Linking goals, assessment and teaching strategies to promote effective learning

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WHAT RESEARCH TELLS US ABOUT TEACHING AND LEARNING

DBER research results

EXPLORATION ACTIVITY

Three instructors taught an introductory physics course during the same semester.

- Prof. A emphasized concepts, careful, logical;
- Prof. B used demonstrations and took extra preparation time;
- Prof. C had a problem solving emphasis.

All used the same textbook and covered the same chapters. All professors received similar evaluations. Pre-test scores on a validated standardized test for each class were the same.

Predict which (if any) professor's class showed the greatest gain in post-test score.

Halloun, I.H. and D. Hestenes, American Journal of Physics, 1985. 53(11): p. 1043-1055.

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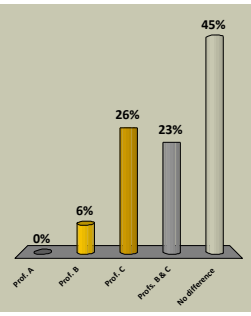
Predict which (if any) professor's class showed the greatest gain in post-test score.

A. Prof. A
B. Prof. B
C. Prof. C
D. Profs. B & C
E. No difference



WHAT DO THESE STUDENT COMMENTS SUGGEST ABOUT TEACHING & LEARNING?

I had a _____ professor who approached it from the level of the student and it was just the greatest course. A lot of them don't care of they don't know how a student learns. They just throw it on the board and expect everyone to be able to see it.

If everybody failed the test, then the teacher behaved as if no one was studying or knew their stuff. Why didn't he think that maybe the class was going too fast, or the test wasn't that good?

They just can't understand your questions. They don't understand why you don't understand, and they can't explain what they are telling you any other way. And they just look at you with this blank stare going, 'I don't understand what your problem is.'

The professor is *by far and away*, I think, the main determining factor in how well you do in a class, and how much you learn. I could give several examples of courses I've taken with one professor, which my room-mate had taken with another. And you'd think they were teaching two different subjects. It's definitely the teacher thing.

Seymour & Hewitt (1997), Talking about Leaving

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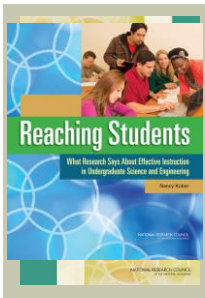
DISCIPLINE-BASED EDUCATION RESEARCH



DBER goals:

- Understand how people learn concepts, practices, and ways of thinking of science and engineering;
- Characterize the nature and development of expertise in a discipline;
- Identify, measure instructional strategies that advance student learning;
- Contribute to the knowledge base to help guide DBER findings to classroom practice;
- Identify approaches to make science and engineering education broad and inclusive.

National Research Council, 2012, Singer, Nielsen, & Schweingruber, (Eds.) National Academies Press.

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What DBER tells us about student learning

1. *Students learn key concepts better when they actively monitor their understanding in a variety of activities inside and outside of class (designed, structured activities).*
2. *Students become better learners when we challenge them to answer questions that require the use of higher order thinking skills.*
3. *Knowledge is socially constructed and people learn best in supportive social settings (e.g., in small collaborative groups).*
4. *Most students rely on ineffective learning strategies and are unaware of more effective techniques.*

Classes that support research-validated teaching strategies may be described as "reformed or student-centered or inquiry-based or active learning environments"

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Active Learning vs. Traditional Lecture

Active learning engages students in the process of learning through activities and/or discussion in class, as opposed to passively listening to an expert. It emphasizes higher-order thinking and often involves group work.

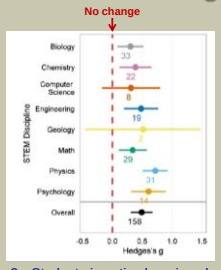
(Freeman et al, 2014)

http://www.ecampusnews.com/files/2010/10/classroom1.jpg

Traditional lecturing - Continuous exposition by the teacher. Student activity limited to taking notes and/or asking occasional, unprompted questions of the instructor.

Freeman et al., 2014, Proceedings of the National Academy of Sciences v.111, #23 p. 8410-8415.

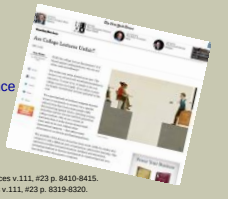
Active Learning vs. Traditional Lecturing



1. Failure rates (DFW) in active learning classes less than in traditional format, 34% → 22% (n=67 studies; 29,300 students)

2. Students in active learning classes out-performed those in traditional classes by ~6% on exams (n=158 studies)

3. Helps all students, reduces performance gaps



Freeman et al., 2014, Proceedings of the National Academy of Sciences v.111, #23 p. 8410-8415.
Wieman, 2014, Proceedings of the National Academy of Sciences v.111, #23 p. 8319-8320.

Student Activity and Learning

*Humans are not information storage machines who receive deliveries of information and store the deliveries in memory. Instead, **humans are sense-makers** who engage in active cognitive processes during learning such as selecting relevant words and pictures, organizing the selected materials into verbal and visual mental models, and integrating the verbal and visual models.*

Richard E. Mayer
Multimedia Learning, 2009, p.158

Adoption of Reformed Teaching Strategies

- Thirty years of DBER has reported gains in student learning that result from the application of research-validated teaching and learning practices
- Various agencies and organizations have called for broad adoption of reformed teaching strategies
- But these practices are far from pervasive in college (science) classrooms

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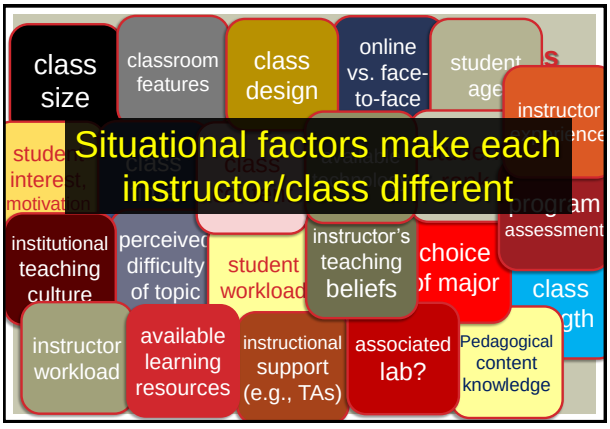
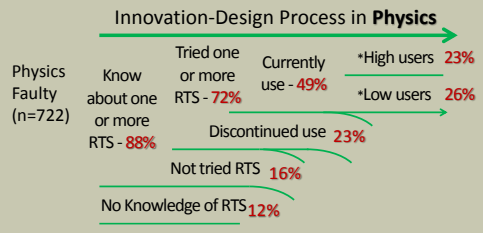
WHY NOT?



ADOPTION OF REFORMED TEACHING STRATEGIES



RTS = reformed teaching strategies
**High users = use 3 or more RTS*
**Low users = use 1 o 2 RTS*

(Henderson et al., 2012)

STUDENT REFLECTION:

Detour into the Minds of Your Students

Thinking about Learning

STUDENT ACTIVITY AND LEARNING

"When we asked students in the traditional class to anonymously write down what they had learned at the end of a particular lecture, one telling comment was:

I can't answer this. In class I just take notes. Then I go home and try to figure out what we talked about."

Student quote, Developmental Biology Class
(Knight & Wood, 2005, Cell Biology Education, v.4. p.298-310)

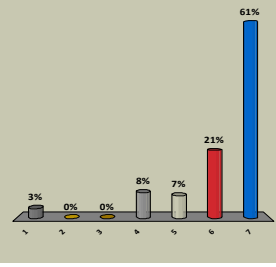
KNOWLEDGE SURVEY

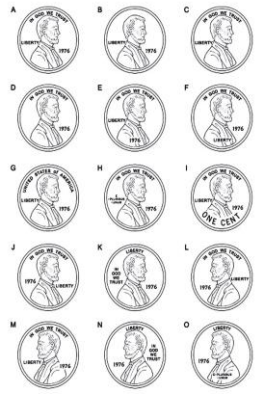
How confident are you that you can recognize a 1 cent coin?

Not confident 1 2 3 4 5 6 7 Very confident

How confident are you that you can recognize a 1 cent coin?

A. 1
B. 2
C. 3
D. 4
E. 5
F. 6
G. 7





Vision Test:

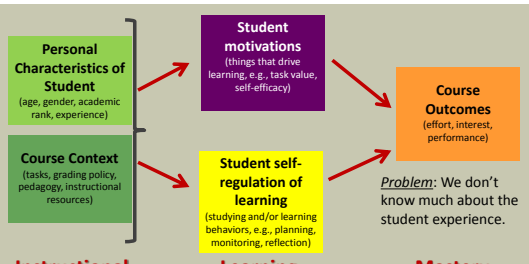
Which of these images is an accurate representation of a penny?

Knowledge Survey (Revised)

Given 15 different images of a penny, how confident are you that you could identify the correct image of a 1 cent coin?

Not confident 1 2 3 4 5 6 7 Very confident

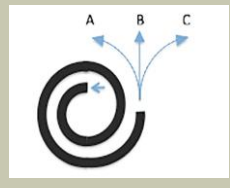
Factors that Influence Student Learning



Problem: We don't know much about the student experience.

Adapted from Pintrich, P. R., & Zusho, A. (2007).

Dunning-Kruger Effect



Imagine that the illustration represents a curved tube lying horizontally on a table.

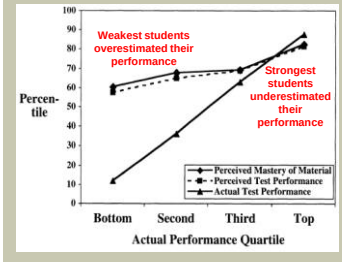
Identify the trajectory a ball would take after it had traveled through the tube.

When looking only at the confidence of people getting 100% vs. 0% right, it was often impossible to tell who was in which group.

Williams, Dunning, Kruger, 2013, Journal of Personality and Social Psychology, v. 104(6), p.976-994
Pacific Standard Magazine, We are all confident idiots, David Dunning, October 27, 2014

Importance of Student Reflection

Students completed a task (e.g., logical reasoning test) and estimated how their score would compare with other students.



Low scoring students

- overestimated their own skill level
- failed to recognize skill in others
- failed to recognize the degree of their insufficient knowledge
- recognized their lack of skill, *only if* they were trained to improve

Dunning et al., 2003. Current directions in psychological science, v.12 #3, p.83-87

Which of the following study strategies do your students use most frequently?

1. Self-explanation - explaining part(s) of their learning process, thus merging new information with prior knowledge
2. Summarization - writing a summary of material from class or readings
3. Practice testing - practice activity completed outside of class, can involve practice problems or even simple flashcards
4. Highlighting, underlining what they determine to be the important parts of the text as they read
5. Rereading - reading material that they have already read at least once before
6. Retrieval practice - reviewing material, practicing recall and retrieval of material by writing down as much information as possible
7. Distributed practice - distributing learning over time, typically days apart
8. Keyword mnemonic - associating an image that has some easily recognizable relation to the word that they are trying to remember

Dunlosky et al., 2013, Psychological Science in the Public Interest, v.14, #1, p.4-58.

Which of the following study strategies do your students use most frequently?

A. Self-explanation
B. Summarization
C. Practice testing
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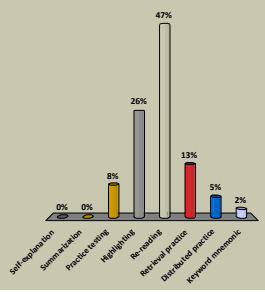
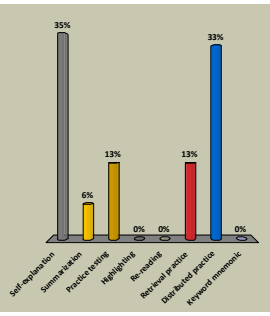


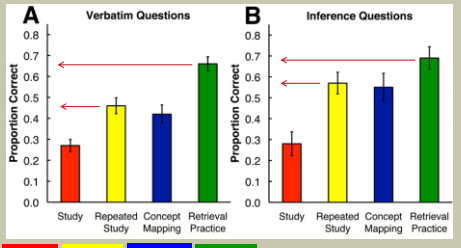
Research shows . . . which study strategies improve student learning?

A. Self-explanation
B. Summarization
C. Practice testing
D. Highlighting
E. Re-reading
F. Retrieval practice
G. Distributed practice
H. Keyword mnemonic



Retrieval Practice

Research on learning shows that **retrieval practice is the most effective study method**: Most students don't know this



Read once | Read 4 separate times | Read, make concept map | Read, try retrieval, repeat

Karpicke, J.D., and Blunt, J.R., 2011, Science Express, January 20, p.1-7.

Retrieval Practice

WHAT IS RETRIEVAL PRACTICE?

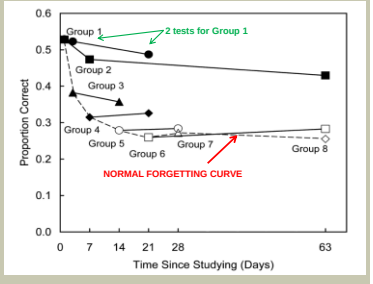
- Review material for initial study period
- Put material away and on a blank piece of paper practice retrieval by recalling and writing down as much information as possible.
- Review material and practice retrieval again
- Do it the first time during or within a few hours of original lesson
- Repeat retrieval process at regular intervals prior to exam (e.g., weekly)

http://animaltheory.blogspot.com/2012/02/labrador-retrievers.html

WHY DOES THAT WORK?

Educational psychology research shows that feedback helps embed learning in long-term memory:

- Think-Pair-Share
- ConcepTests
- Concept Sketches
- Concept Maps
- Venn Diagrams
- Lecture Tutorials
- Minute Papers
- Demo predictions
- Classroom Notebooks



Roediger & Karpicke, 2006

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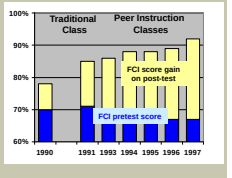
FORMATIVE ASSESSMENT STRATEGIES

Peer instruction (& Conceptests)

Development of technique by Eric Mazur, Harvard

- ✓ Short lecture (10-20 minutes)
- ✓ Conceptest – conceptual multiple choice question
- ✓ Individual students signal answers (clickers)
- ✓ Student groups may discuss answers (peer instruction)
- ✓ Explanation of correct answer



Mazur, E., 1997, Peer instruction: A user's manual: Prentice Hall, 253p.

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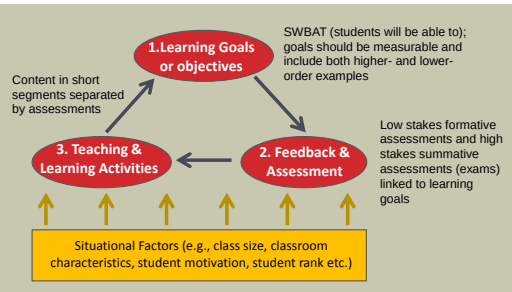
NOW YOU DO IT

1. Take two minutes to summarize the principal ideas from the presentation so far.
2. Compare your notes with a neighbor.

How can we embed these practices in our classes?

BACKWARD COURSE/LESSON DESIGN



Creating Significant Learning Experiences: An Integrated Approach to Designing College Courses, L. Dee Fink, 2003

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STUDENT ACTIVITY AND LEARNING

A traditional science instructor concentrates on teaching factual knowledge, with the implicit assumption that expert-like ways of thinking about the subject come along for free or are already present. But that is not what cognitive science tells us. It tells us instead that students need to develop these different ways of thinking by means of extended, focused, mental effort.

C. Wieman, Nobel Prize winner, Change, 2007, Sept/Oct, p. 9-15.

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OBSERVATION: IT IS DIFFICULT FOR INSTRUCTORS IN LARGE CLASSES TO RECOGNIZE STUDENT LEARNING DIFFICULTIES WITHOUT ONGOING FORMATIVE ASSESSMENT STRATEGIES.

More instructor understanding of student learning

Learning assessment

Less instructor understanding of student learning

Understanding Student Learning

- On-going assessment through student dialog in small classes
- Instructor grading of short answer and essay questions
- Computer grading of multiple choice questions using bubble-sheets

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FEEDBACK & ASSESSMENT

Assessment - activities that are undertaken to provide information to be used as feedback to modify teaching and learning practices

- ***Formative assessment*** – low stakes/no stakes, evidence used to measure how well students are learning and to help the teacher to improve ongoing instruction
  - Small group discussion exercises (Think-Pair-Share)
  - Conceptests (group vote/class meta-analysis)
  - Student worksheets, minute papers
- ***Summative assessment*** - the use of data, assembled at the end of particular sequence of activities, to provide an overview of learning

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STRATEGIES THAT SUPPORT STUDENT LEARNING

Provide assessment and feedback opportunities during class:

- Reading Quizzes
- Think-Pair-Share
- ConcepTests
- Concept Sketches
- Concept Maps
- Venn Diagrams
- Lecture Tutorials
- Minute Papers
- Classroom Notebooks

Create an environment that fosters learning to learn[1]

- Provide assessments that encourage effort (e.g., allow for revisions)
- Provide visual, graphic and organizational structures to help students "chunk" information (e.g., graphic organizers, concept maps, reading reflections)

[1]Based on research findings from Zimmeran, B. J. (1989); Kaatje Kraft, pers. comm.

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What does it all mean for instructors?

Instructors may facilitate learning by providing:

- Clear learning objectives
- Assessments linked to learning objectives
- Regular assignments with feedback
- Opportunities to explicitly reflect on learning processes
- Explicit directions on strategies for studying

Lukes, 2014

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How are the geosciences doing?

Teaching in the discipline

On the Cutting Edge PD Program

On the Cutting Edge
Professional Development for Geoscience Faculty 2012-13

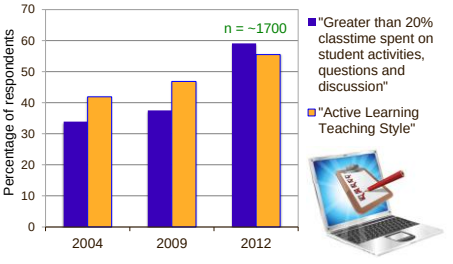
- 12 year professional development program
- 118 workshops/events
- Attended by 1800 geoscience faculty, 600 graduate students/post-docs

On the Cutting Edge
Professional Development for Geoscience Faculty 2012-13

On the Cutting Edge

Geoscience Faculty Survey

- Active learning becoming more common in geoscience classrooms



Measuring Teaching Practices

Reformed Teaching Observation Protocol[1]

- Describes teaching process on five subscales
  - Lesson design by instructor
  - Propositional knowledge of instructor
  - Procedural knowledge (what students do)
  - Student-Student Interactions
  - Student-Teacher Interactions
- Five statements per subscale; total scores 0-100

Observer perspective

18) There was a high proportion of student talk and a significant amount of it occurred between and among students (quantity of interactions)				
No student-student talk 0	Students talk to each other at least once (about lesson content) 1	Student-student talk occurs at least 10% of the time during the course of the class 2	Student-student talk occurs more than 25% of the time during the course of the class 3	In any given moment during the lesson, students are more likely to be talking to each other than the teacher (>50% student to student) 4

[1]Sawada et al., 2002; MacIsaac and Falconer, 2002

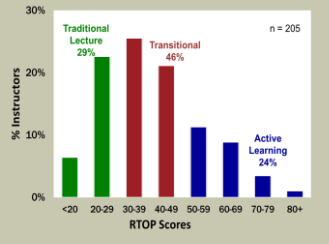
Measuring Teaching Practice

Reformed Teaching Observation Protocol[1]

- Maximum score = 100
- Reformed classrooms featuring more active learning practices have higher RTOP scores

Budd et al. (2013)
26 instructors, 66 classes
Average RTOP score = 41.5

Classroom Observation Project
205 instructors/classes
Average RTOP score = 39.7



[1]Sawada et al., 2002; MacIsaac and Falconer, 2002; Budd et al., 2013

Observed Teaching Practices

	Most Traditional Lecture n=10	Mean Traditional Lecture n=10	Mean Transitional Lecture n=22	Mean Active Learning n=12	Most Active Learning n=11
No/few questions asked by instructor	50%	27%	0%	0%	0%
No/few questions from students	60%	36%	9%	0%	0%
Students are passive/not asked to do anything	70%	36%	4%	0%	0%
No student-student interaction/ conversation	70%	80%	32%	0%	0%
Student-student interactions or group work	0%	9%	59%	100%	91%
Students read graphs, maps, use data	20%	27%	27%	67%	45%
Students answer open-ended questions	0%	0%	4%	17%	45%
Instructor assesses students (new or prior knowledge)	10%	18%	18%	33%	45%
Lesson adjustments based on student work or prior knowledge	0%	0%	9%	33%	54%

What explains these differences?

How many of these statements are TRUE?

i. RTOP scores varied between introductory and majors courses.

ii. RTOP scores varied among different types of academic institutions.

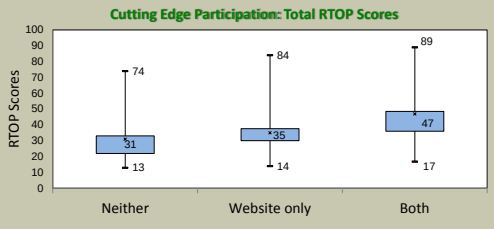
iii. RTOP scores were statistically different for full professors and assistant professors.

iv. RTOP scores were higher for instructors who had participated in significant professional development.

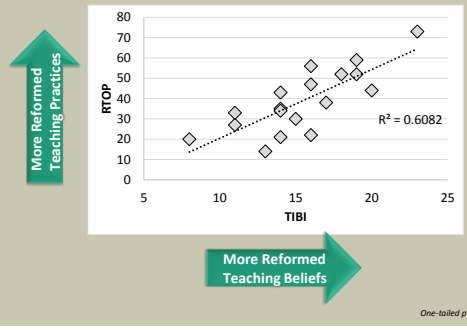
A. 1
B. 2
C. 3
D. 4

PD Participation vs. RTOP scores

How did participation in OtCE events and use of web resources impact teaching practice?



Teaching Practices vs. Teaching Beliefs



One-tailed p value: <0.005

InTeGrate
Interdisciplinary Teaching about Earth for a Sustainable Future

InTeGrate: Interdisciplinary Teaching about Earth for a Sustainable Future

- *NSF STEP Center = STEM Talent Expansion Program*
- Focused on undergraduate education

Two required goals:

- National impact on increasing number of students in STEM pipeline
- Address a national grand challenge: in InTeGrate's case, environmental sustainability and resource limitations.

http://serc.carleton.edu/integrate/

InTeGrate Curriculum Development & Revision Rubric

Guiding principles:

- Grand challenge facing society
- Interdisciplinary problem solving
- Geoscientific habits of mind
- Authentic geoscience data
- Systems thinking

Pedagogical excellence:

- Learning objectives & goals
- Assessment & measurement
- Resources & materials
- Learning strategies
- Alignment of module/course elements

http://serc.carleton.edu/integrate/

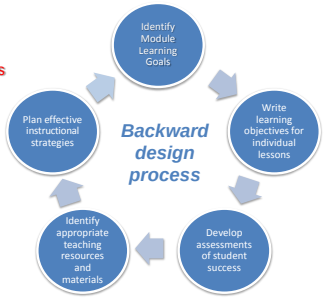
InTeGrate
Interdisciplinary Teaching of Geoscience for a Sustainable Future

InTeGrate Materials Development Process

Pass Assessment Rubric

- Overarching Goals
- Learning Objectives & Outcomes
- Assessment & Measurement
- Resources & Materials
- Instructional Strategies
- Alignment

Pilot Materials
Use data to make changes



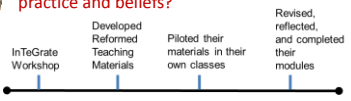
InTeGrate
Interdisciplinary Teaching of Geoscience for a Sustainable Future

Case Study on Instructional Change

InTeGrate Materials Development

Teams of authors spent 1-2 years creating new resources for their courses. They received instruction on pedagogy through workshops and webinars and feedback about their lessons from a team of coaches and assessment specialists.

Did it have an impact on their teaching practice and beliefs?



Coached by curriculum and pedagogy experts

InTeGrate
Interdisciplinary Teaching of Geoscience for a Sustainable Future

Case Study on Instructional Change

11 Modules/6 units each

- Earth's Mineral Resources
- Climate of Change
- A Growing Concern (Soils)
- Living on the Edge (Earthquakes, volcanoes)
- Hazards and Risk: Hurricanes
- Environmental Justice & Freshwater
- Carbon, Climate & Energy
- Systems Thinking
- Changing Biosphere
- Oceans Sustainability
- Earth's Thermostat

InTeGrate Materials Development

Data collection instruments

- Reformed Teaching Observation Protocol (RTOP)[1] — Teaching Practices
- Teacher Beliefs Interview (TBI)[2] — Teaching Beliefs
  - Scored 7-35

[1] Sawada and Piburn., 2002; [2] Luft and Roehrig, 2007

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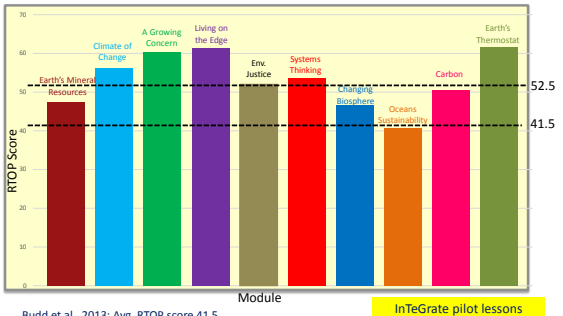
Teaching Practice Data

(Average RTOP score per module)



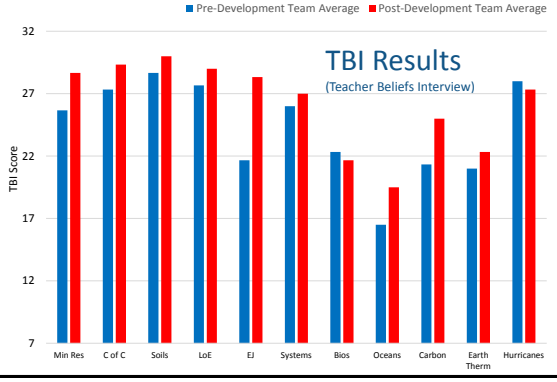
Budd et al., 2013: Avg. RTOP score 41.5
COP, 2015: Avg. RTOP score 39.7

InTeGrate pilot lessons
Avg. RTOP score 52.5

InTeGrate
Interdisciplinary Teaching about Earth for a Sustainable Future

TBI Results

(Teacher Beliefs Interview)



WHY DID THAT WORK?

Characteristics of Successful Materials Development:

1. Deliberate focus on changing instructor conceptions about teaching and learning.

3. Sustained, focused efforts, lasting weeks, months or longer.

2. Instructors apply new knowledge and/or skills to create teaching and learning activities.

4. Instructors receive feedback on teaching materials and practices (and observe others).

Garet et al., 2001; Henderson et al., 2011; NRC, 2012

What Did We Learn?

Discipline-based education research:

1. . . can show us how to improve student learning
2. . . but it is hard to make changes without sufficient time, access to resources, and institutional/community support
3. . . which are becoming more readily available across STEM disciplines
4. . . and will allow instructors the autonomy to design courses best suited to the characteristics and interests of their students.