Unlocking scientific reasoning:

How Inquiry-based Labs can be a key!

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1. Dawson College, 2.Vanier College, 3. John Abbott College, 4. Collège André-Laurendeau, 5. McGill University

AQPC colloque annuel, June 9, 2022 (session # 508)

aqpc

Éducation et Enseignement supérieur Québec

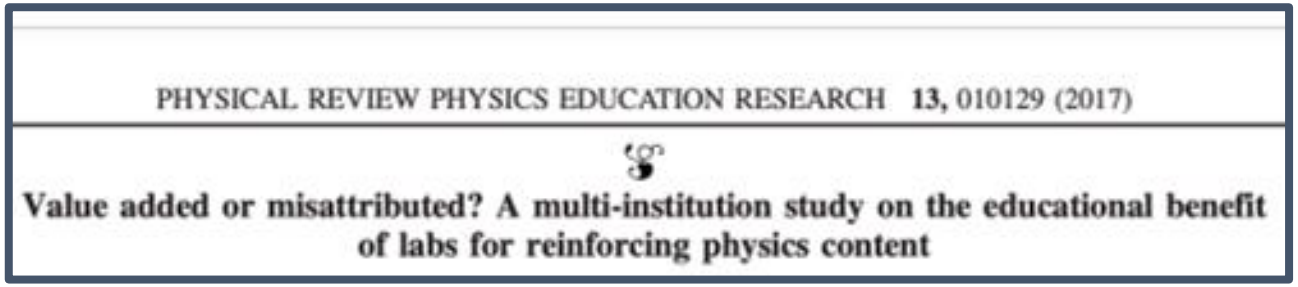
Ice Breaker Question:

What is the purpose of labs?

Why are we interested in Inquiry-Based Labs?

What is the purpose of Labs in general?

- Learn and support theory competencies.
- Learn the Lab competencies/ apply the scientific method.



PHYSICAL REVIEW PHYSICS EDUCATION RESEARCH 13, 010129 (2017)

Value added or misattributed? A multi-institution study on the educational benefit of labs for reinforcing physics content

"…we found universally and precisely **no added value** to learning course content…..departments [should] **reexamine the goals** …of their lab "

New Science Program: Integrative course

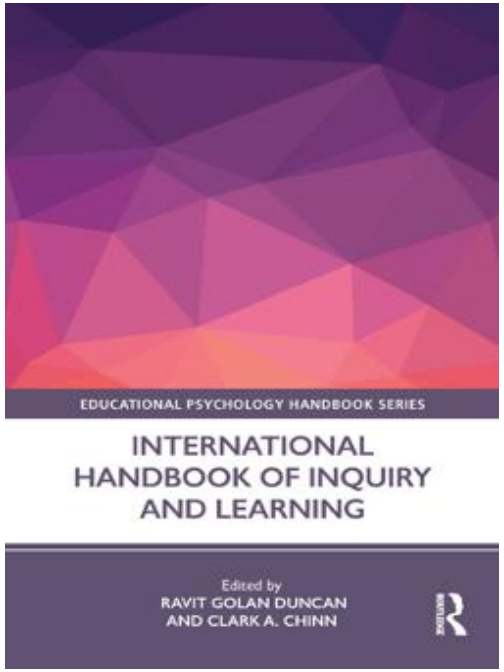
Overview

1. Introduction: what is Inquiry-Based Lab?
2. Theoretical foundation
3. Research questions & methods
4. Case study – Physics
5. Case study – Biology
6. Results
7. Implications for practice

Inquiry-Based *Learning*- A form of Active Learning

Duncan & Chinn's (2020) Definition:

1) New ideas or new knowledge
2) Active learning & Cognitive engagement
3) Empirical - using evidence
4) Reasoning with some degree of complexity
5) Epistemic agency
6) Inquiry communities (peer review/validate)



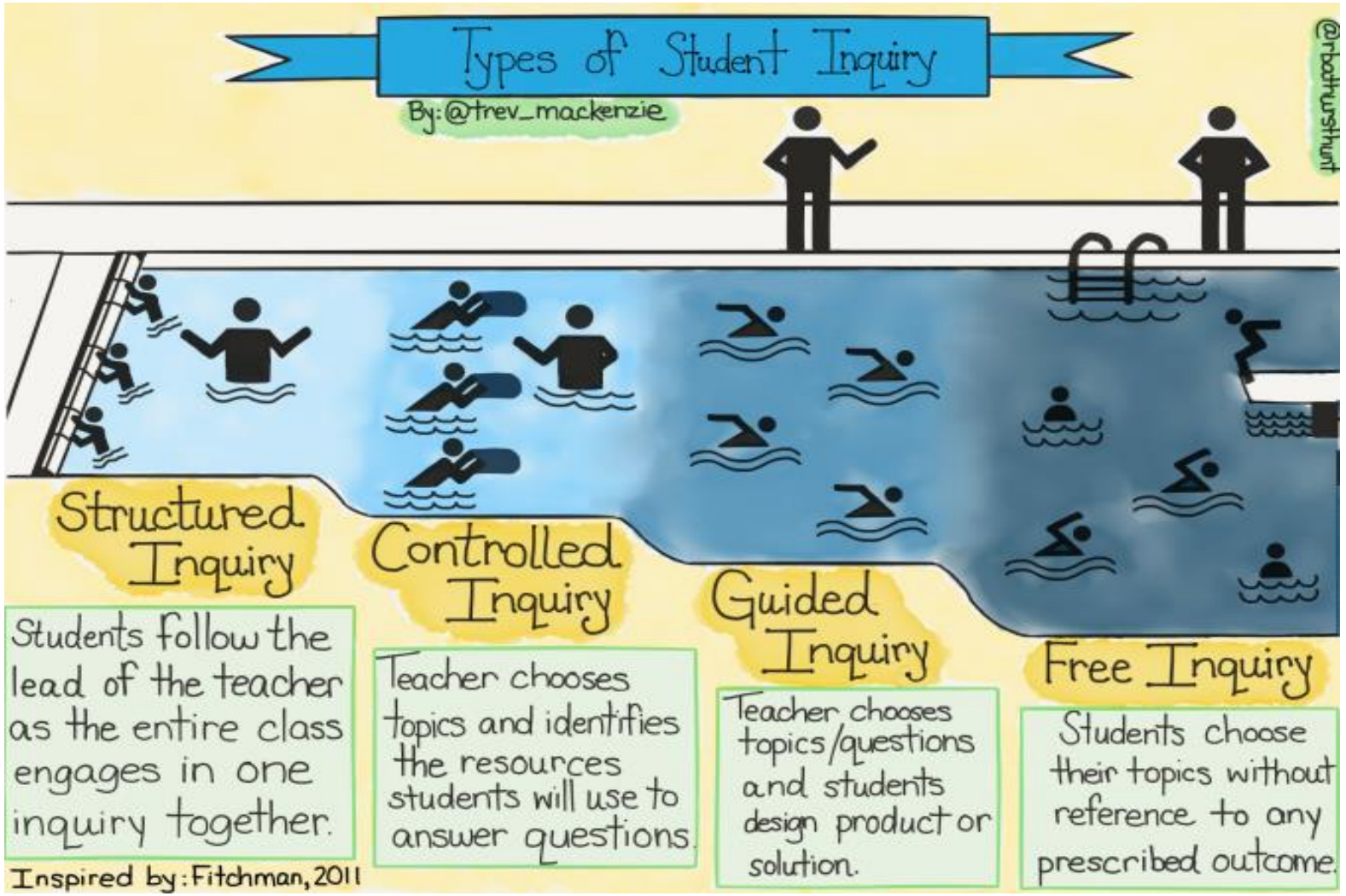
Inquiry-Based *Lab* adds:

1. situates learning within the context of investigating authentic scientific problems
2. frames solutions within the use of some sort of data collection and analysis

Inquiry to learn

Learn to inquire

A Heuristic for Inquiry Learning



Less choice

More choice

To make choices you need tools/resources/scaffolds

Inquiry Based Labs:
Using an Inquiry Based Learning Approach to Learn Inquiry

Inquiry Activities

Level of Inquiry

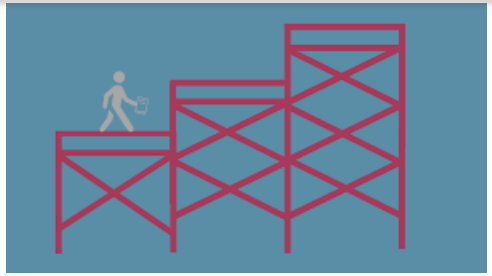
	Source of the Question	Data Collection Methods	Interpretation of Results
Level 0: Verification	Given by teacher	Given by teacher	Given by teacher
Level 1: Structured	Given by teacher	Given by teacher	**Open to student**
Level 2: Guided	Given by teacher	**Open to student**	**Open to student**
Level 3: Open	**Open to student**	**Open to student**	**Open to student**

How?

By Scaffolding

(Table from Blanchard et al., 2010)

What is Scaffolding?



(Duncan & Chinn, 2020; Reiser & Tabak, 2014; Quintana, 2021; Quintana et al., 2004; Saleh et al., 2021; Weinberger et al., 2005)

Scaffolding functions (What to scaffold)		**Scaffolding forms / Means of Support (How to scaffold)**
Cognitive	Sensemaking (inquiry tasks, e.g., hypothesis testing, data interpretation)	Structure of Activities & Artifacts (roles & actions & phases scripts)
	Articulation & Reflection	
Social	Communication	Interactions (prompts/suggestions/questions)
Meta-cognitive	Managing (inquiry & communication) Processes	Computational tools (software-realized scaffolding)

Our Constrained Definition of Scaffold

Type of support	Basic idea	Intended audience
Scaffolds	Explain or take over the more demanding parts of an action	Learners who do not have the proficiency to perform an action themselves or cannot perform the action from memory

Note. Based on T. De Jong and Lazonder (2014), with minor textual modifications.

Scaffolds are teacher-designed tools that help carry out a learning process, known to be challenging, by structuring & supporting the process.

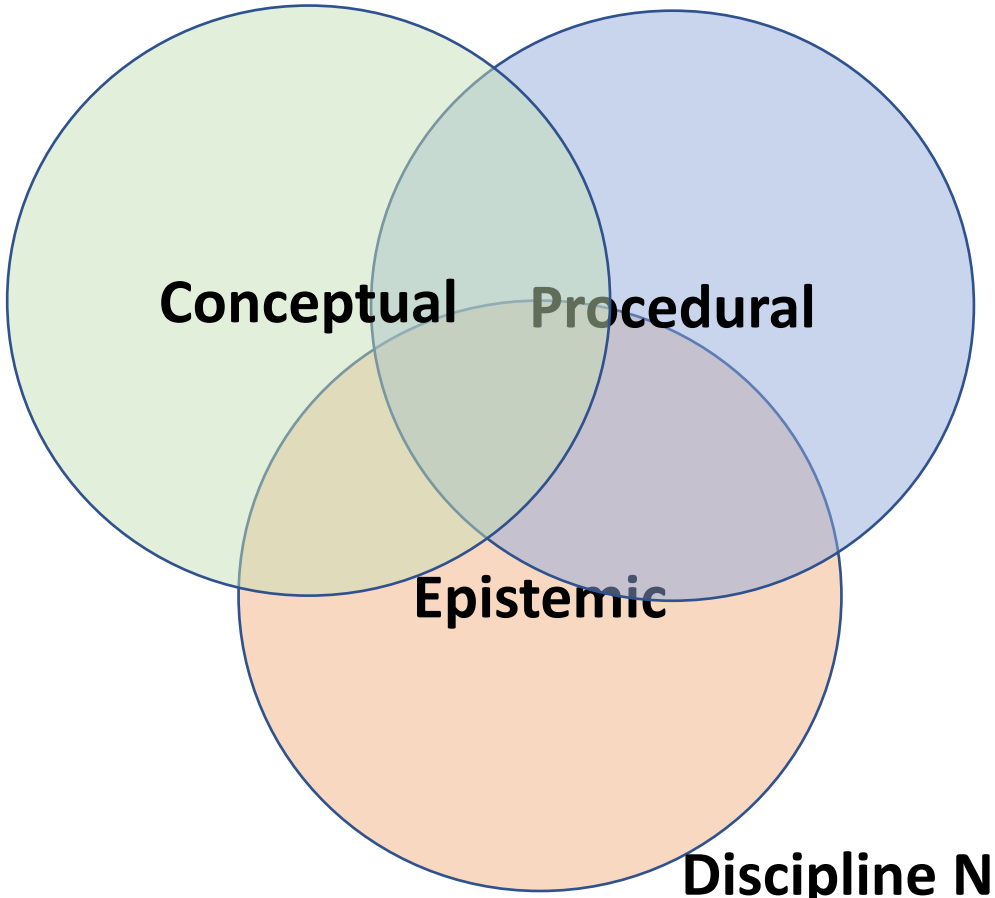
Scaffolds can be: · Cognitive · Procedural · Epistemic · (Metacognitive)

Most useful to structure processes that are too complicated or there is insufficient knowledge.

Ways of thinking about theory and inquiry lab competencies

Resonant Harmonics

Write a research Question



Operate a Freq.Generator

Identify dependent and Independent variables

Applying the scientific method
”Thinking like a scientist”

Discipline Norms

Importance for the scientific method

Research Questions

- Identify the forms of scaffolding that best support learning in science in the context of inquiry-based instruction.
- Conduct design-based research (DBR) to assess the development of the scientific process.

Methods

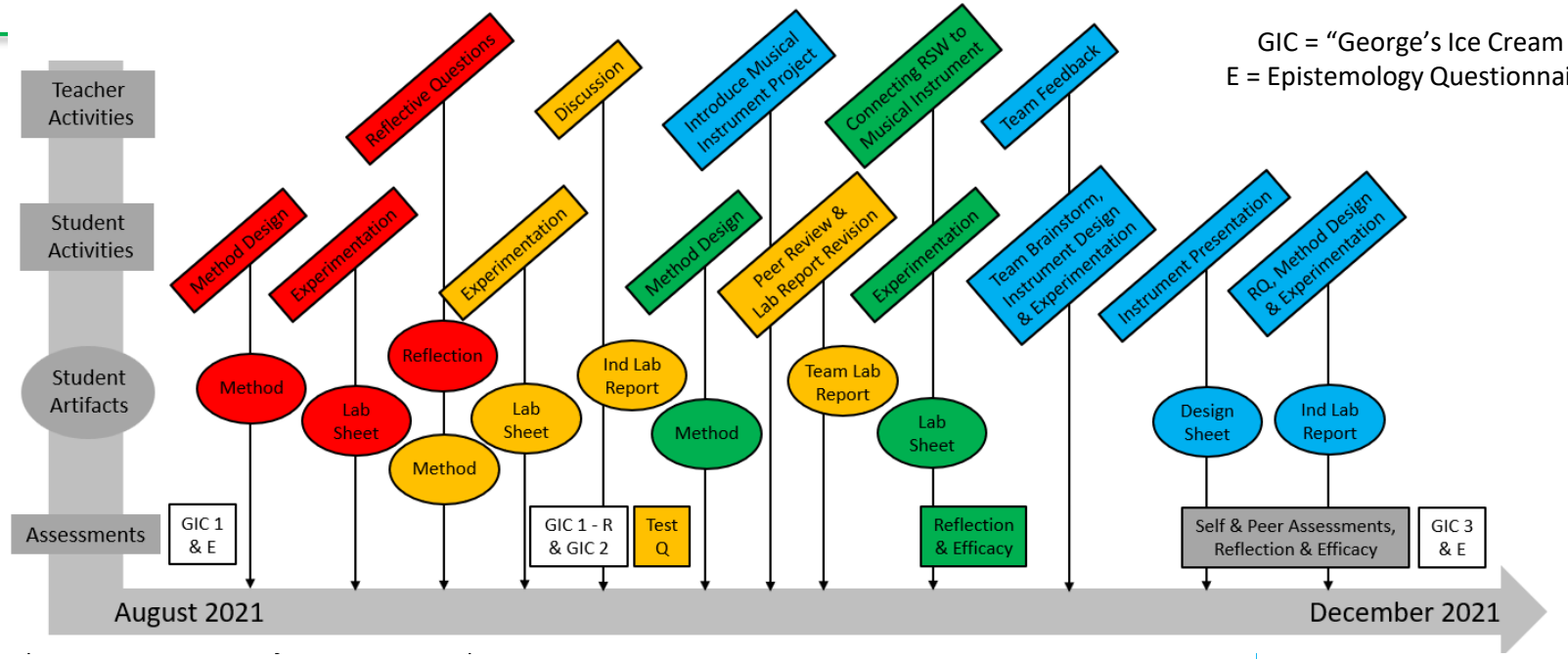
- Two case studies, each featuring a unique IBL implementation:
  - (1) Design focus, in Physics.
  - (2) Experimental focus with scaffolded lab-reports, in Biology.

Measures

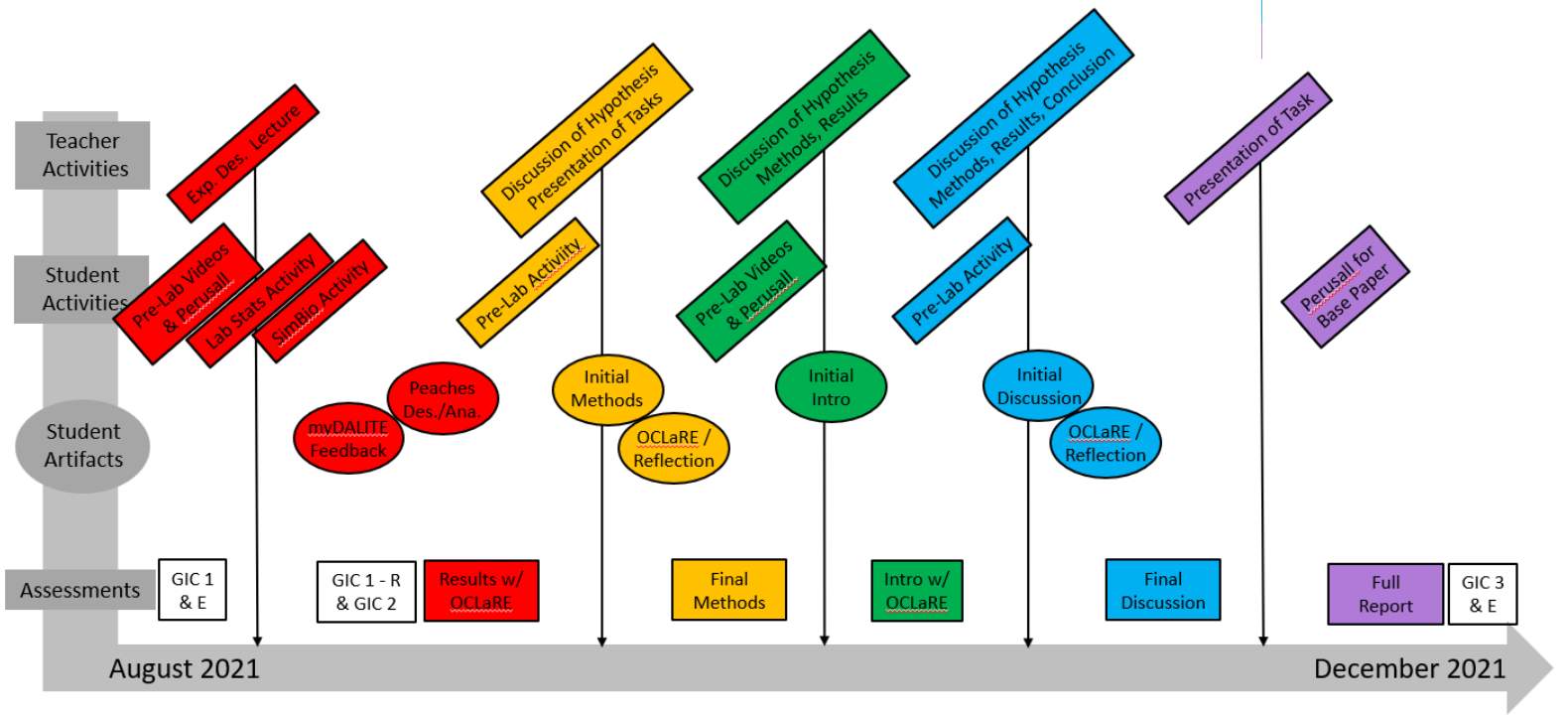
- (1) Topic-Specific Epistemic Beliefs Questionnaire (TSEBQ).
- (2) George's Ice cream (GIC).

GIC = "George's Ice Cream
E = Epistemology Questionnaire

Mapping the design for Inquiry-Based Labs over a Waves and Modern Physics semester



Mapping the design for Inquiry-Based Labs over a General Biology 1 semester



Mapping the design for Inquiry-Based Labs over a Waves and Modern Physics semester

- First real trial was fall 2021 (fully in person).
  - Only fall 2021 is presented today.
  - Modifications took place for winter 2022 and even more for next year…
  - They also had a few "traditional" labs and phets too.

Scientific modeling & evidence-based reasoning

Table from Blanchard et al., 2010

Inquiry Activities

Scaffolding Levels

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Mapping the design for Inquiry-Based Labs over a Waves and Modern Physics semester

Focus of the Lab Competence; Students do:

a) Ask research questions (RQ) – Module 4
b) Design methods/procedures to collect data (Method Design) – Modules 1-4
c) Collect data, analyze & interpret results (Experimentation) – Modules 1-4
d) Write lab reports (Lab Report) – Modules 2 & 4

1. SHM – block-spring system
2. SHM – simple pendulum
3. Resonant standing waves
4. Musical Instrument

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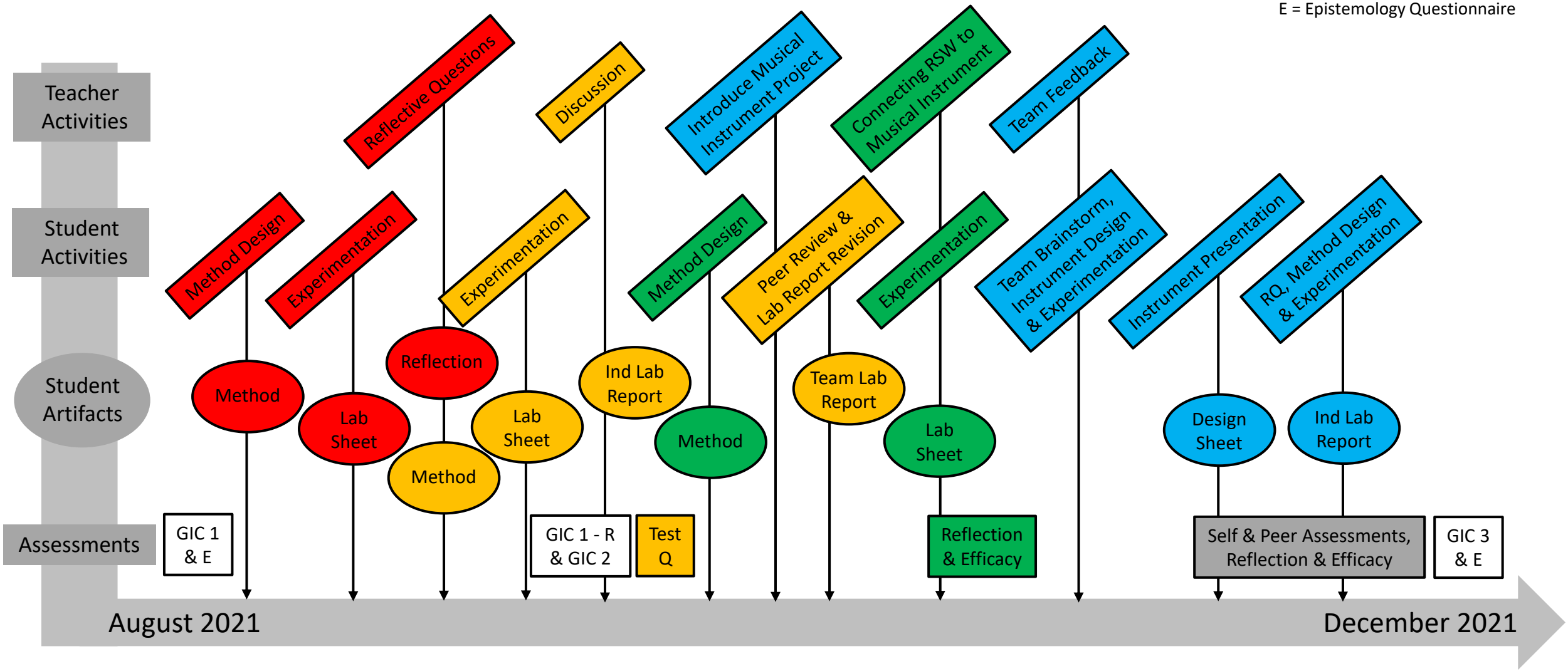

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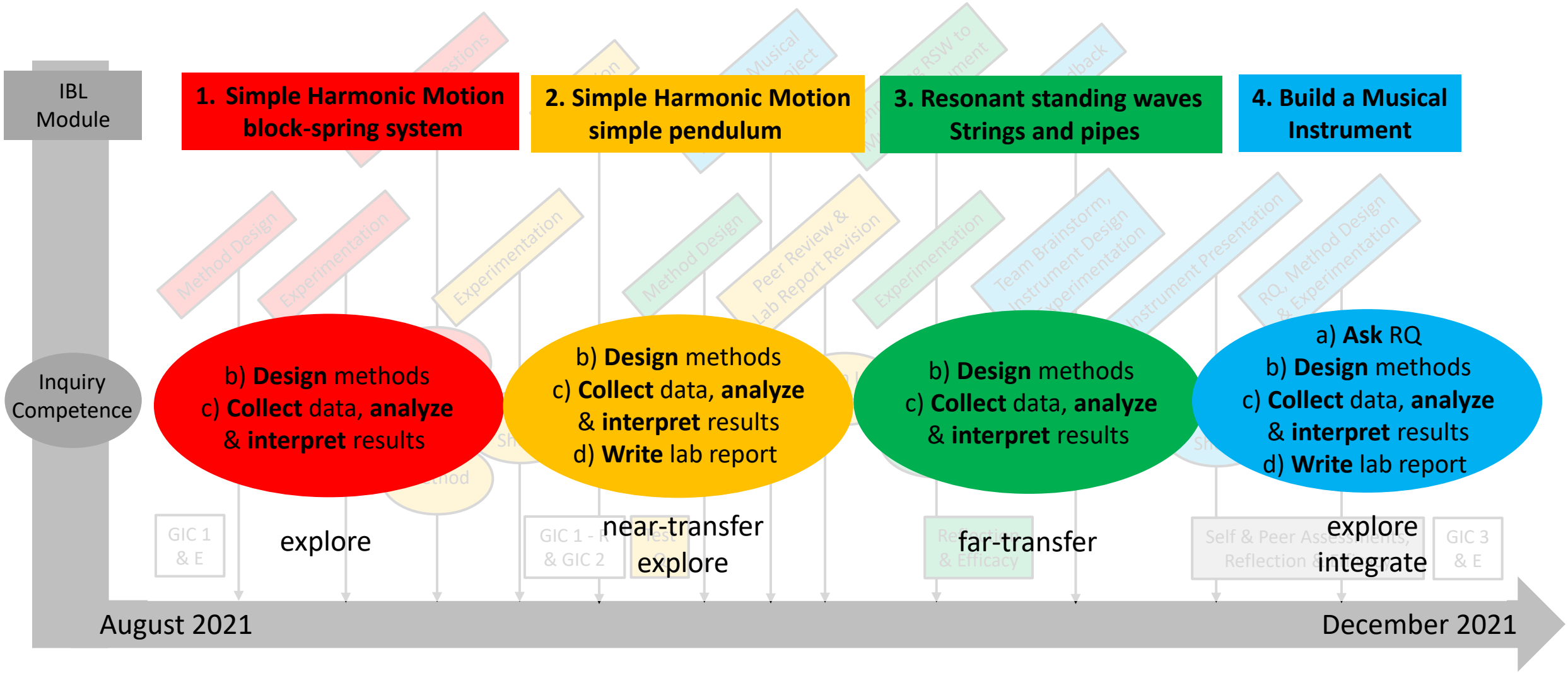
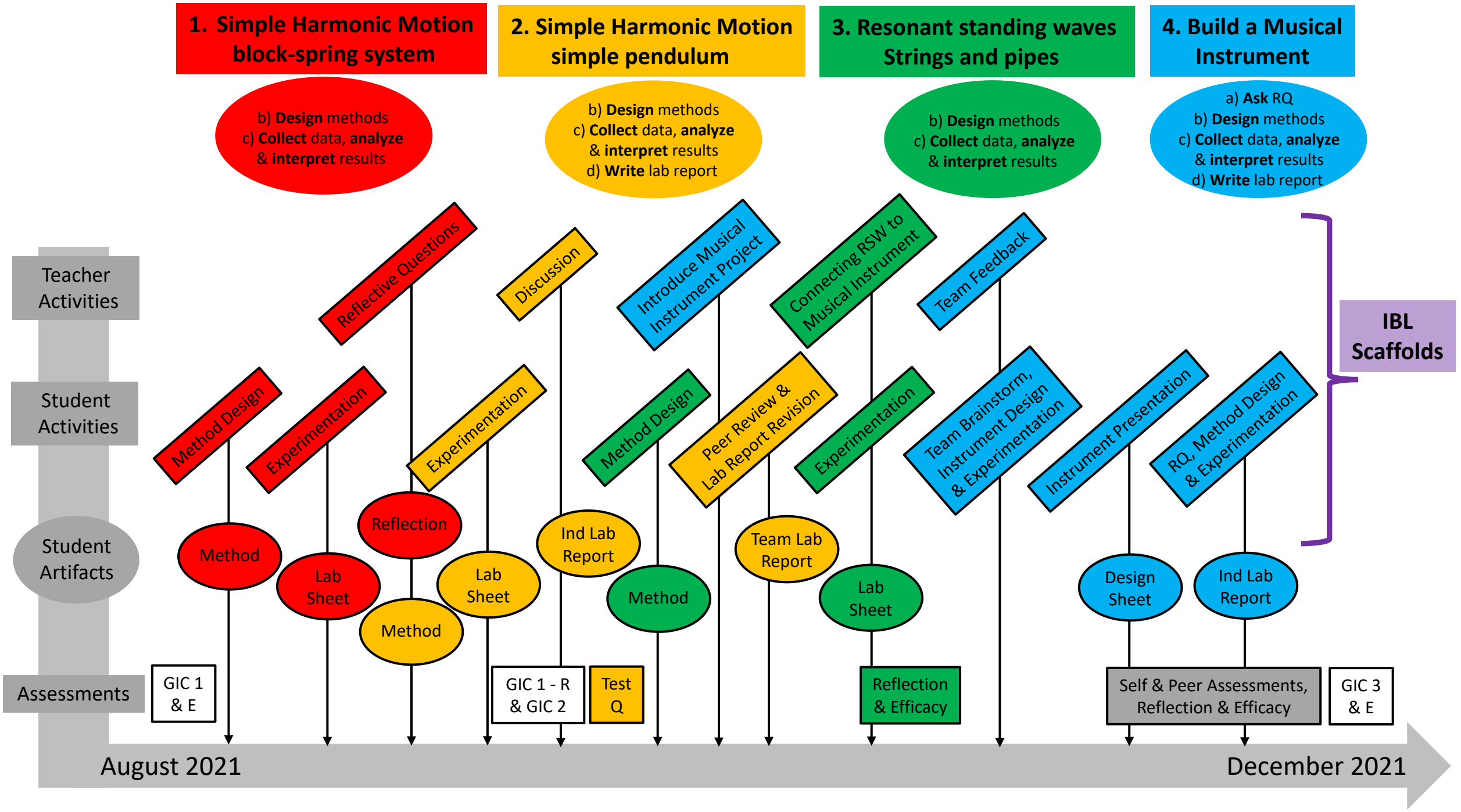
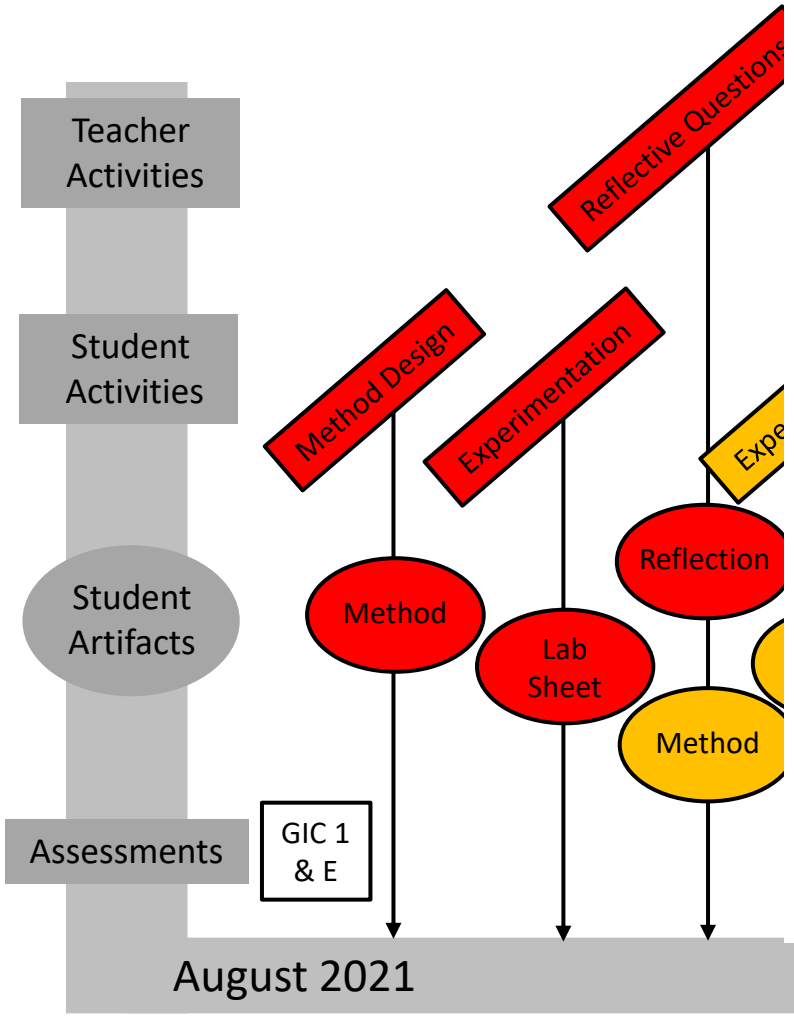



1. Simple Harmonic Motion block-spring system
2. Simple Harmonic Motion simple pendulum
3. Resonant standing waves Strings and pipes
4. Build a Musical Instrument
b) Design methods
c) Collect data, analyze & interpret results
b) Design methods
c) Collect data, analyze & interpret results
d) Write lab report
b) Design methods
c) Collect data, analyze & interpret results
a) Ask RQ
b) Design methods
c) Collect data, analyze & interpret results
d) Write lab report
Teacher Activities
Student Activities
Student Artifacts
Assessments
Reflective Questions
Discussion
Introduce Musical Instrument Project
Connecting RSW to Musical Instrument
Team Feedback
Method Design
Experimentation
Experimentation
Method Design
Peer Review & Lab Report Revision
Experimentation
Team Brainstorm, Instrument Design & Experimentation
Instrument Presentation
RQ, Method Design & Experimentation
IBL Scaffolds
Method
Lab Sheet
Reflection
Method
Lab Sheet
Ind Lab Report
Method
Team Lab Report
Lab Sheet
Design Sheet
Ind Lab Report
GIC 1 & E
GIC 1 - R & GIC 2
Test Q
Reflection & Efficacy
Self & Peer Assessments, Reflection & Efficacy
GIC 3 & E
August 2021
December 2021

1. SHM – block-spring system



Given the context of a hanging block-spring system, you need to experimentally research the following two research questions:

1) Does the amplitude of the motion affect the period of the motion?
2) Does the mass of the hanging block affect the period of the motion?

Your goal is to prepare the "methods" (or "procedures") that will allow an experimenter to answer the research questions.

You should work in teams of 4 students (two pairs per team; Rhys will provide more instructions in class). You will have equipment available if you wish to experiment during the lab session. You can prepare multiple methods per research question if you wish.

Week 1 – Prepare "Method Design" and some "mess about" in the lab.
Week 2 – Perform experiment. Collect data, analyze & interpret results

Working in pairs, you need to submit by the end of class:

1) The procedure chosen to perform these experiments. Highlight all modifications between the assignment submission and what was actually done during this lab period.
2) The data collected.
3) The data analysis.
4) The answers to the two research questions.
5) Any comments that you wish to share regarding your procedures, analysis, etc.

1. SHM – block-spring system

Week 2 – Reflection in myDALITE. “Expert” analysis provided to students.

i) Reflect and describe the procedures they think provided the expert data.

ii) They reflect (compare/contrast) between this new procedure AND the one they used for their experiment.

iii) Prompt them to prepare a new “methods” for a SHM based simple pendulum experiment.

SHM research questions Q2

Read the “SHM research questions - data and analysis” pdf provided in our course LEA space. With respect to Table 2, Graph 1 and its analysis that allows to answer the research question, “Does the mass of the hanging block affect the period of the motion?”; please provide what you think is the procedure/methods that led to the data collection and analysis.

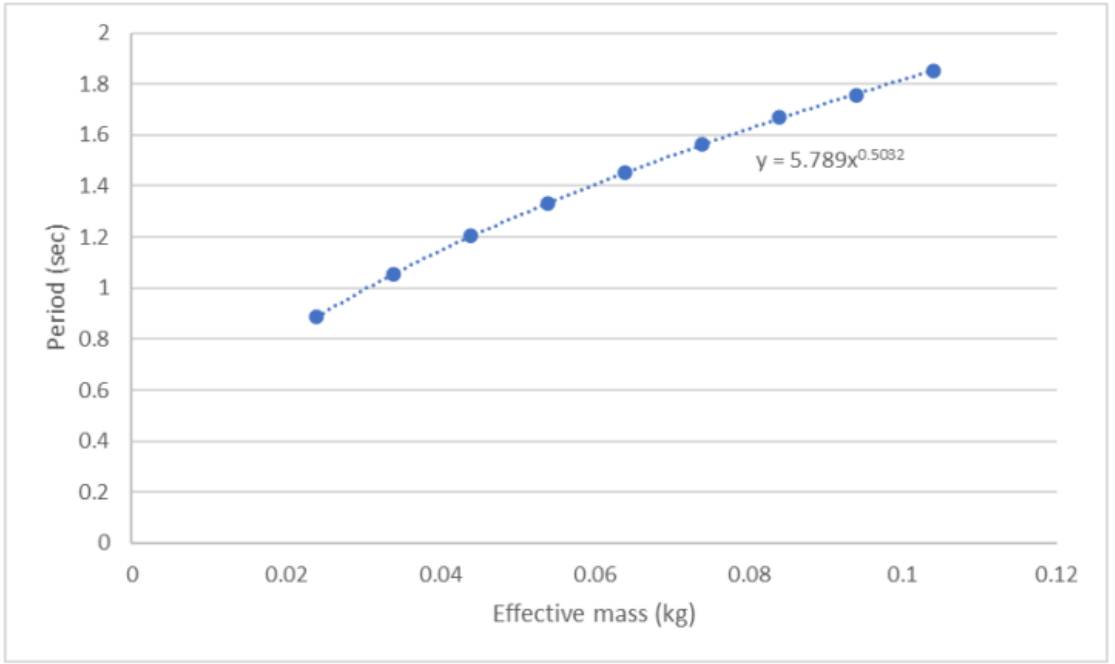
Discipline: Physics
Categories: Reflection, research methods
Student answers: 36

Table 2: Measuring period of SHM mass-spring system for different hanging masses

		DATA COLLECTION						
Hanging mass (g)	Effective mass (kg)	10 Periods trial 1 (sec)	10 Periods trial 2 (sec)	10 Periods trial 3 (sec)	10 Periods average (sec)	10 Periods mean deviation (sec)	Period average (sec)	Period mean deviation (sec)
20.0	0.024	8.87	8.79	8.90	8.85	0.04	0.885	0.004
30.0	0.034	10.56	10.61	10.52	10.56	0.03	1.056	0.003
40.0	0.044	12.03	12.09	11.98	12.03	0.04	1.203	0.004
50.0	0.054	13.33	13.28	13.35	13.32	0.03	1.332	0.003
60.0	0.064	14.52	14.49	14.55	14.52	0.02	1.452	0.002
70.0	0.074	15.61	15.66	15.59	15.62	0.03	1.562	0.003
80.0	0.084	16.75	16.67	16.73	16.72	0.03	1.672	0.003
90.0	0.094	17.56	17.54	17.62	17.57	0.03	1.757	0.003
100.0	0.104	18.45	18.55	18.51	18.50	0.04	1.850	0.004

* Amplitude kept constant at 8.0 cm.
* Same spring (unknown spring constant) used (and same is in part 1); m_S = 0.012 kg.

Graph 1: Period of SHM mass-spring system as a function of effective mass



2. SHM – simple pendulum

Week 1 – Perform experiment. Collect data, analyze & interpret results.

Given the context of a simple pendulum, you need to experimentally research the following two research questions:

1) **Does the maximum angular displacement of the motion affect the period of the motion?**
2) **Does the length of the pendulum affect the period of the motion?**

Working in pairs, you need to submit by the end of class:

1) The procedure chosen (from the myDALITE assignment) to perform these experiments. Highlight all modifications between the assignment submission and what was actually done during this lab period.
2) The data collected.
3) The data analysis.
4) The answers to the two research questions.
5) Any comments that you wish to share regarding your procedures and analysis, including a comparison to what you did today to what you did last week (for the block-spring experiment).

I provide data to everyone and the lab report guidelines & rubric.

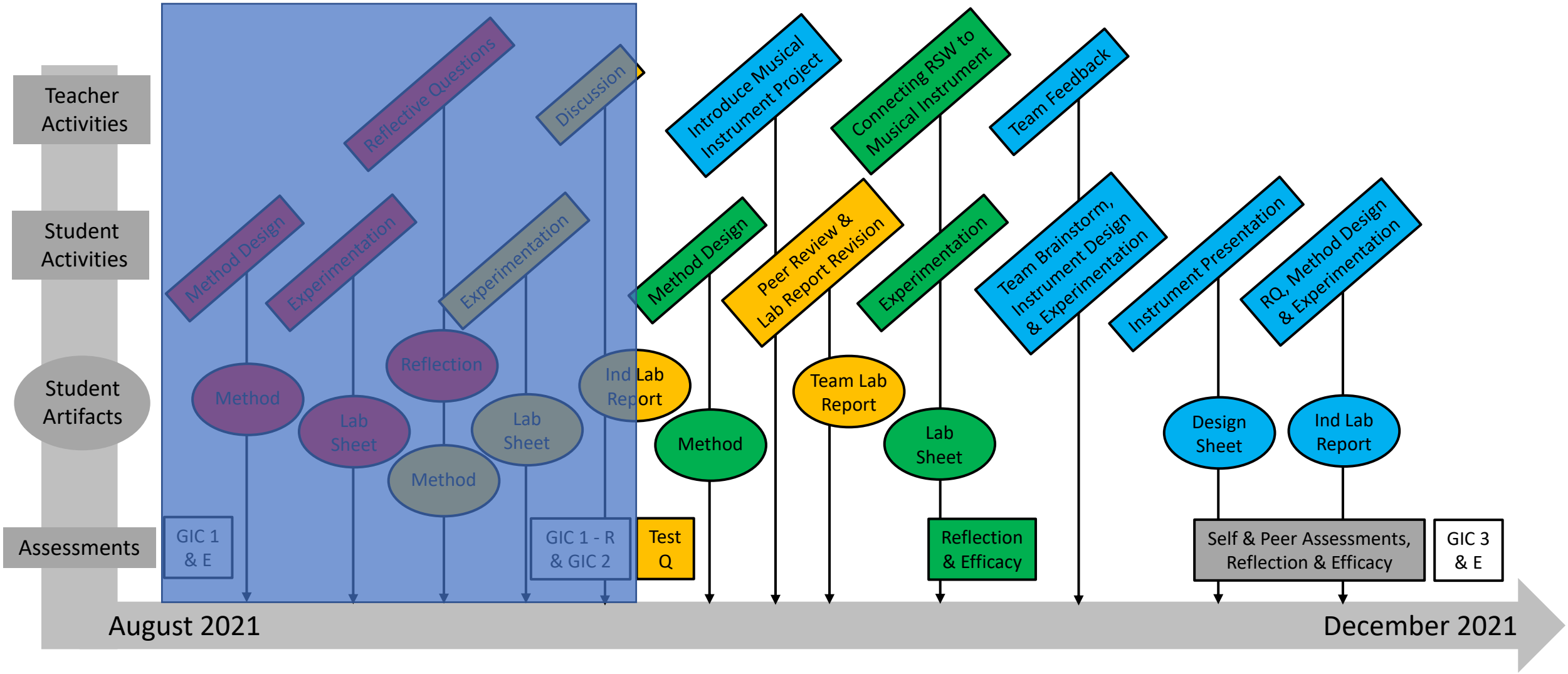
i) Individual Lab Report.

ii) Peer Assessment.

iii) Final Team Lab Report.

		AMPLITUDE (degrees)																	
		5 Trial 1	5 Trial 2	5 Trial 3	10 Trial 1	10 Trial 2	10 Trial 3	15 Trial 1	15 Trial 2	15 Trial 3	25 Trial 1	25 Trial 2	25 Trial 3	35 Trial 1	35 Trial 2	35 Trial 3	45 Trial 1	45 Trial 2	45 Trial 3
LENGTH (m)	0.20	9.01	8.48	8.81	9.11	9.05	8.67	9.04	9.82	9.73	9.92	9.72	10.20	9.55	10.58	10.43	10.08	9.94	10.62
	0.40	12.61	12.70	12.21	12.63	13.28	12.10	13.10	13.33	12.98	13.12	13.35	13.33	12.91	13.50	13.37	13.56	13.64	13.71
	0.60	15.91	15.65	15.93	15.82	16.00	15.57	15.64	16.15	16.20	16.57	16.02	15.91	16.60	16.75	15.77	16.53	17.22	16.82
	0.80	18.20	18.05	17.53	18.05	18.10	17.48	18.19	18.69	18.55	18.26	18.91	18.82	18.76	19.11	18.62	19.03	19.21	19.88
	1.00	20.08	20.97	19.93	19.86	20.17	20.57	20.53	20.90	20.33	20.57	21.03	20.97	20.94	21.12	21.32	21.95	21.53	21.42
	2.00	29.15	28.00	28.52	29.12	28.84	28.25	29.69	29.53	29.20	29.05	30.15	29.97	30.52	30.11	30.62	30.85	31.11	29.88
	5.00	44.89	45.33	44.90	45.05	44.41	44.81	45.12	44.57	46.06	46.15	45.91	46.29	46.45	46.10	46.65	47.18	47.37	48.48

3. Resonant standing waves & 4. Musical Instrument



4. Musical Instrument

Summary of deliverables; each student will:

1) Build a musical instrument.
2) Present and play their musical instrument in class (tentative date, November 29). You should be able to link your experiments to your final product and be able to comment on the instrument's potential and limitations.
3) Complete the Instrument Specification Sheet (tentative due date, December 1).
4) Conduct an experiment(s) based on a research question(s) and prepare a lab report (tentative due date, December 5).
5) Complete a "Peer and Self Assessments and Learning Reflection" (this document will be provided to you). You will have the opportunity to assess your work and contributions for the group, and to assess your peers' work and contributions (tentative due date, December 8).

CHALLENGE: Each student will build, present, and play a musical instrument.

Constraints and guidelines:

- Your instrument must be STRING or PIPE based. You may have 1+ string(s) OR pipe(s).
- You must play a simple medley using at least 3 frequencies (or notes). It does not have to sound good (but it would be nice if it does)!
- Your instrument must be made with household and/or recycled items. You should not have to purchase anything, but if you do, you cannot spend more than $10.
- You will have to present and play your instrument for the class (during class time) and/or submit a short video.
- You will report on your design (e.g., desired fundamental frequency(ies)), experimental procedure(s), research and knowledge transfer enabling you to build your instrument. There will be an "Instrument Specification Sheet" (this will be provided to you) to fill out and you will have to prepare a "Lab Report" based on a research question (of your choice) based on your instrument (further instructions will be provided to you).
- No prior musical knowledge is necessary for this challenge.

Scaffolding the Scientific Process in Biology Inquiry-Based Labs

- Fall 2021 - **Online**
  - Labs incorporated synchronous and asynchronous elements

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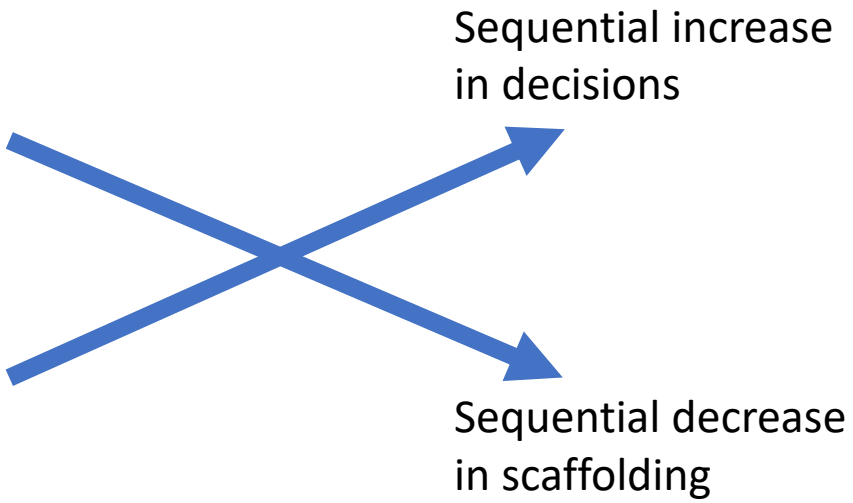

Scaffolding the Scientific Process in Biology Inquiry-Based Labs

- Fall 2021 - **Online**
  - Labs incorporated synchronous and asynchronous elements
- Different paradigm
  - Sequentially examine, scaffold, each element of the scientific process
  - Approach based on sections of a scientific paper
  - Students consider each separate section within the context of the whole paper

Introduction	Methods	Results	Discussion
Formulate hypothesis based on background info	Design experiments Select analytical approach	Analyze Data Present/Interpret Results	Conclusions Evaluate confidence

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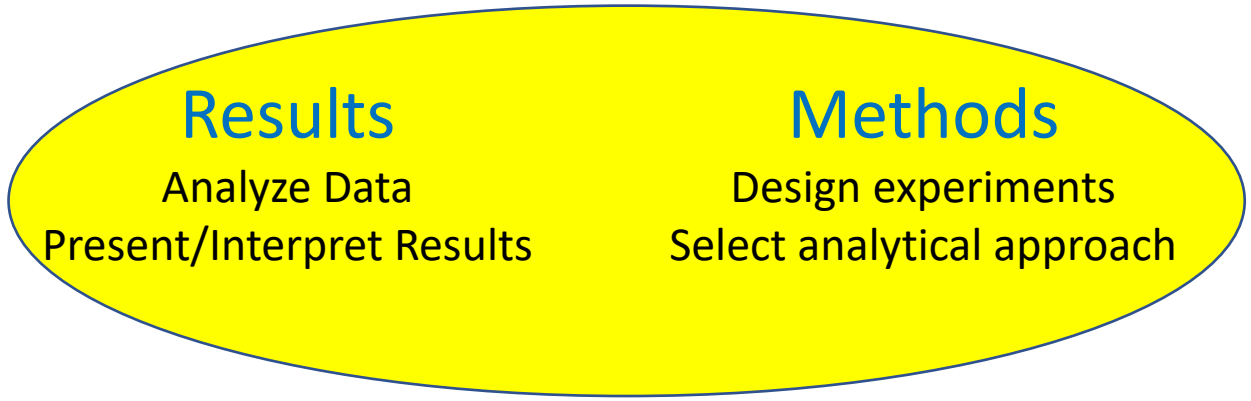


Introduction
Formulate hypothesis
based on background info

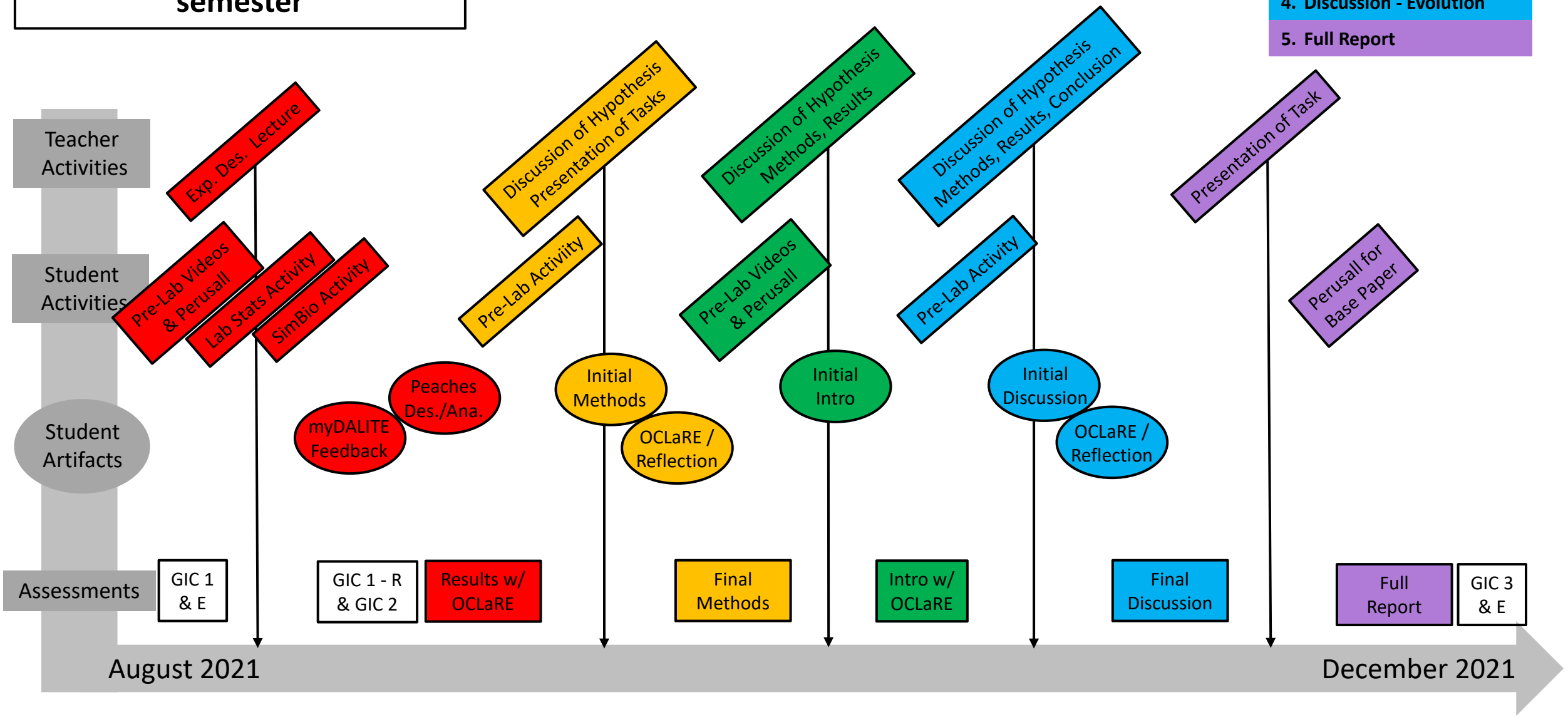
Discussion
Conclusions
Evaluate confidence

Fundamental base for scientific process

Mapping the design for Inquiry-Based Labs over a General Biology 1 semester

GIC = "George's Ice Cream
E = Epistemology Questionnaire

1. Results – Experimental Design and Statistics
2. Methods - Cells
3. Introduction - Genetics
4. Discussion - Evolution
5. Full Report



Scaffolding Tools

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- myDALITE
- Perusall

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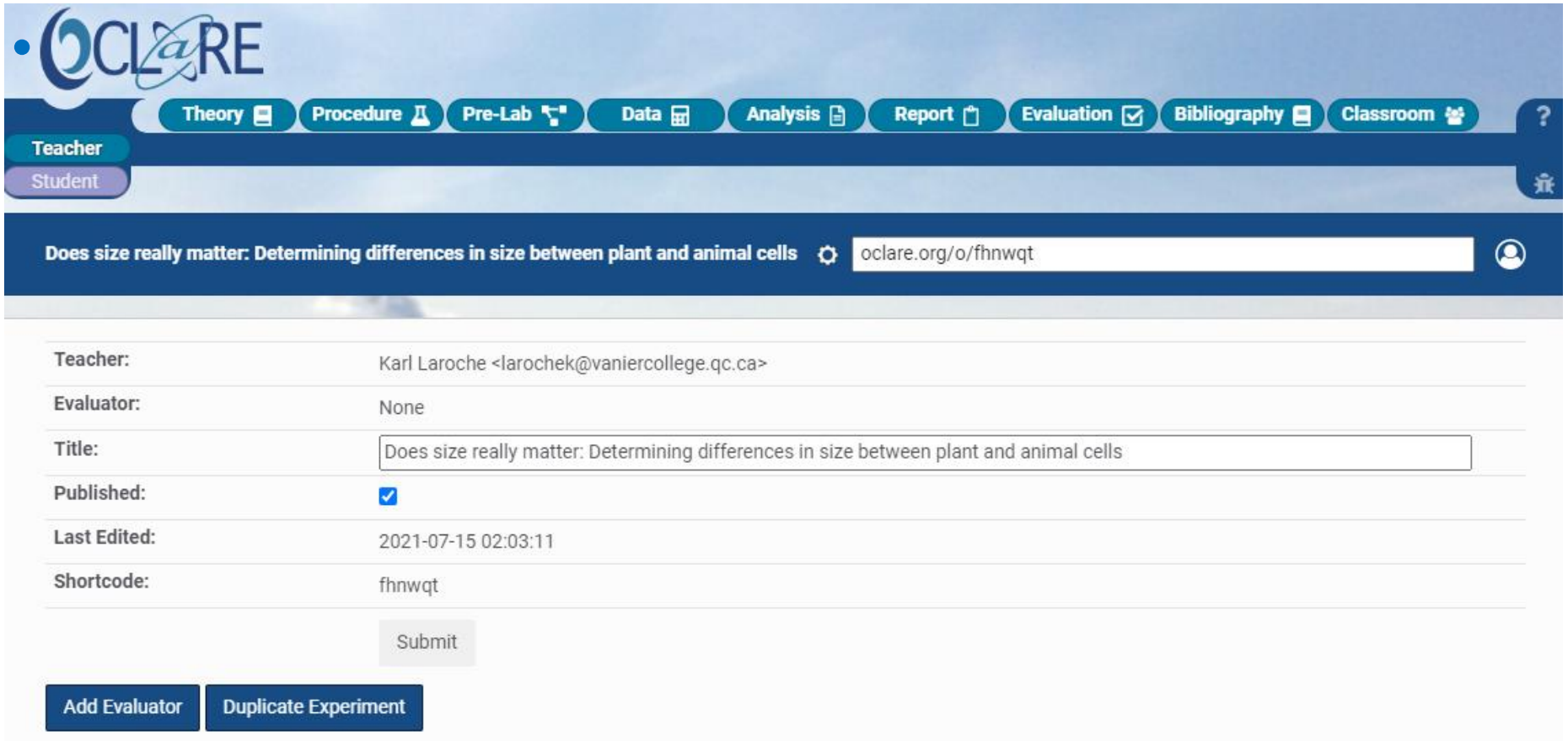

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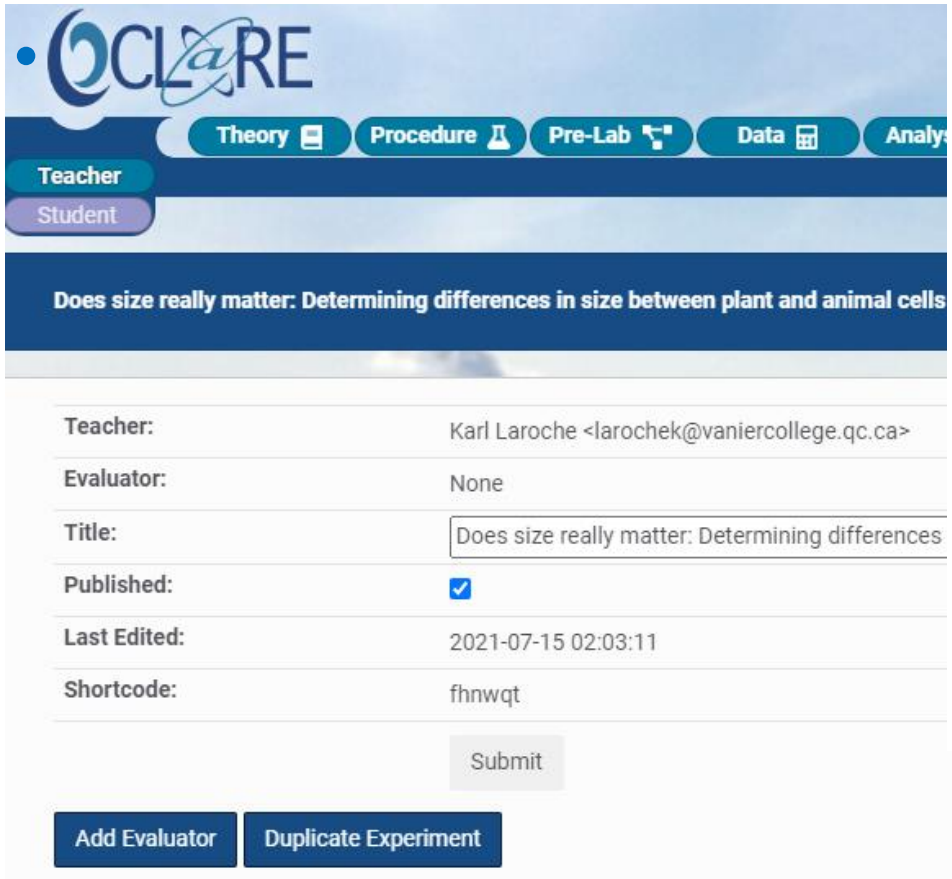


Does size really matter: Determining differences in size between plant and animal cells

Karl Laroche[1]

[1] *Vanier College, 821 Avenue Sainte-Croix, Montreal, Quebec H4L 3X9 Canada*

(Dated: June 1, 2022)

The goal of this experiment was to determine whether plant cells and animal cells are different in size. To test the hypothesis that plant cells are larger than animal cells, the dimensions of 20 human cheek (epithelial) cells and 20 onion epidermal cells were determined using computer software and subjective depth measures using microscope Vernier scales. Their areas (A) and volumes (V) were calculated based on the simplifying assumptions that the cheek cells are perfectly cylindrical and the onion cells are shaped like bricks, and the means of these measures were directly compared. Onion cell A and V are shown to be significantly greater than these measures for cheek cells ($p<<0.001$), while onion cells have a lower SA/V ratio ($p=0.04$). These results are significant enough to overcome any uncertainty from the measurements and assumptions, and provide strong evidence that onion epidermal cells are larger than human cheek cells. However, it remains that our results are only one small piece towards answering the overall general question on plants and animals, and much more research across different cell types and species is required to further support our conclusion.

I. INTRODUCTION

A common adage in biology is "form follows function." This principle can readily be applied to cells and their size. Previous research has demonstrated that cells with different functions within a single organism often differ greatly in size. For example, while some replenishable cells common to animals (red blood cells, for instance) are small and similar in size, others, such as important long-term nervous-system cells, are larger (2) (1).

If the principle applies to cells within a single organism, surely it should also apply across very different organisms, such as plants and animals. Thus, the focus of this study is on determining whether plant cells and animal cells are different in size. This research question has been addressed numerous times in the literature (3), but it remains important to replicate and confirm previous research findings, and this will be the goal of this study.

Plants and animals are very different groups of organisms. While both groups are eukaryotic, with their cells metabolic activity, and the cell is unable to survive.

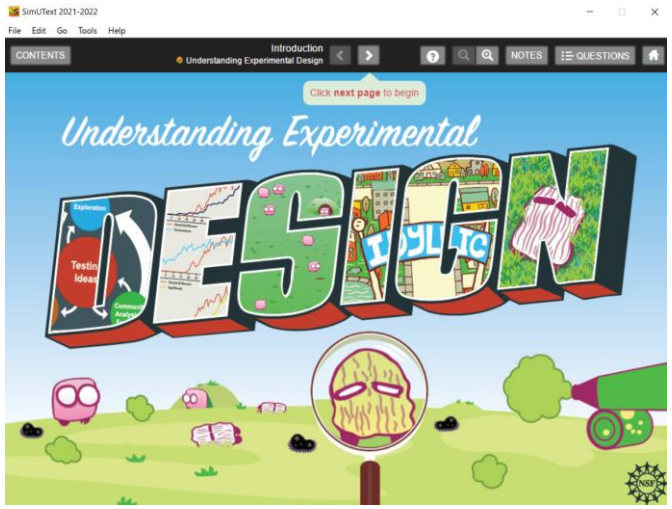
However, cells have evolved mechanisms to somewhat overcome this physical limitation. One of these is the emergence of large central vacuoles, which are mostly filled up with water and thus devoid of metabolic activity. In some cells, the vacuole can occupy up to 90% of a cell's internal volume (5), allowing the cell to get much larger, thus greatly increasing its surface area while limiting the amount of metabolically active volume.

Given the cellular differences between plants and animal, especially the presence of a large central vacuole in plant cells, it is hypothesized that plant cells are larger than animal cells. To test this hypothesis, an experiment was conducted to compare human (animal) epithelial cells and onion (plant) epidermal cells. Onion cells are expected to have greater size, but should also display a lower SA/V ratio.

II. MATERIALS & METHODS

Scaffolding Tools

- Moodle
- myDALITE
- Perusall
- OCLaRE
- SimBio



SimUText 2021-2022

File Edit Go Tools Help

CONTENTS | Section 2: Save the Simploids! | Understanding Experimental Design | 9 / 18 | NOTES | QUESTIONS

SETUP | CONDUCT TEST | DATA | DONE

+ ADD STUDY PLOT | + ADD STUDY PLOT | + ADD STUDY PLOT | + ADD STUDY PLOT

+ ADD STUDY PLOT | + ADD STUDY PLOT | + ADD STUDY PLOT | + ADD STUDY PLOT

Q2.9. Add study plots and set variables for each plot in the space above according to your experimental design.

Click Check My Setup to get feedback: Check My Setup

When you're ready, click CONDUCT TEST (top) to view and run your experiment.

YOUR HYPOTHESIS:

?

NONE

TIME

0

DAYS

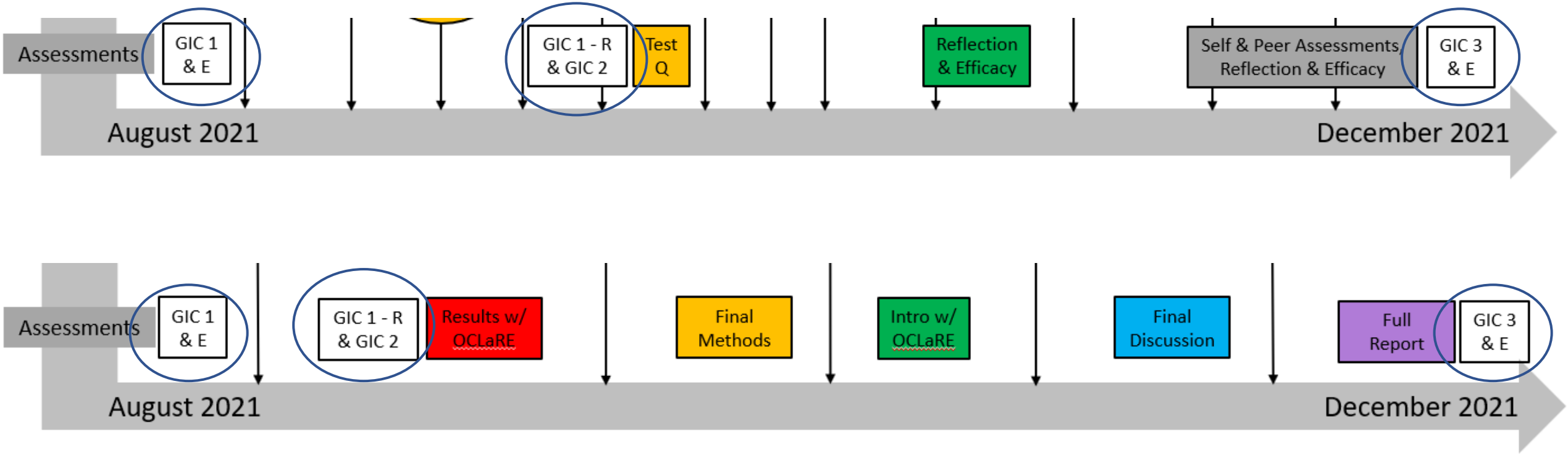
Scaffolding Tools

- Moodle
- myDALITE
- Perusall
- OCLaRE
- SimBio

SimBio Virtual Labs®

EvoBeaker®: How the Guppy Got Its Spots

Tools used to measure student scientific reasoning and epistemic beliefs



Epistemological Questionnaire

- The questionnaire is supposed to measure four different dimensions of epistemological beliefs about the topic of climate:
  - Certainty of knowledge about climate
  - Simplicity of knowledge about climate
  - Source of knowledge about climate
  - Justification for knowing about climate

Dimensions of topic-specific epistemological beliefs as predictors of multiple text understanding

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Issues concerning climate are highly topical and often mentioned in the media. We can read daily about issues such as climate change, pollution of the atmosphere, global warming, extreme weather, rise in ocean levels, and melting of ice in polar regions. This is material that we often encounter in newspapers and magazines, as well as on TV and radio. Most people who do research on climate have a background in natural science, for example in physics, chemistry, biology, or meteorology. The following questions concern knowledge about climate and how one comes to know about climate. There are no right or wrong answers to these questions; it is your personal beliefs that interest us. Use the scale below to answer the questions. If you strongly agree with a statement, use 10; if you strongly disagree, use 1. If you more or less agree with a statement, use a number between 1 and 10 that best expresses your belief.

		Strongly disagree									Strongly agree
		1	2	3	4	5	6	7	8	9	10
1.	Climate researchers can find the truth about almost everything concerning climate.....	#:									
2.	When I read about issues concerning climate, the author's opinion is more important than mine.....	#:									
3.	With respect to climate problems, I feel I am on safe ground if I only find an expert statement.....	#:									

Epistemological Questionnaire – Comparison weeks 1 & 15

Q43: “The only thing we know for certain about climate problems, is that nothing is certain”

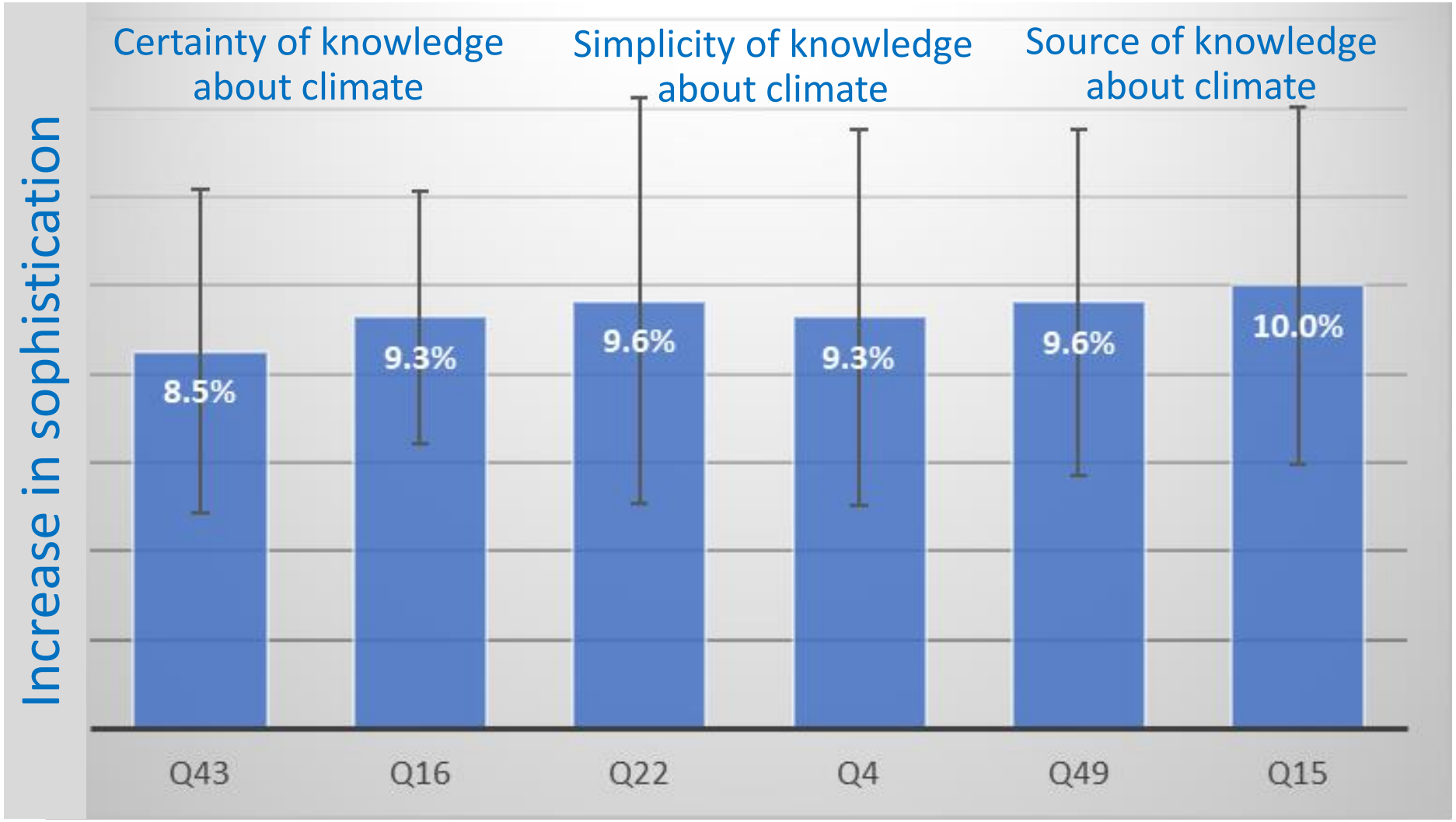
Q16: “Within climate research, truth is unchanging” (Reversed scale; improvement shown)

Q22: “Knowledge about climate consists of highly interrelated concepts rather than an accumulation of facts”

Q04: “Within climate research, facts are more important than theories” (Reversed scale; improvement shown)

Q49: “When I read about issues related to climate, I try to form my own understanding of the content”

Q15: “Ordinary people have no basis for speaking about issues concerning climate” (Reversed scale; improvement shown)



George's ice-cream

George wanted to examine if the colour of the wrapper of specific ice cream affects the time it takes ice cream to melt. In order to answer this question, he performed the following test:

He bought several ice creams with different colour wrappers, measured each ice cream's mass as it is shown in the table below, and put all together in a freezer. He then removed all of the ice cream from the freezer at the same time, placed them all on his car's front dashboard, and measured the time it took each ice cream to melt.

	Flavour	Wrapper Colour	Mass (g)	Melting Time (min)
1	Lemon	White	80	8
2	Lemon	Brown	80	8
3	Chocolate	Green	100	6
4	Chocolate	Yellow	120	9
5	Vanilla	Blue	120	11
6	Strawberry	Black	120	12

According to George's test and his measurements, can you say whether the colour of the cream's wrapper affects the melting time? Explain your reasoning, mentioning which of the ab measurements you used to reach your conclusion.

Assume that you are a scientist working for the company producing these ice cream bars. Their main concern is to maximize the amount of time their ice cream bars can remain solid outside of a fridge. The company realizes that there may be many research questions. You must propose one **specific** research question to help the company address their concern; and design a methodology (procedure/methods) appropriate for answering your question. Write your answer as if you are speaking to your colleague.

The company produces the following types of ice cream bar flavours, sizes and varieties:

Flavour	Wrapper Colour	Available sizes (g)	Varieties	Special ingredients
Lemon	White	80, 160	Regular	Regular: None
			Sugar-free	Sugar-free: sucralose and binding agents
Chocolate	White	80, 160	Regular	Regular: none
			Chunky	Chunky: chocolate chips
Strawberry	White	80, 160	Regular	Regular: Pieces of strawberry
			Sugar-free	Sugar-free: sucralose and binding agents
Vanilla	White	80, 160	Regular	None

Steve wanted to examine if the string type of a fixed string affects the fundamental frequency of the sound produced. In order to answer this question, he performed the following test:

He set up several fixed strings of different tensions and lengths in a classroom. He noted the string type, plucked the string and measured the fundamental frequency of the sound produced.

	Tension (N)	String Type	Length (cm)	Frequency (Hz)
1	55	Bronze Light	40	630
2	55	Steel	40	630
3	80	Nylon	70	450
4	80	Nickel	90	350
5	50	Phosphor Bronze Medium	90	290
6	100	Polymer Coated	90	390

According to Steve's test and his measurements, can you say whether the string type of a fixed string affects the fundamental frequency of the sound produced? Explain your reasoning, mentioning which of the above measurements you used to reach your conclusion.

George's ice-cream

- PRE-TEST:
  - **Majority of students** could recognize that the variables were not controlled.
  - Most inferred there was a dependent variable (DV), but none used the term DV.
  - Most recognized that mass was a confounding variable, but none used the term.
  - Half tried to explain why the results are muddled BUT do not clearly explain not being able to draw any conclusions from the data.
  - Some students talking about the data that have patterns and trying to draw some conclusions even when there are so many confounding variables.
  - Less than 10% explicitly said that there was insufficient data and that the experiment was flawed.
- DELAYED POST-TEST:
  - **ALL students were able to explain the need to control variables** and were able to distinguish DV and IVs (though only a few named them as such).
  - **All students suggest there is confounding** but less than 25% state it clearly enough to be able to code it as such (these students stated it as the need to make separate experiments).
  - Main improvement – **the need for more trials** and suggesting a reason why.
  - Half are explicit about needing more data to make better conclusions.
- In summary: there is a modest improvement in their explanation of the problem with George's experiment, but there appears to be more confidence in making their claim.

George's ice-cream – Student example 1

- **PRE**: Lemon: 2 wrapper colours -> same mass, same melting Time (6 seconds for 1g to melt) Chocolate: 2 wrapper colours -> Green: 360s to Melt 100g -> 3.6 seconds to melt 1g - Yellow: 340s to melt 120g -> 4.5 seconds to melt 1g Vanilla : 660 seconds to melt 120g -- 5.5 seconds to melt lg Strawberry: 720 seconds to melt 120g -> 6 seconds for 1g. The wrapper colour does not affect the ice cream's Melting time. The reasoning for this is that it is known that darker colours absorb more energy from light sources than lighter colours do, so it would be expected that the brown wrapped lemon ice cream would melt faster than the white one, but it doesn't. The lemon ice cream is a good sample because both are the same mass, so that can be ruled out as an area for change. The difference in melting time for the chocolate ice creams is the mass. The difference in time between all the 120g ice creams is the chemical composition of the ice creams, as chocolate is known to melt quickly If the wrapper colour had an effect, then the strawberry one would melt faster as black absorbs the mass ...

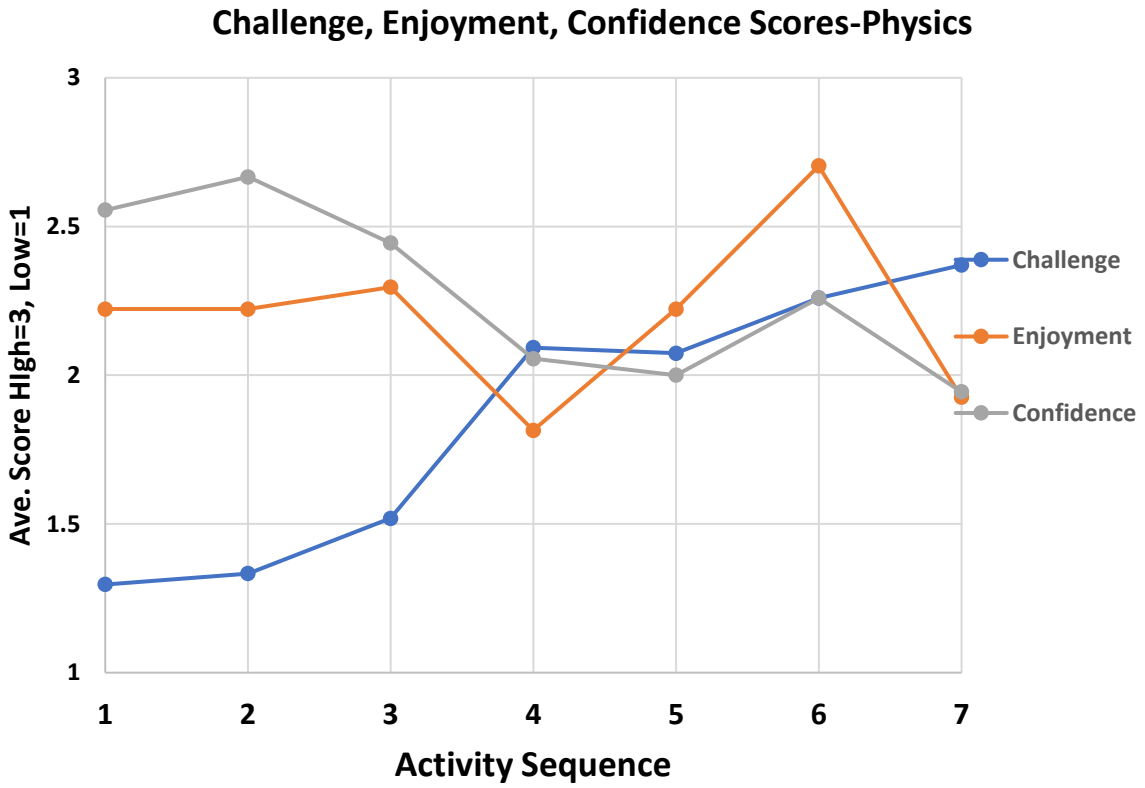
- **DELAYED**: The biggest source of error would be that you're changing 2 independent variables at the same time. On trial 1 and 2 you had the right idea but then afterwards you start changing multiple variables at a time. I would recommend you do 3 separate trials where flavour/mass, flavour/wrapper and wrapper/mass are kept constant so you can determine what influences the melting time.

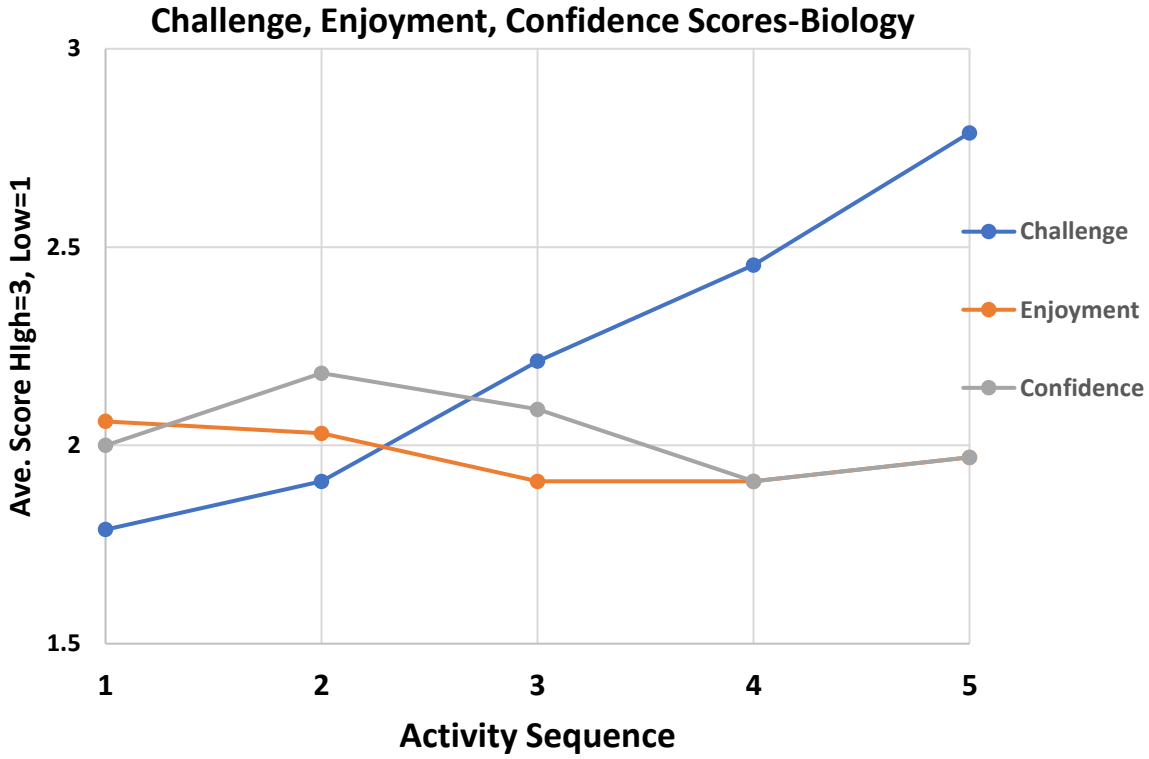
George's ice-cream – Student example 2

- **PRE**: I would say that the colour of the wrapper does and doesn't and here's why. Firstly, I would say it doesn't because if we look at white, brown and black they all have 10 grams melting in 1 minute. Because you would do 80/8=10 and 120/12=10. Although, on the flip side I also say it does because if we look at Green, it has 20 more grams than the two lemon flavours except it takes 2 minutes less to melt, compared to the lemon flavours.

- **DELAYED**: You had too many variables at once. You wanted to determine whether the wrapper colour, the mass or the flavour influenced [the melting speed].
  - You could have made three different experiments.
  - Changing the flavour, and keeping the wrapper colour and mass constant.
  - Changing the flavour, but keeping the wrapper and mass the same.
  - Changing the mass, but the flavour and wrapper the same.
  - You can then determine the melting speed to see what factor influences the most the melting time.

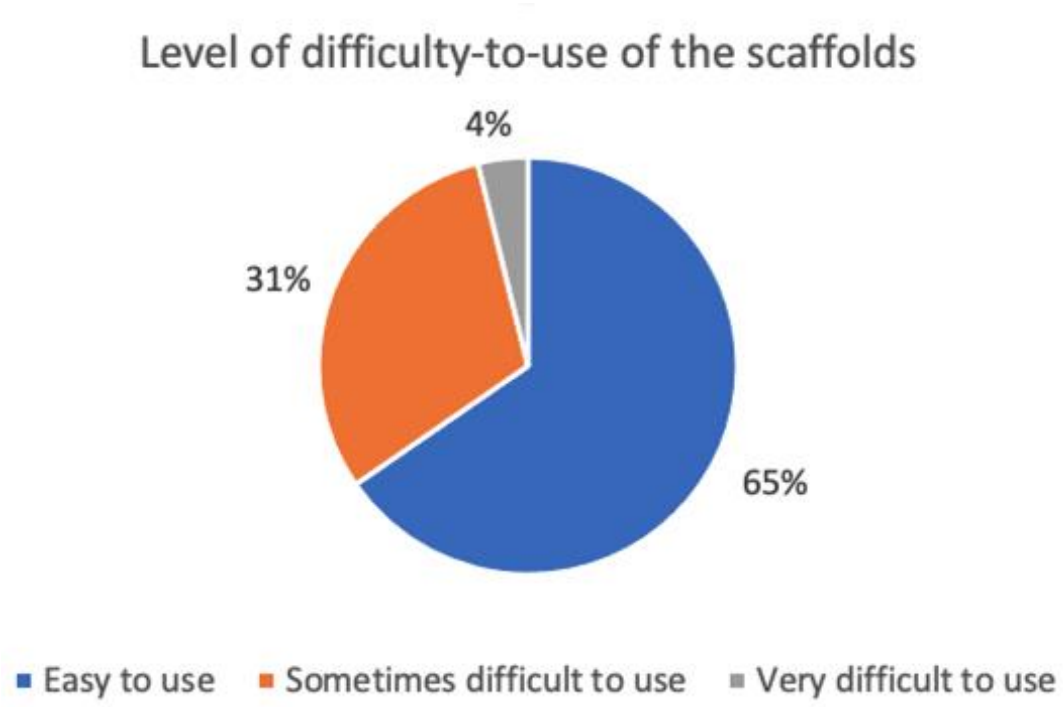
Student self-reflection about the level of challenge, enjoyment and confidence for the activities throughout the semester

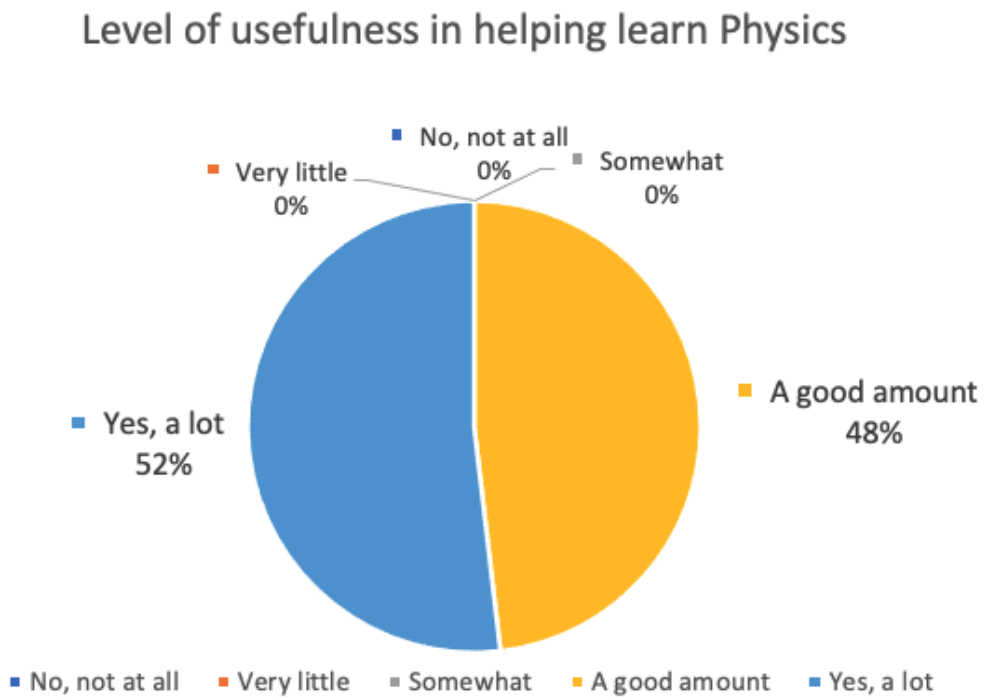




Student overall perception (Rhys' students)

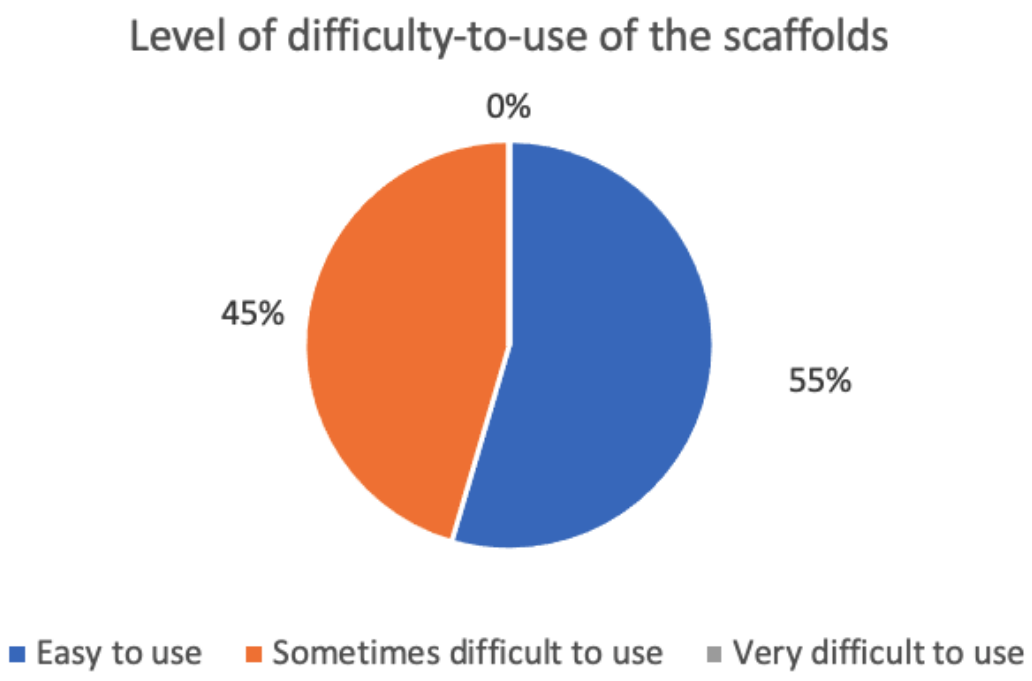
How accessible were the scaffolds provided to students in the course?	*How useful were the engagement with scaffolds provided in the course to students?*

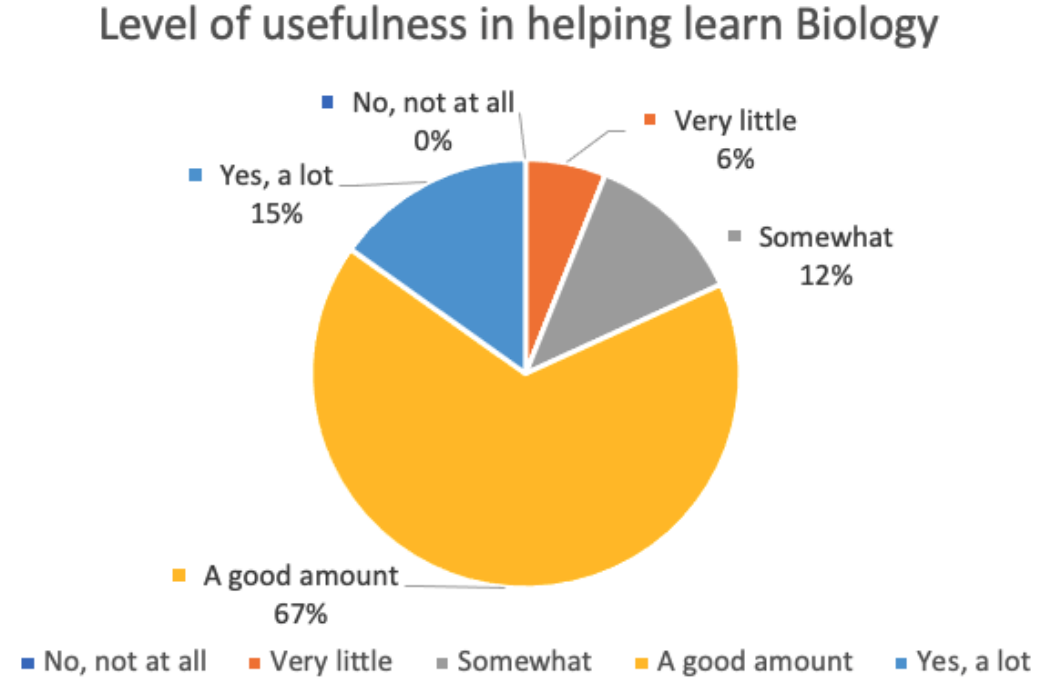




Student overall perception (Karl's students)

How accessible were the scaffolds provided to students in the course?	*How useful were the engagement with scaffolds provided in the course to students?*





Lessons Learned & Future Directions

- Incorporating IBL in a semester-long course is feasible for other college courses.
- Designing IBL takes macro and micro level planning.
- Giving students opportunities to explore and make decisions could be the first step to transition into IBL.

- Examining student learning data.
- Adding more contextual relevance.
- Provide more social and meta-cognitive level scaffoldings.

Conclusions

- Two case studies, each featuring a unique IBL implementation:
  - (1) Design focus, in Physics.
  - (2) Experimental focus with scaffolded lab-reports, in Biology.

- Students in both approaches showed improvements in their scientific reasoning with positive changes to their epistemic beliefs.

- Zone-of-Proximity Scaffolding is critical to inquiry-lab successful learning.

Thank You

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