Getting a holistic view: Documenting change in undergraduate science teaching

Anne Egger[1], Devarati Bhattacharya[1], Leighanna Hinojosa[1], Ellen Iverson[2], and Anthony Carpi[3]

[1]Central Washington University
[2]Carleton College
[3]John Jay College, CUNY

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Abstract

There is a lot going on in introductory undergraduate science classrooms. Students bring their culture, background, and previous science experiences; instructors bring their knowledge, attitudes, and experience in science and in teaching. Students are there for a variety of reasons, and a substantial proportion will become K-12 teachers: that introductory course may be their primary science experience as an adult learner. How future teachers learn science is of critical importance to how they teach science, but few college science classes reflect the vision of the 2012 Framework for K-12 Science Education, in which "students actively engage in scientific and engineering practices in order to deepen their understanding of crosscutting concepts and disciplinary core ideas" (p. 217). The vision of the Teaching with Investigation and Design in Science (TIDeS) project is that future teachers will learn science as undergraduates the way they are expected to teach science in the K–12 classroom: engaging all students in science investigation and engineering design in a discourse-filled, context-rich, inclusive learning process. TIDeS seeks to catalyze transformation of introductory science courses by supporting faculty in the development and implementation of high-quality, rigorously tested, inclusive curricular materials that focus investigation and design. The project has two broad research questions: (1) How do the beliefs and practices of instructors change with developing and/or implementing new curricular materials? (2) What is the impact of the use of these new materials on diverse students? To address these questions, the TIDeS team developed a suite of research probes aligned with the project's guiding principles and with each other (see figure). The probes include a semi-structured, pre-/post- faculty interview, a quantitative and qualitative classroom observation protocol, a pre-/post- student survey, a syllabus rubric, and rubrics for the curricular materials and student readings. Our preliminary data suggest that, in combination, the probes will provide a holistic picture of what teaching with investigation and design in introductory college-level science courses looks like, how it differs from an active learning classroom, and how it can support the preparation of future teachers.

TIDeS
Teaching with Investigation and Design in Science

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[1] Central Washington University
[2] John Jay College, City University of New York
[3] Science Education Resource Center, Carleton College

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The undergraduate science classroom:

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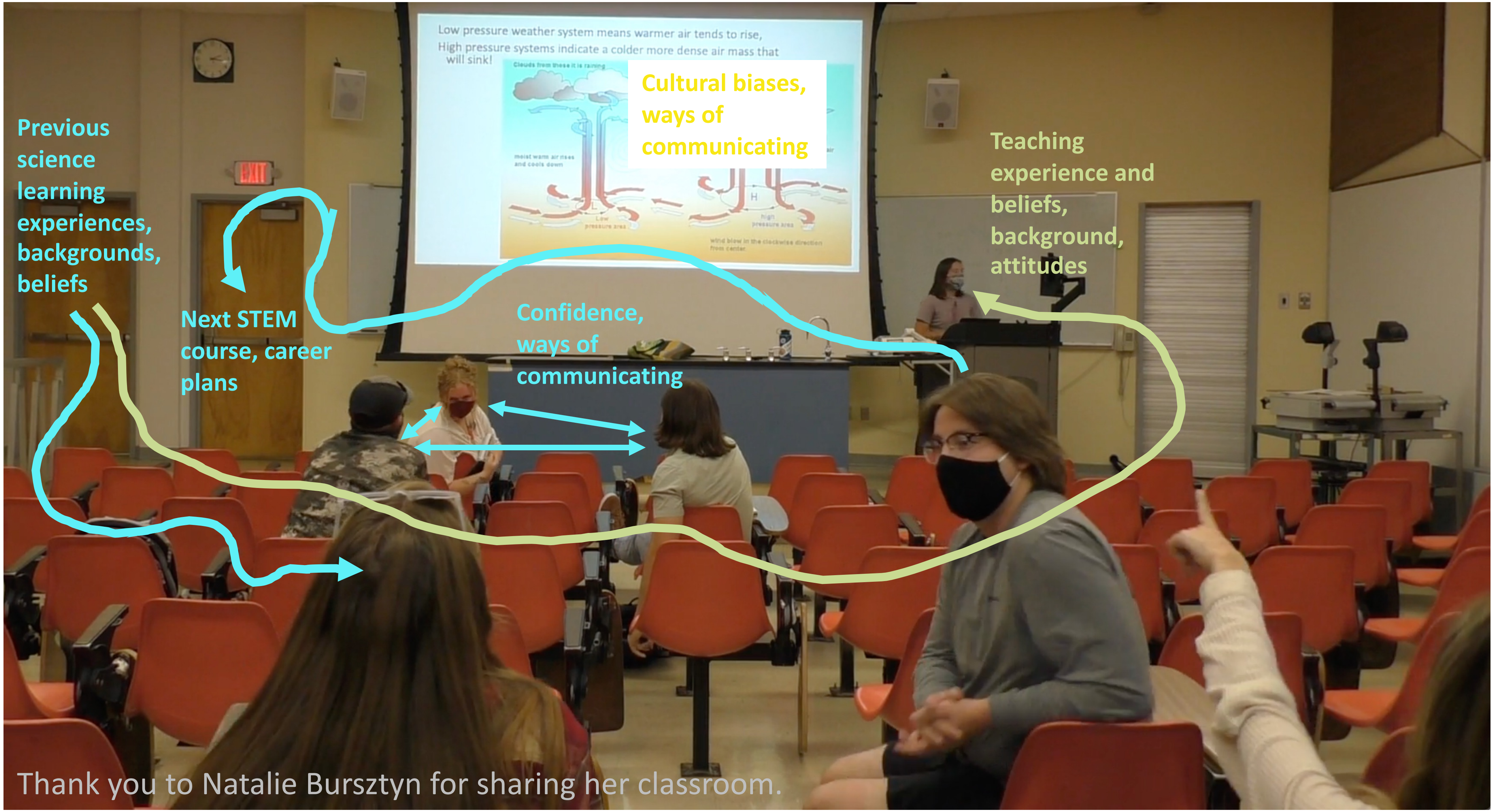


One career: K-12 teaching

Science teachers with no courses beyond introductory in…

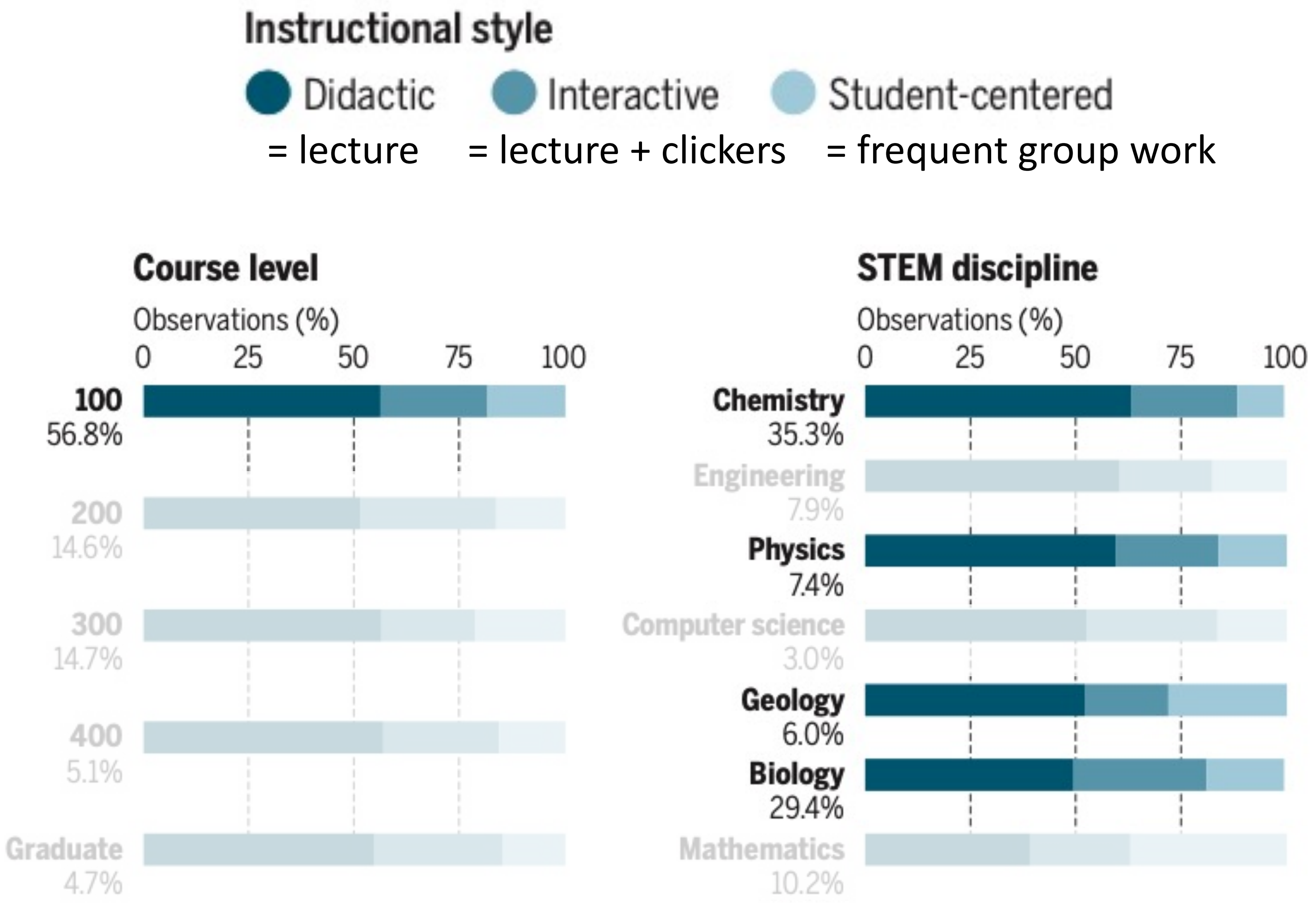
	Middle school	High school
Earth science	31%	31%
Life science	18%	5%
Physical science	64%	30%

Elementary teachers' coursework in…

	Elementary
Earth, life, and physical science	34%
2 of the 3 areas	36%
1 of the 3 areas	23%

Banilower et al., 2018, NSSME+

What do we know about those intro courses?

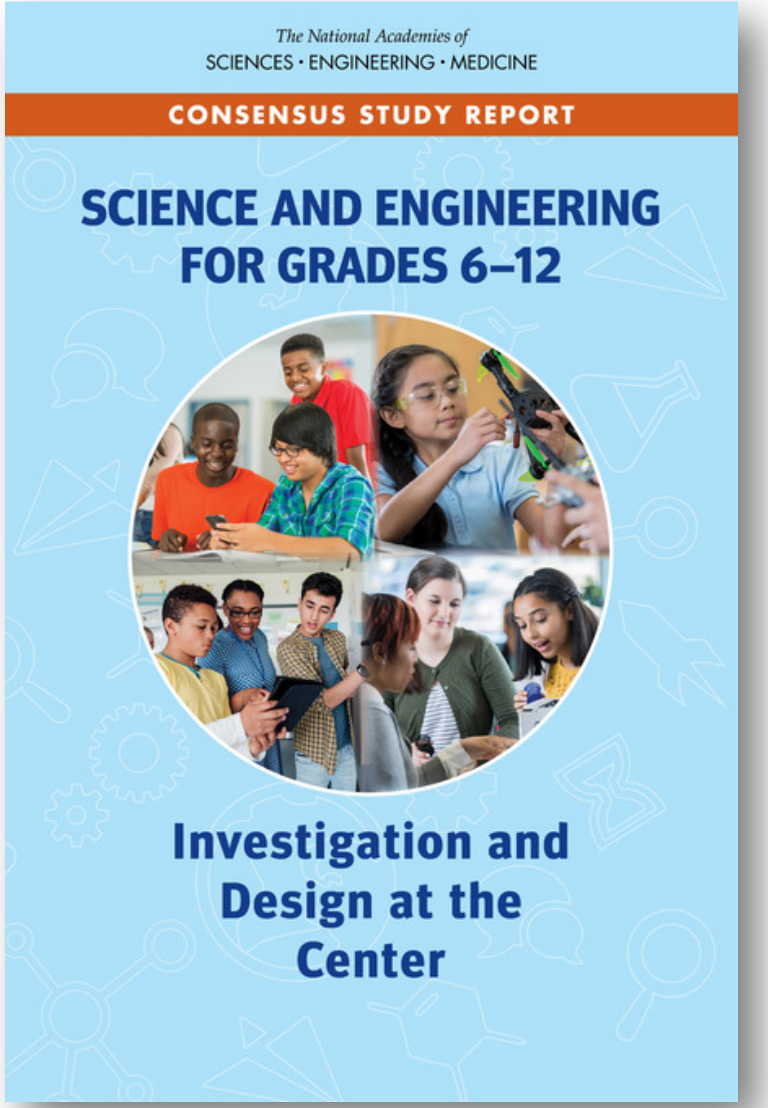


Stains et al., 2018, *Science*

What do we expect from K-12 teachers?

Students should "actively engage in scientific and engineering practices in order to deepen their understanding of crosscutting concepts and disciplinary core ideas."

Framework for K-12 Science Education (2012), p. 217



Our vision is that future teachers will *learn* science as undergraduates the way they are expected to *teach* science in the K-12 classroom.

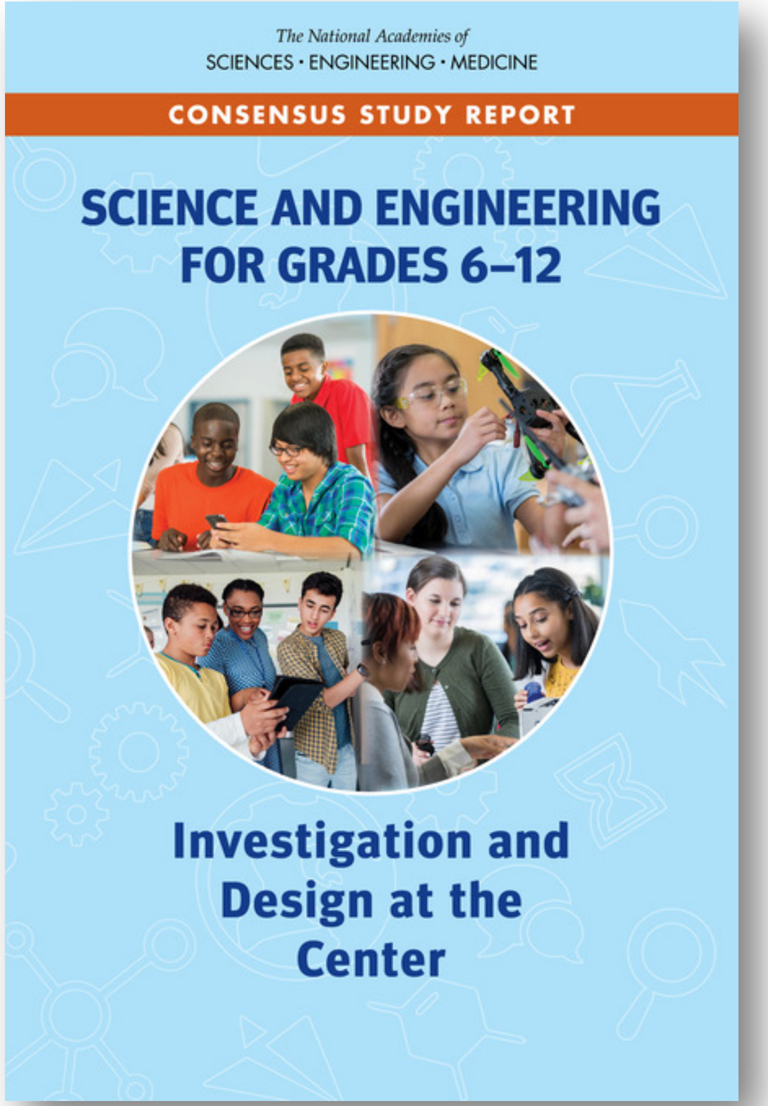
- We believe that *all* undergraduates are potential future teachers.
- We know that the science courses that enroll the most undergraduates are introductory-level, general education courses.
- These introductory courses and the faculty who teach them are the focus of our efforts.

How will we realize our vision?

- Establish guiding principles that help us implement investigation and design
- Support teams of faculty in developing and testing new curricular materials that engage students in investigation and design (TIDeS website)
- Produce new open educational resources for students (Visionlearning) that pair with curricular materials
- Develop a holistic view of what an undergraduate science course centered on investigation and design looks like

TIDeS guiding principles

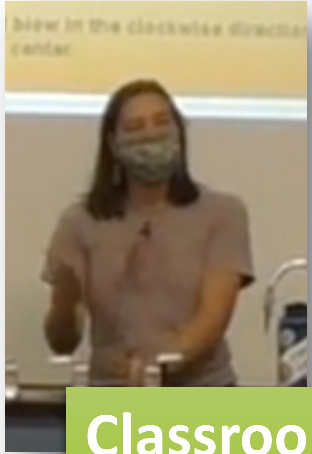
- Students will *engage in scientific investigation and engineering design* to deepen their understanding of core ideas.
- Faculty and the curricular materials they use will cultivate a learning environment where *all students are treated equitably*, have equal access to learning, and feel valued and supported in their learning.
- Students will *engage in addressing questions and solving problems* that are *relevant* to their lives.
- Students will *engage in authentic and meaningful scenarios* that make *use of real data and models* and reflect the actual practice of science and engineering.



Getting a holistic view

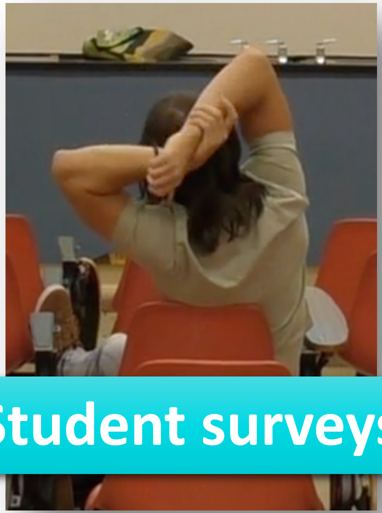
The research component of the project:

- How do instructor teaching practices differ between what they are doing now and with the new materials?
- How do instructor beliefs about teaching and learning change as they develop and implement new materials?
- How do student beliefs and attitudes change when they are learning in classrooms with the new materials?



Classroom observations
Syllabus analysis

Interviews



Student surveys

Rubrics that guide development

Instruments focused on instructors

Classroom Observation Protocol for Undergraduate STEM (COPUS)

(Smith et al., 2013)

- Quantifies what students are doing and what the instructor is doing every two minutes
- Can quantify and compare pre-/post- observations within project to test for change in teaching practice
- Can compare to STEM teaching more broadly to define investigation and design and how it differs from student-centered

Science Discourse Instrument (SDI)

(Fishman et al., 2017)

- Qualitative analysis of student-student and student-instructor interactions
- Deepens understanding of the quality of the quantitative observations
- Can compare pre-/post- analyses to test for change in teaching practice
- Can provide examples for use in professional development

Faculty beliefs interview

- Developed from Teacher Beliefs Interview *(Luft and Roehrig, 2007)*
- 7 questions, semi-structured, responsive interview protocol *(Rubin & Rubin, 2012)*
- Can compare pre- and post- interviews within project to explore change with intense professional development

Instrument focused on students

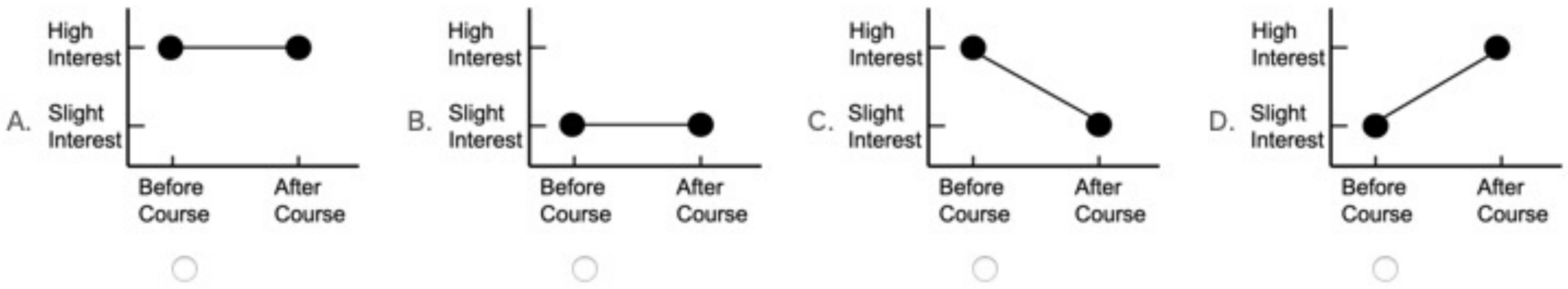
Beliefs in Investigation and Design Survey (BIDS)

- Pre-/post- course survey for students designed based on the InTeGrate Attitudinal Instrument (https://serc.carleton.edu/integrate/about/iai.html), knowledge surveys, beliefs surveys
- Beliefs questions
- Confidence questions
- Career questions (post- only)
- Demographic questions (pre-only)

The following items describe science and engineering-related tasks. Don't actually try to complete the tasks. Instead, rate your confidence in being able to address the task, or if you do not understand it.

	Highly confident	Somewhat confident	Not at all confident	I do not understand the task
I can evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based	○	○	○	○

Which of the following graphs most accurately depicts your level of interest in a career in **teaching** science or engineering before and after taking this course?



Instruments focused on materials

		STRENGTH OF PRESENCE				
	Criteria *(Must all be strong)*	**Strong**	**Moderate**	**Weak**	**Absent**	**Notes**
Guiding Principles	Courses engage students in scientific investigation and engineering design to deepen their understanding of core ideas.					
	Materials cultivate a learning environment where all students are treated equitably, have equal access to learning, and feel valued and supported in their learning.					
	Materials engage students in addressing questions and solving problems that are relevant to their lives.					
	Materials engage students in authentic and meaningful scenarios that make use of real data and models and reflect the actual practice of science and engineering.					
Learning goals and Objectives	**Criteria** *All must be at least moderate and at least 4 of 6 must be strong*	**Strong**	**Moderate**	**Low**	**Absent**	**Notes**
	Learning goals are expressed as performance expectations with practices as the verb (e.g., develop models, analyze data, construct explanations).					
	Learning objectives are sequenced to build towards the learning goals/performance expectations.					
	Learning objectives and goals explicitly support student use of data as evidence in constructing explanations.					
	Learning objectives and goals are appropriate for the intended use of the course/module					
	Learning objectives and goals are clearly stated in language suitable for the level of the students.					

Rubrics

- TIDeS materials development rubric, based on InTeGrate rubric *(Steer et al., 2019)*
- Visionlearning rubric for reading materials (https://www.visionlearning.com/en/)
- Syllabus rubric, based on rubric from UVA *(Palmer et al., 2014)*

That’s another talk.

Getting a holistic view

Timeline	Instructors *(n = 13)*			Course materials		Students
	Beliefs	*Practices*		*Activities*	*Readings*	*Beliefs*
	Faculty beliefs interview	**Classroom observations**	**Syllabus rubric**	**Materials rubric**	**Visionlearning rubric**	**BIDS**
Year 1: Recruiting	Development and pilot	Practice COPUS and SDI		Development	Development	Development and pilot
Year 2: Development	Initial interview (prior to intervention)	Observations of current practices	Analysis of current syllabus	Rubric use	Rubric use	Pre-/post-course survey in current courses
Year 3: Implementation		Observations with new materials	Analysis of new syllabus			Pre-/post-course survey in revised courses
Year 4: Revision and implementation	Final interview	Observations with new materials	Analysis of new syllabus			Pre-/post-course survey in revised courses
Year 5: New implementation	Interviews before and after		Analysis of old and new			Pre-/post-course survey

Hypotheses

These instruments in combination will:

- Provide a holistic picture of what teaching with investigation and design in introductory undergraduate science courses looks like
- Demonstrate how investigation and design differs from active learning
- Demonstrate and produce supports for instructors to implement new materials to better support future teachers

Image from Carnegie Mellon University: https://www.cmu.edu/engineering/materials/facilities/undergraduate/undergraduate-facilities.html

TIDeS

Teaching with Investigation and Design in Science

Learn more:

https://serc.carleton.edu/tides/index.html

Get in touch:

Anne.Egger@cwu.edu

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