Characterizing instruction in introductory science courses

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National undergraduate enrollment increased 45% between 1997 and 2011

Enrollment by attendance status

Enrollment in postsecondary degree-granting institutions of full-time students increased 54 percent between 1997 and 2011; and is projected to increase 12 percent between 2011 and 2022.

Enrollment in postsecondary degree-granting institutions of part-time students increased 32 percent between 1997 and 2011; and is projected to increase 16 percent between 2011 and 2022.

For more information: Tables 20–22

Figure 19. Actual and projected numbers for enrollment in all postsecondary degree-granting institutions, by attendance status: Fall 1997 through fall 2022

Enrollment by level of student

Enrollment in postsecondary degree-granting institutions of undergraduate students increased 45 percent between 1997 and 2011; and is projected to increase 13 percent between 2011 and 2022.

Enrollment in postsecondary degree-granting institutions of postbaccalaureate students increased 43 percent between 1997 and 2011; and is projected to increase 19 percent between 2011 and 2022.

For more information: Tables 27–28

Figure 20. Actual and projected numbers for enrollment in all postsecondary degree-granting institutions, by level of degree: Fall 1997 through fall 2022

Michigan State University (MSU) undergraduate enrollment increased 11% between Fall 2000 and Fall 2013.
At MSU, College of Natural Science (CNS) undergraduate enrollment increased 52% between Fall 2000 and Fall 2013.
CNS courses also serve students from Lyman Briggs College (LBC); LBC enrollment increased 31% between Fall 2000 and Fall 2013.
Total enrollment in introductory science courses increased considerably
The percentage of seniors in a key second-tier genetics course increased from ~40% to >70%, pushing out underclassmen.
The percentage of seniors in a key second-tier genetics course increased from ~40% to >70%, pushing out underclassmen.

I took this course last semester and received a 1.5. I need to finish with at least a 2.0 in this course when I graduate in Spring 2013 to still be eligible for veterinary school, which I already applied to at Michigan State University and Iowa State University. If I do not get an override for this course, I will automatically be rejected from both veterinary programs, and will not graduate from undergraduate school on time!
The percentage of seniors in a key second-tier genetics course increased from ~40% to >70%, pushing out underclassmen.

[This section] is one of the only ones that doesn't conflict with my other classes. Section 005 also works. Also of note, I need this class to graduate on time and have been waiting for an opening for months, please help me.
The percentage of seniors in a key second-tier genetics course increased from ~40% to >70%, pushing out underclassmen.

Getting an override into this class would allow me to complete all requirements before I graduate and it would allow me to graduate on time instead of having to maybe take this course the following summer. I would greatly appreciate an override as soon as possible because when applying for financial aid this past year I was unable to get the full amount because I was unable to register for this course on time and so my funds were cut due to not registering for the 12 credit minimum (full time student) to get the full amount.
More than 70% of CNS undergraduates are in a biological sciences degree program

Mathematics
- Actuarial science
- Computational mathematics
- Mathematics
- Statistics
- Etc.

Physical sciences
- Astrophysics
- Chemistry
- Geological sciences
- Physics
- Etc.

Biological sciences
- Biochemistry and molecular biology
- Biomedical laboratory science
- Human biology
- Microbiology and molecular genetics
- Neuroscience
- Physiology
- Plant biology
- Premedical
- Zoology
- Etc.

Data for Fall 2013, Michigan State University, Office of the Registrar, Enrollment and Term End Reports, College Enrollment, Students by Major – Undergraduate.
Undergraduate biological sciences students are spread across five departments and four programs.
Elements of education reform

Structures

Pedagogy

Curriculum
MSU’s Association of American Universities (AAU) Project: Creating a Coherent STEM Gateway

Overall goal
Transform instruction in introductory biology, chemistry, and physics courses so that they focus on scientific practices, crosscutting concepts, and core ideas of the disciplines

Three levers for change
Disciplinary discussions
STEM Alliance
STEM Gateway Fellows program

Research question
How will these three levers affect “what” students are taught (curriculum) and “how” students are taught (pedagogy)?

How will we measure change?
Three-dimensional learning assessment protocol (3D-LAP)
Three-dimensional learning observation protocol (3D-LOP)

https://stemedhub.org/groups/aau
Acknowledgements for the AAU project

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   Keenan Noyes
Zach Nusbaum
The overall goal of the project is to transform instruction in introductory science courses so that they focus on three-dimensional learning.

### 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

### Core ideas

The core ideas are identified by groups of faculty in the disciplinary discussions.

Our three levers for change align with Henderson’s work on facilitating change in STEM instructional practices.
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**Diagram**

- **Curriculum & Pedagogy**: Prescribed to Emergent
- **Reflective Teachers**: Individuals
- **Policy**: Prescribed to Emergent
- **Shared Vision**: Environments

**Acknowledgments**

We expect the three levers to affect both “what” students are taught (curriculum) and “how” students are taught (pedagogy).

We are measuring change in both “what” and “how” students are taught with two protocols that our group is developing:

The Three-Dimensional Learning Assessment Protocol (3D-LAP) focuses on classroom assessments.

The Three-Dimensional Learning Observation Protocol (3D-LOP) focuses on classroom instruction.
We coded an example MSU class using the COPUS protocol – it looks like it is a great class!

| Instructor                          | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 | 42 | 44 | 46 | 48 |
|-------------------------------------|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Listening                           |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Individual                         |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Clicker Groups                      |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Answering Question                  |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Student Question                    |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Lecturing                           |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Real-time Writing                   |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Follow UP                           |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Pose Question                       |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Clicker Question                    |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Answering Question                  |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Moving/Guiding                      |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| 1 on 1                              |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Demo/Visuals                        |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Administration                      |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
| Waiting                             |   |   |   |   |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |

But, when we code the same class with the 3D-LOP instrument, we find that three-dimensional learning is largely absent.

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<th>1</th>
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<th>4</th>
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“how” students are taught

“what” students are taught
The six teaching activities that constitute the “how” of the protocol

1. Clicker questions
   Students respond with personal response instruments

2. Tasks
   Students work together or alone to solve a problem, construct a diagram, etc.

3. Interactions
   Substantive and possibly lengthy exchanges between the instructor and students

4. Lecture
   Instructor-directed presentation of content-related information

5. Administration
   “Housekeeping” items such as exam logistics, scheduling, and announcements

6. Miscellaneous
   Anything that does not fit above

Mutually exclusive and complete
We coded video recordings of introductory biology, chemistry, and physics classes in Fall 2013 and Spring 2014

<table>
<thead>
<tr>
<th>Course</th>
<th># recordings</th>
<th># recordings by discipline</th>
<th># recordings analyzed here</th>
<th># instructors represented</th>
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The overall distribution shows that instructors lecture during the majority of class time.

- Lecture: 67%
- Clicker questions: 14%
- Tasks: 13%
- Interaction: 2%
- Miscellaneous: 1%
- Administration: 3%
Clicker questions 5%
Tasks 40%
Interaction 4%
Lecture 46%

Administration 4%
Miscellaneous 1%

Clicker questions 26%
Tasks 1%
Interaction 0%
Lecture 84%

Clicker questions 9%
Tasks 2%
Interaction 2%
Lecture 84%

Miscellaneous 0%
Administration 3%
Lecture 46%

Miscellaneous 0%
Administration 4%
Lecture 70%
Interactio 0%
Clicker questions
9%
Tasks
2%
Interaction
2%
Lecture
84%
Administration
4%
Miscellaneous
0%

Clicker questions
26%
Tasks
1%
Interaction
0%
Lecture
70%
Administration
3%
Miscellaneous
0%

Clicker questions
5%
Tasks
40%
Interaction
4%
Lecture
46%
Administration
4%
Miscellaneous
1%
Percent of class time spent on this teaching activity

Instructor (de-identified)

Clicker Q  Task  Interaction  Lecture  Admin  Misc

B1  B2  B3  B4  B5  B6  B7  B8  B9  C1  C2  C3  C4  C5  C6  C7  C8  P1  P2  P3  P4  P5  P6  P7  P8  P9  P10  P11  P12
The three-dimensional learning observation protocol...

• Can be used to characterize both “what” and “how” students are taught.

• Can be applied across science disciplines.

• Can provide a framework for other adopters to assess the instruction of the core ideas that are important to them.

• Can generate evidence of change in instructional practice over time as part of a transformation effort.
Investigating grade penalties (and bonuses!) at five CIC universities

For example, 13,988 students took BS161 at MSU between Fall 2006 and Summer 2014.

The average student that has a 3.0 GPA will earn a BS161 grade that is between a 2.0 and 2.5.

Grade penalties in absolute terms are small, but they are reliably present.

Five CIC universities are undertaking a concerted effort to evaluate grade penalties and bonuses.
Thanks!
Template