Toward Epistemologically Responsive Design-Based Research

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Goals for K-16 STEM education are not about accumulating certain science facts

"… some knowledge of science and engineering is required to engage with the major public policy issues of today as well as to make informed everyday decisions" (National Research Council, 2012, p. 7)

"as a growing number of societal challenges, from preserving the environment to advancing human health and quality of life, intersect with biology, future scientists, and non-scientists alike must become adept at making connections among seemingly disparate pieces of information, concepts, and questions, as well as be able to understand and evaluate evidence" (Bauerle et al., 2011, p. 3)

We aim for science learning environments to open space for learners to *"explore and discuss differences between knowledge in multiple contexts"* (Elby & Hammer, 2001, p. 564) that resemble contexts they may encounter in post-school life.

To what extent are our approaches to designing, assessing, and refining STEM learning environments aligned with our goals?

Canon-Responsive Design-Based Research

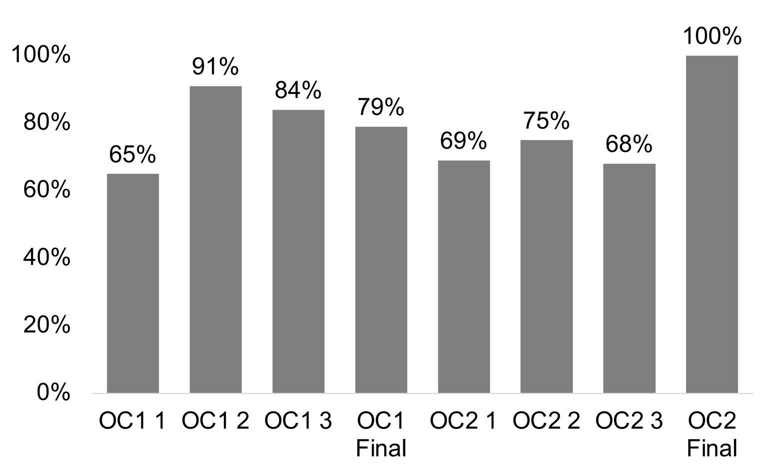
Exemplar: Organic Chemistry I and II

Reflect

Consider how materials should be modified to better support student construction of canon-aligned answers

The control enactments differed from the experimental enactment mainly by assessment emphasis (with control courses placing little emphasis on 3D tasks on high-stakes exams). As such, the research team concluded that courses which support construction of canon-aligned explanations, arguments etc. should place substantial emphasis on these sorts of tasks on exams.

Later iterations of the course increased emphasis on tasks which meet 3D-LAP (Laverty et al., 2016) criteria for potentially eliciting evidence of 3D learning.



Design

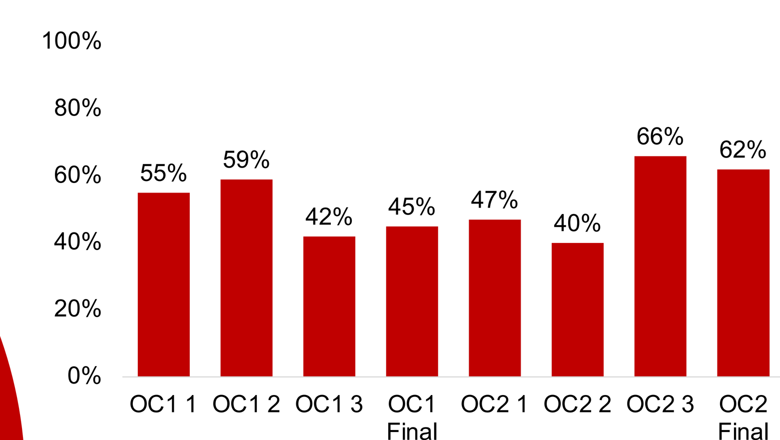
Define how students should integrate science knowledge and activities throughout the semester

Example Performance Expectation (PE):

Evaluate the validity of claims as to the **outcome of a chemical process** by connecting the **structure of relevant reactants, products or transition states to their relative energies.**

Build curricular materials with the potential to support this knowledge-in-use

In designed courses, most points on high-stakes assessments meet 3D-LAP (Laverty et al., 2016) criteria for potentially engaging students in 3D performances.

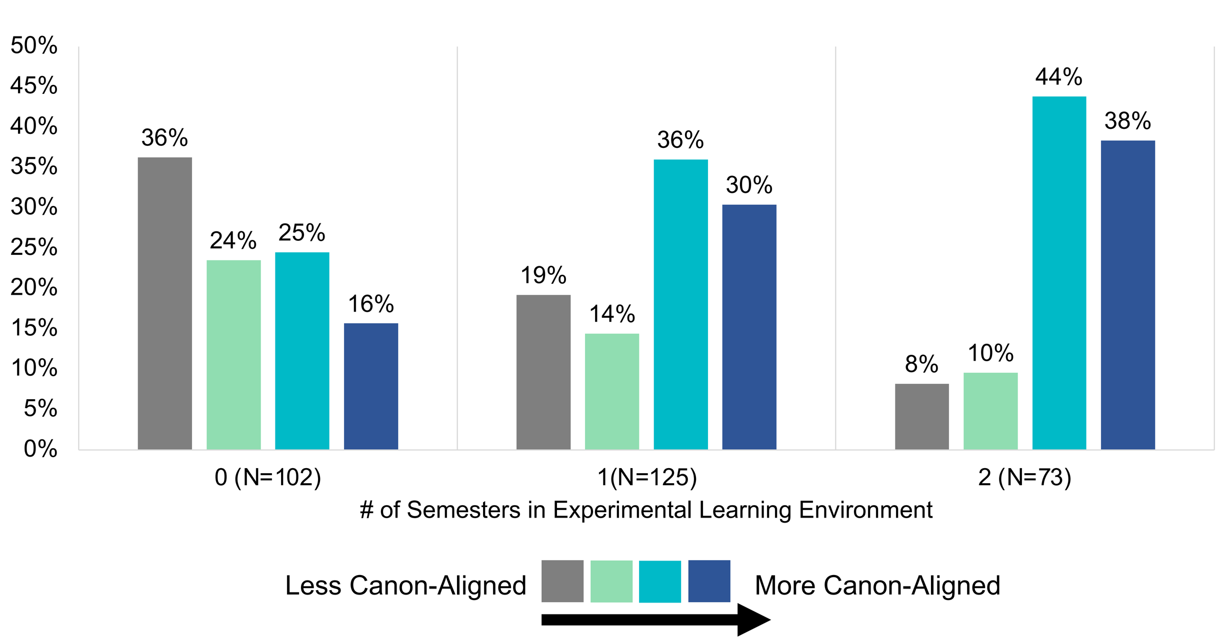


Interpret

Analyze the extent to which students' knowledge products align with canon

Compare the relative correctness of student knowledge products between control and treatment groups

Students enrolled in experimental courses for more semesters constructed more canon-aligned responses (DeGlopper et al., 2022).



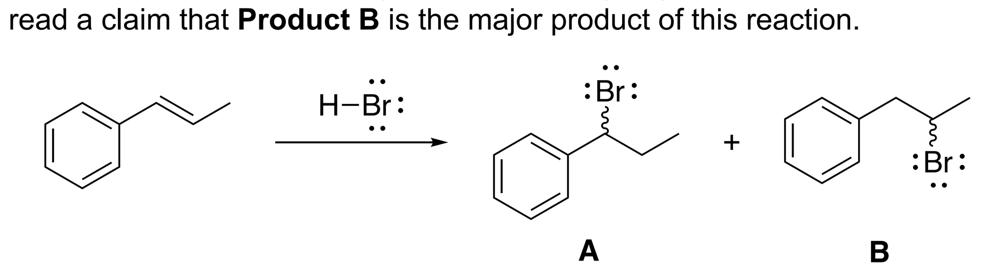
Implement

Enact designed courses

Collect written student artifacts from control and treatment groups and/or conduct interviews

Diagnostic prompts which asked students to connect core ideas to phenomena were given to control and treatment groups.

Consider the reaction between hydrobromic acid (HBr) and the alkene shown below. You read a claim that **Product B** is the major product of this reaction.



1. Draw a mechanism for the reaction above that leads to **Product A.**
2. Draw a mechanism for the reaction above that leads to **Product B.**
4. Would you expect **Product B** to be the major product of this reaction? Explain your answer using the mechanisms and potential energy surface you drew in parts 1-3.

Epistemologically-Responsive Design-Based Research

Exemplar: Chemistry Learning Environments Anchored in Phenomena (ChemLEAP)

Reflect

Consider how materials might be refined to better open space for a range of productive ways of knowing and learning

Extremely scaffolded student- and teacher- materials may have communicated that engaging in discrete performances in the "right" way was the point of class work.

Revised materials support class exploration of a range of unit- and lesson-level questions

Revised materials support the class in deciding how and why to model, explain etc.

Lesson 3 -

Pre-Activity Items:

1. As a class, select a question from the driving questions board to focus on for this lesson. Write the question we agree on next to the "Lesson 3 - " heading.
2. To get started, pick one substance that was affected by the process of heating in Lesson 1. Draw a model of this substance at low and high temperatures to explain how heating affects that substance.
   a. Substance in my model: ______________________
   b. Observation I am modeling:
   c. Model and Description explaining how heating affects my substance

Low Temperature	Middle Temperature	High Temperature
Description:		

Box 1. Model explaining how heating affects

Lesson 5 - What happens to substances when the temperature rises?

Pre-Activity Items:

1. Review the driving questions board. What question(s) from the driving questions board will be addressed in this experiment?
2. Consider the temperature vs time plot you drew in Lesson 3. Redraw your models of what is happening in Region (2) on the micro-scale as water is being heated from Lesson 3 in Box 1.

Beginning of Region (2)	Middle of Region (2)	End of Region (2)

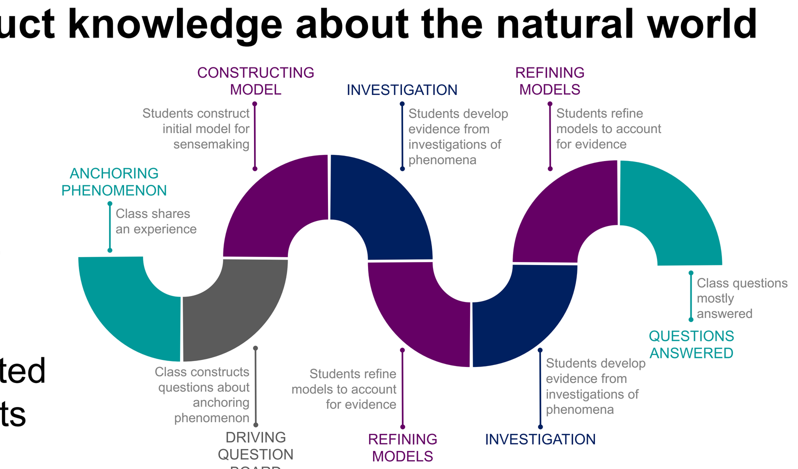
Box 1. Models of Region (2)

3. How do differences in your drawings help to illustrate your prediction to the question: *When heating your substance, what changes occurred on the micro-scale?*

Design

Define spaces for students and teachers to negotiate how and why to construct knowledge about the natural world

ChemLEAP adopts a storyline approach (Reiser et al., 2021) to each unit of instruction. Units are sequenced such that explanatory models can be elaborated within and between units



Build curricular materials with the potential to support this knowledge-in-use

Interpret

Describe views on knowing and learning manifest in student and teacher behavior

Infer how our course design influences how and why students construct knowledge

When considering refining the course, we looked for epistemological messages (Russ, 2018) from the course consistent with the "classroom game" (Lemke, 1990).

In enactments of V1 of our materials, we commonly observed engagement in "pseudopractices" (Berland & Hammer, 2012). That is students constructed knowledge that mimicked the structure of scientific practices to please the teacher or address a worksheet prompt (rather than make sense of their experience). For example, consider these snippets from dialogue related to constructing a model to explain a phase change:

Teacher: *You're only using six particles* [referencing a worksheet prompt]*. They can be any shape that you want but you're showing how they interact with each other.*

Kate: [referencing prompting for a description of a picture] *Do we even need a description?*
Tim: *YES!*
Kate: *No, we don't*
Tim: [reading] *with your model, provide a brief description of how …*

Implement

Enact designed courses

Collect videos of class activities and conduct interviews with students and instructors

One-on-one semi-structured interviews, designed to capture the nuance of student thinking as they negotiate class-embedded messages about knowledge and knowing (Russ, 2018) were conducted throughout the semester.

Sample Interview Prompts
We're going to take a look at how other students responded to a test question. Please read through each sample response and let me know your initial impressions. a. What ideas do you see each person using in their response? b. Where do you think they got these ideas? c. Do you think these responses provided convincing evidence that the person understands what the instructor is trying to assess? Why or why not?
Based on your reading of this assignment and your memory from class, why do you think your instructor is asking these questions?
Do you think *[whatever they said the instructor was after]* will be useful outside the classroom? Why or Why not?

Class construction or revision of questions, models, arguments etc. was captured on video

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