Deconstructing the lab notebook and scaffolding assessments in a coursebased undergraduate research experience (CURE)

Laura L. Atkinson

Mount Royal University, Department of Biology, 4825 Mount Royal Gate SW, Calgary, Alberta, T3E 6K6, Canada (latkinson@mtroyal.ca)

The pedagogical framework of a course-based undergraduate research experience (CURE) involves having students learn essential experimental techniques, design an experiment, carry out the experiment, interpret data and communicate results (McLaughlin & Coyle, 2016). Common assessments used in a CURE are a research proposal, lab notebook, and manuscript/poster/presentation. However, there are several challenges with the use of the lab notebook as an assessment tool. For example, grading of the lab notebook often occurs after an experiment is complete. Errors in understanding or calculations are not caught prior to the students performing the experiment which can lead to a waste of expensive reagents and potentially limit the ability to do CUREs with molecular techniques. Furthermore, finding and assessing information in a lab notebook is extremely time consuming and comments may not be read or understood. To address these issues, I deconstructed the lab notebook into experimental plans and data submissions. Using these assessments, my observations in the lab (echoed in student feedback) are that students come to the lab more prepared, understand the protocol, and feel confident in their ability to troubleshoot if something goes wrong. Importantly, the experimental plans can be peer graded in class while the instructor goes over the information. This provides important, timely, and relevant feedback to the students. Lastly, the use of experimental plans and data submissions allows the scaffolding of assessments for the scientific communication pieces (manuscript/poster/presentation).

Keywords: CURE, assessment, experimental design, molecular biology, C2C12 muscle cell line, lab notebook, scaffolding, pedagogy

Link To Supplemental Materials: https://doi.org/10.37590/able.v43.sup2

Introduction

Course-based undergraduate research experiences (CUREs) have been shown to increase content knowledge, technical skills (Szteinberg and Weaver 2013; Brownell et al. 2015), persistence in science (Hanauer et al. 2012), and student access to undergraduate research (Bangera and Brownell 2014).

Using the four step CURE pedagogical framework described by McLaughlin and Coyle (2016), it was noted that a large majority of the pedagogical framework falls under the assessment of the lab notebook (Figure 1). However, lab notebooks are very time consuming to grade and this could be an obstacle to adopting CUREs in lower-level undergraduate laboratories. Further, lab notebooks are often only worth 10% or 20% of the course

grade. In order to address this, the lab notebook was deconstructed into experimental plans and data submissions. Deconstructing the lab notebook with experimental plans and data submissions allows a larger weighting of the course to be applied where significant student effort is going (doing experiments and collecting data). It also provides an opportunity to have collaborative assessments (poster, manuscript, presentation) with lesser weighting to ensure individual student knowledge and contribution.

Fourth year Advanced Molecular Biology CURE

BIOL 4202 is a 6 hour per week lab course with no lecture or tutorial component. In this course, students use mouse C2C12 muscle cells to study the process of muscle cell differentiation. When plated, C2C12 myoblasts (MB) will proliferate until they are confluent and then differentiate into mature myotubes (MT) over the course of 12-14 days. In Winter 2021, the students looked at the change in gene expression of selected markers at different time points of the growth and differentiation of the C2C12 cells. The students learned cell culture at the onset of the semester and started growing their cultures while planning their research projects. It is important to note that this was the first-time gene expression studies were being performed in this class so students spent a significant amount of time during the first trial performing validation experiments in order to get their gene expression data. For iteration, the students aimed to repeat their experiments three times (3 trials).





Student Outline

Table 1. Course Schedule (6 hours per week in lab). Experimental plans are initially difficult for students, so the weighting of the plans increases as students gain experience and proficiency.

						Due Dates for	
wook	Lab Schodulo	Due Dates for Experimental	Woight	Due Dates for Data	Woight	Communication	Woight
WEEK			weight		weight	End of week 1:	weight
						Flowchart of overall	
1	Lab safety, learn cell culture					experiments	1
		End-week 1: Primer design					
		complete (target and reference					
		Mid-week 2: MIOF Guideline					
		Paper (full citation in reference					
		list) - identify important points					
2	Trial 1- plate cells	for your study data	3				
	- · · · · · · · · · · · · · · · · · · ·	End of week 2: RNA isolation,					
	I rial 1- change media, take	cDNA synthesis and Dynamic					
	cells at appropriate days	reaction	8				
	Trial 1- change media. take	End of week 3: Optimal	Ŭ				
	microscopy images, sample	Reference Gene/Primer					
3	cells at appropriate days	Efficiency	10				
	Trial 1-RNA isolation, cDNA						
	synthesis, qPCR validation	End of week 4: Relative gene		End of Week 4: Figure 1. RNA			
4	transcriptase reaction)	expression	5	Range of RT reaction	6		
				End of week 5: Figure 3.			
	qPCR validation (optimal			Optimal Reference			
-	reference gene, primer			Gene/Figure 4. Primer			
5	efficiency)			Efficiency	6		
	expression						
		•	1	End of week 6: Figure 5.			
				Relative Gene			
0				Expression/Figure 6.	0		
6	Trial 2- plate cells		1	Microscopy images	0		
	Trial 2- change media take						
	microscopy images, sample					End of week 7: Poster	
	cells at appropriate days					draft	5
	Trial 2- change media, take						
0	microscopy images, sample						
ð	Trial 2- RNA isolation cDNA				ł		+
	synthesis, aPCR dene					End of week 9:	
9	expression					Manuscript outline	5
10	Trial 3- plate cells						
	Trial 3- change media, take						
	microscopy images, sample						
	Trial 3- cell culture			End of week 11: Trial 2 Data			
11	microscopy, sampling			and Trial 1&2 Data Compiled	5		
	Trial 3 - RNA isolation, cDNA				-	End of week 12: Final	
1	synthesis, qPCR gene					Poster (video	
12	expression					presentation)	15
13						End of week 13: Website	5
						End of semester: Manuscript	15

Table 2. Grade Breakdown for Course. The course grade breakdown reflects the expected effort and importance of the experimental plans and data submissions with them worth almost 50% of the course.

	Weight		
Flowchart of overall experiments	1%		
Experimental Plans	26%		
Data Submissions	23%		
Good Lab Practice	5%		
Poster draft	5%		
Website	5%		
Manuscript outline	5%		
Poster presentation	15%		
Final manuscript	15%		

Instructions to Students

The following general information is provided to students regarding experimental plans and data submissions. At the beginning of the semester, students are provided with all protocols needed for the semester.

Lab Notebook Folder

- Each student should open a google folder and name it "First name Last name Lab Notebook". This is your electronic lab notebook where you will save your experimental plans and data submissions.
- Share the folder with your instructor: [instructor email]
- Your lab notebook folder should contain a separate google doc entry for each day that you are in the lab, all experimental plans and data submissions.
- Each entry should be identified by the date and title of the entry. For example, "Sept 16, 2021 Experimental Plan Serial Dilutions and DNA quantification" or Sept 17, 2021 Lab Serial Dilutions and DNA quantification".
- It is very important to keep detailed notes of what was done in the lab.
- Your entry should contain all calculations and notes about anything that was done differently.
- Raw data and details of any problems, troubleshooting should be included.
- Lab notebooks are not graded. However, if you encounter an issue in your experiment or the outcome, your instructor will consult your lab notebook in order to assist you in troubleshooting.

Flowchart of Overall Experiments

The flowchart should depict an overview of the entire project and how each experiment fits into it.

Experimental Plans

Each student should have an experimental plan for each experiment performed in the lab (outlined in schedule). The experimental plan should include:

- 1. the protocol with all details (amounts, concentrations) specific for your experiment
- 2. the purpose of each step (ie. which tube is your DNA in after adding reagent x?)
- 3. each reagent and what it is being used for in the experiment (ie. ethanol is being used to precipitate DNA)
- 4. any controls that are needed for the experiment and what purpose those controls serve

Your experimental plan should demonstrate:

- thoughtfulness put into the design of your experiment so that meaningful results are obtained
- a strong understanding of how you will interpret the results

Data Submissions

Each student should have a data submission for each set of data obtained (outlined in schedule).

- Raw data needs to be depicted in a figure or table (or both).
- Each data submission should include:
 - 1. an explanation of the purpose of this data in the overall project
 - 2. a figure(s) of the data for that experiment with proper figure captions
 - 3. key results of the data should be outlined in point form below the figure
 - 4. clear interpretation of the results

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Materials

All students were required to bring their laptop to every lab. They were also required to keep all their files in a shared Google Drive.

Notes for the Instructor

Experimental plans allow students to come prepared to lab and have any misconceptions or errors fixed prior to the beginning of the experiment. Students have reported that the completion of experimental plans makes them feel more prepared and confident in the lab, have a deeper understanding of the protocol and its purpose, and derive more meaning from the data. Experimental plans can be peer-graded in lab prior to the start of the experiment. (See Appendix for a student example and accompanying marking breakdown)

Data submissions ensure that students are interpreting and presenting the data correctly. Information from the data submission then forms the basis of the results section of the manuscript, thus providing a scaffold to the final manuscript.

Experimental plans and data submission marking breakdowns (rubrics) require some initial time commitment for the instructor to identify the required components. However, once established, grading is quick and can be readily shared with students.

The use of experimental plans and data submissions should be easily adaptable to lower-level undergraduate research experiences and teaching assistants. Their use greatly reduces the marking load of instructors while providing timely and important feedback to the students. Lastly, experimental plans and data submissions can be scaffolded (Figure 5.); thus, allowing students to gain valuable feedback as they are writing their manuscript/poster or other communication-type assessment.



Figure 2. The use of experimental plans and data submissions allows the scaffolding of assessments to write a manuscript. Experimental plans can be used by students to then write the written methods section of their manuscript. Each data submission becomes a figure of the manuscript. This allows students to receive continuous feedback on the components of their manuscript prior to final grading.

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About the Author

Laura Atkinson is an Assistant Professor at Mount Royal University. She has experience teaching anatomy, physiology, biochemistry, cell biology, microbiology, molecular biology and pharmacology.

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