Creating a Coherent STEM Gateway for Teaching and Learning: An AAU STEM Initiative Project

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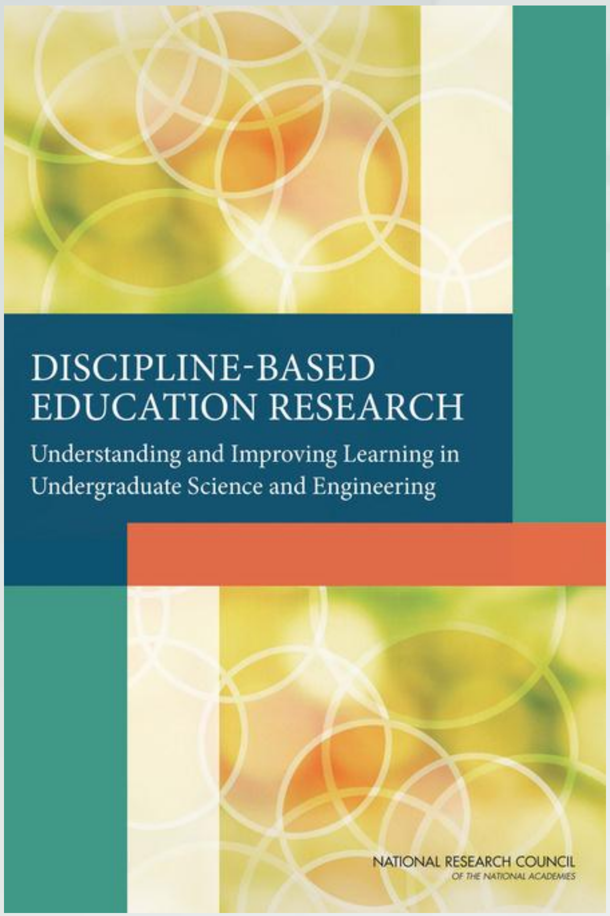
Transforming Institutions Conference

October 24, 2014

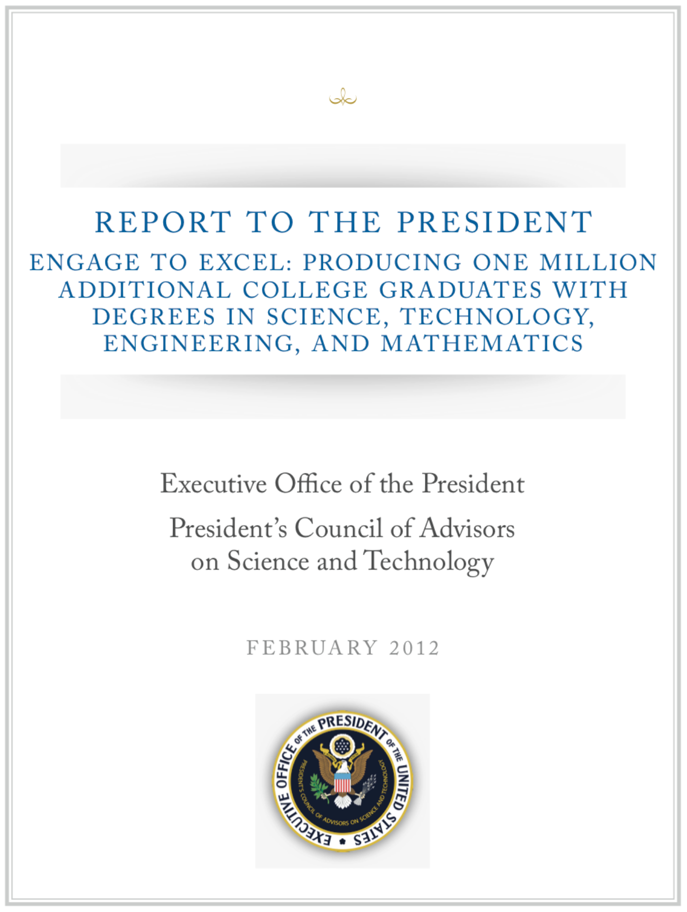
Discipline-Based Education Research



“DBER and related research have not yet prompted widespread changes in teaching practice among science and engineering faculty. Strategies are needed to effectively promote the translation of findings from DBER into practice.”

Gateway Courses

"The first two years of college are the most critical to the retention and recruitment of STEM majors."


REPORT TO THE PRESIDENT

ENGAGE TO EXCEL: PRODUCING ONE MILLION ADDITIONAL COLLEGE GRADUATES WITH DEGREES IN SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS

Executive Office of the President

President's Council of Advisors on Science and Technology

FEBRUARY 2012

Traditional Gateway Curriculum

AAU STEM Education Initiative

The goal of this program is “to improve the quality of undergraduate teaching and learning in science, technology, engineering, and mathematics (STEM) fields.”

The MSU “AAU Project”

- Creating a coherent STEM gateway at Michigan State University
  - STEM Alliance
  - STEM Gateway Fellowship
  - Disciplinary Discussions

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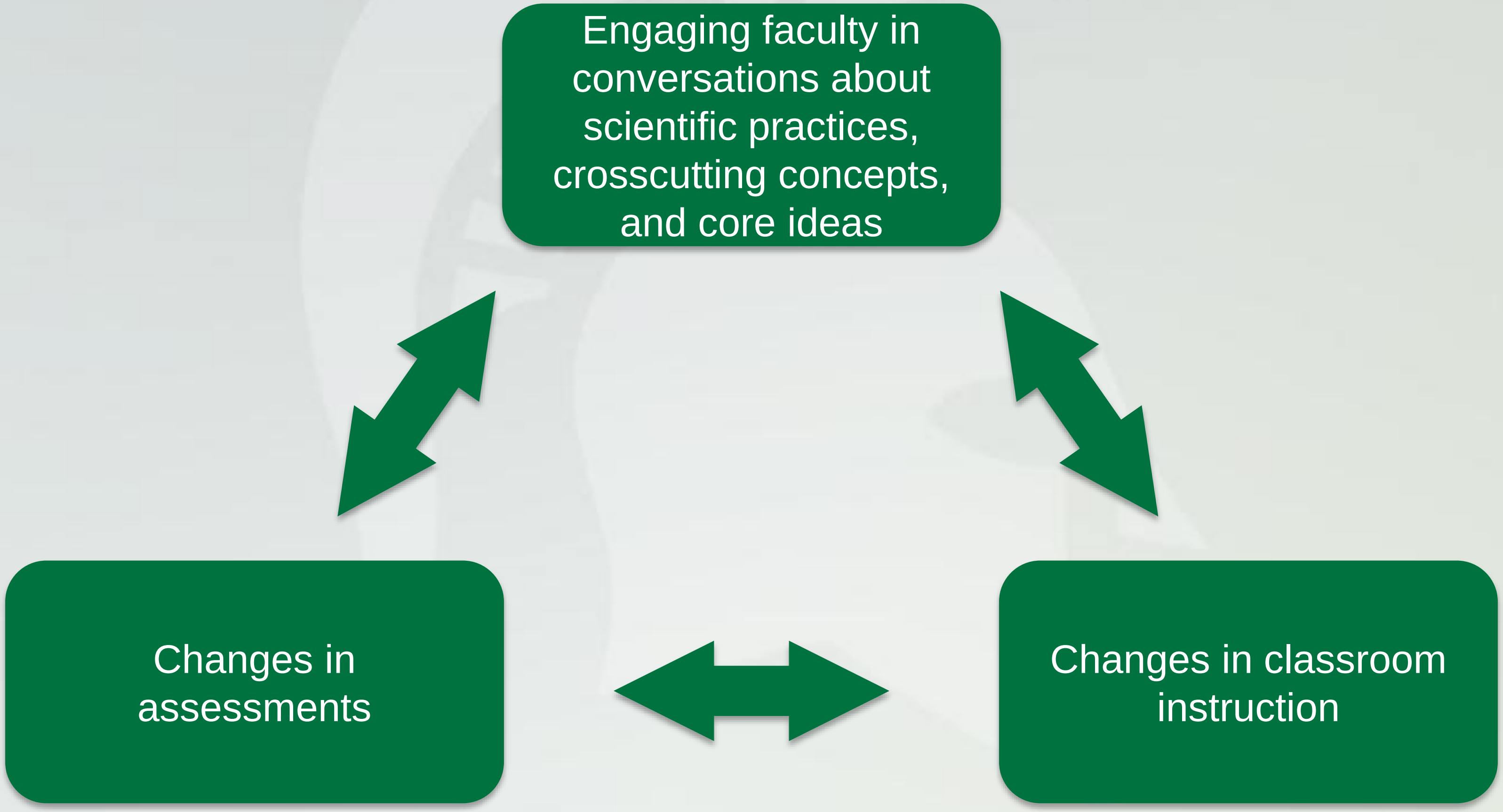
Disciplinary Discussions



NRC. (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas.* Washington DC: The National Academies Press.

Scientific Practices

1. Asking questions
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Crosscutting Concepts

1. Patterns
2. Cause and effect: Mechanism and explanation
3. Scale, proportion, and quantity
4. Systems and system models
5. Energy and matter: Flows, cycles, and conservation
6. Structure and function
7. Stability and change

Definition of Core Ideas

1. Essential to the study of the discipline
2. Required to explain lots of phenomena
3. Provide a way to learn new ideas and generate predictions

Disciplinary Core Ideas

- Physics
  - Energy, Heat, & Work
  - Charge & Current
- Chemistry
  - Matter is composed of atoms
  - Molecular structure predicts macroscopic properties
- Biology
  - Evolution
  - Cell Theory of Life

Goals

Scientific Practices

Crosscutting Concepts

Disciplinary Core Ideas

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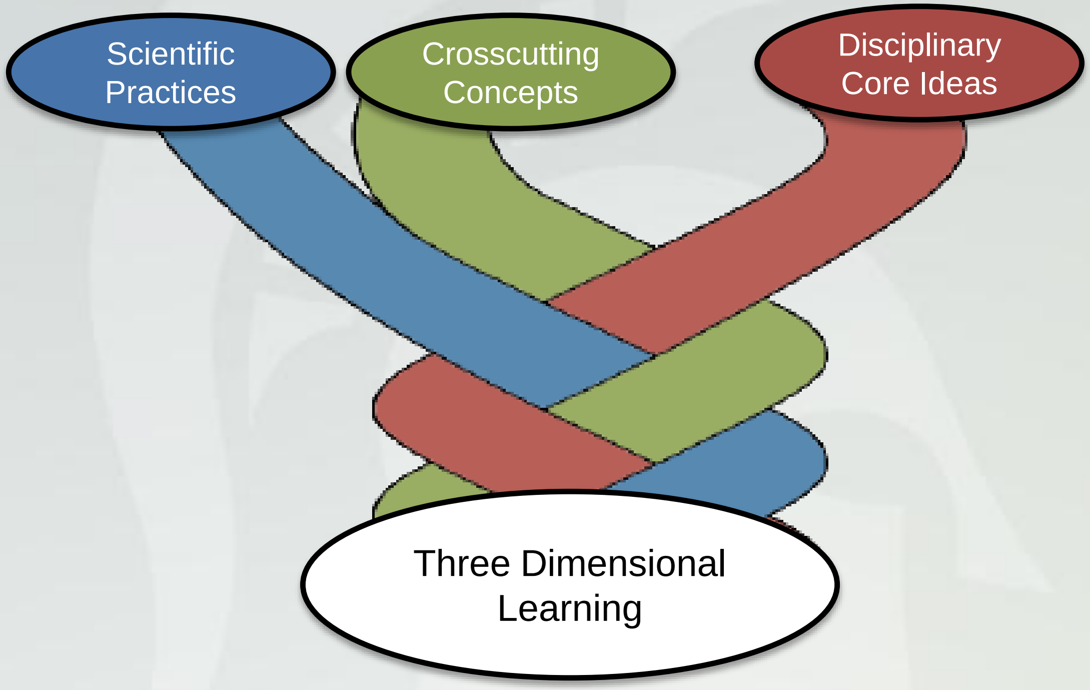
Goals



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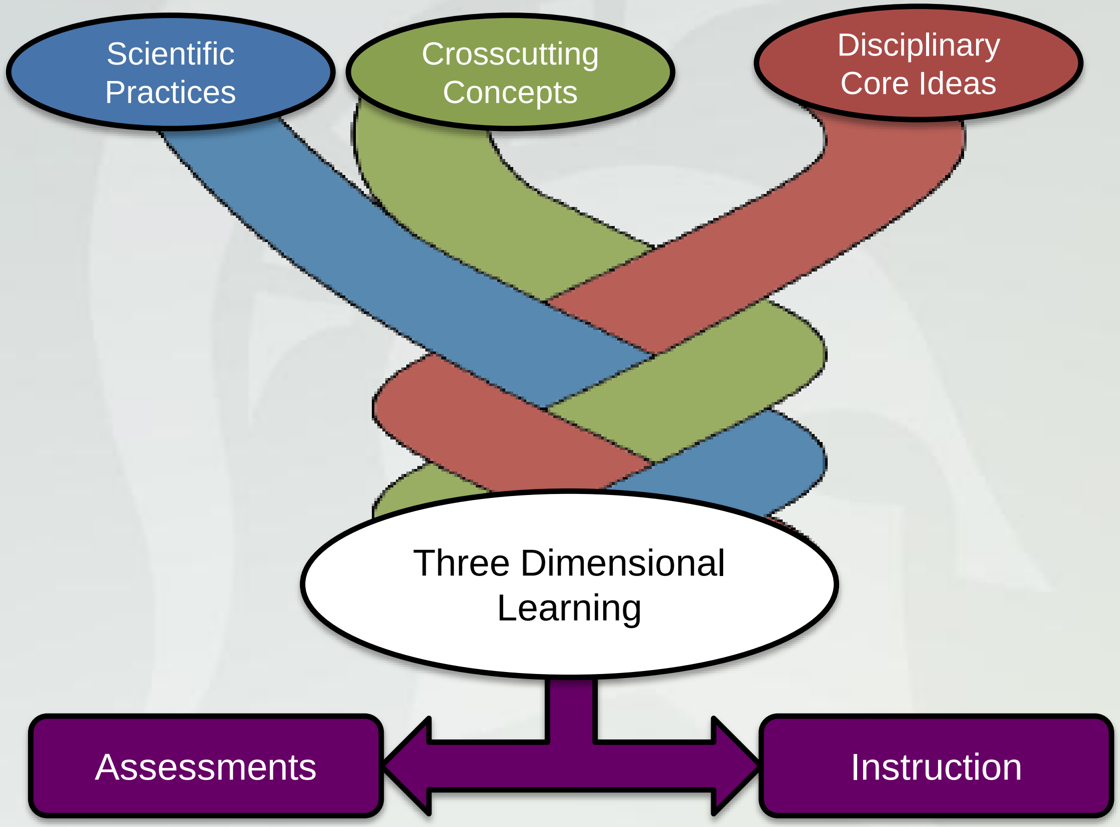
Goals



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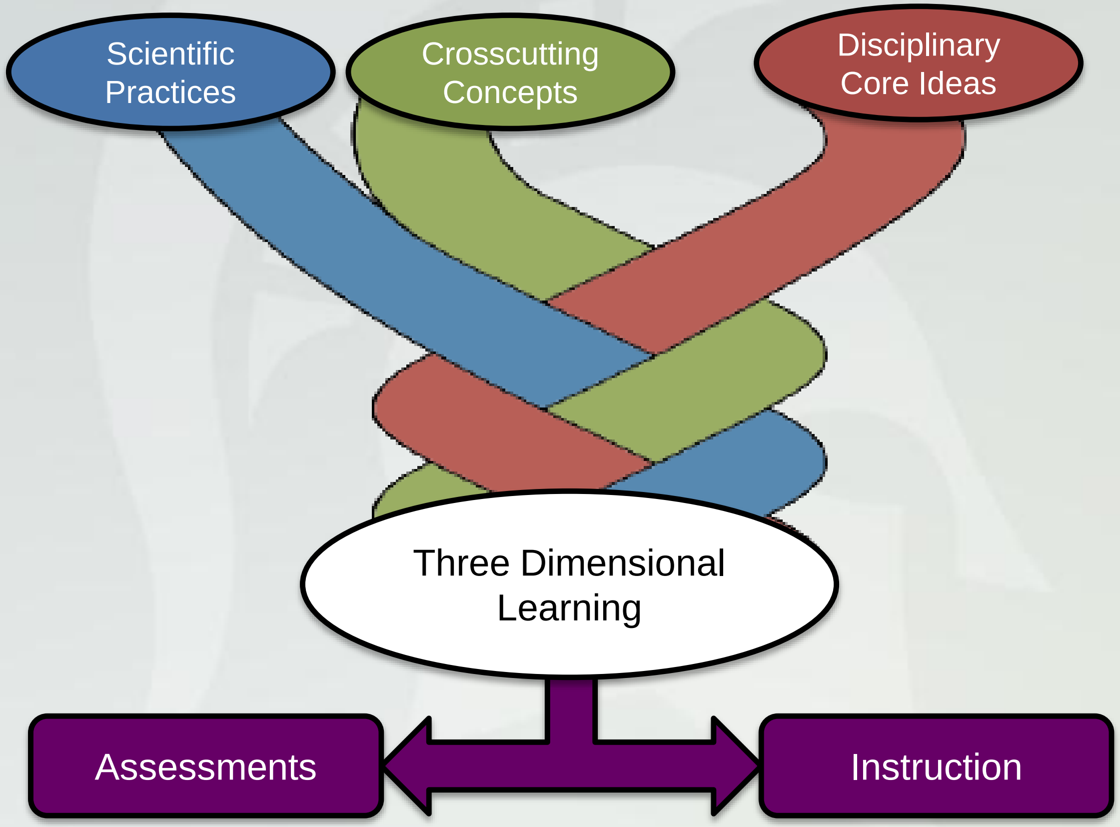
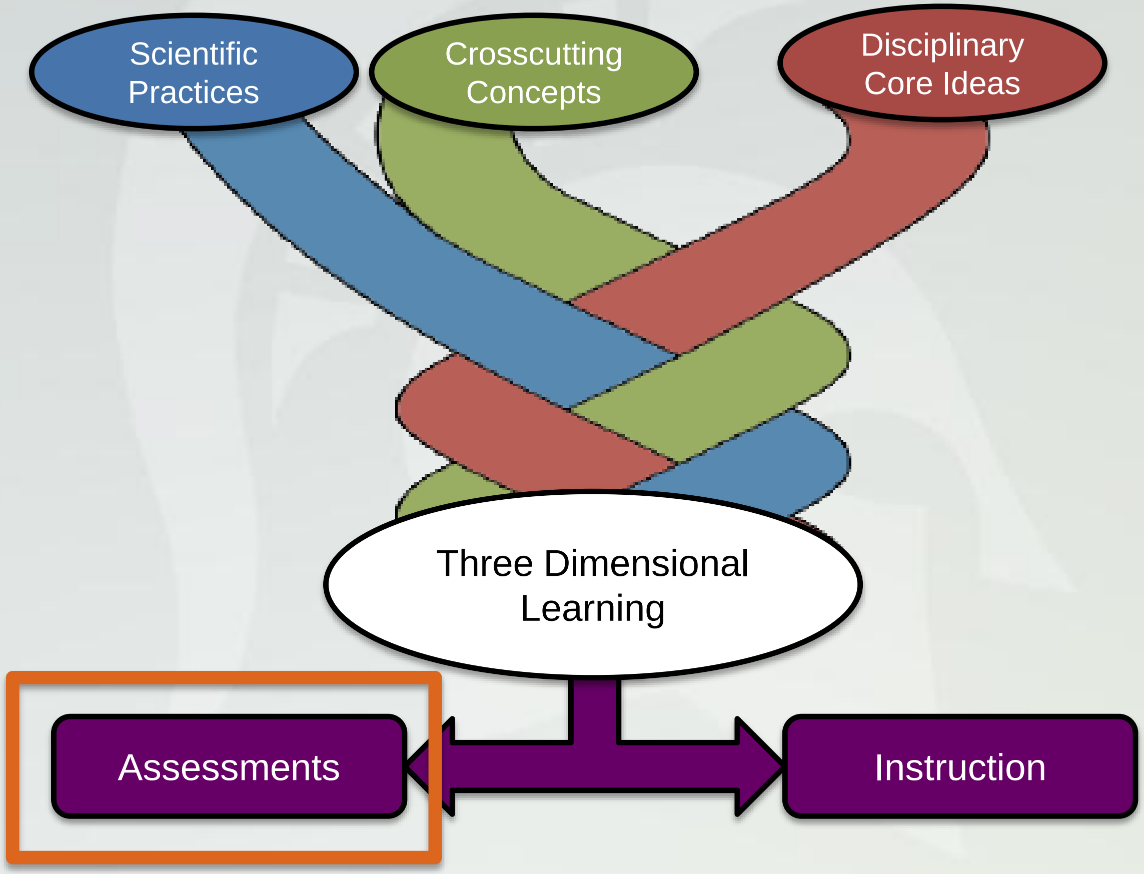
How do we measure success?

Goals


Scientific Practices
Crosscutting Concepts
Disciplinary Core Ideas
Three Dimensional Learning
Assessments
Instruction

Characterizing Assessments



Importance of Assessment

"*to educate and improve* student performance, not merely to *audit* it"

Wiggins, G. (1998). *Educative assessment*: *Designing assessments to inform and improve student performance.* San Francisco, CA: Jossey-Bass

"*if you don't assess what's important, what's assessed* ***becomes*** *important*"

Lauren Resnick

21. Start with the number of protons in the nucleus of a lithium atom

… multiply by the number of 3s electrons in a magnesium atom in its ground state

… add the number of unpaired electrons in an oxygen atom in its ground state

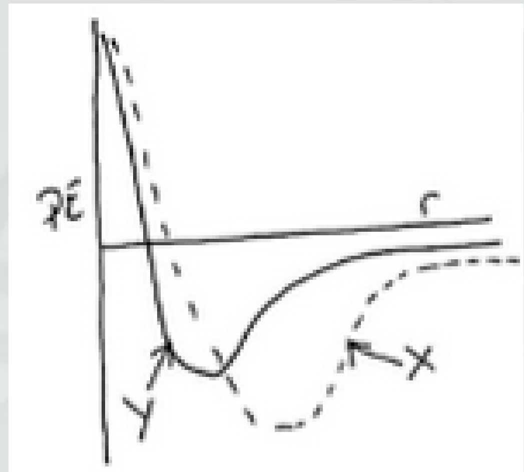
… subtract the number of π orbitals in a triple bond

… add the number of neutrons in the nucleus of the ^{14}C isotope

What is the result?

a. 6	c. 10	e. 12	g. 14	i. 16
b. 8	d. 11	f. 13	h. 15	j. 18

In the diagram below, which curve would represent the substance with the highest boiling point?



A. X because the particles interacting must be heavier, therefore they are harder to move into the gas phase.

B. X because the potential well is deeper, therefore more energy must be added to separate the particles.

C. Y because the particles are smaller and fit together better, therefore more energy must be added to separate the particles.

D. Y because the atoms are lighter, therefore they should be easier to move around.

How can we measure change in assessments over time?

Three Dimensional Learning Assessment Protocol: 3D – LAP

Characterize assessment questions

Assist in rewriting exam questions

Part 1: Assessing 3D Learning

Scientific Practices (SP)

Yes/No?

If yes, which SP?

Explicit/Implicit?

Part 1: Assessing 3D Learning

Scientific Practices (SP)

Yes/No?

If yes, which SP?

Explicit/Implicit?

Crosscutting Concepts (CC)

Yes/No?

If yes, which CC?

Explicit/Implicit?

Part 1: Assessing 3D Learning

Scientific Practices (SP)	Yes/No? If yes, which SP? Explicit/Implicit?
Crosscutting Concepts (CC)	Yes/No? If yes, which CC? Explicit/Implicit?
Disciplinary Core Ideas (DCI)	Yes/No? If yes, which DCI? Explicit/Implicit?

Part 2: Question Quality

Identify if the question:

MC or open-ended

Situated in a phenomenon

Provide explicit information about student understanding

Meets accepted practices for valid item construction

Discarded, requires major revision, requires minor revision, revision with addition of more questions, use as is with additional questions, use as is

Example of argumentation

Which is a stronger base? CH_3OH or CH_3NH_2?

- CH_3NH_2

- Claim

Example of argumentation

Which is a stronger base? CH_3OH or CH_3NH_2?

- CH_3NH_2 because N is less electronegative than O

- Claim
- Scientific Principle

Example of argumentation

Which is a stronger base? CH_3OH or CH_3NH_2?

- CH_3NH_2 because N is less electronegative than O and therefore is better able to donate a lone pair into a bond with an acid.

- Claim
- Scientific Principle
- Reasoning

Possible Exam Question

Which is a stronger **base**? CH_3NH_2, or CH_3OH

A. CH_3NH_2, because N is more electronegative than O, and therefore is not as able to donate its lone pair into a bond with an acid.
B. CH_3NH_2, because N is less electronegative than O, and therefore is better able to donate its lone pair into a bond with an acid.
C. CH_3OH, because O is more electronegative than N, and therefore is not as able to donate its lone pair into a bond with an acid.
D. CH_3OH, because O is less electronegative than N, and therefore is better able to donate its lone pair into a bond with an acid.

Dimension	Present?	Type
SP	Yes (explicit)	Engaging in argumentation
CC	Yes (explicit)	Cause and Effect
DCI	Yes (explicit)	Molecular Structure and properties

Compare traditional and transformed exams

	Traditional Exam Questions																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
SP																				
CC																				
DCI																				

	Transformed Exam Questions																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
SP																								
CC																								
DCI																								

Implicit SP

Explicit SP

Implicit CC

Explicit CC

Implicit DCI

Explicit DCI

How can we maximize the ability to assess 3D learning?

Make clusters of questions

Another chemistry exam using the 3D-LAP

	Exam Question Number																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Scientific Practices																								
Crosscutting Concept																								
Disciplinary Core Ideas																								

National Research Council. Developing Assessment for the Next Generation Science Standards. Washington, DC: The National Academies Press, 2013.

Question 1 in cluster

18. When a bond between two atoms is broken:
    A. Energy is released to the surroundings
    B. Energy is absorbed from the surroundings
    C. The kinetic energy of the system increases
    D. The energy of the two atom system does not change because energy can neither be created nor destroyed

Question 2 in cluster

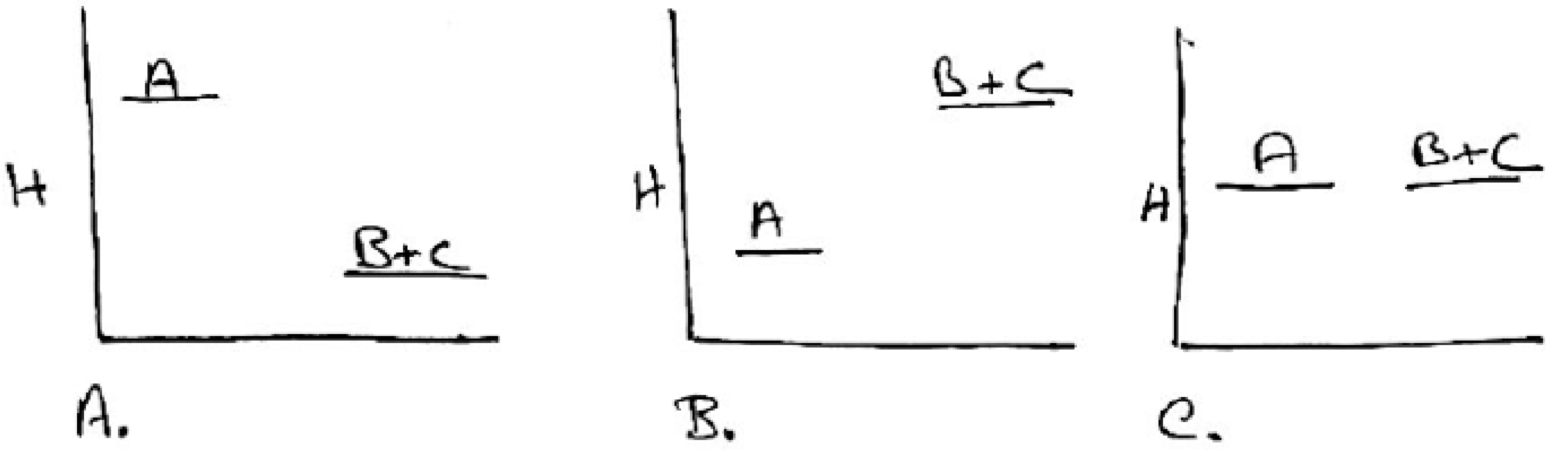
19. What is the enthalpy change for this reaction? (use the table of average bond energies to calculate)

$$C_2H_4 + HBr \rightarrow CH_3CH_2Br$$

A. –58 kJ/mole
B. –326 kJ/mole
C. +326 kJ/mole
D. +58 kJ/mole

Question 3 in cluster

20. The reaction A → B + C has an enthalpy change of +286 kJ/mol.
Which reaction energy diagram is most likely to represent this energy change?



D. It depends on the temperature.

Question 4 in cluster

21. For the reaction in Question 20 (above), which statement is true?
    A The reaction is **exothermic** and the bond strengths (Bond dissociation energies) of the **products** are greater than the **reactants.**
    B. The reaction is **endothermic** and the bond strengths (Bond dissociation energies) of the **products** are greater than the **reactants.**
    C. The reaction is **exothermic** the bond strengths (Bond dissociation energies) of the **reactants** are greater than the **products.**
    D. The reaction is **endothermic** the bond strengths (Bond dissociation energies) of the **reactants** are greater than the **products.**

Another chemistry exam using the 3D-LAP

	Exam Question Number																							
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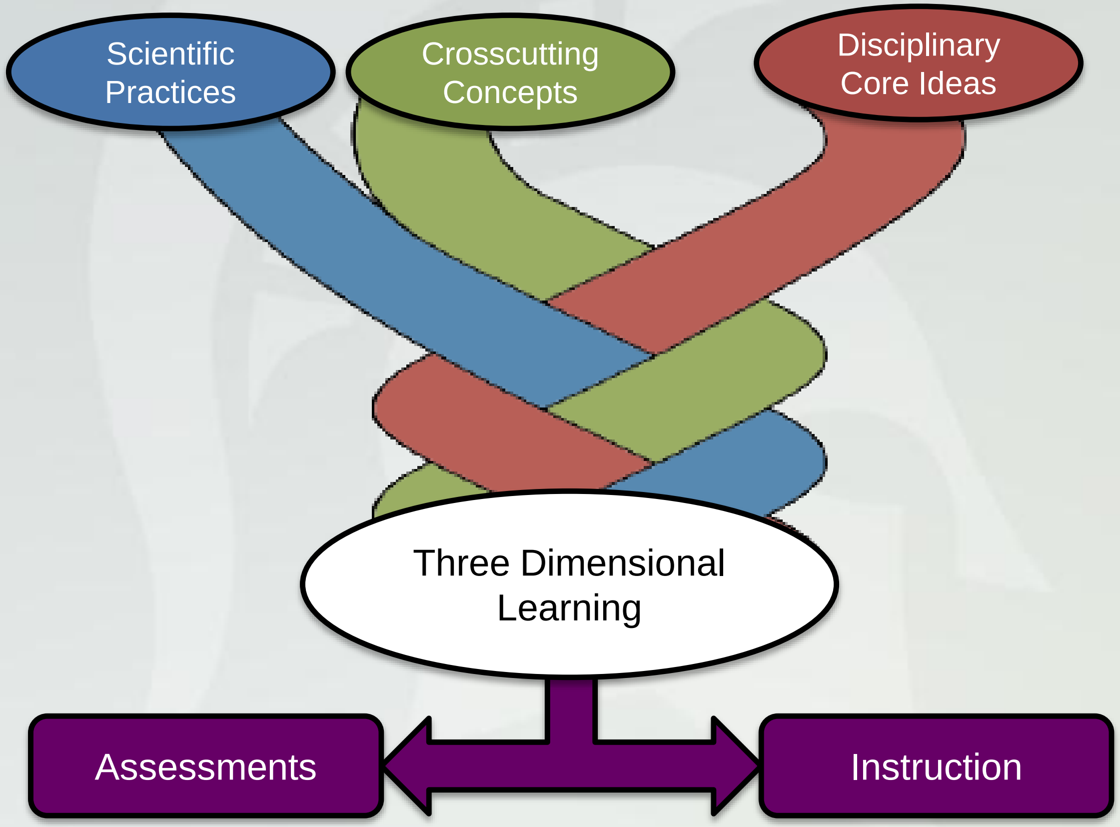
Goals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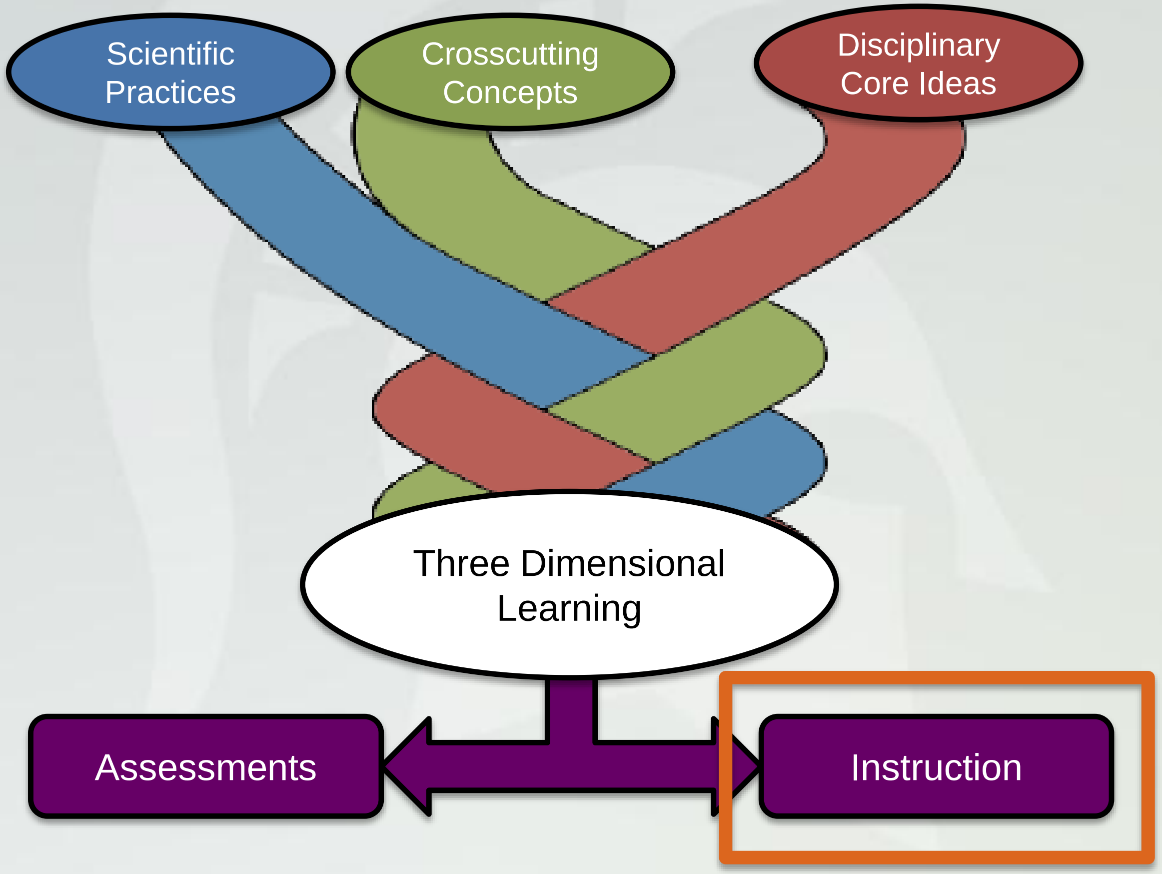
Characterizing Instruction



Existing Observation Protocols

- Such as TDOP, RTOP, COPUS, etc.
- Focused on “How” the class is taught
- Don’t tell you about “What” is being taught

Three-Dimensional Learning Observation Protocol (3D-LOP)

"How"

1. Clicker Questions
2. Tasks
3. Interactions
4. Lecture
5. Administration
6. Miscellaneous

- Instructor Questions
- Students Speaking

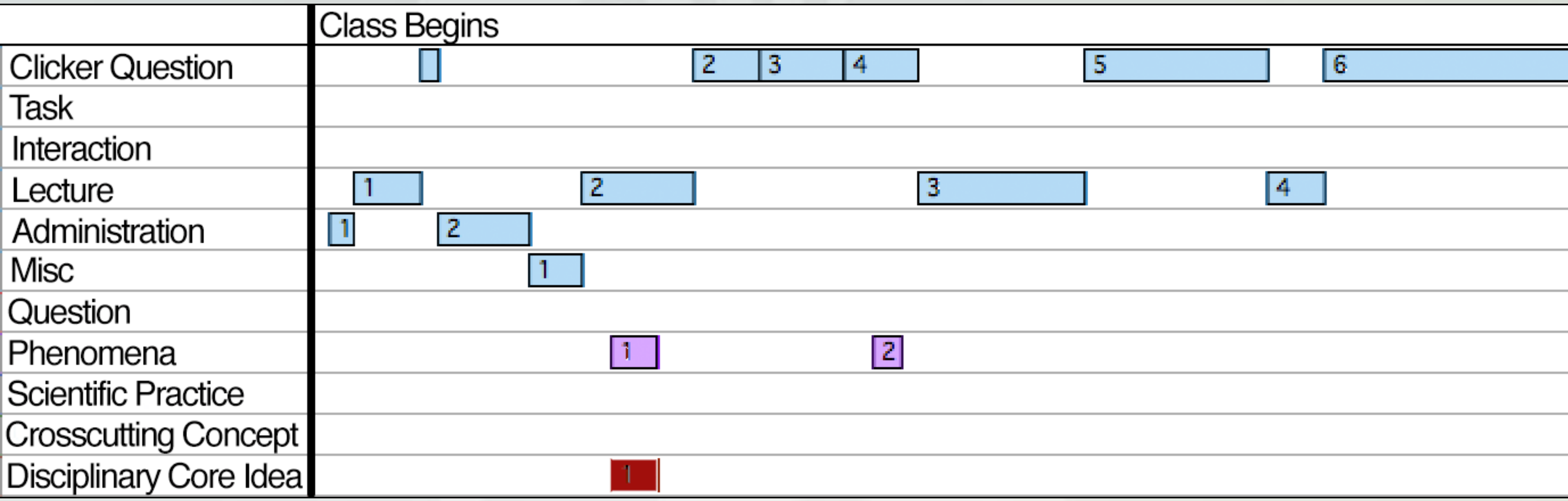
"What"

- Scientific Practices
- Crosscutting Concepts
- Disciplinary Core Ideas

- Phenomena

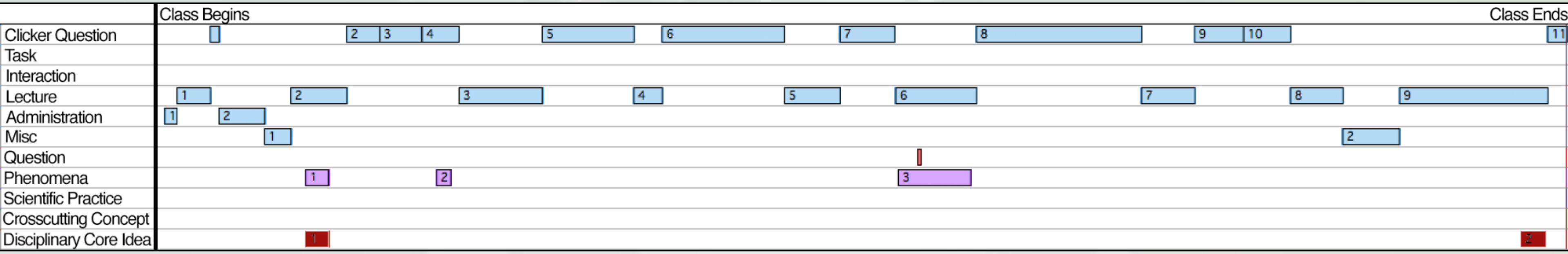
The 3D-LOP

First half of class



The 3D-LOP

Whole class



Conclusions

- Both “what” and “how” we teach are important
- The 3D-LAP characterizes assessments in meaningful ways
- The 3D-LOP characterizes both the “what” and “how” of instruction

Acknowledgements: the MSU AAU team

- Melanie Cooper
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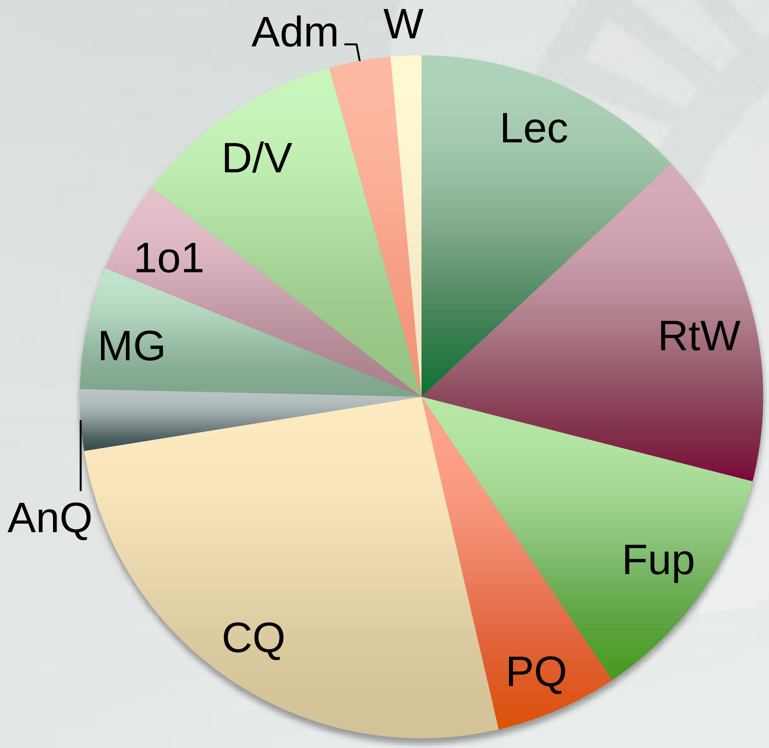
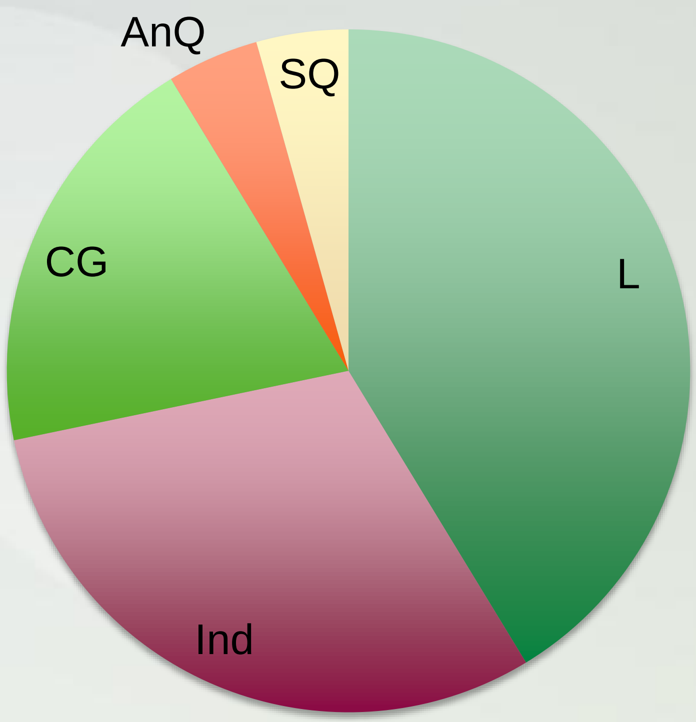
- Sonia M Underwood
- Becky Matz
- Cori Fata-Hartley
- Biological Sciences Faculty
- Chemistry Faculty
- Physics Faculty
- CNS Deans

Classroom Observation Protocol for Undergraduate STEM (COPUS)

Instructor is doing:

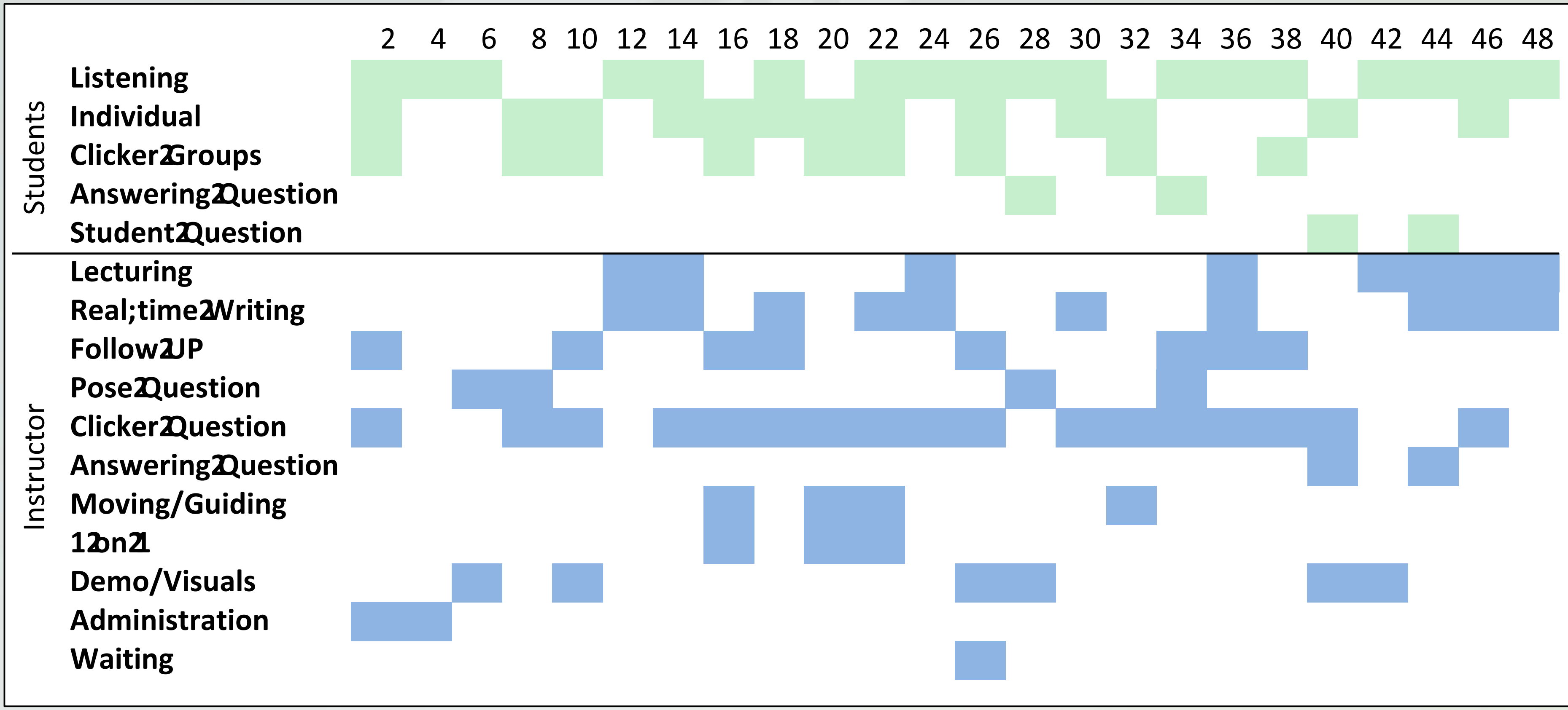


Students are doing:



Smith, M. K., Jones, F. H., Gilbert, S. L., & Wieman, C. E. (2013). The Classroom Observation Protocol for Undergraduate STEM (COPUS): A New Instrument to Characterize University STEM Classroom Practices. *CBE-Life Sciences Education*, *12*(4), 618-627.

COPUS on a timeline



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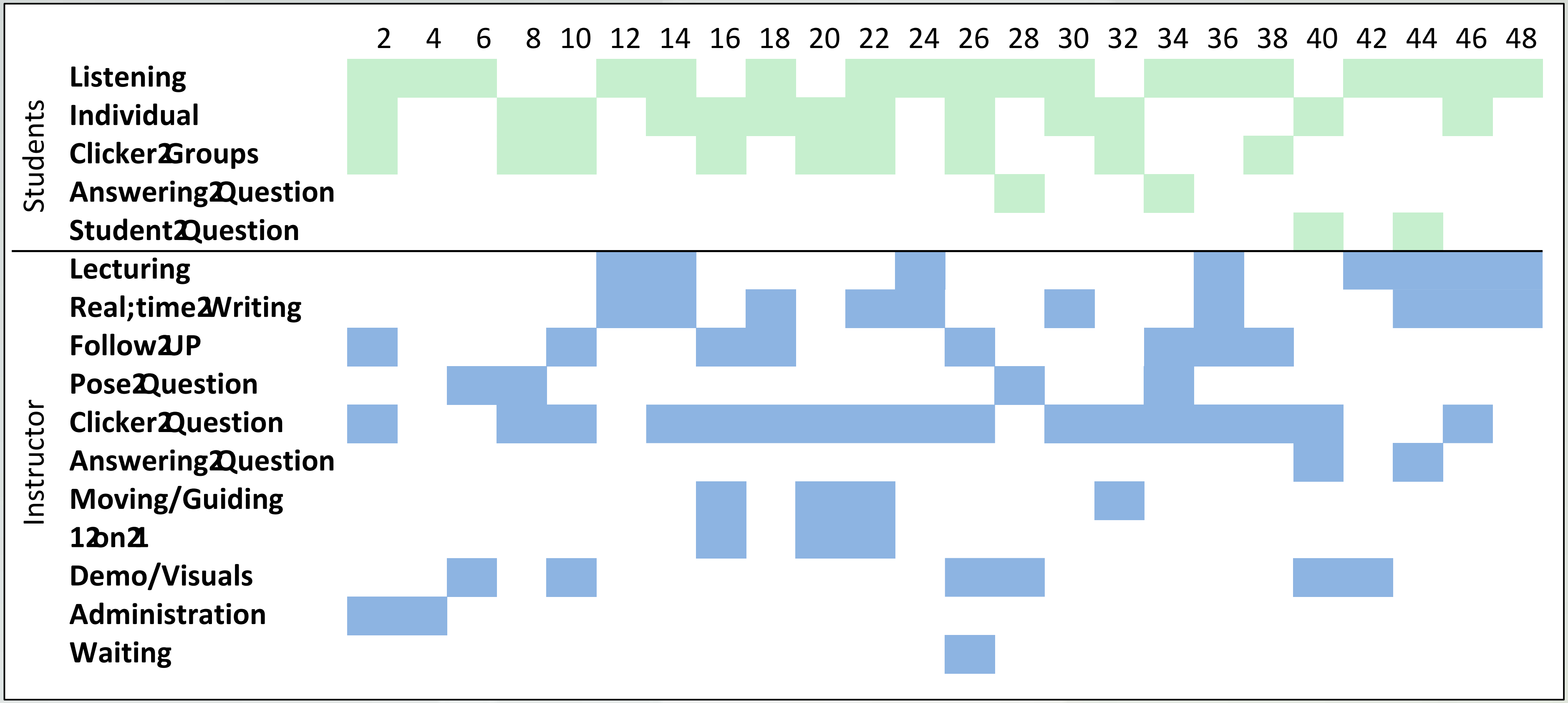
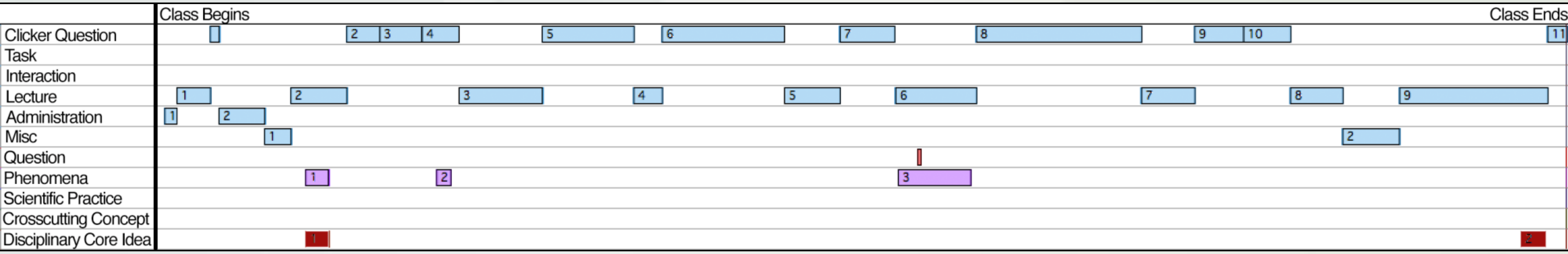

2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48
Students
Listening
Individual
Clicker2Groups
Answering2Question
Student2Question
Instructor
Lecturing
Real;time2Writing
Follow2UP
Pose2Question
Clicker2Question
Answering2Question
Moving/Guiding
12on21
Demo/Visuals
Administration
Waiting


Class Begins
Class Ends
Clicker Question
Task
Interaction
Lecture
Administration
Misc
Question
Phenomena
Scientific Practice
Crosscutting Concept
Disciplinary Core Idea

Traditional Gateway Curricula

"Mile wide and an inch deep"

Part 1: Assessing 3D Learning

Scientific Practices (SP)	P1 (Does the item contain a practice - yes/no) P2 (If there is a practice, which practice is presented) P3 (If there is a practice, is the practice

Part 1: Assessing 3D Learning

Scientific Practices (SP)	P1 (Does the item contain a practice - yes/no) P2 (If there is a practice, which practice is presented) P3 (If there is a practice, is the practice explicit/implicit)
Crosscutting Concepts (CC)	CC1 (Is there a crosscutting concept (CC) - yes/no) CC2 (If there is a CC, which CC is present)

Part 1: Assessing 3D Learning

Scientific Practices (SP)	P1 (Does the item contain a practice - yes/no) P2 (If there is a practice, which practice is presented) P3 (If there is a practice, is the practice explicit/implicit)
Crosscutting Concepts (CC)	CC1 (Is there a crosscutting concept (CC) - yes/no) CC2 (If there is a CC, which CC is present) CC3 (If there is a CC, is the CC explicit/implicit)
Disciplinary Core Ideas (DCI)	DCI1 (Is there a disciplinary core idea (DCI) - yes/no) DCI2 (If there is a DCI, which DCI is present) DCI3 (If there is a DCI, is the DCI explicit/implicit)