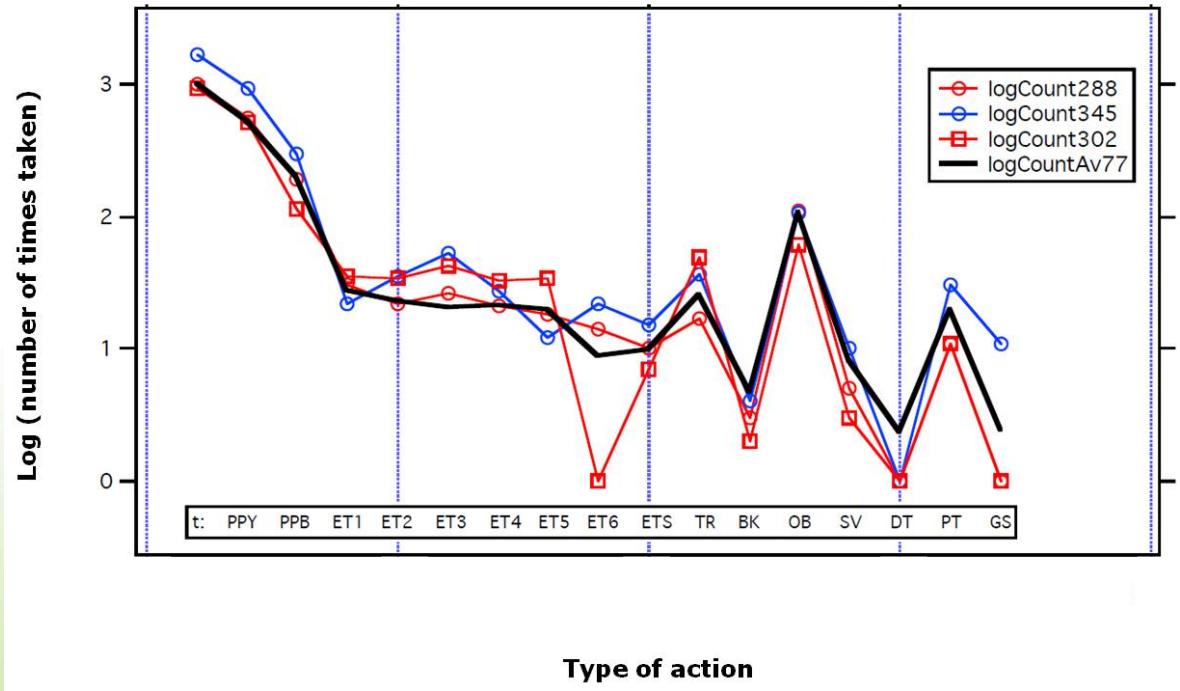


These student actions mirror precisely how the real experiment should be done in the laboratory

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# ACTION LOGS - FREQUENCIES

- We can also plot the frequency of the various actions

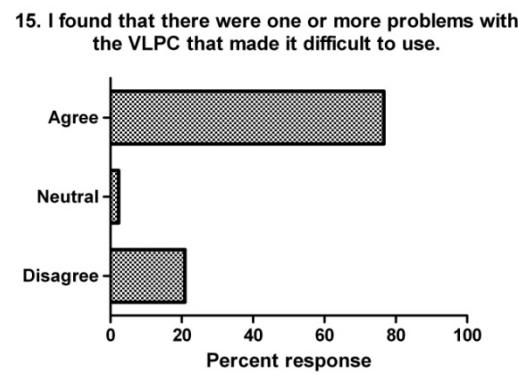
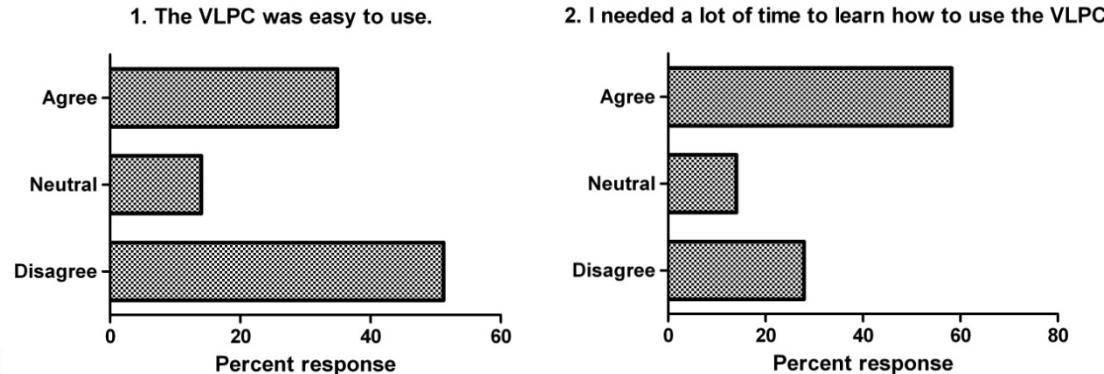


This powerfully demonstrates the remarkable consistency of frequencies of actions across many individual students.

# FINAL SURVEY

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- 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.

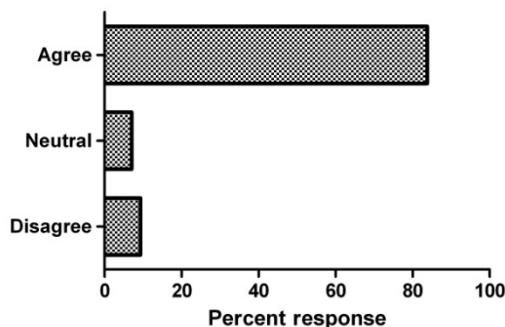
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# FINAL SURVEY

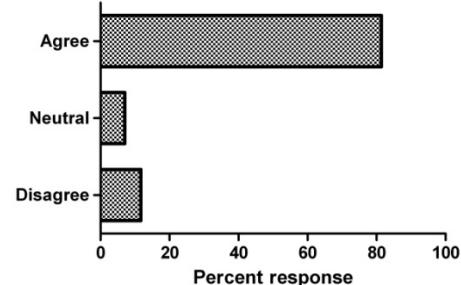
- Student preparation for the real laboratory task:

**Positive or extremely positive**

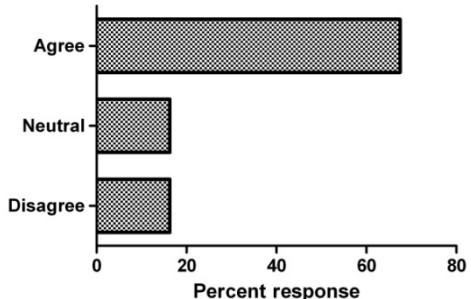
3. The VLPC helped me to understand how to prepare serial drug dilutions.



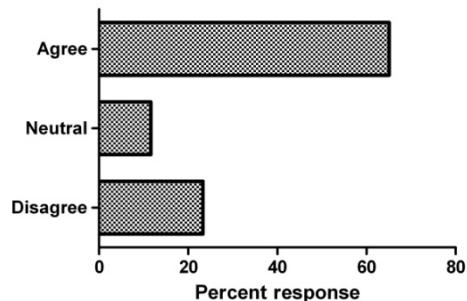
10. Practicing with the program helped me in the use of a real organ bath apparatus (adding drugs, washing).



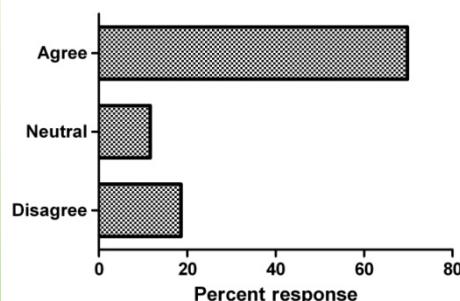
6. The VLPC helped me to identify lab equipment when I did the real laboratory exercise.



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.



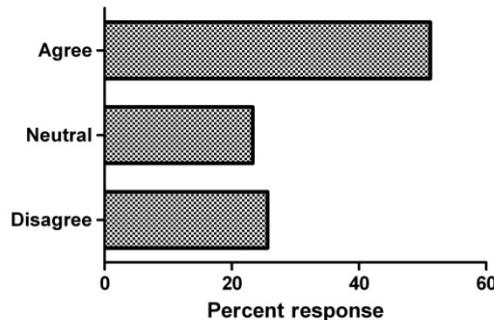
The VLPC helps students prepare for, and complete, the practical task.

# FINAL SURVEY

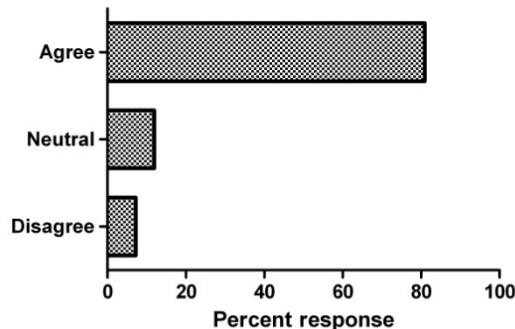
- Confidence and anxiety:

Positive or  
extremely positive

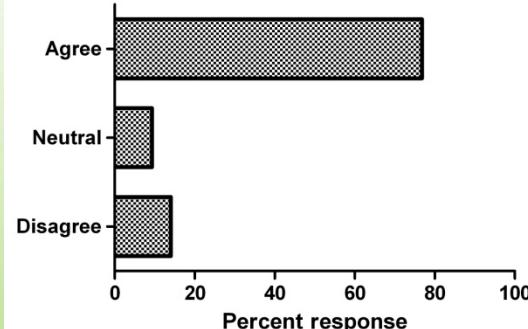
4. I felt confident in using and navigating around the VLPC program.



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.

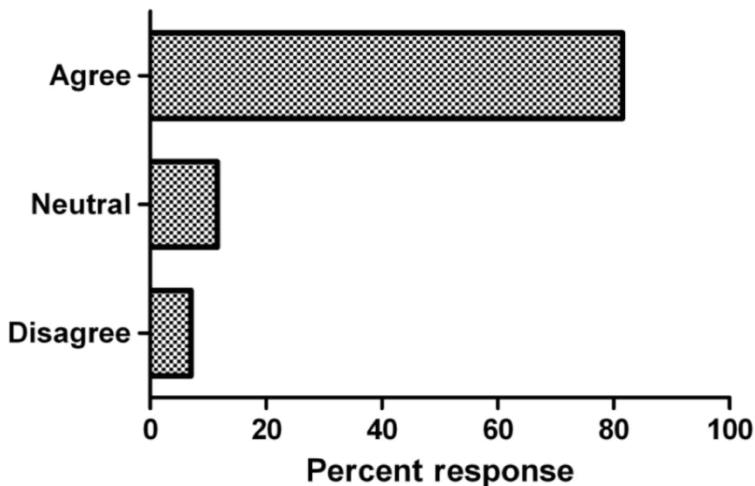


The VLPC decreased student in-lab anxiety while boosting confidence.

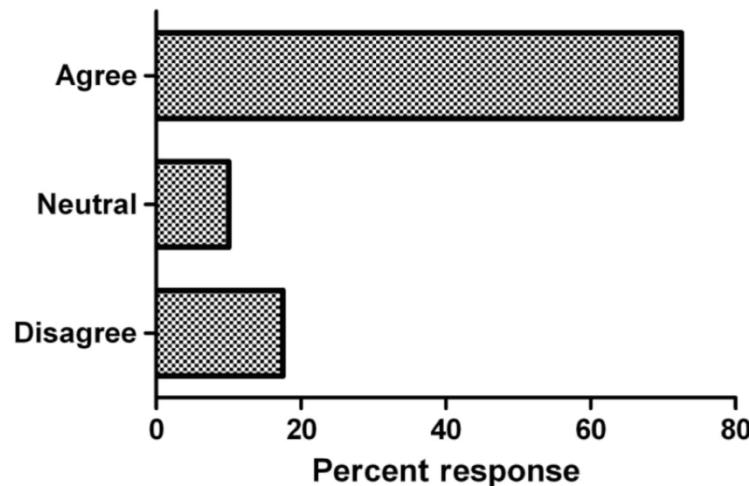
# FINAL SURVEY

- 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

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## **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?***

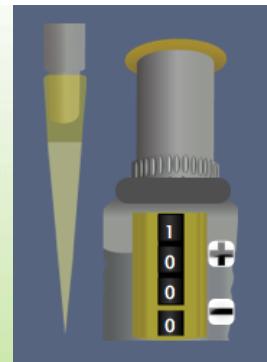
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# Preparation of the Ach serial dilutions

<i>To make a working stock solution of</i>	<i>pipette</i>	<i>of</i>	<i>&amp; 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



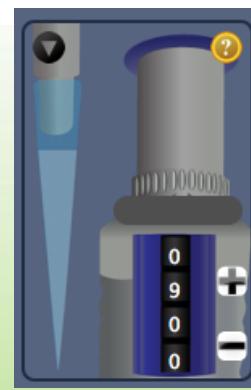
Select and label  
an empty tube



Yellow pipettor



Concentrated  
Ach stock



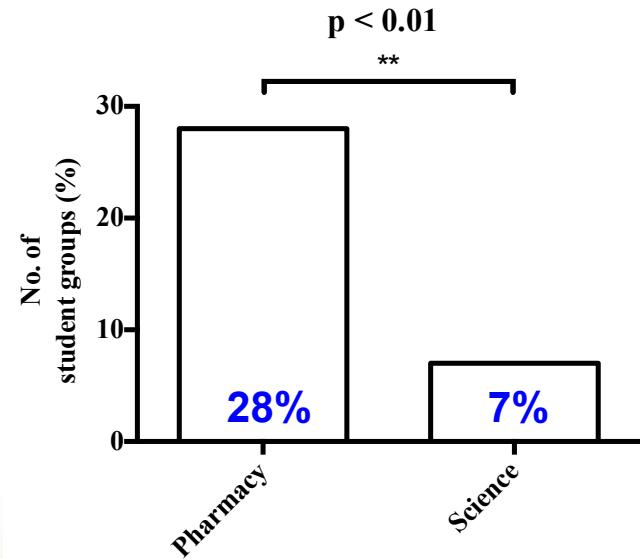
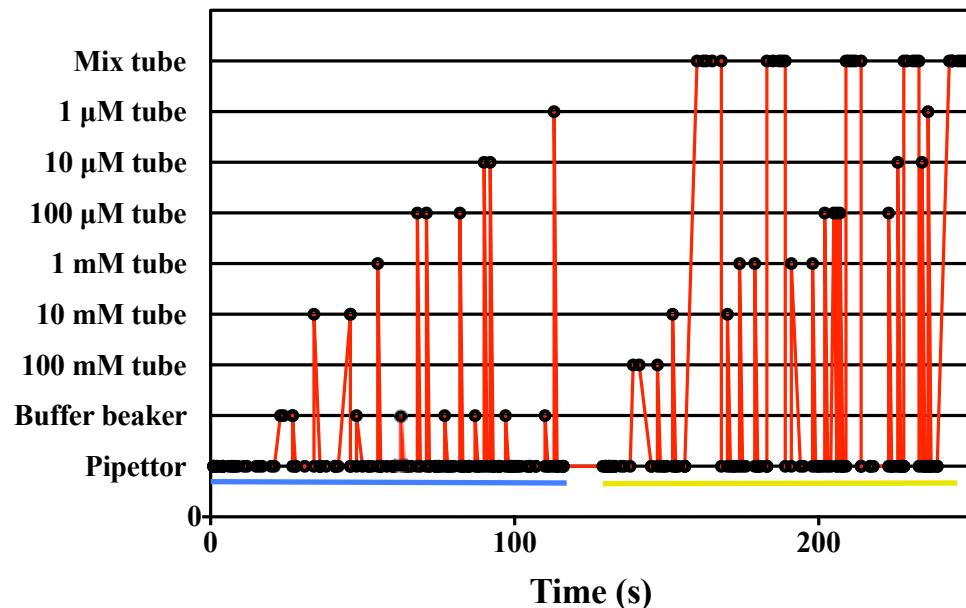
Blue pipettor



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 EC<sub>50</sub>)

## Table of organ bath final concentrations

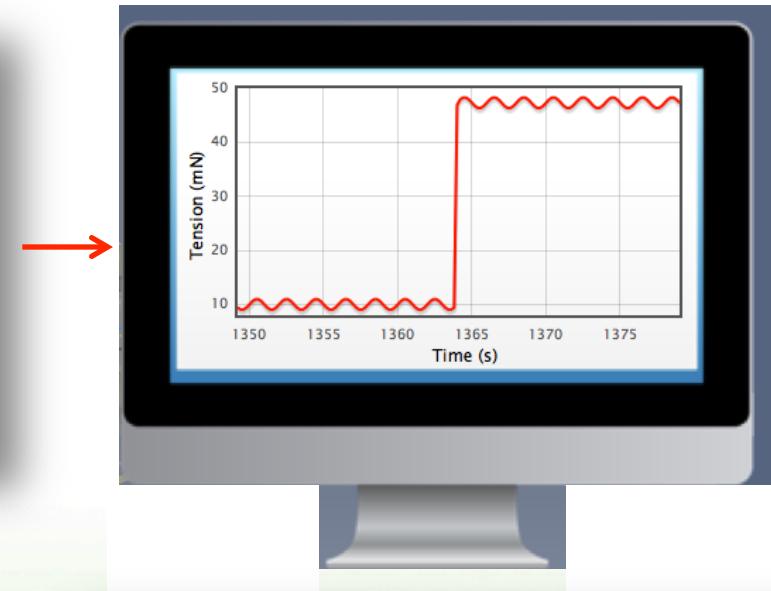
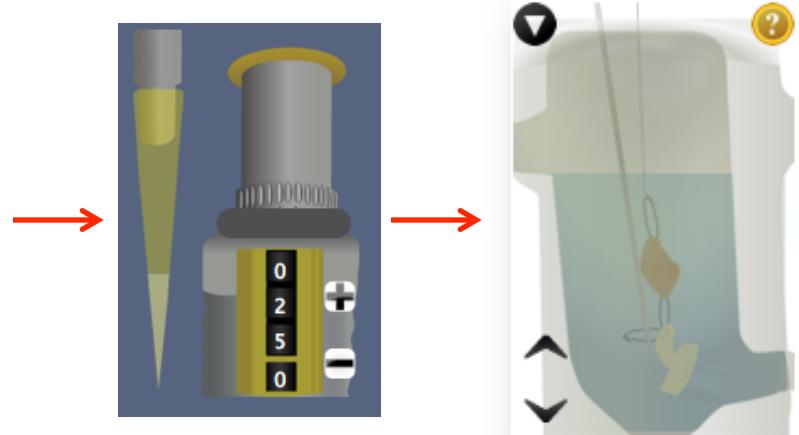
Serial dilution

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 $\mu\text{M}$	25 $\mu\text{l}$	25 ml	1 nM
1 $\mu\text{M}$	75 $\mu\text{l}$	25 ml	3 nM
10 $\mu\text{M}$	25 $\mu\text{l}$	25 ml	10 nM
10 $\mu\text{M}$	75 $\mu\text{l}$	25 ml	30 nM
100 $\mu\text{M}$	25 $\mu\text{l}$	25 ml	100 nM
100 $\mu\text{M}$	75 $\mu\text{l}$	25 ml	300 nM
1 mM	25 $\mu\text{l}$	25 ml	1 $\mu\text{M}$
1 mM	75 $\mu\text{l}$	25 ml	3 $\mu\text{M}$
10 mM	25 $\mu\text{l}$	25 ml	10 $\mu\text{M}$
10 mM	75 $\mu\text{l}$	25 ml	30 $\mu\text{M}$

students complete this section before VLPC task

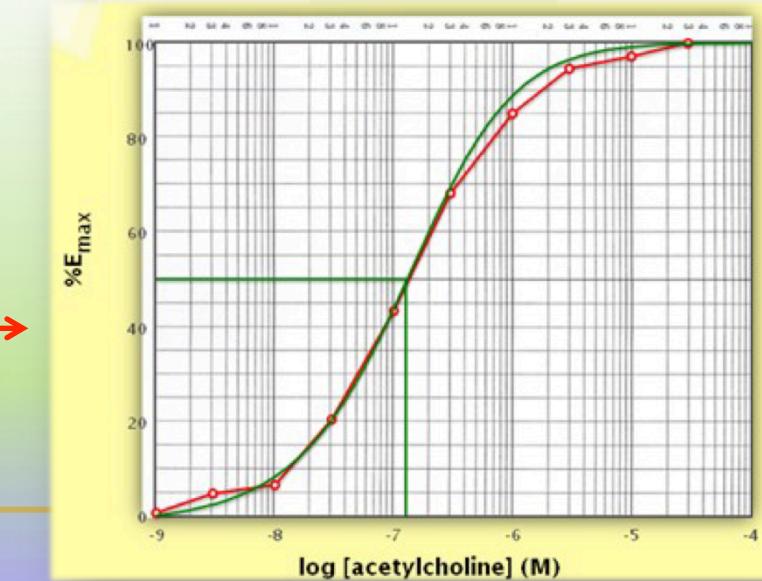
# Protocol for generating the concentration-response curve



Net Contractile Force (mN)

[ACh] (M)	Trial 1	Trial 2	Trial 3	Average	%E <sub>max</sub>
$1 \times 10^{-9}$	0	0.2	0.1	0.1	100
$3 \times 10^{-9}$					
$1 \times 10^{-8}$					
$3 \times 10^{-8}$					
$1 \times 10^{-7}$					
$3 \times 10^{-7}$					
$1 \times 10^{-6}$					
$3 \times 10^{-6}$					
$1 \times 10^{-5}$					
$3 \times 10^{-5}$					

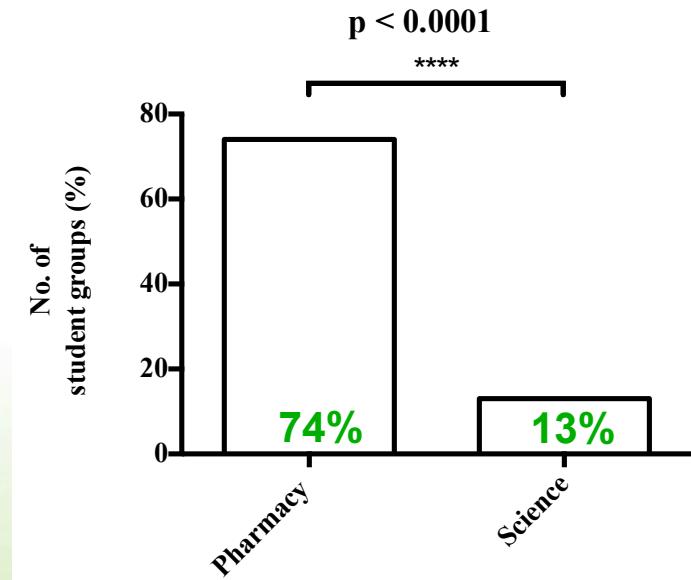
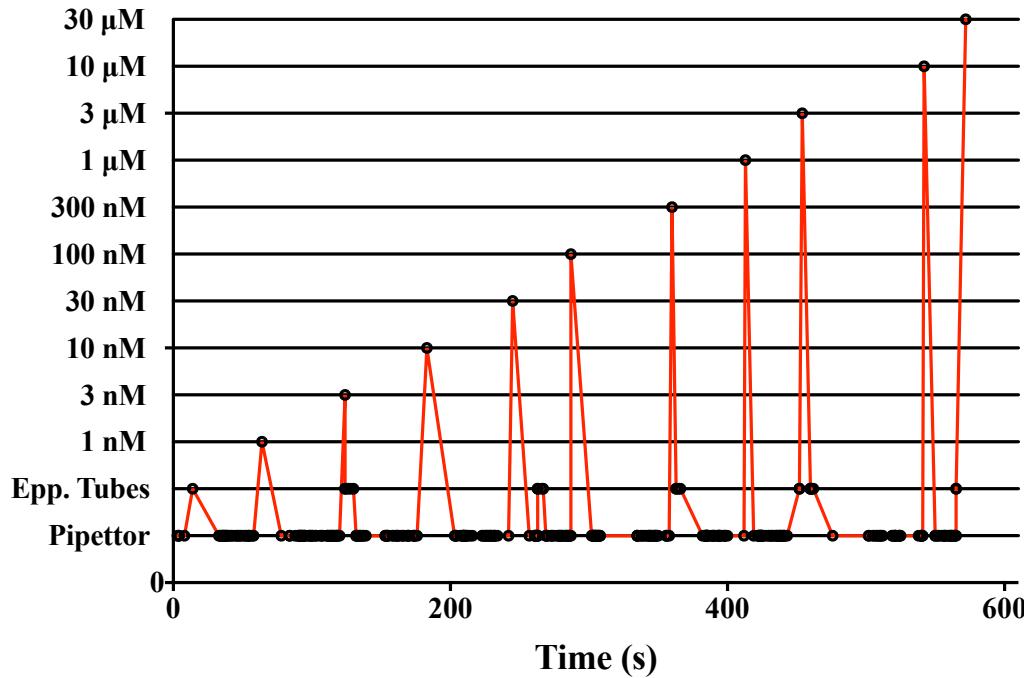
Triplicate measurements for: 1nM ACh Plot & Finish



# 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:

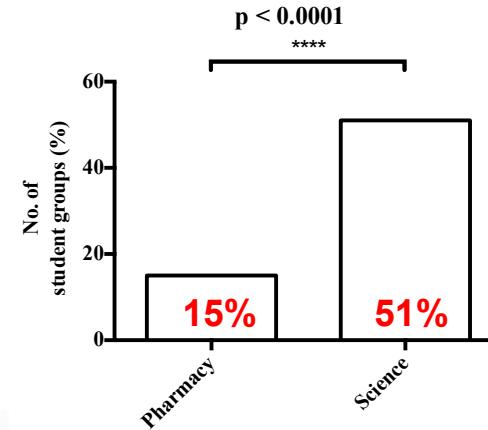
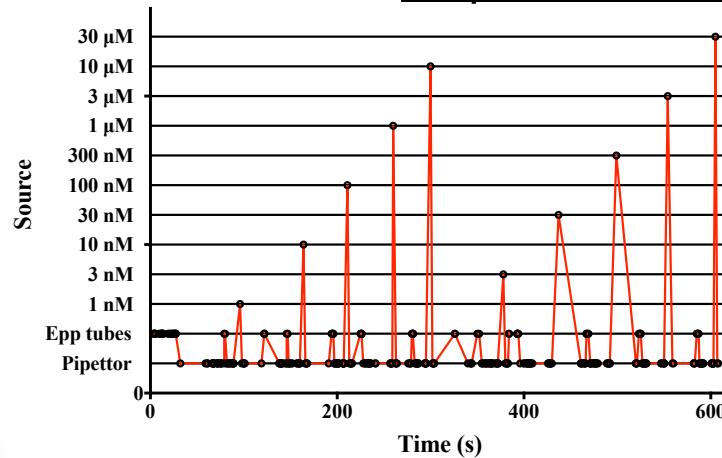
<i>Use my working stock solution of:</i>	<i>pipette volume</i>	<i>into organ bath volume of</i>	<i>Final concentration in organ bath</i>
1 $\mu\text{M}$	25 $\mu\text{l}$	25 ml	1 nM
1 $\mu\text{M}$	75 $\mu\text{l}$	25 ml	3 nM
10 $\mu\text{M}$	25 $\mu\text{l}$	25 ml	10 nM
10 $\mu\text{M}$	75 $\mu\text{l}$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

Some student groups were generating their concentration-response curve by completing all of the 25  $\mu\text{l}$  additions first and then completing the 75  $\mu\text{l}$  additions; others were doing it the other way around.

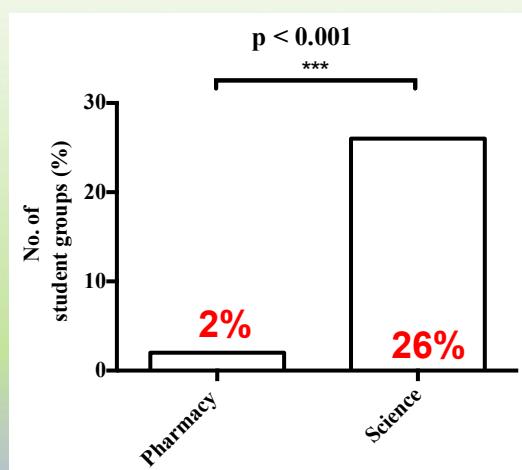
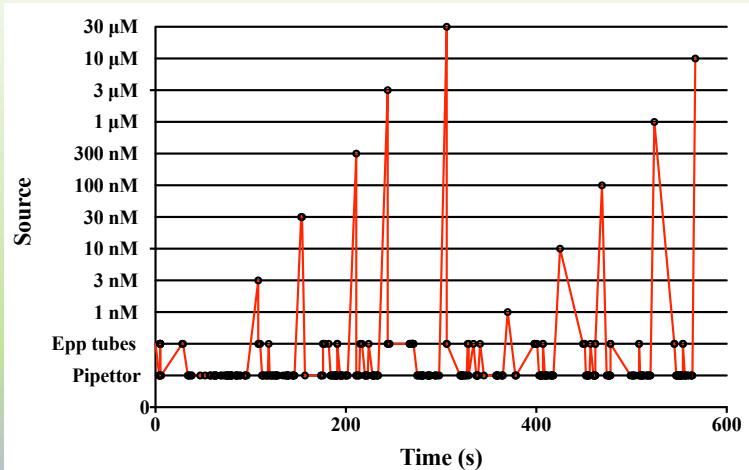
This was revealed by the action logs...

# Results: INCORRECT generation of concentration-response curve

## 25 µl additions then 75 µl additions



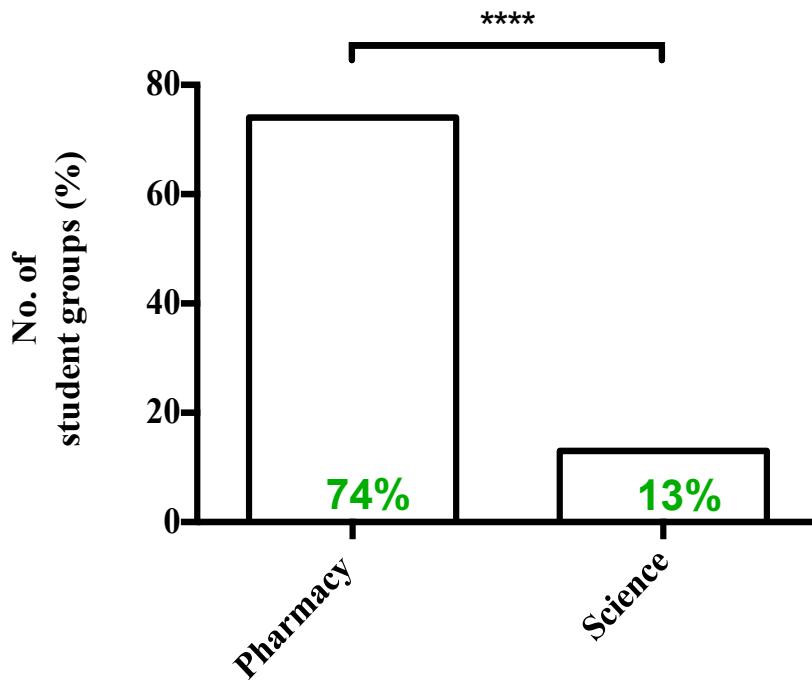
## 75 µl additions then 25 µl additions



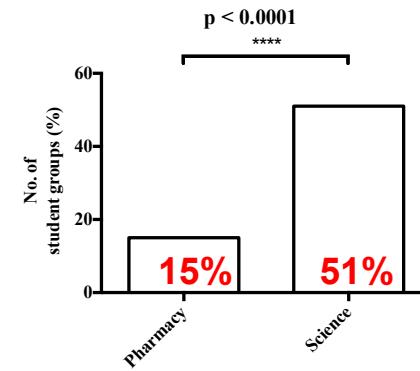
N.B. Therefore, 9% of pharmacy and 10% of science student groups completed the concentration-response curve via a process that does not follow any of these patterns.

# Summary of correct & incorrect student approaches, and time taken

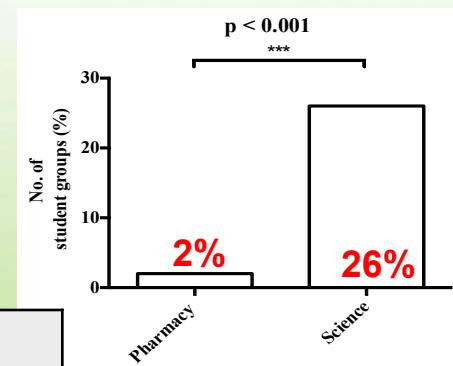
**Recall: CORRECT**  $p < 0.0001$



**INCORRECT: 25 µl then 75 µl**



**INCORRECT: 75 µl then 25 µl**



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

# Error types, and frequencies of these errors

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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"><li>• frequently</li><li>• always</li></ul>	26 13	62 7
	Failing to change tips between use	6	16

# Conclusions

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- 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.

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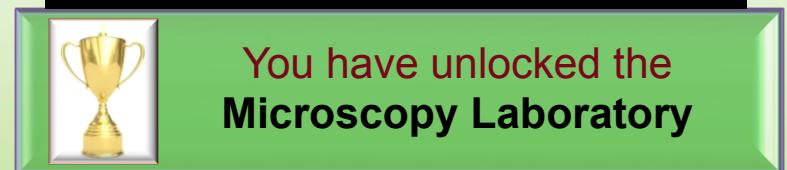
# GAMIFIED Vlabs

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



A screenshot of a game's career mode leaderboards. The interface shows a "CAREER LEADERBOARDS" section with tabs for "GLOBAL" and "FRIENDS". The "GLOBAL" tab is selected, displaying a list of top 10 players with their names, skill levels, scores, kills, and play times. The player at the top is [ag] Samzor with a score of 73535.

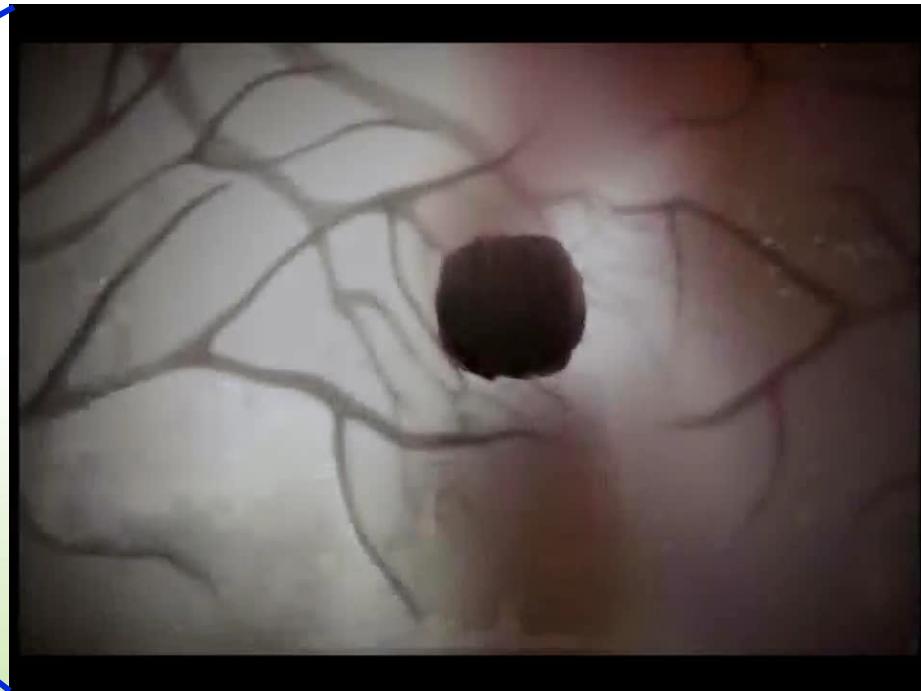
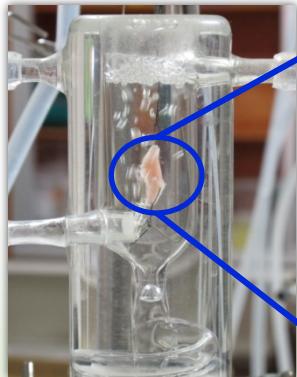
#	NAME	SKILL	SCORE	KILLS	PLAY TIME
1	[ag] Samzor	2956 ★	73535	3288	19h 44m
2	Bloodlust	2753 ★	44669	2301	14h 35m
3	marr	2705 ★	37182	2090	11h 27m
4	Fishzilla	2638 ★	35689	1882	11h 17m
5	[whc] demo	2590 ★	43840	2649	15h 11m
6	[LP] Socron	2538 ★	33629	1977	14h 20m
7	Steverman	2489 ★	41282	2290	17h 57m
8	Grillet	2466 ★	39936	2092	11h 47m
9	SOULKEEPER	2459 ★	37676	2061	14h 10m
10	At the Gates	2444 ★	43273	2474	16h 39m
1	[ag] Samzor	2956 ★	73535	3288	19h 44m



-- Unlockable achievements --

# SuperEye: From macro to micro

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