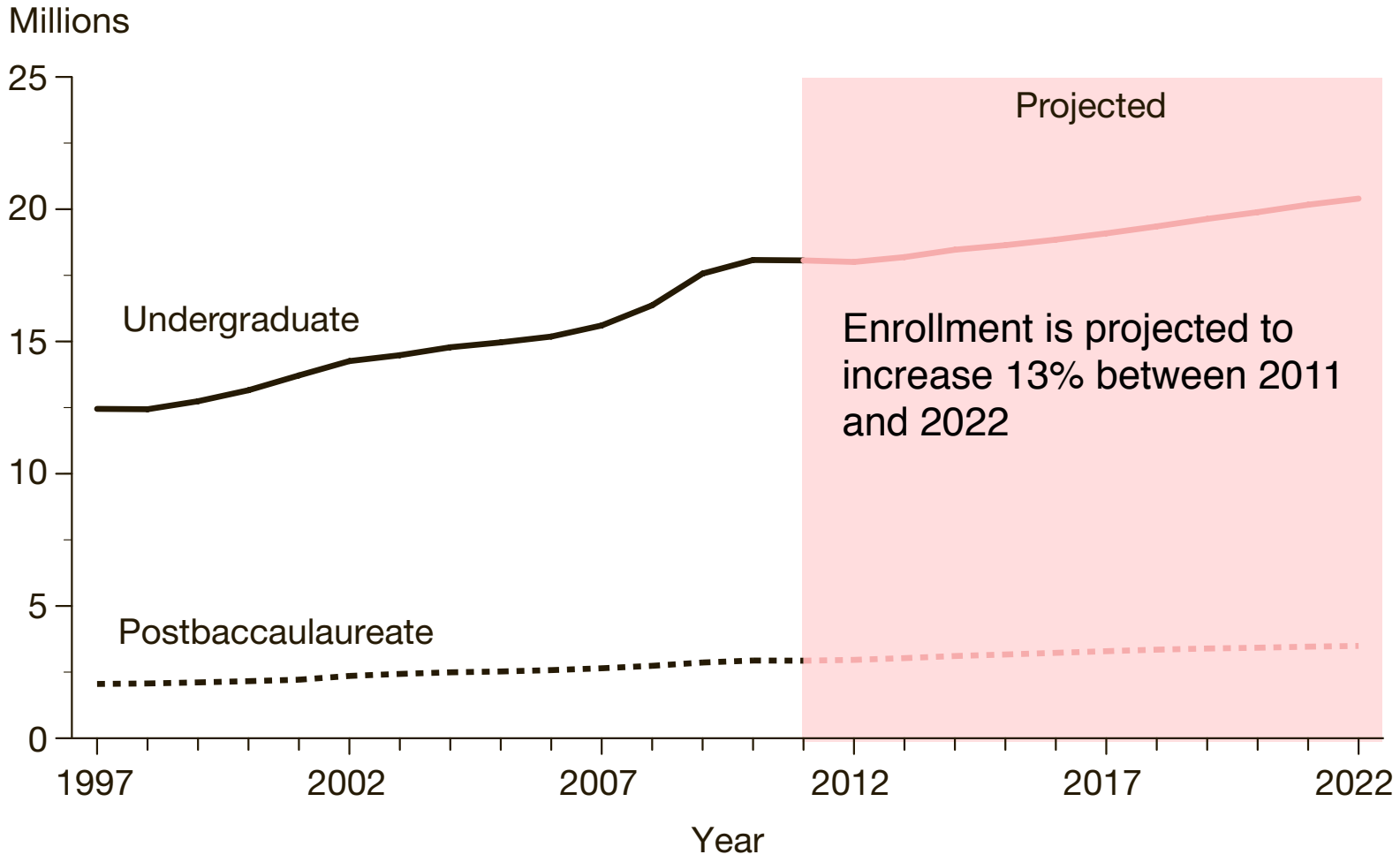
Characterizing instruction in introductory science courses

Becky Matz

CREATE for STEM Institute, Michigan State University

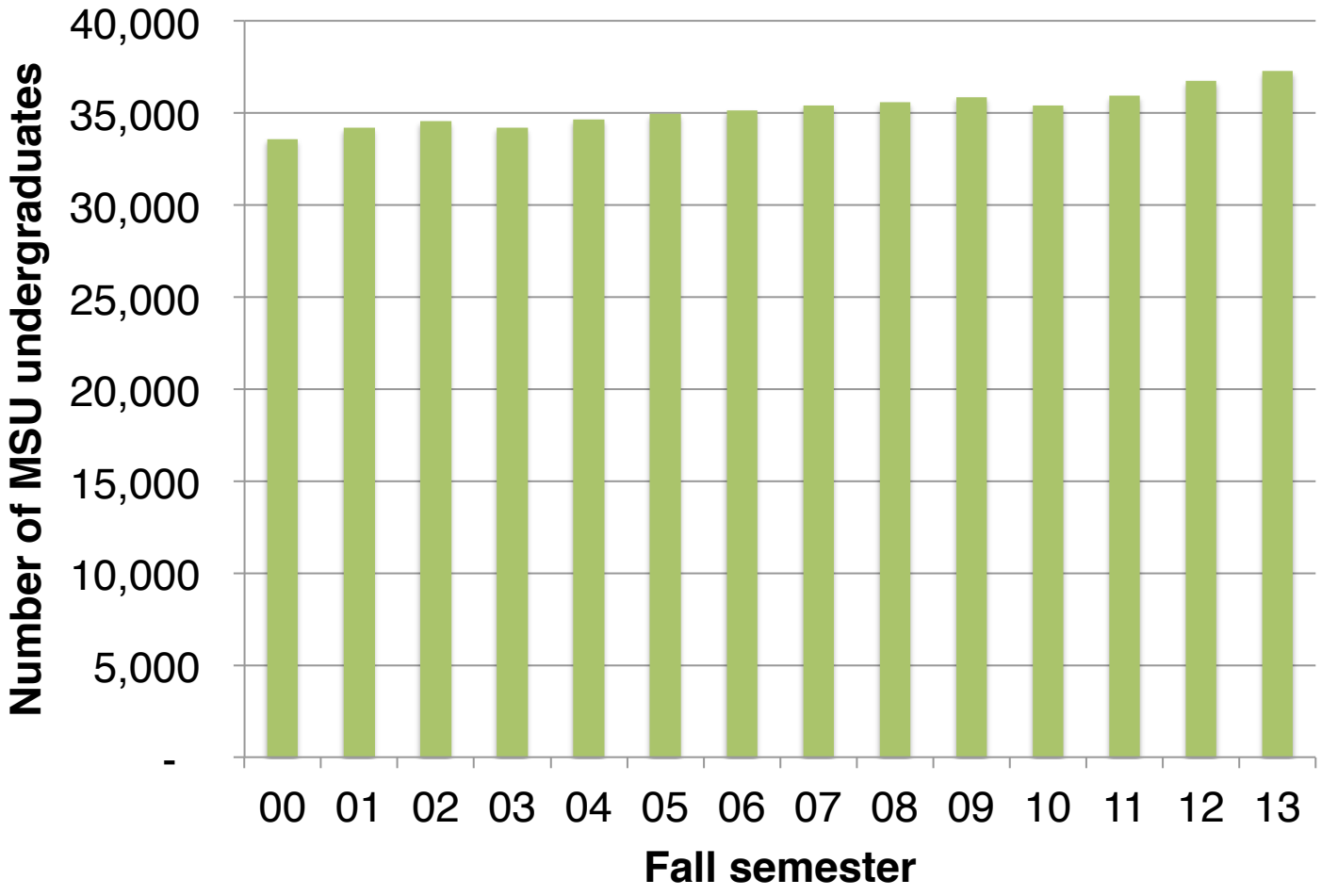
Student Learning and Analytics at Michigan (SLAM) Seminar
University of Michigan
March 13, 2015

National undergraduate enrollment increased 45% between 1997 and 2011



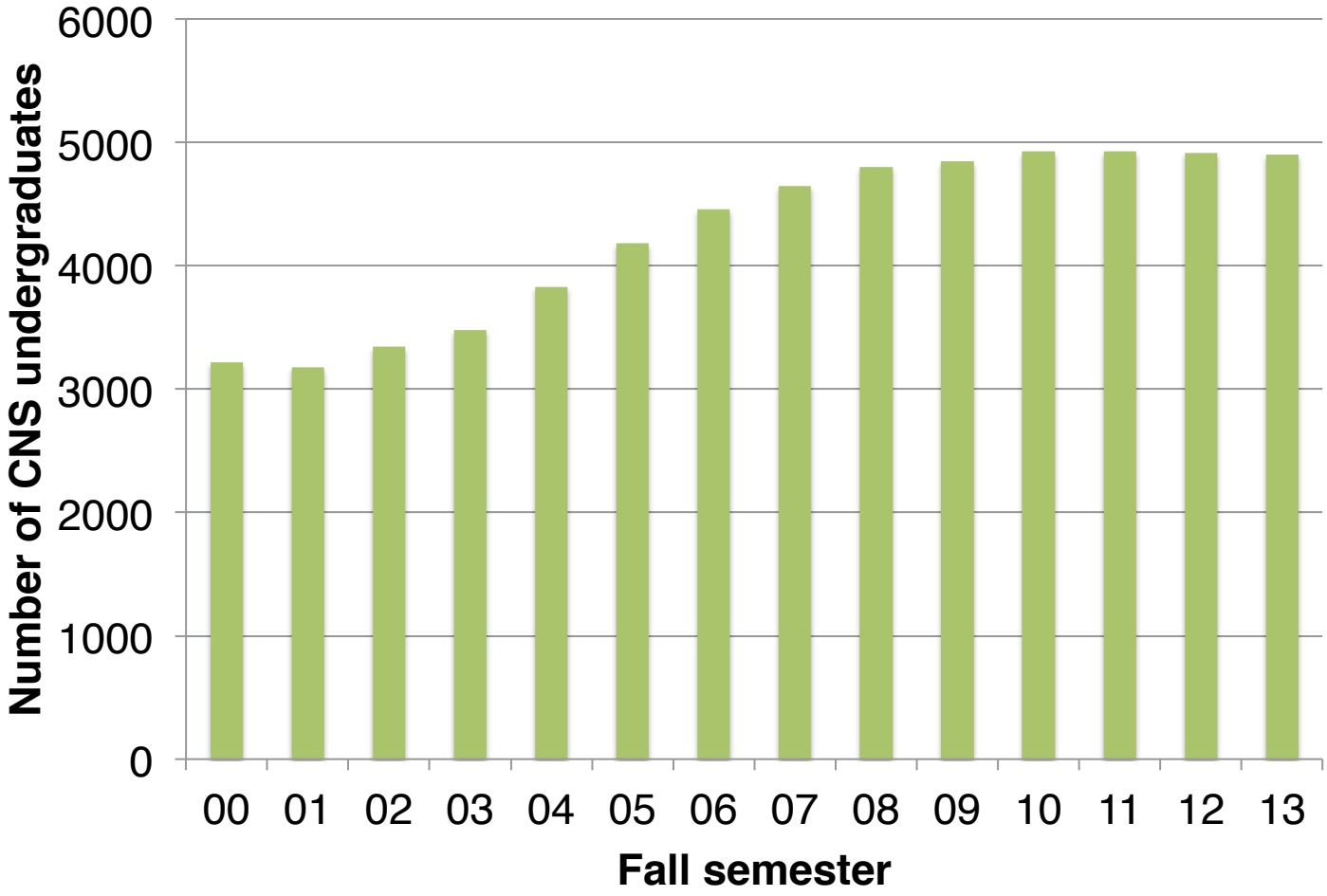
U.S. Department of Education, National Center for Education Statistics, Integrated Postsecondary Education Data System (IPEDS) "Fall Enrollment Survey" (IPEDS-EF:97-99); IPEDS Spring 2001 through Spring 2012, Enrollment component; and Enrollment in Degree-Granting Institutions Model, 1980-2011.

Michigan State University (MSU) undergraduate enrollment increased 11% between Fall 2000 and Fall 2013



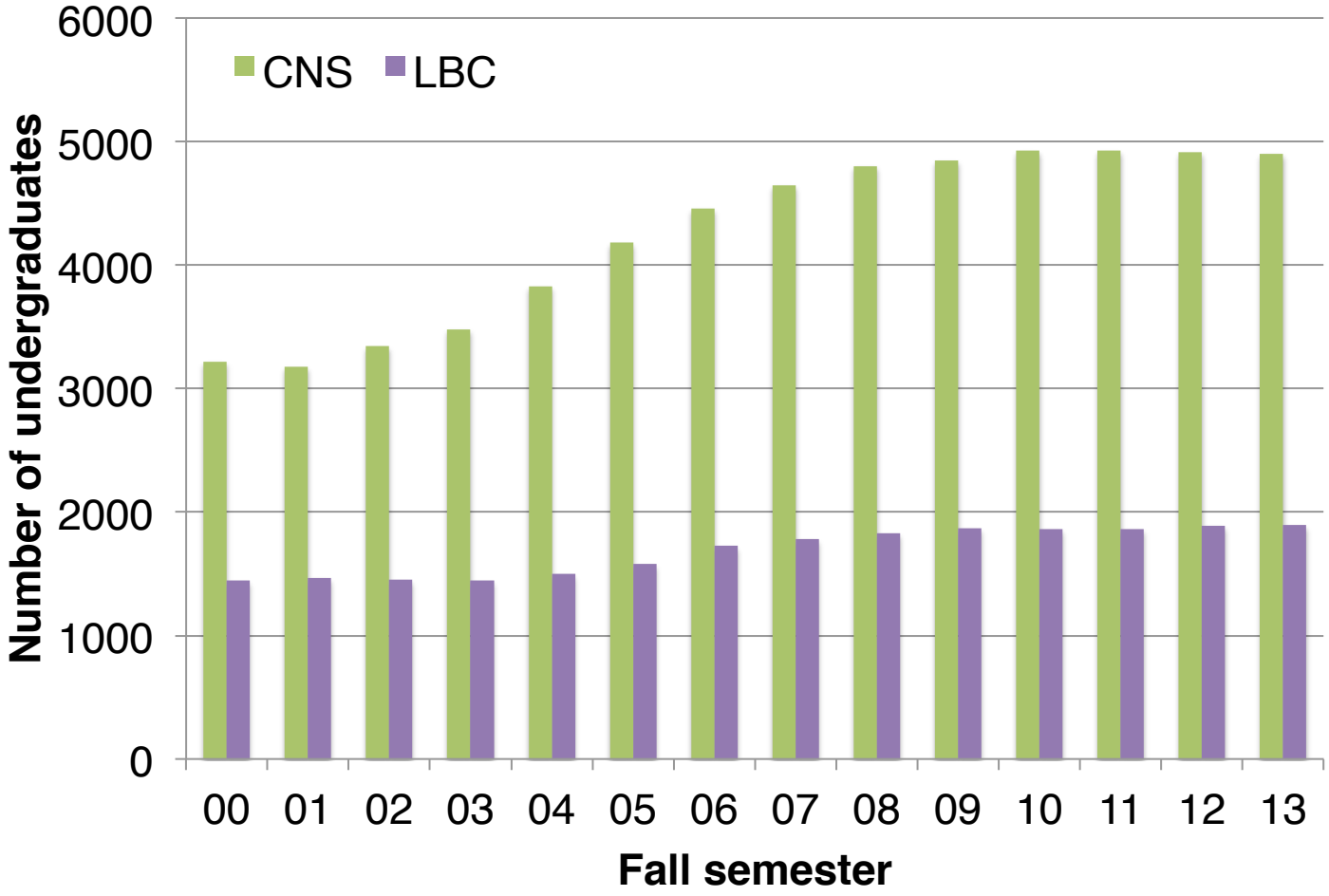
Michigan State University, Office of the Registrar, Enrollment and Term End Reports, University Enrollment, Trend of Student Enrollments.

At MSU, College of Natural Science (CNS) undergraduate enrollment increased 52% between Fall 2000 and Fall 2013



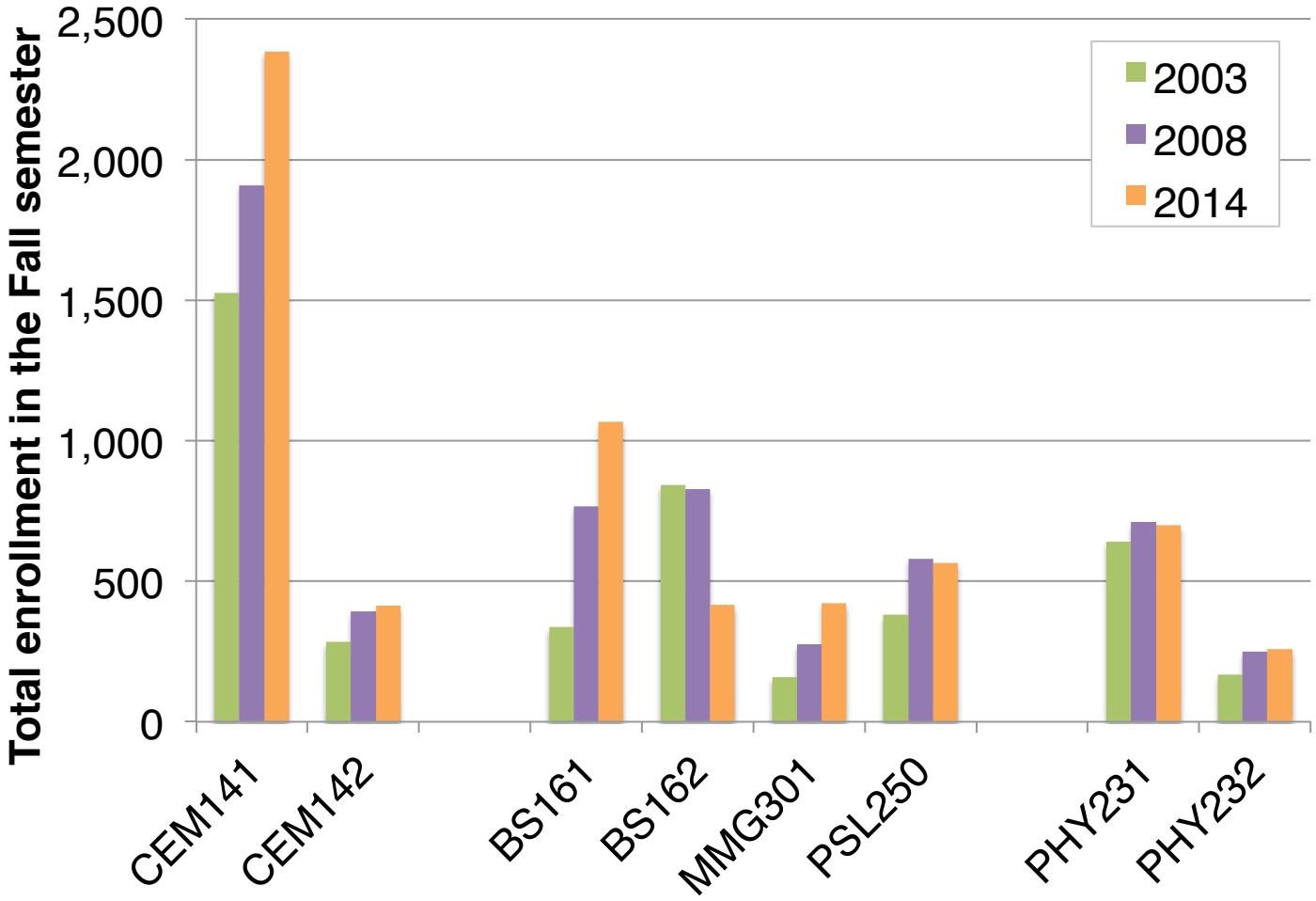
Michigan State University, Office of the Registrar, Enrollment and Term End Reports, College Enrollment, Trend of Student Enrollment by College.

CNS courses also serve students from Lyman Briggs College (LBC); LBC enrollment increased 31% between Fall 2000 and Fall 2013



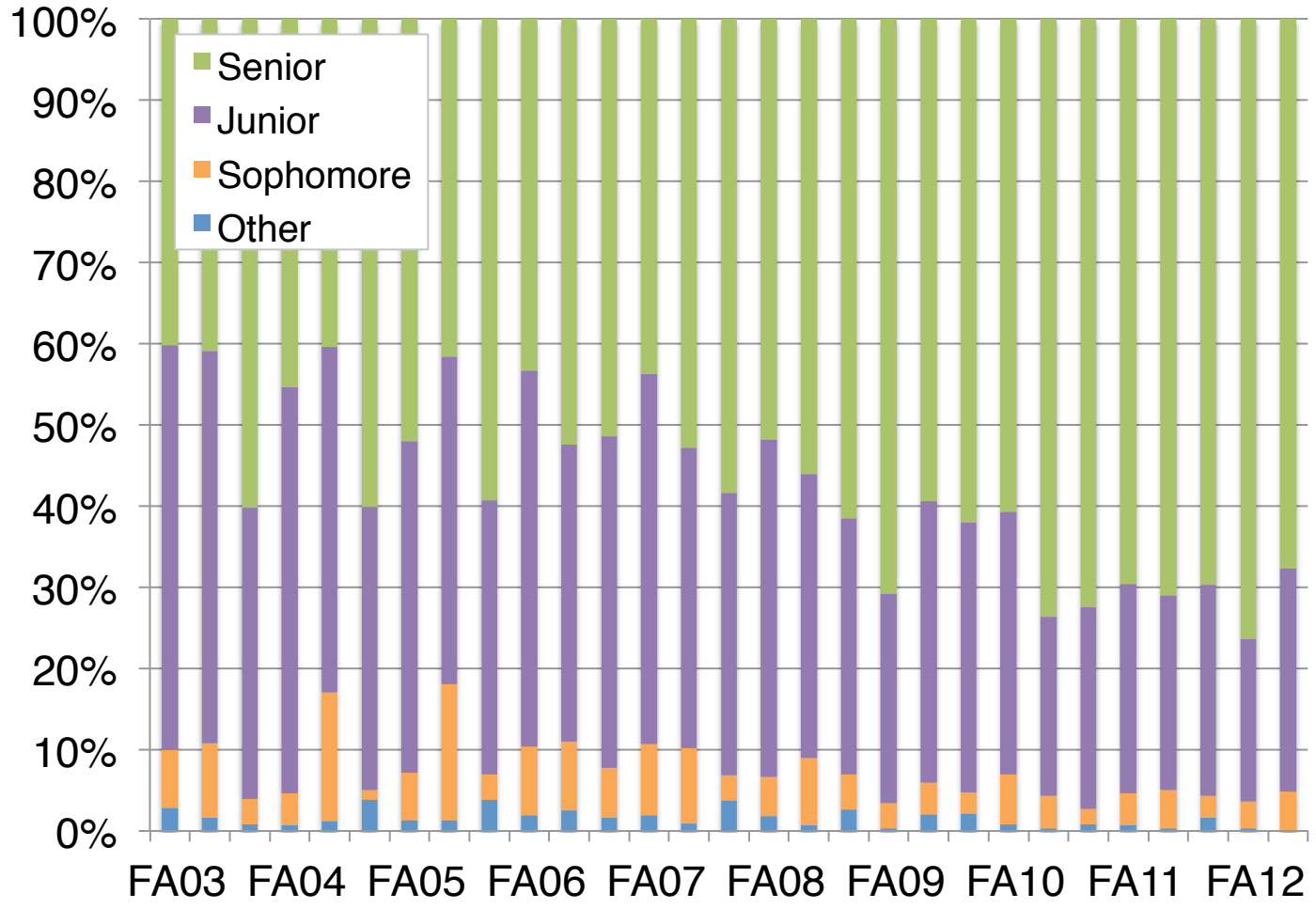
Michigan State University, Office of the Registrar, Enrollment and Term End Reports, College Enrollment, Trend of Student Enrollment by College.

Total enrollment in introductory science courses increased considerably



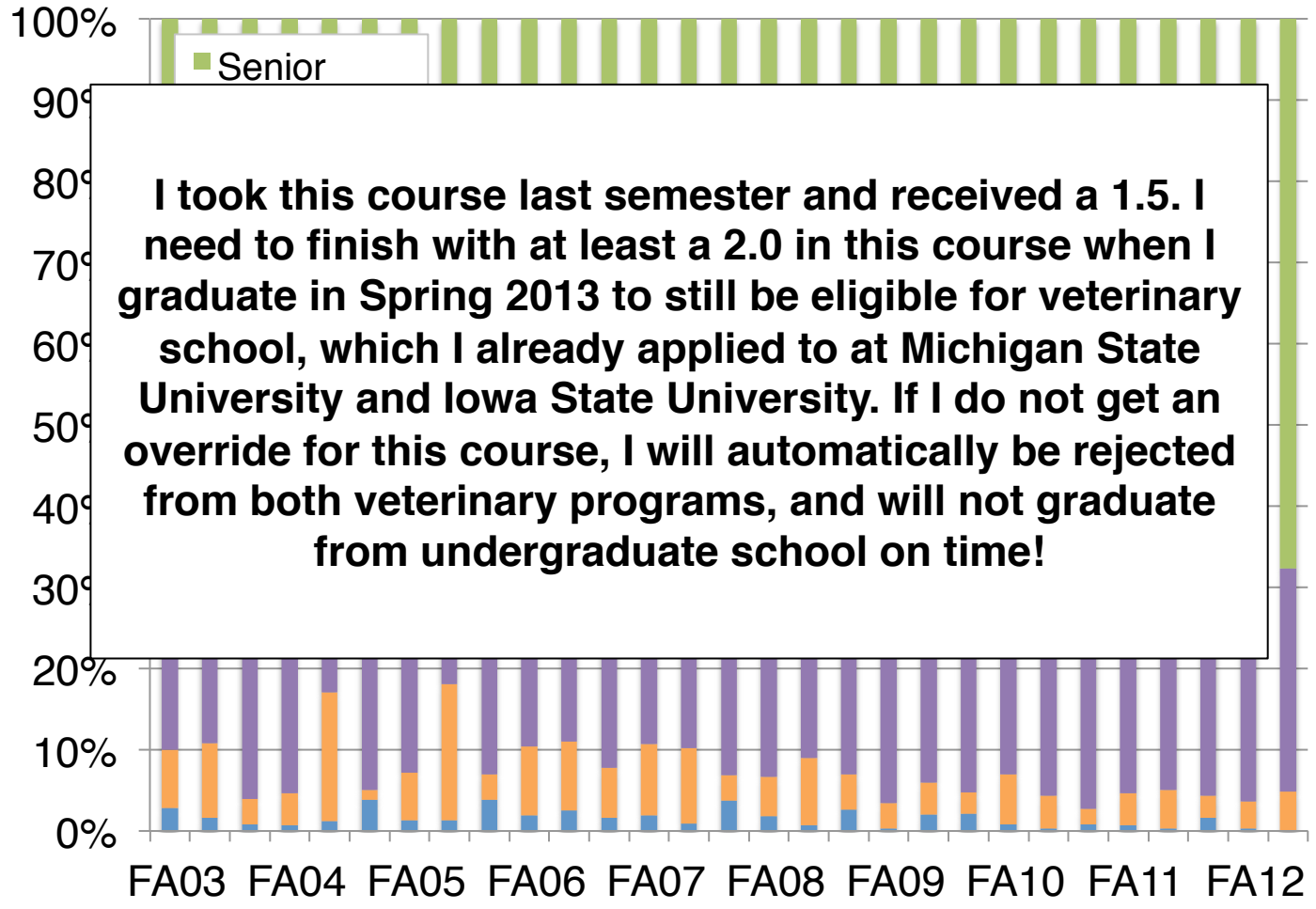
Michigan State University, Schedule of Courses, schedule.msu.edu.

The percentage of seniors in a key second-tier genetics course increased from ~40% to >70%, pushing out underclassmen.



Michigan State University, Office of the Registrar, Data Request #55947, ZOL341 enrollments.

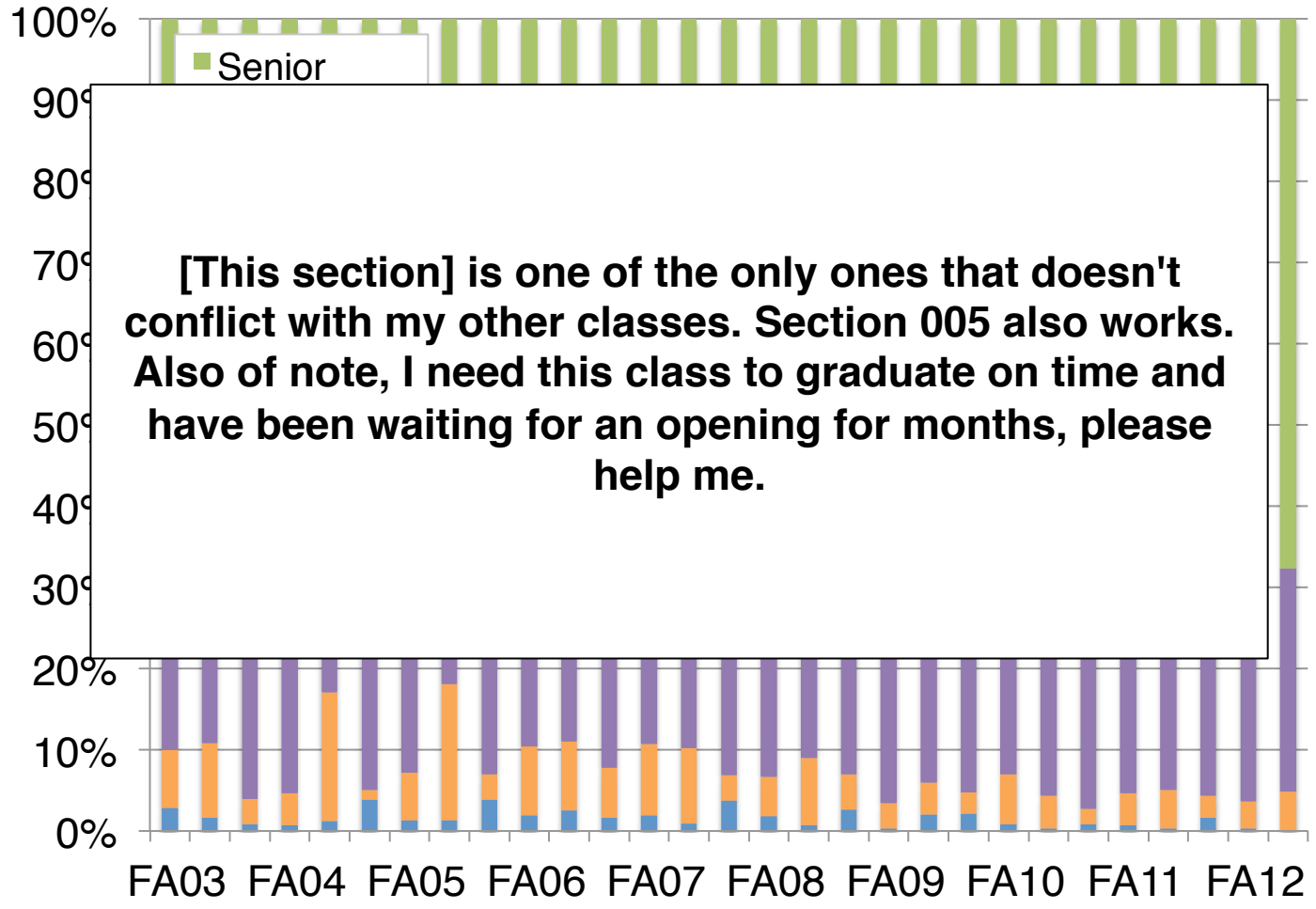
The percentage of seniors in a key second-tier genetics course increased from ~40% to >70%, pushing out underclassmen.



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!

Michigan State University, Office of the Registrar, Data Request #55947, ZOL341 enrollments.

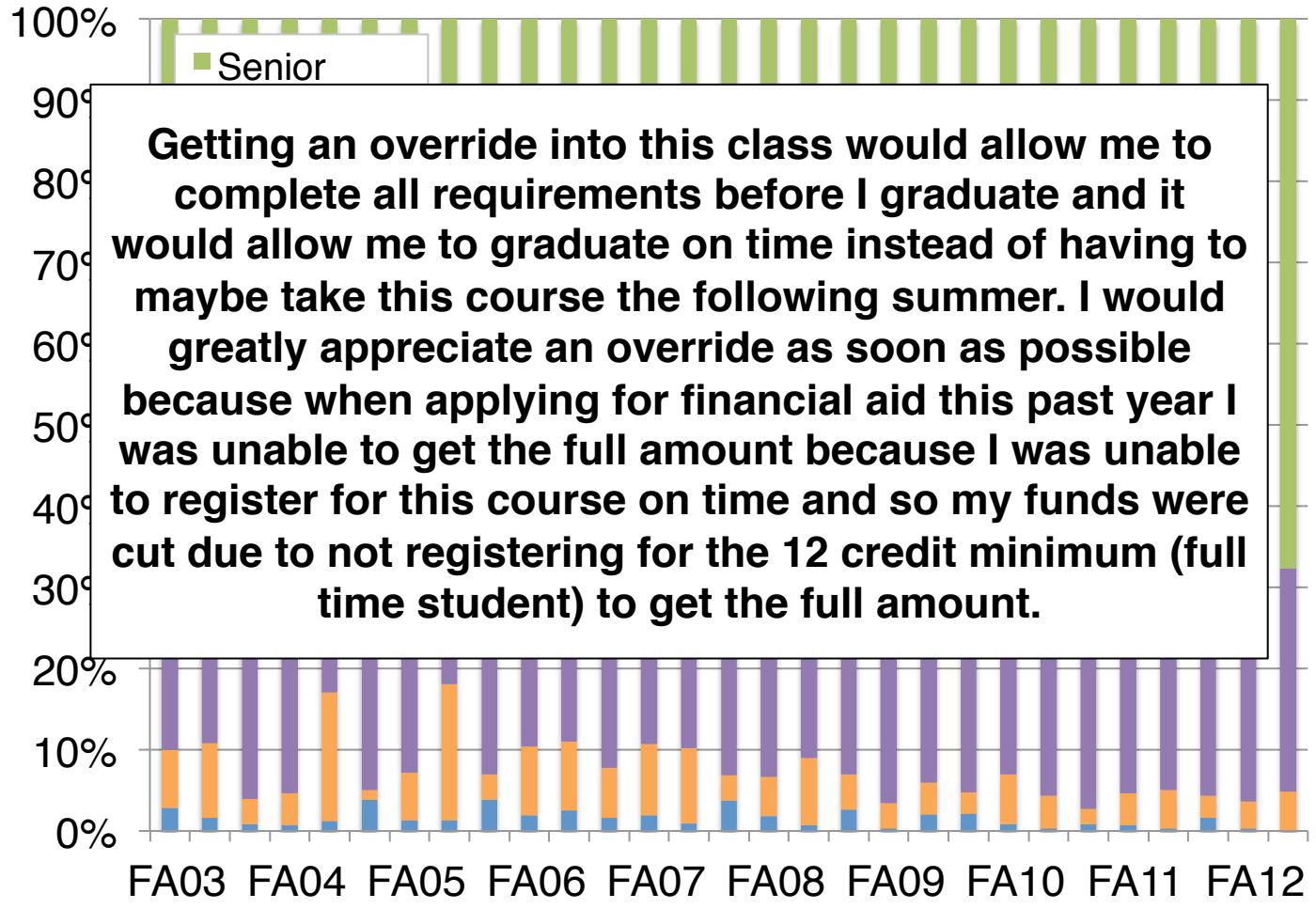
The percentage of seniors in a key second-tier genetics course increased from ~40% to >70%, pushing out underclassmen.



[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.

Michigan State University, Office of the Registrar, Data Request #55947, ZOL341 enrollments.

The percentage of seniors in a key second-tier genetics course increased from ~40% to >70%, pushing out underclassmen.

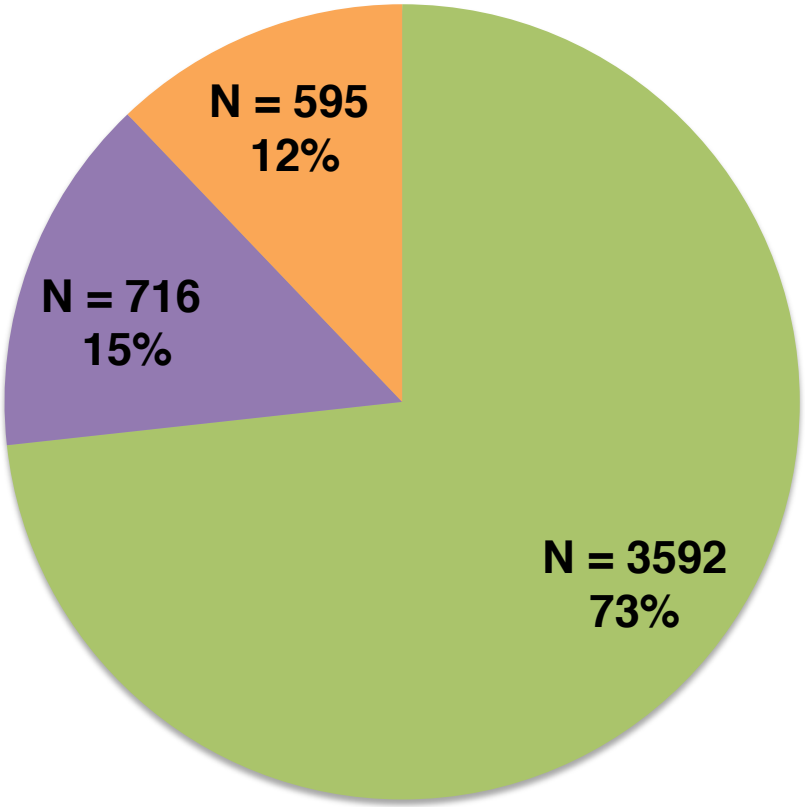


Michigan State University, Office of the Registrar, Data Request #55947, ZOL341 enrollments.

More than 70% of CNS undergraduates are in a biological sciences degree program

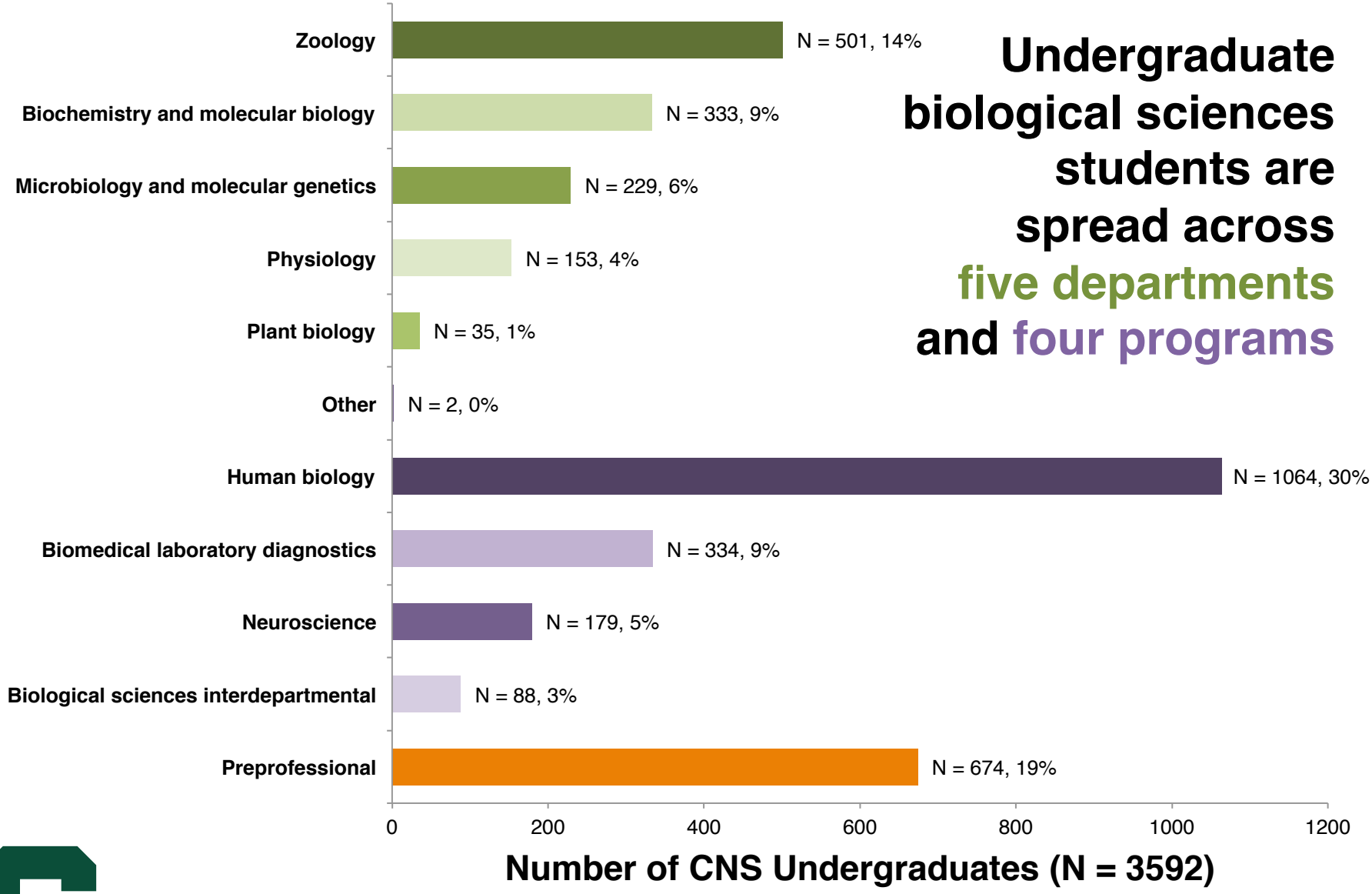
Mathematics
Actuarial science
Computational mathematics
Mathematics
Statistics
Etc.

Physical sciences
Astrophysics
Chemistry
Geological sciences
Physics
Etc.



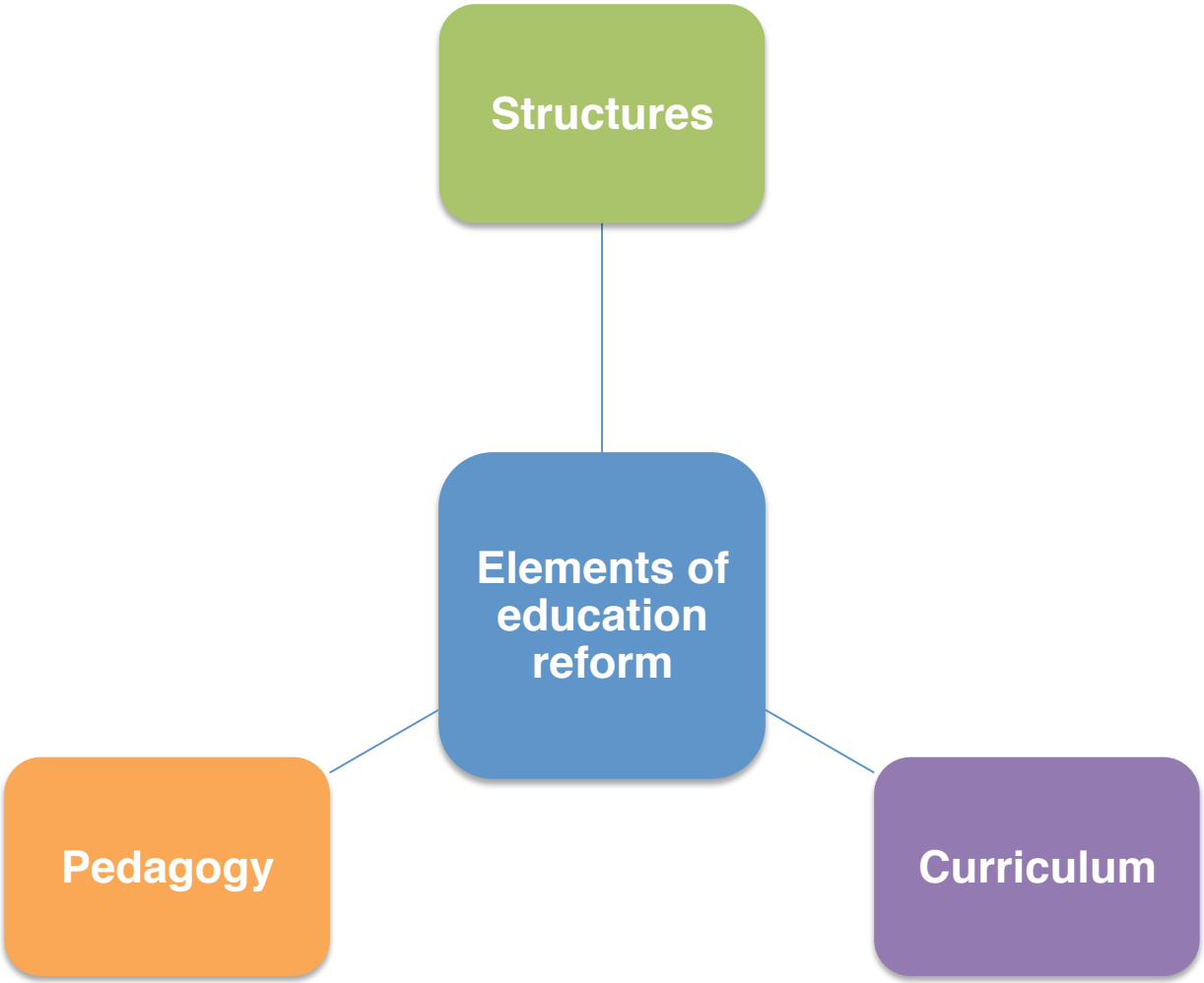
Biological sciences
Biochemistry and molecular biology
Biomedical laboratory science
Human biology
Microbiology and molecular genetics
Neuroscience
Physiology
Plant biology
Premedical
Zoology
Etc.

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

Data for Fall 2013, Michigan State University, Office of the Registrar, Enrollment and Term End Reports, College Enrollment, Students by Major – Undergraduate.


Structures
Elements of education reform
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

Melanie Cooper
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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

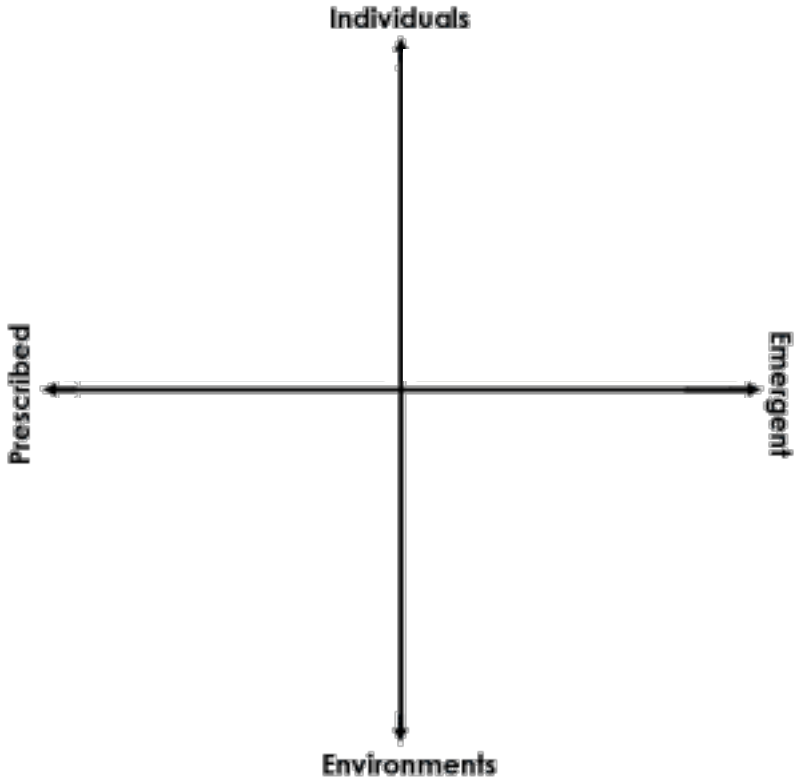
1. Patterns
2. Cause and effect: Mechanism and explanation
3. Scale, proportion, and quantity
4. Systems and system models
5. Energy and matter: Flows, cycles, and conservation
6. Structure and function
7. Stability and change

Core ideas

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

National Research Council. (2012). A framework for K-12 science education: Practices, crosscutting concepts, and core ideas. Washington, DC: The National Academies Press.

Our three levers for change align with Henderson's work on facilitating change in STEM instructional practices



Henderson, C., Beach, A., Finkelstein, N. (2011). Facilitating change in undergraduate STEM instructional practices: An analytic review of the literature. Journal of Research in Science Teaching, 48(8), 952-984.
http://wmich.edu/changeresearch

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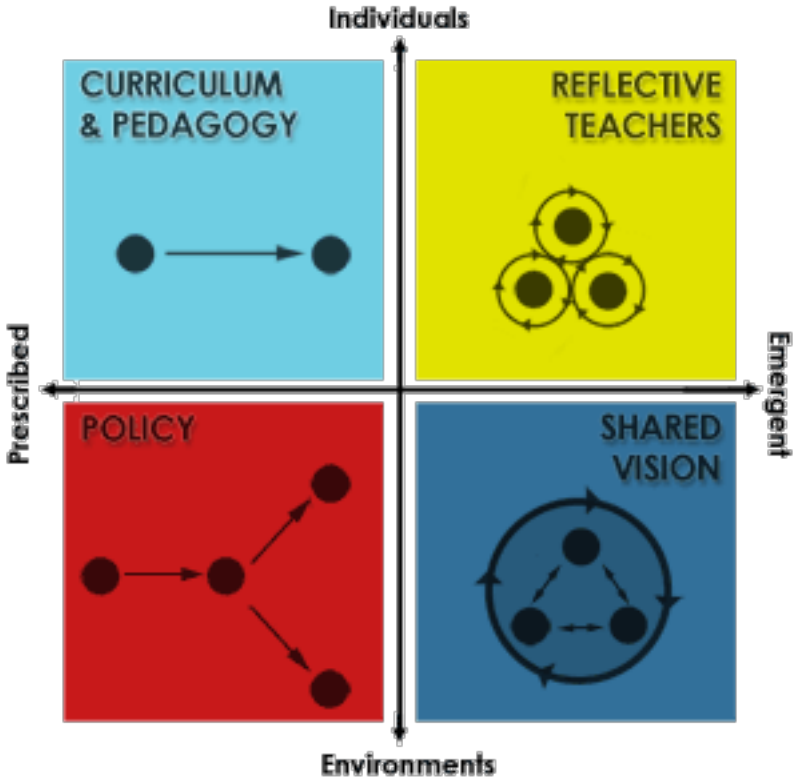

Henderson, C., Beach, A., Finkelstein, N. (2011). Facilitating change in undergraduate STEM instructional practices: An analytic review of the literature. Journal of Research in Science Teaching, 48(8), 952-984.
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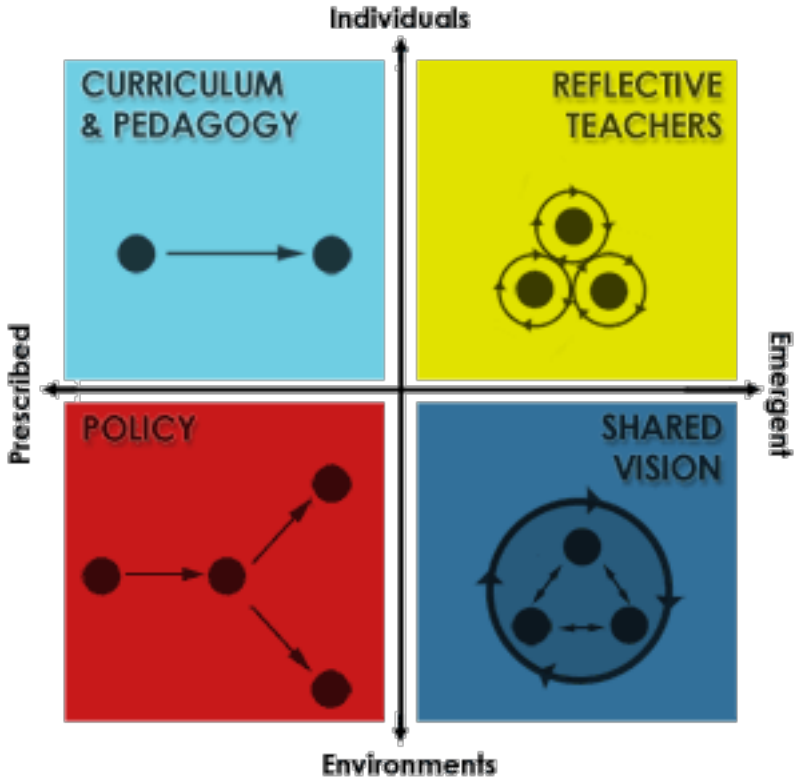


STEM Gateway Fellows program

STEM Alliance

Disciplinary discussions

Henderson, C., Beach, A., Finkelstein, N. (2011). Facilitating change in undergraduate STEM instructional practices: An analytic review of the literature. Journal of Research in Science Teaching, 48(8), 952-984.
http://wmich.edu/changeresearch

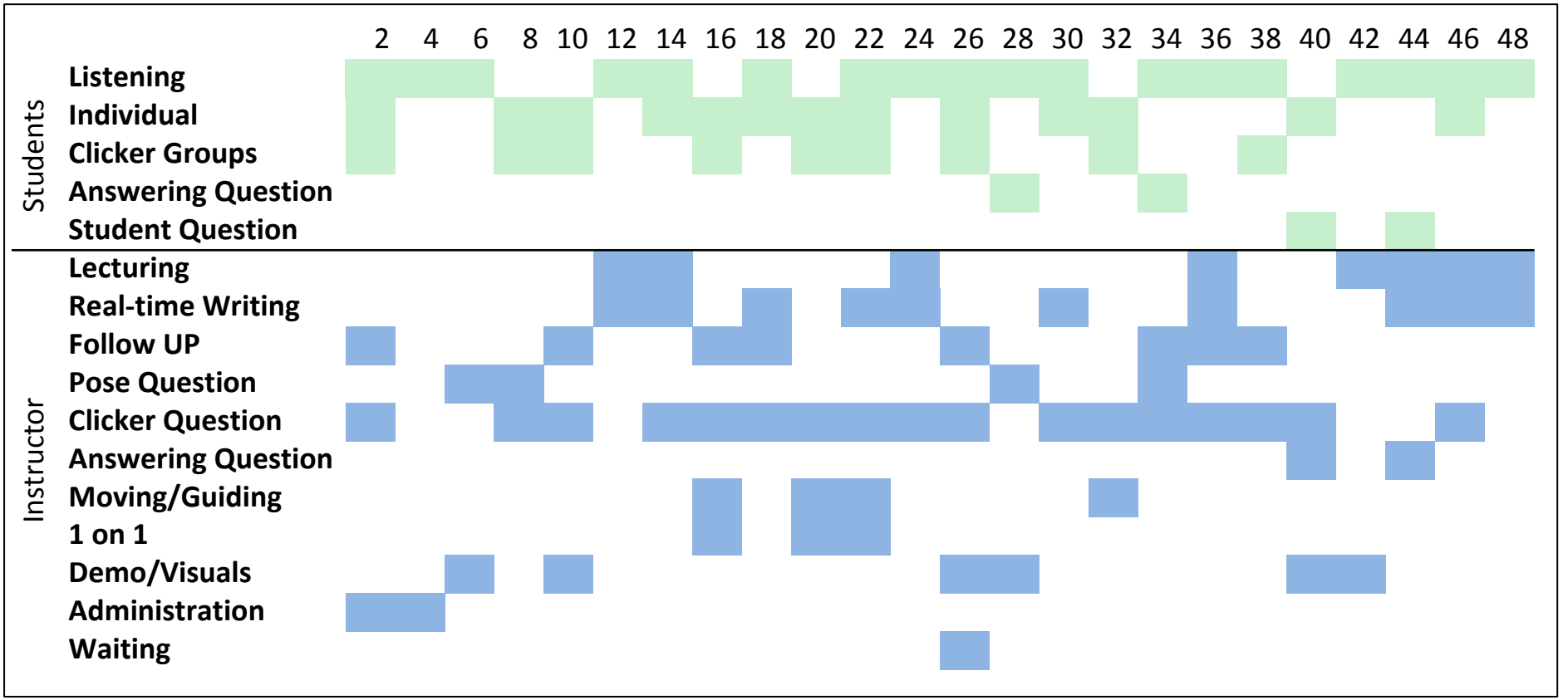
We expect the three levers to affect both “what” students are taught (curriculum) and “how” students are taught (pedagogy)

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***.

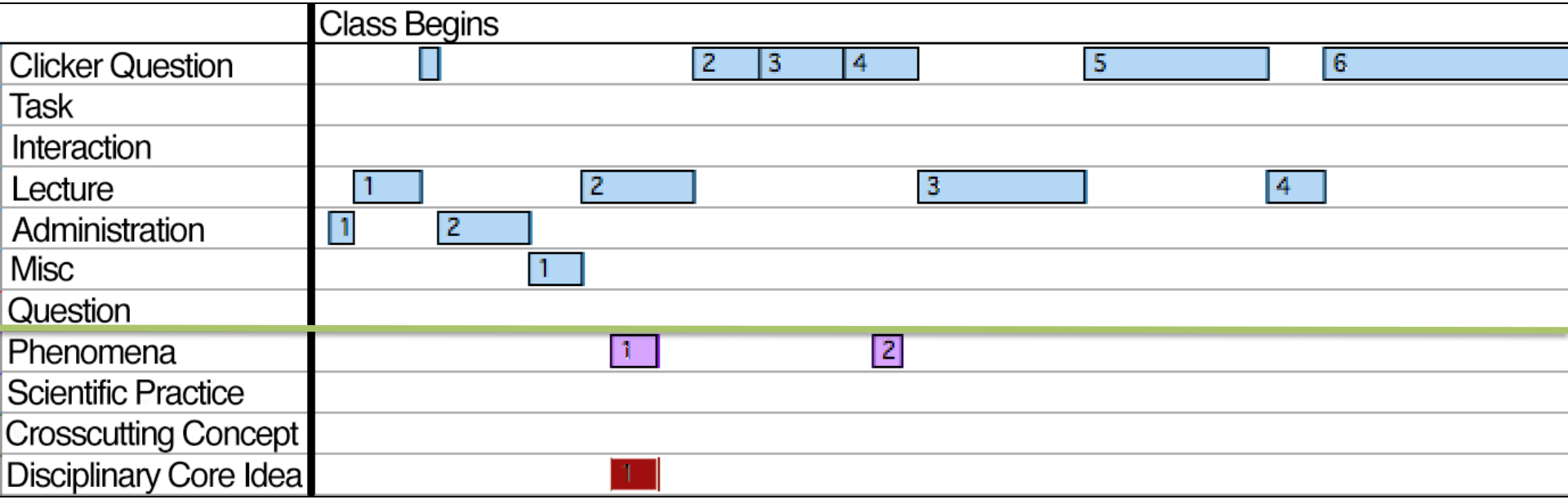
We coded an example MSU class using the COPUS protocol – it looks like it is a great class!



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.

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

“how” students are taught



“what” students are taught

The six teaching activities that constitute the "how" of the protocol

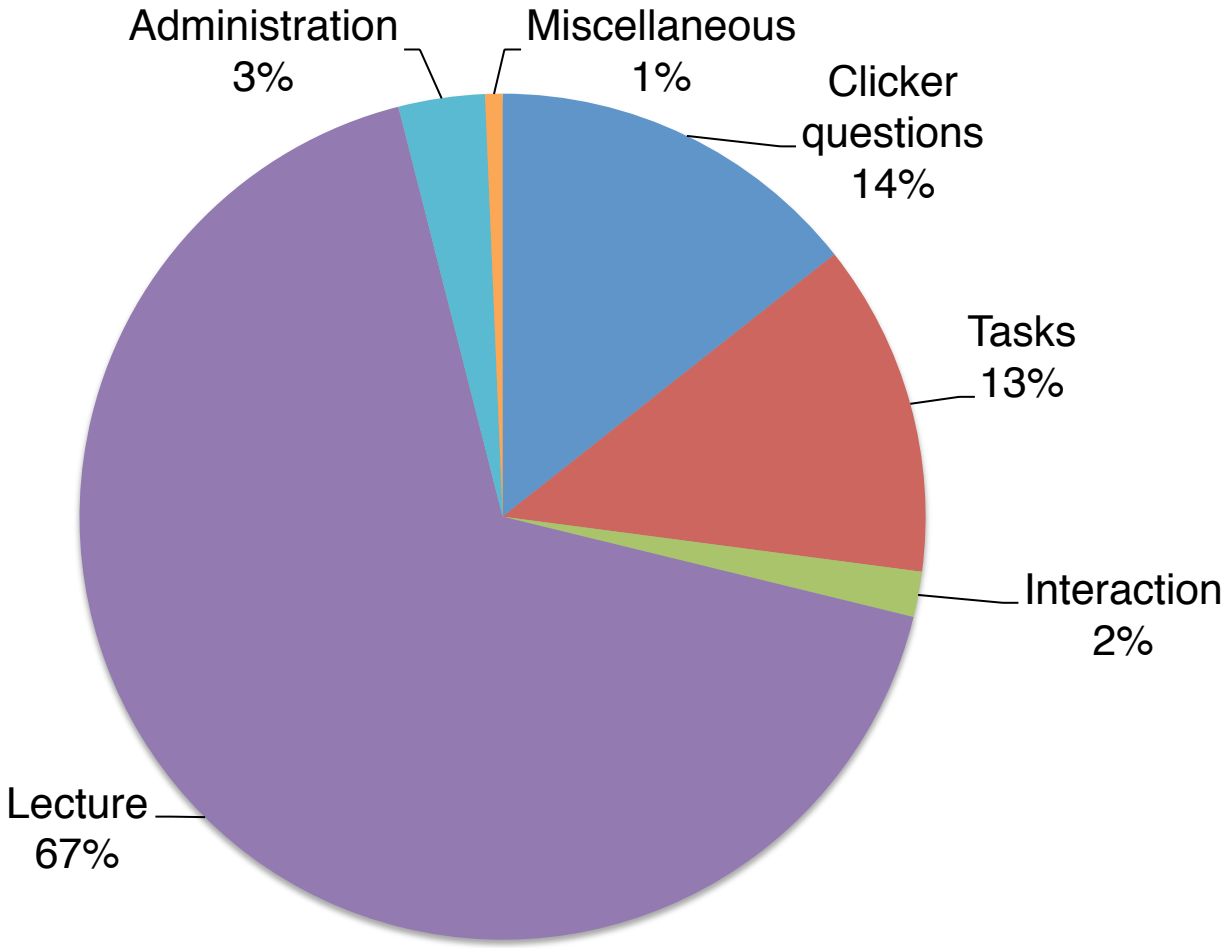
Mutually exclusive and complete

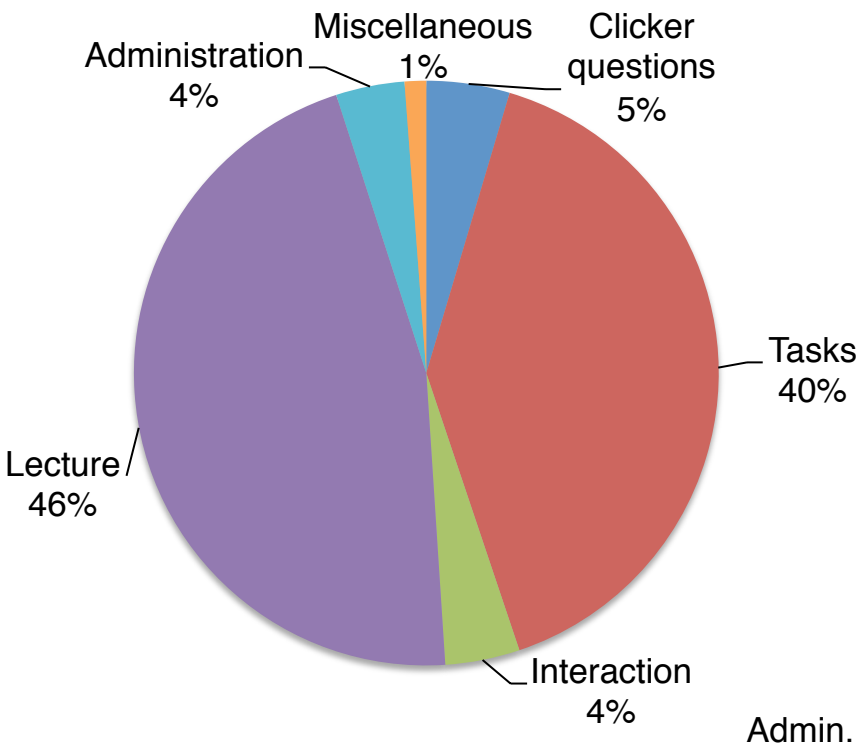
1. Clicker questions	Students respond with personal response instruments
2. Tasks	Students work together or alone to solve a problem, construct a diagram, etc.
3. Interactions	Substantive and possibly lengthy exchanges between the instructor and students
4. Lecture	Instructor-directed presentation of content-related information
5. Administration	"Housekeeping" items such as exam logistics, scheduling, and announcements
6. Miscellaneous	Anything that does not fit above

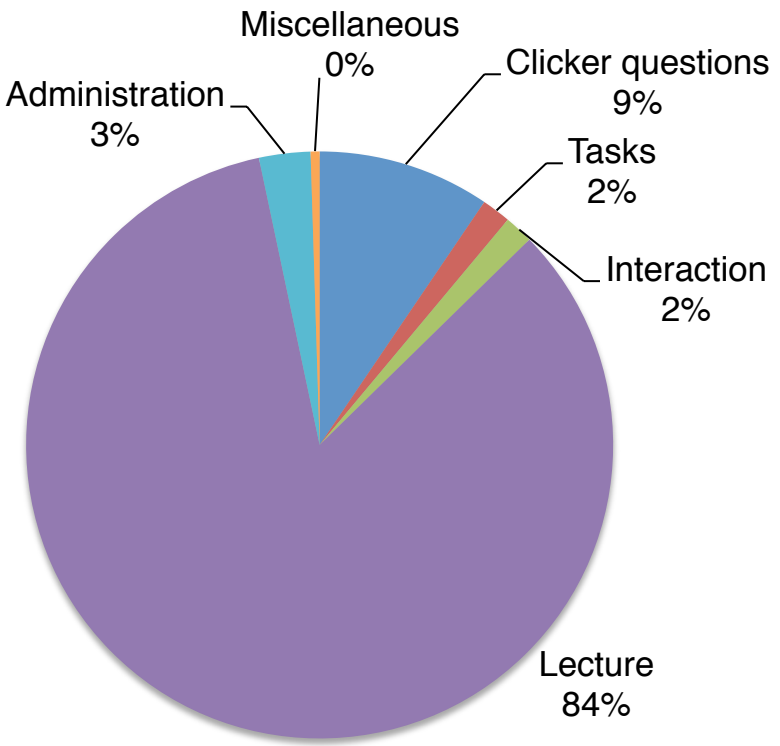
We coded video recordings of introductory biology, chemistry, and physics classes in Fall 2013 and Spring 2014

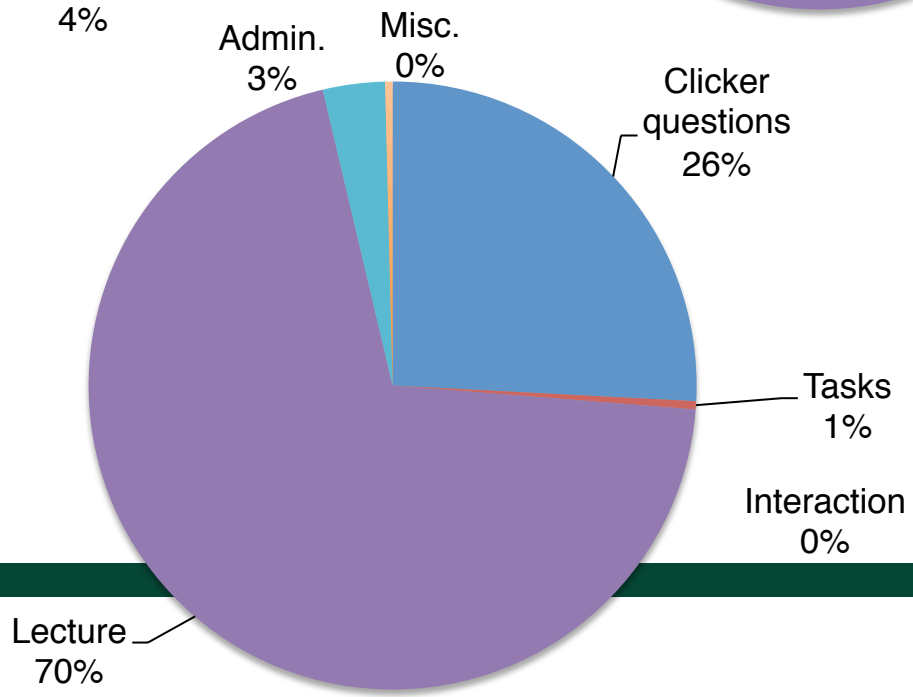
	Course	# recordings	# recordings by discipline	# recordings analyzed here	# instructors represented
Biology	BS161	9	23	14	9
	BS162	14			
Chemistry	CEM141	21	33	22	8
	CEM142	6			
	CEM151	3			
	CEM152	3			
Physics	PHY183	12	39	24	12
	PHY184	10			
	PHY231	8			
	PHY232	9			

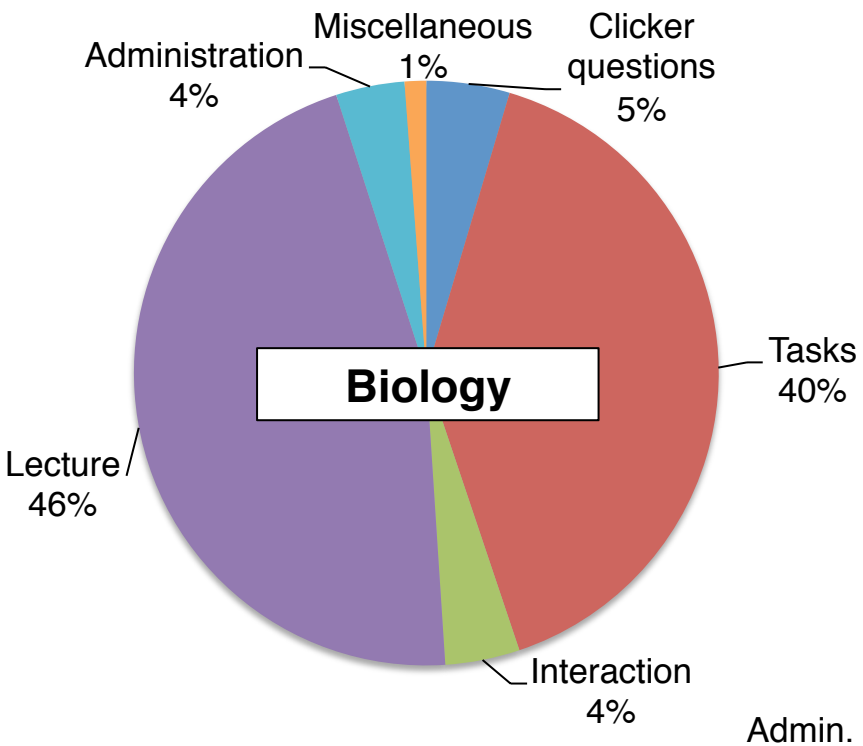
The overall distribution shows that instructors lecture during the majority of class time

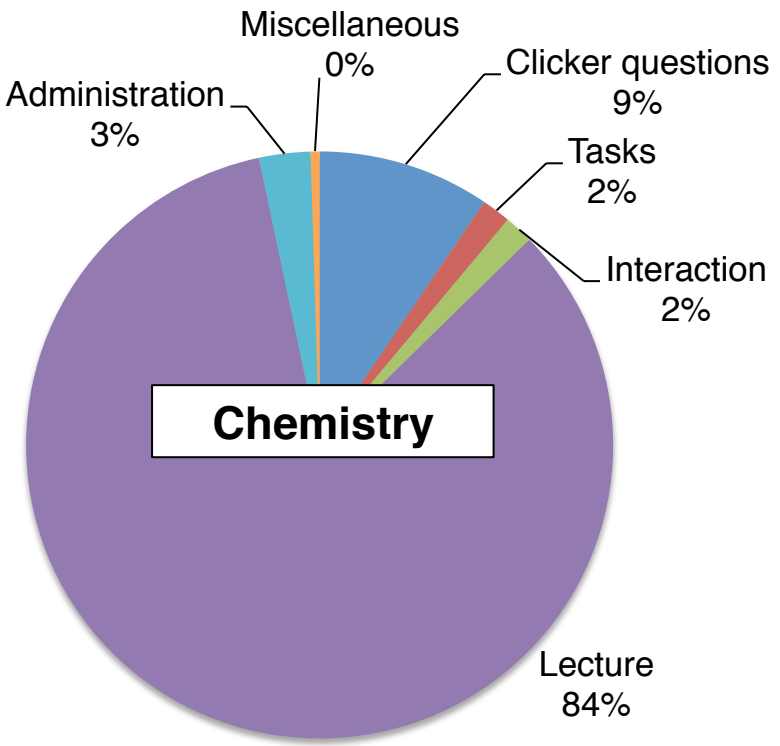


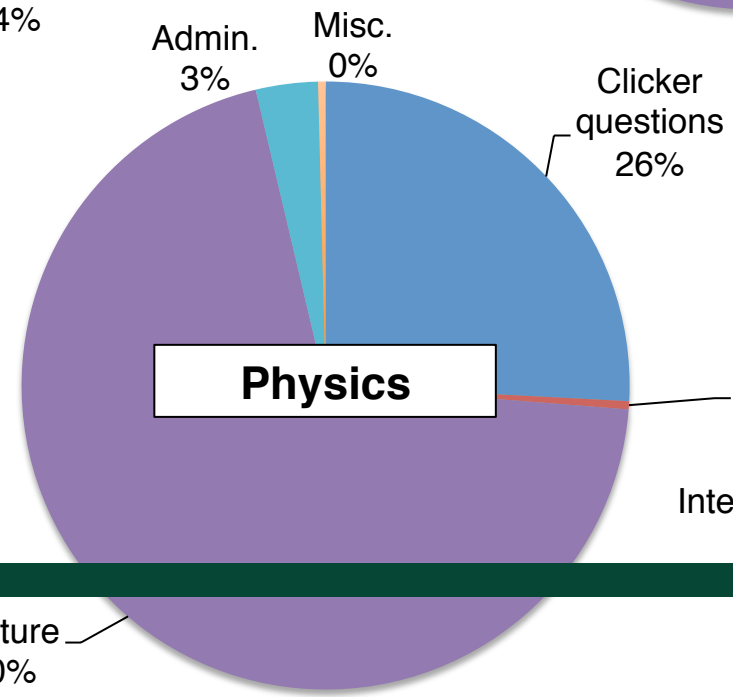

Administration
4%
Miscellaneous
1%
Clicker
questions
5%
Tasks
40%
Interaction
4%
Lecture
46%

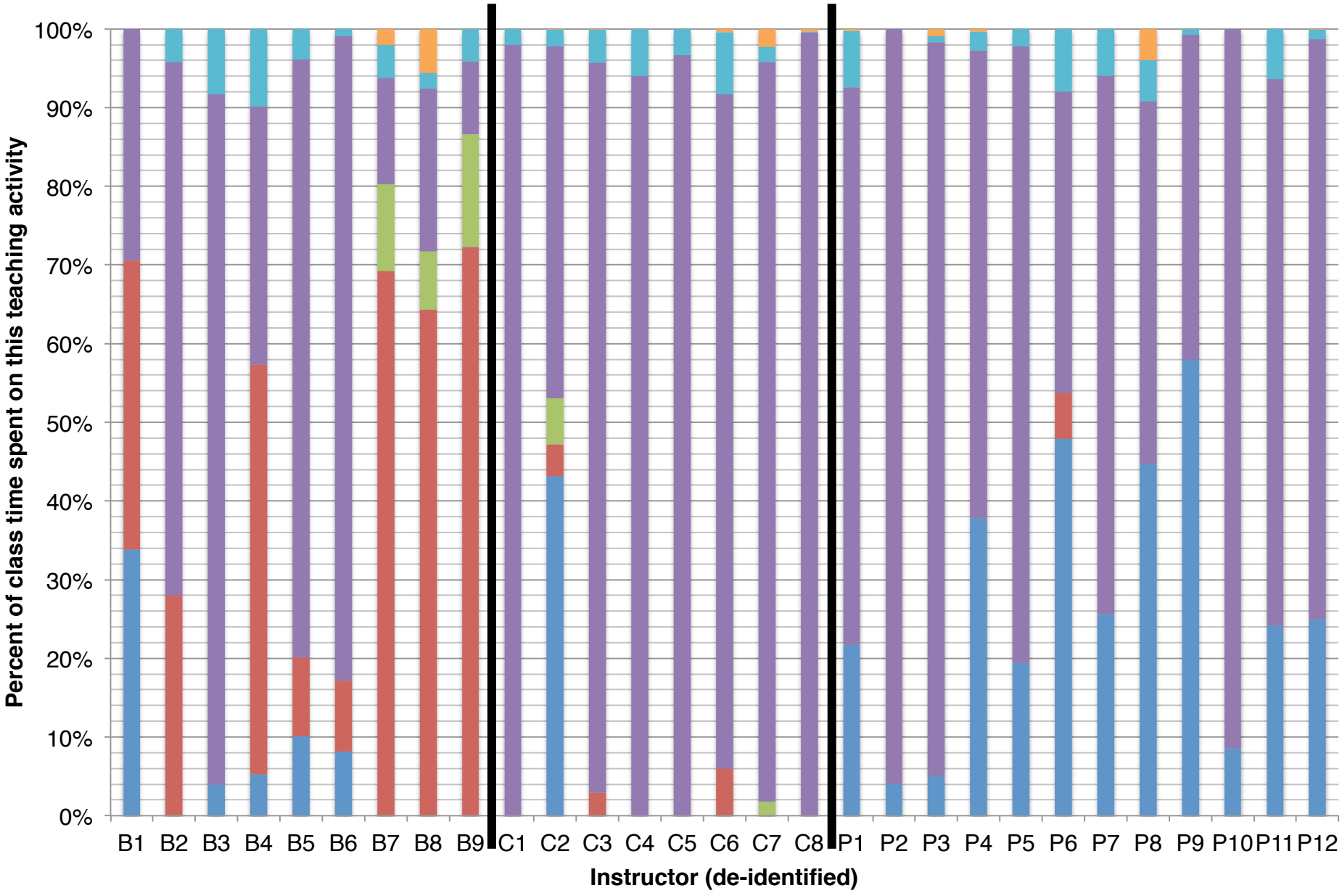

Miscellaneous
0%
Clicker questions
9%
Administration
3%
Tasks
2%
Interaction
2%
Lecture
84%


Admin.
3%
Misc.
0%
Clicker
questions
26%
Tasks
1%
Interaction
0%
Lecture
70%


Biology
Administration 4%
Miscellaneous 1%
Clicker questions 5%
Tasks 40%
Lecture 46%
Interaction 4%


Chemistry
Miscellaneous 0%
Clicker questions 9%
Administration 3%
Tasks 2%
Interaction 2%
Lecture 84%


Physics
Admin. 3%
Misc. 0%
Clicker questions 26%
Tasks 1%
Interaction 0%
Lecture 70%


Percent of class time spent on this teaching activity
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
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
Instructor (de-identified)
Clicker Q
Task
Interaction
Lecture
Admin
Misc

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.

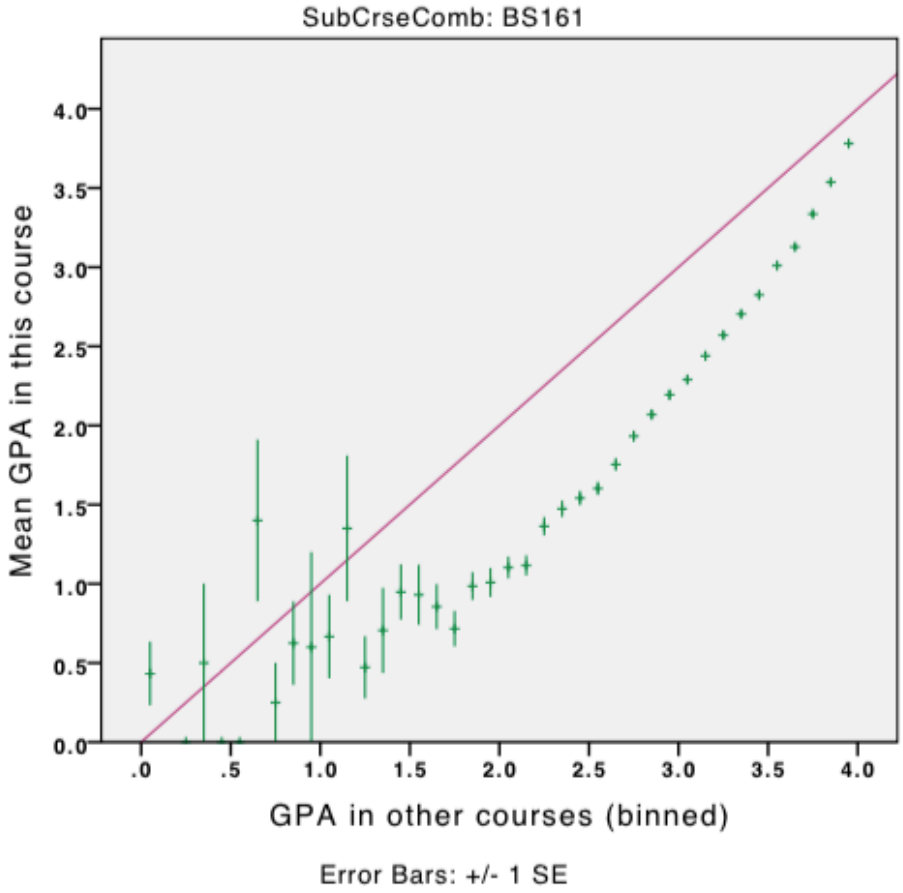
Investigating grade penalties (and bonuses!) at five CIC universities

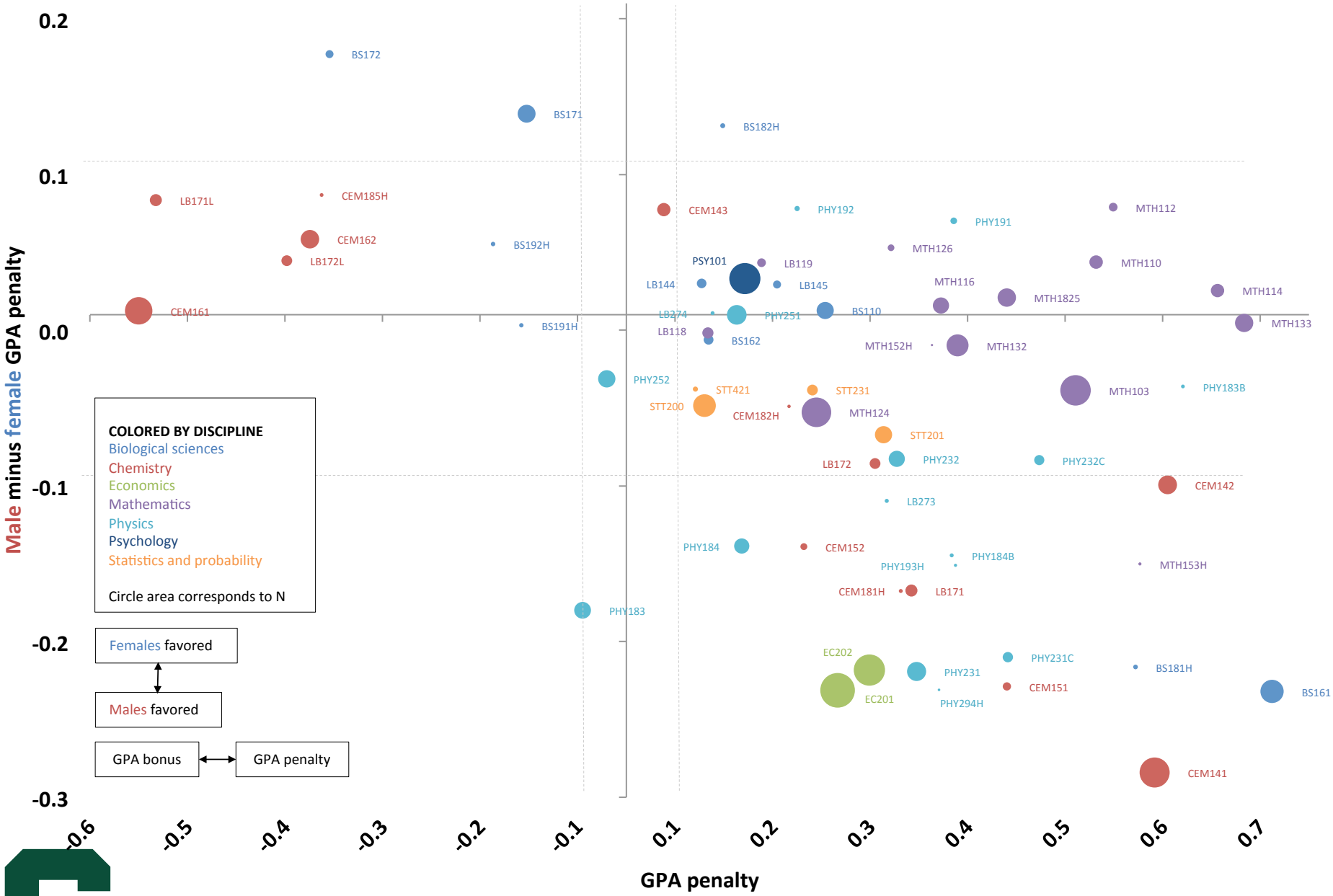
For example, 13,988 students took BS161 at MSU between Fall 2006 and Summer 2014.

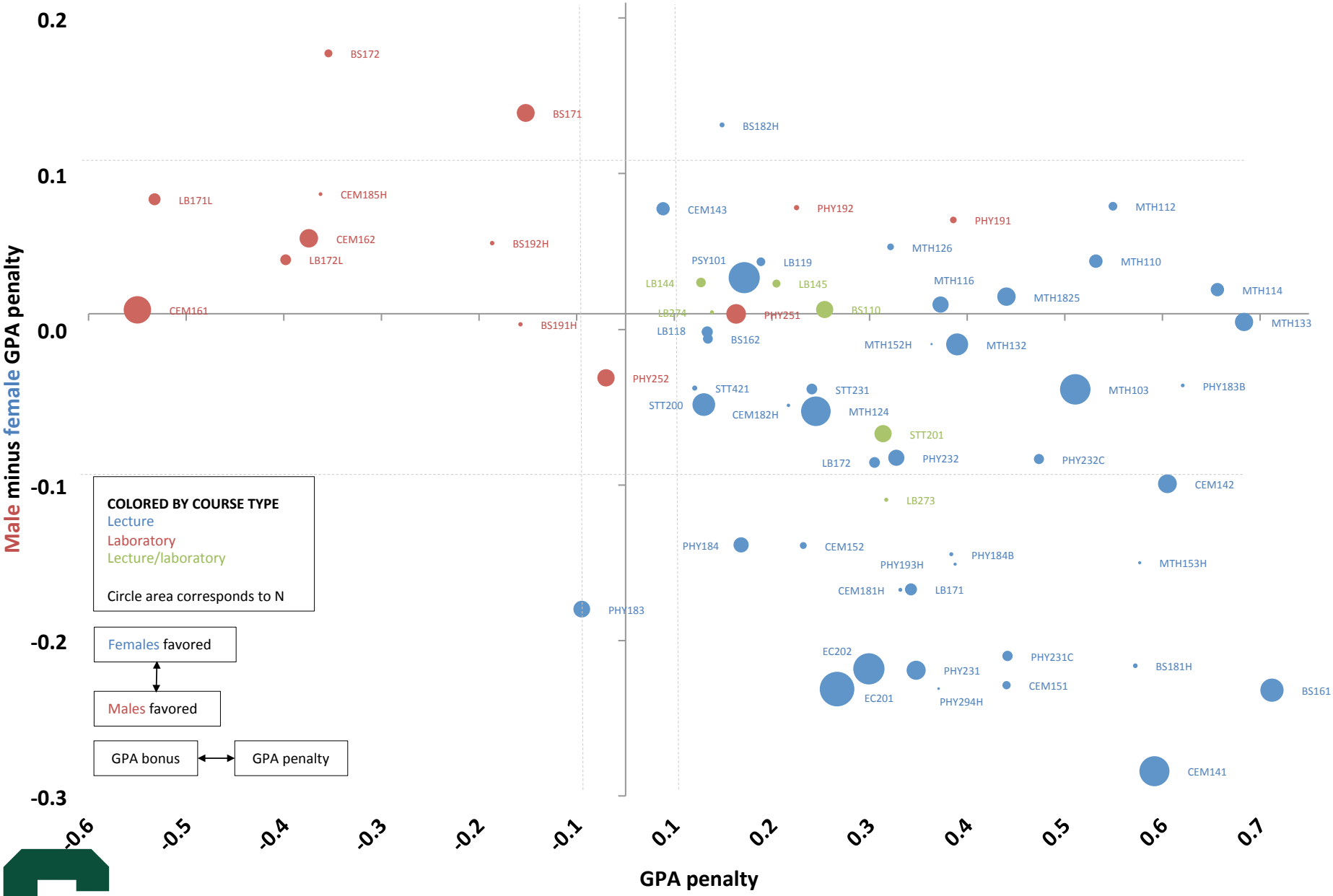
The average student that has a 3.0 GPA will earn a BS161 grade that is between a 2.0 and 2.5.

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.




Male minus female GPA penalty
GPA penalty
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.6
-0.5
-0.4
-0.3
-0.2
-0.1
0.1
0.2
0.3
0.4
0.5
0.6
0.7
BS172
BS171
BS182H
LB171L
CEM185H
CEM162
LB172L
BS192H
CEM161
BS191H
CEM143
PHY192
PHY191
MTH112
MTH126
MTH110
PSY101
LB119
LB144
LB145
MTH116
MTH1825
MTH114
LB274
PHY251
BS110
MTH133
LB118
BS162
MTH152H
MTH132
PHY252
STT421
STT231
MTH103
PHY183B
STT200
CEM182H
MTH124
STT201
LB172
PHY232
PHY232C
CEM142
LB273
PHY184
CEM152
PHY184B
PHY193H
MTH153H
CEM181H
LB171
PHY183
EC202
PHY231C
BS181H
PHY231
CEM151
BS161
EC201
PHY294H
CEM141
COLORED BY DISCIPLINE
Biological sciences
Chemistry
Economics
Mathematics
Physics
Psychology
Statistics and probability
Circle area corresponds to N
Females favored
Males favored
GPA bonus
GPA penalty


Male minus female GPA penalty
GPA penalty
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.6
-0.5
-0.4
-0.3
-0.2
-0.1
0.1
0.2
0.3
0.4
0.5
0.6
0.7
BS172
BS171
BS182H
LB171L
CEM185H
CEM143
PHY192
PHY191
MTH112
CEM162
BS192H
MTH126
LB172L
PSY101
LB119
MTH110
LB144
LB145
MTH116
MTH114
CEM161
LB274
PHY251
BS110
MTH1825
BS191H
LB118
BS162
MTH133
MTH152H
MTH132
PHY252
STT421
STT231
MTH103
PHY183B
STT200
CEM182H
MTH124
STT201
LB172
PHY232
PHY232C
CEM142
LB273
PHY184
CEM152
PHY184B
PHY193H
MTH153H
CEM181H
LB171
PHY183
EC202
PHY231C
BS181H
PHY231
CEM151
BS161
EC201
PHY294H
CEM141
COLORED BY COURSE TYPE
Lecture
Laboratory
Lecture/laboratory
Circle area corresponds to N
Females favored
Males favored
GPA bonus
GPA penalty

Thanks!

TEMPLATE

TEMPLATE

Template