SLAM MICHIGAN

Symposium on Learning Analytics at Michigan

Concurrent Enrollment in Lecture and Laboratory Enhances Student Performance and Retention

Rebecca L. Matz and Mark M. Banaszak Holl
rslahti@umich.edu

Department of Chemistry
University of Michigan

Symposium on Learning Analytics at Michigan
September 28, 2011

Introduction

Laboratories are important tools for teaching and learning in the sciences

- Engagement with scientific phenomena
- Favorable attitudes towards science
- Problem-solving abilities
- Improving scientific thinking

CHEMISTRY

Hofstein, A., & Lunetta, V. N.. (1982). Review of Educational Research, 52(2) 201-217.
Hill, B. W. (1976). Journal of Research in Science Teaching, 13(1) 71-77.
Ben-Zvi, R., Hofstein, A., Samuel, D., & Kempa, R. F. (1976). Journal of Chemical Education, 53(9), 575-577.

Introduction

Learning goals for science laboratories

- Enhancing mastery of subject matter
- Developing scientific reasoning
- **Understanding the complexity and ambiguity of empirical work**
- **Developing practical skills**
- Understanding the nature of science
- Cultivating interest in science
- Developing teamwork abilities

National Research Council. (2006). America's lab report. Washington, D.C.: The National Academies Press.
Millar, R. (2004). The role of practical work in the teaching and learning of science. Washington, D.C.

Introduction

Laboratories are also expensive to staff and run

- Budget restrictions
- Safety concerns
- Standardized exam scores

Baker, N., & Verran, J. (2004). Nature Reviews Microbiology, 2(4), 338-342.
Banilower, E. R., Green, S., & Smith, P. S. (2004). Chapel Hill, NC: Horizon Research.
National Research Council. (2006). America's lab report. Washington, D.C.: The National Academies Press.

Concurrent vs. Nonconcurrent Enrollment

Many Universities Offer Nonconcurrent Enrollment For Introductory Science Courses

University	Biology		Chemistry		Physics	
	C	NC	C	NC	C	NC
Indiana University		✓		✓	✓	
Michigan State University		✓		✓		✓
Ohio State University	✓		✓		✓	
Pennsylvania State University	✓			✓	✓	
Purdue University		✓	✓		✓	
University of Illinois		✓		✓	✓	
University of Iowa	✓		✓		✓	
University of Michigan		✓		✓		✓
University of Minnesota	✓		✓		✓	
University of Nebraska		✓	✓			✓
University of Wisconsin	✓		✓		✓	

Percent of 40 large, public, U.S. universities that offer nonconcurrent enrollment:

38% - Biology

43% - Chemistry

33% - Physics

Benefits of Concurrent and Nonconcurrent Enrollment

Benefits of nonconcurrent enrollment

- Eases scheduling conflicts
- Eases financial burden
- Reduces "risk" of taking a 4- or 5-credit course

Benefits of concurrent enrollment

- Promotes transfer
- Promotes interest in science
- Heightens reasoning skills of lower ability students

CHEMISTRY

Bransford, J. D., & Schwartz, D. L. (1999). Review of research in education. American Educational Research Association.
Hofstein, A., & Lunetta, V. N. (2004). Science Education, 88(1), 28-54.
White, B. Y., & Frederiksen, J. R. (1998). Cognition and Instruction, 16(1), 3-118.

Previous Studies of Concurrent vs. Nonconcurrent Enrollment

Saunders & Dickinson, 1979

- Community college
- General biology
- Studied 500 students over 1 year
- Concurrent students achieved higher exam scores and reported more positive attitudes

Long, McLaughlin, & Bloom, 1986

- Large, public university
- General physics
- Studied 2,500 students over 5 years
- Concurrent enrollment helped final grades of "middle" students

CHEMISTRY

Saunders, W. L., & Dickinson, D. H. (1979). Journal of Research in Science Teaching, 16(5), 459-464.
Long, D. D., McLaughlin, G. W., & Bloom, A. M. (1986). American Journal of Physics, 54(2), 122-125.

General Chemistry At University of Michigan

Study Background and Hypothesis

Studied 10,000 students over 6 years; current student demographics

Hypothesis: concurrent enrollment will positively impact students' lecture

(1) final grades

(2) retention rates

An interesting context because of collaborative nature of laboratory course

U.S. Department of Education, National Center for Education Statistics. (2011). Digest of education statistics.

General Chemistry At University of Michigan

Regular lecture
Regular lab

Concurrent

Nonconcurrent

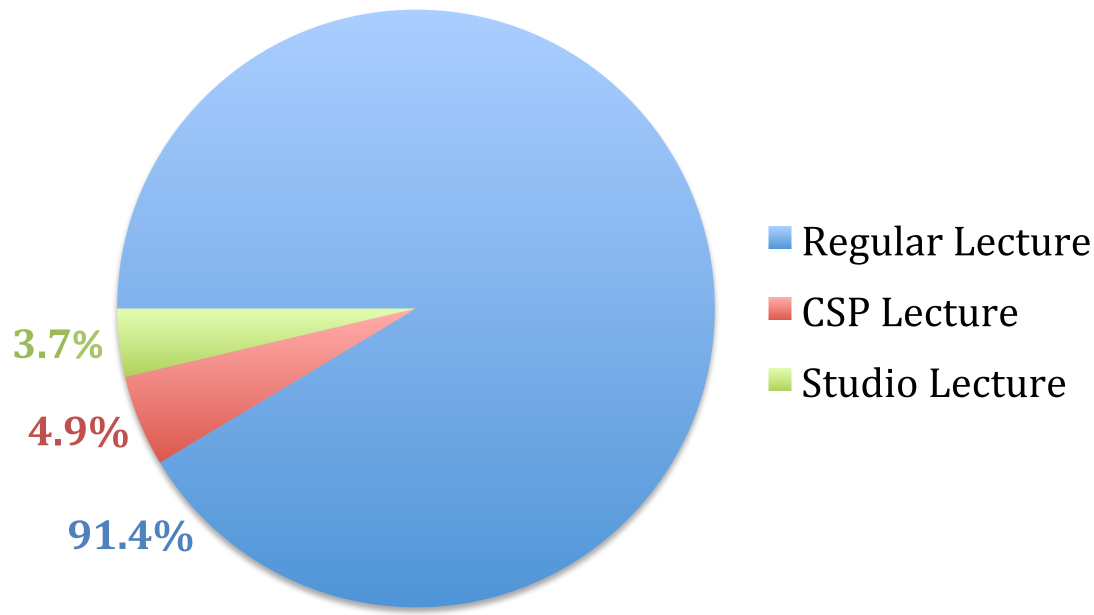
CSP lecture
Regular lab

Concurrent

Nonconcurrent

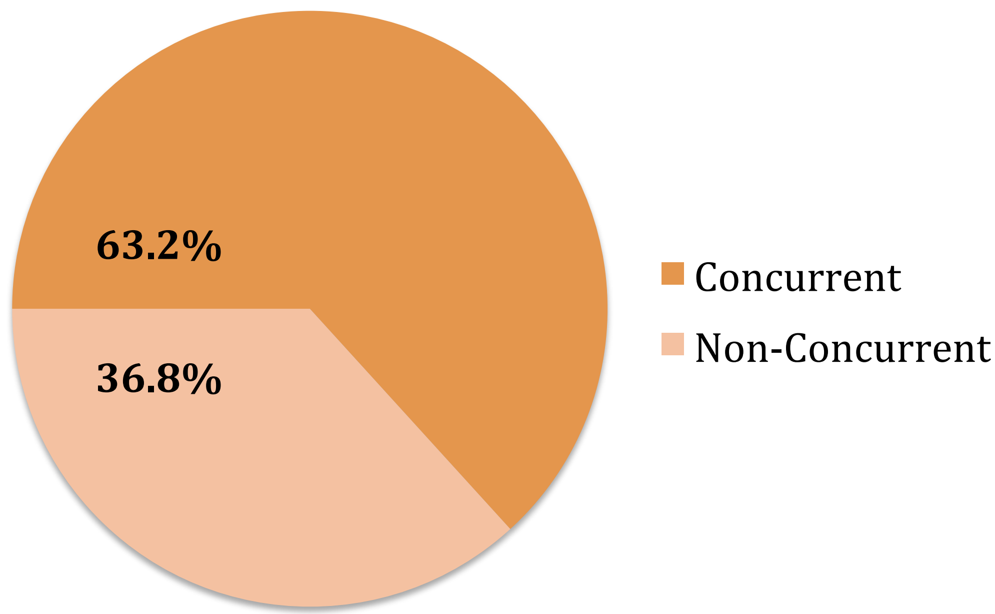
Studio lecture
Studio lab

Concurrent



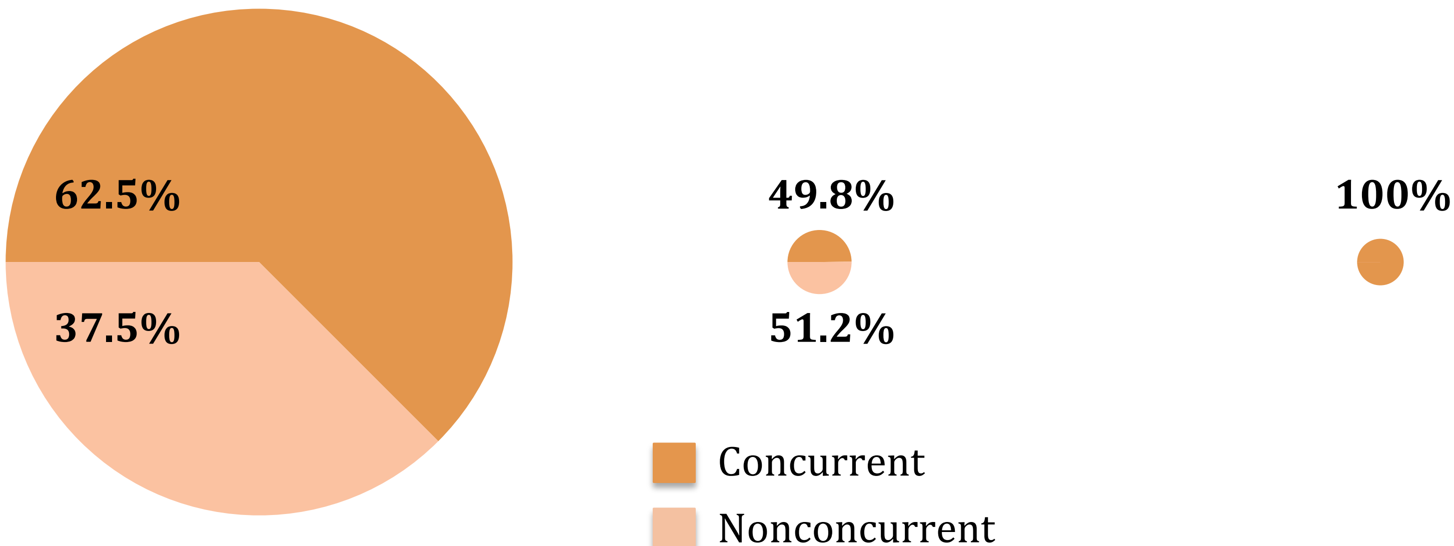
Concurrent vs. Nonconcurrent Enrollment in General Chemistry

Regular lecture Regular lab	CSP lecture Regular lab	Studio lecture Studio lab
Concurrent	Concurrent	Concurrent
Nonconcurrent	Nonconcurrent	



Concurrent vs. Nonconcurrent Enrollment in General Chemistry

Regular lecture Regular lab	CSP lecture Regular lab	Studio lecture Studio lab
Concurrent	Concurrent	Concurrent
Nonconcurrent	Nonconcurrent	



The Data Set

9,438 students

Enrolled in a general chemistry lecture
during a fall term between 2002 and 2007

Demographics

e.g., gender, ethnicity

Scores

e.g., high school GPA, SAT, placement exam scores

Chemistry Courses

e.g., final grades, withdrawal dates

Methodology: Regression Models

Methodology: Regression Models

Final Grades in the Lecture

Linear Regression

Withdrawal Rate from the Lecture

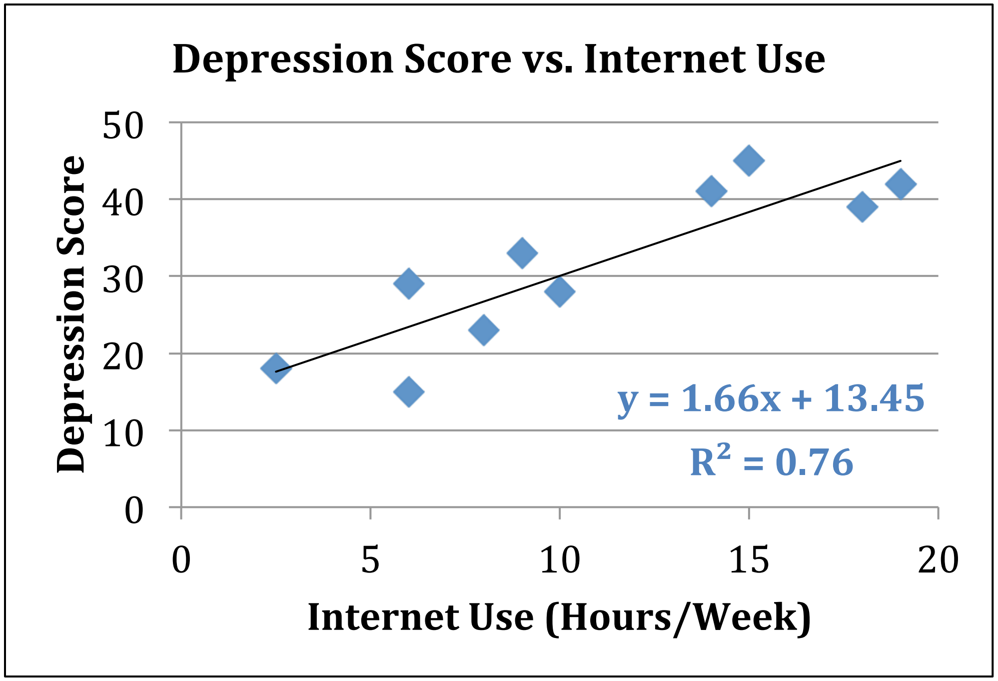
Binary Logistic Regression

Methodology: Regression Model for Final Grades

Final Grades in the Lecture

Linear Regression

$y = b \cdot x + a$



Withdrawal Rate from the Lecture

Binary Logistic Regression

Creswell, J. W. (2008). *Educational Research.* Upper Saddle River, NJ: Pearson Education, Inc.

Methodology: Regression Model for Withdrawal Rate

Final Grades in the Lecture

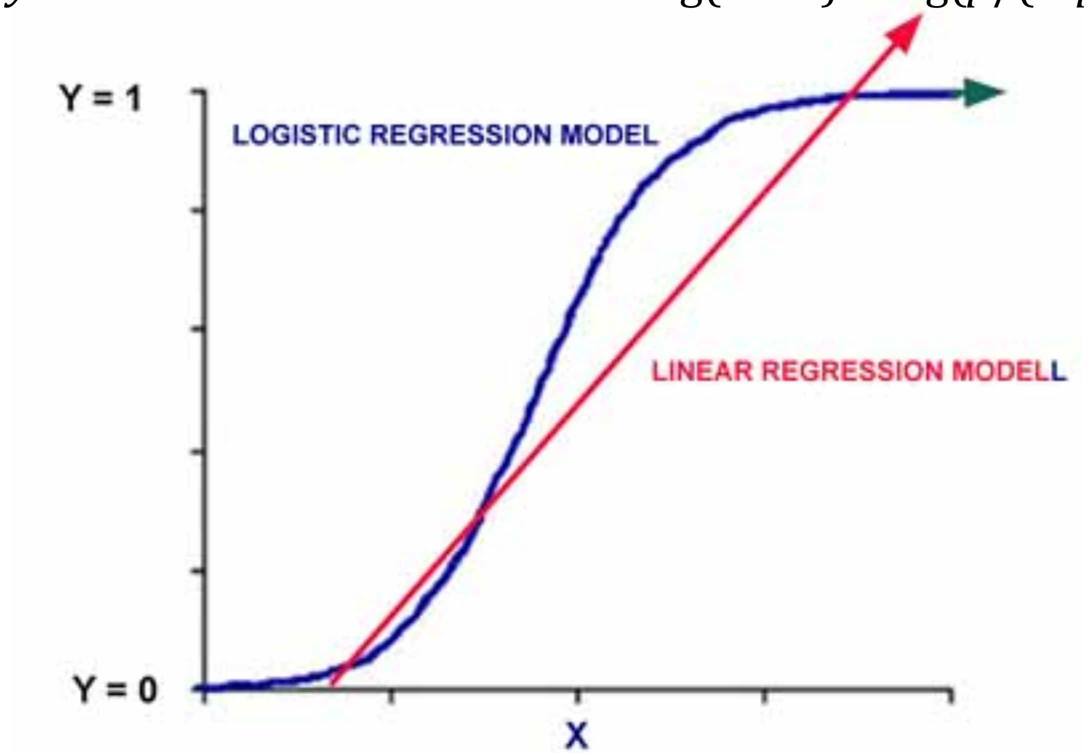
Linear Regression

$y = b \cdot x + a$

Withdrawal Rate from the Lecture

Binary Logistic Regression

$\log(\text{odds}) = \log(p/(1\text{-}p)) = b \cdot x + a$

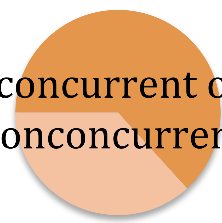


Garson, G. D. Logistic Regression, 2009. North Carolina State University (NCSU).
http://faculty.chass.ncsu.edu/garson/PA765/logistic.htm.

Predictor Variables Used in Regression Models

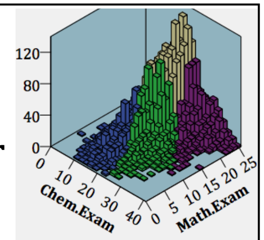
Final Grades in the Lecture	Withdrawal Rate from the Lecture
Linear Regression	Binary Logistic Regression
$y = b_1 \cdot x_1 + b_2 \cdot x_2 + b_3 \cdot x_3 + b_4 \cdot x_4 + b_5 \cdot x_5 + a$	$\log(\text{odds}) = b_1 \cdot x_1 + b_2 \cdot x_2 + b_3 \cdot x_3 + b_4 \cdot x_4 + b_5 \cdot x_5 + a$

Five Predictor Variables

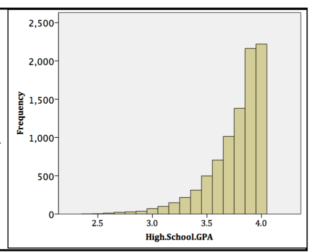


concurrent or nonconcurrent?

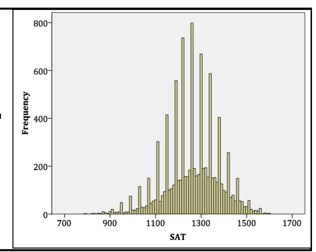
cluster number



high school GPA



comp. SAT

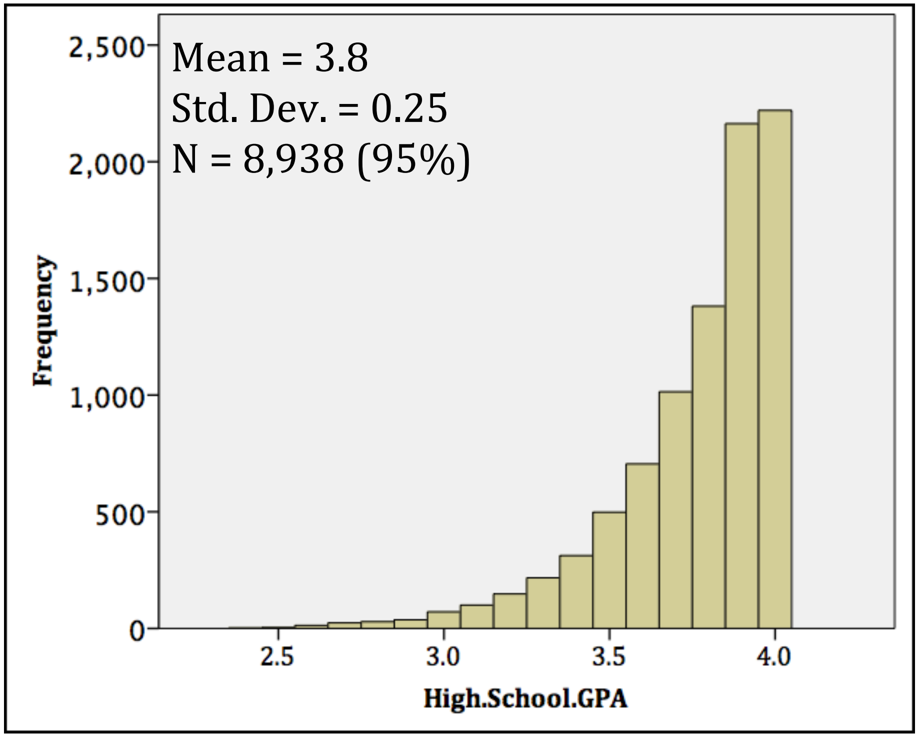


interaction of enrollment (C or NC)and cluster number

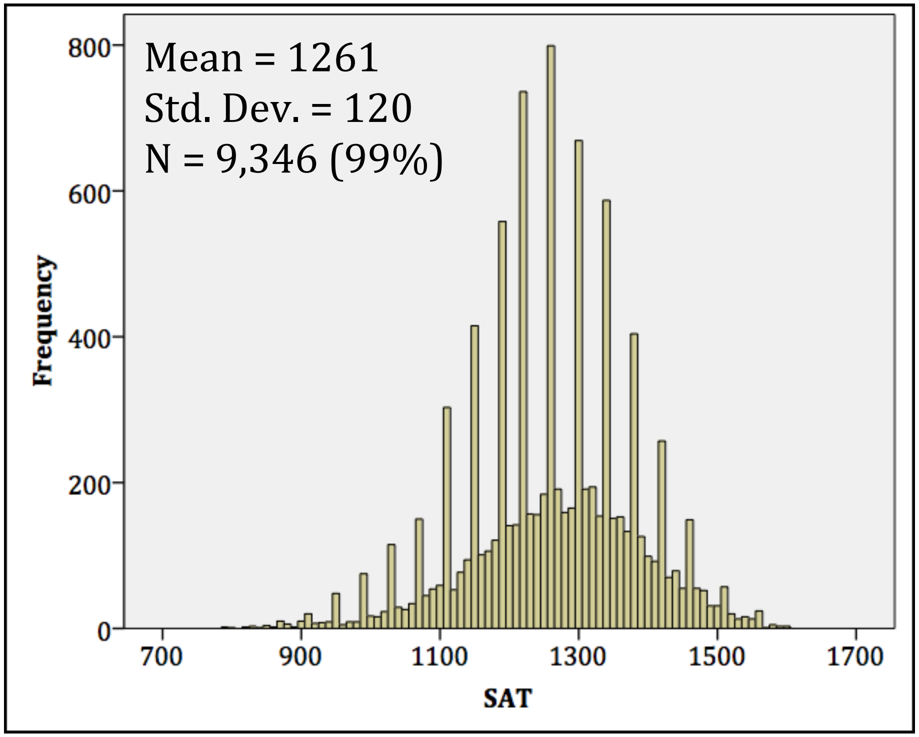
CHEMISTRY

Predictor Variables: High School GPA and SAT

High School GPA



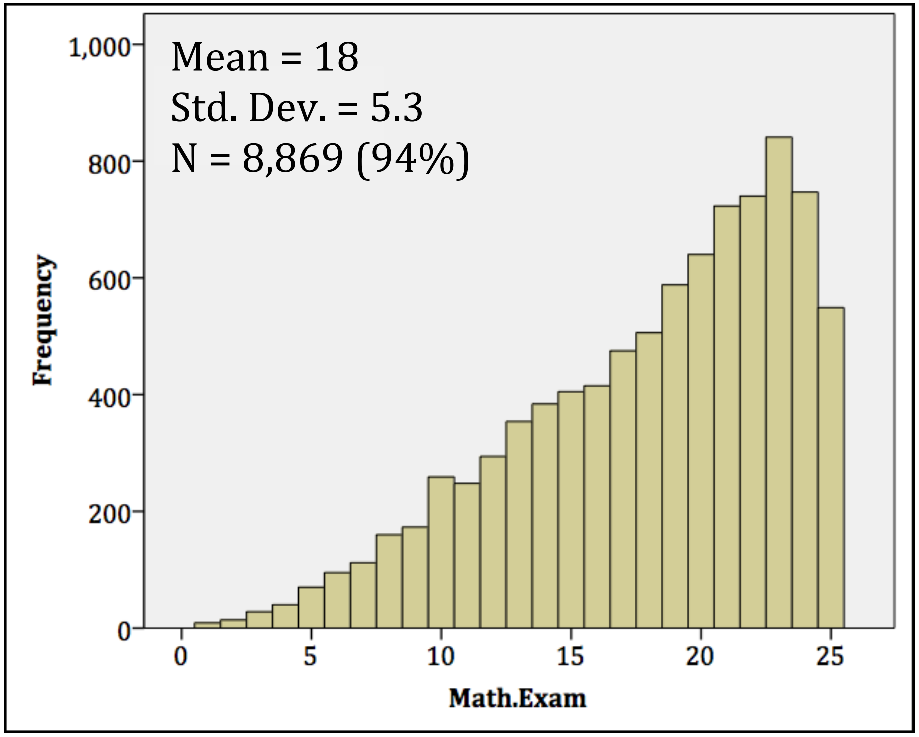
SAT Score



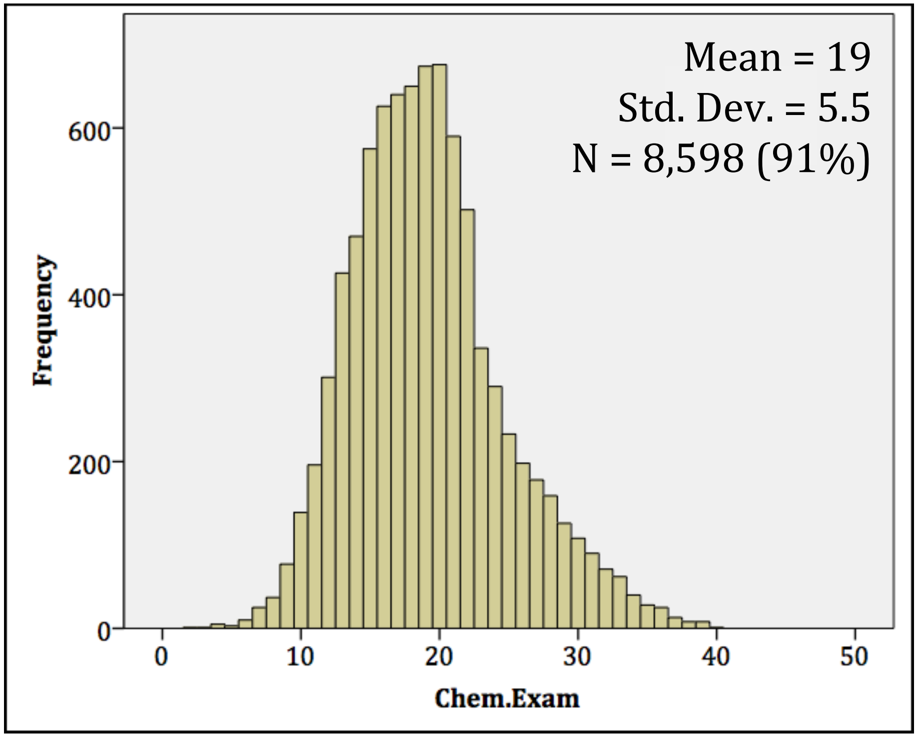
Daugherty, T. K., & Lane, E. J. (1999). Social Behavior and Personality: An International Journal, 27(4), 355-361.
Wolfe, R. N., & Johnson, S. D. (1995). Educational and Psychological Measurement, 55(2), 177-185.

Grouping Students by K-Means Cluster Analysis

Mathematics Placement Exam
/25



Chemistry Placement Exam
/40

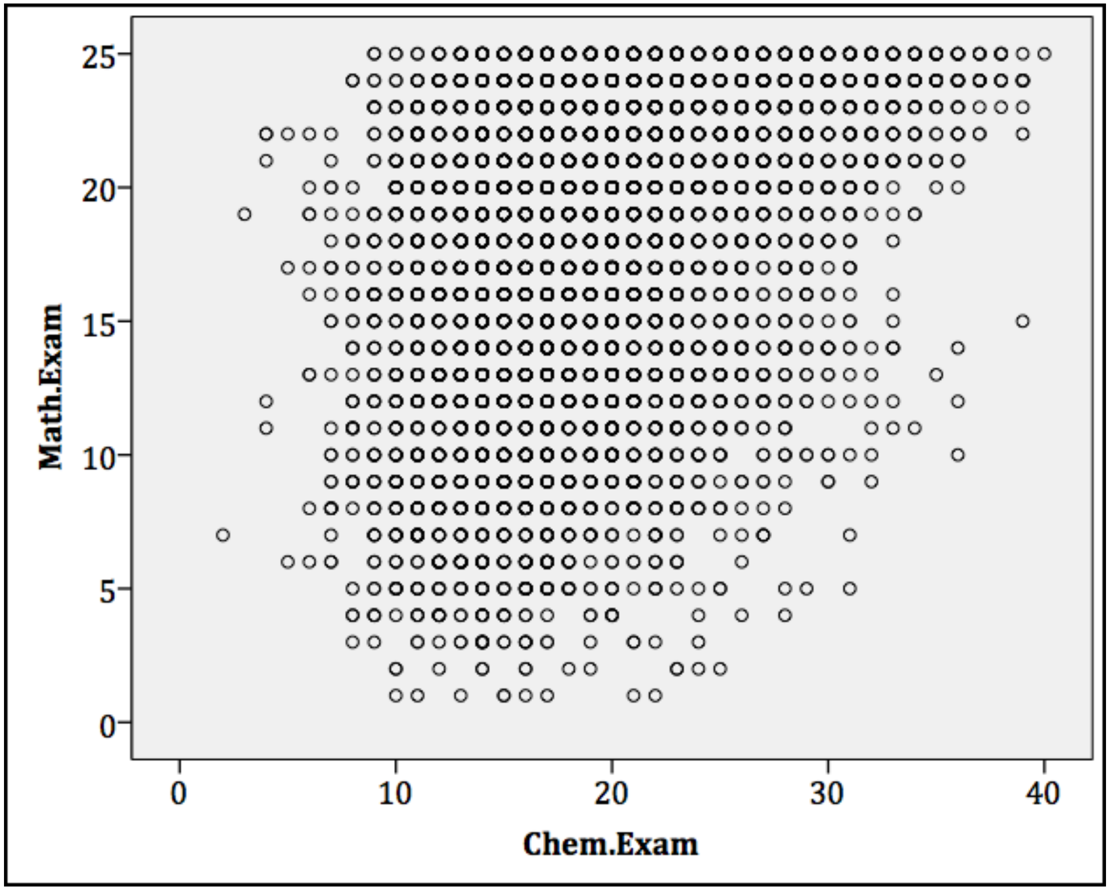


CHEMISTRY

Grouping Students by K-Means Cluster Analysis

Mathematics Placement Exam /25

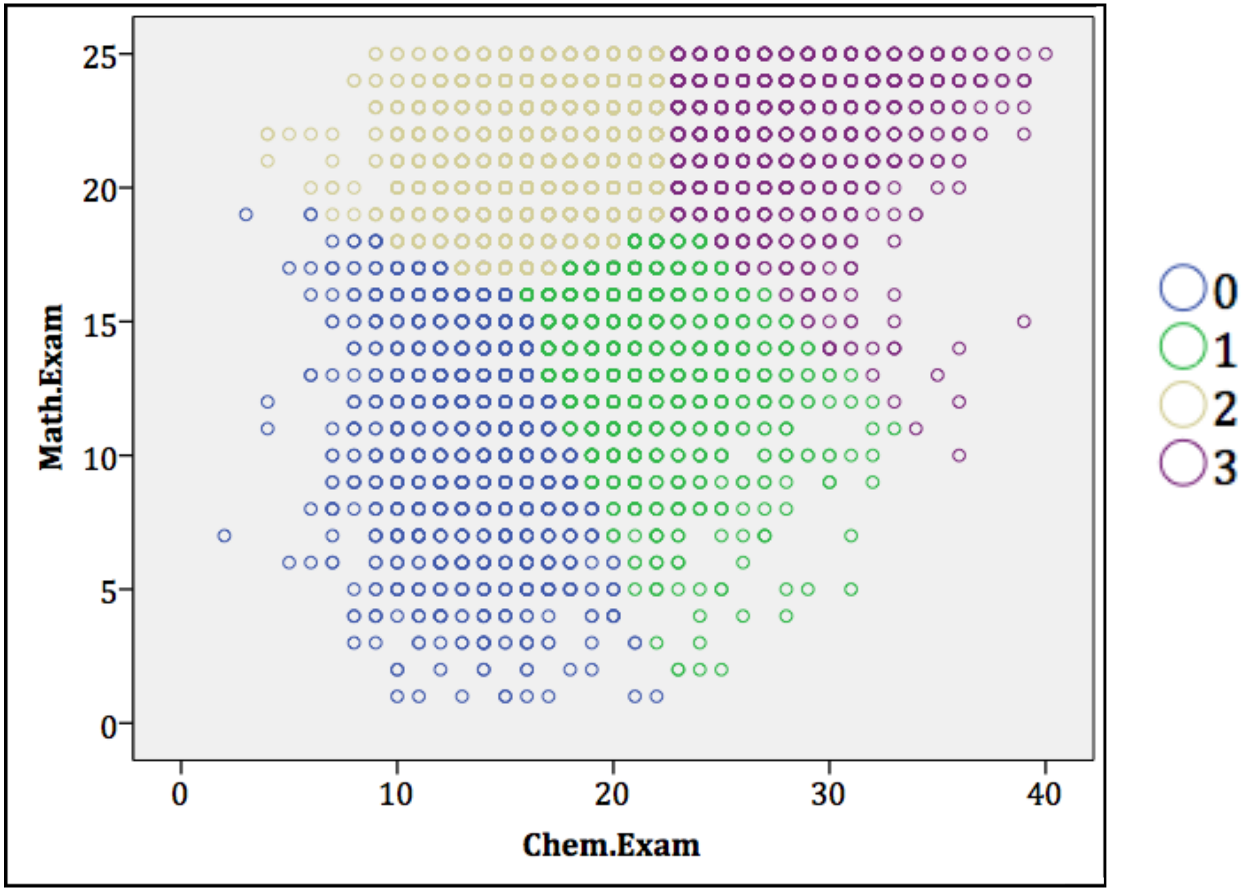
Chemistry Placement Exam /40



Grouping Students by K-Means Cluster Analysis

Mathematics Placement Exam /25

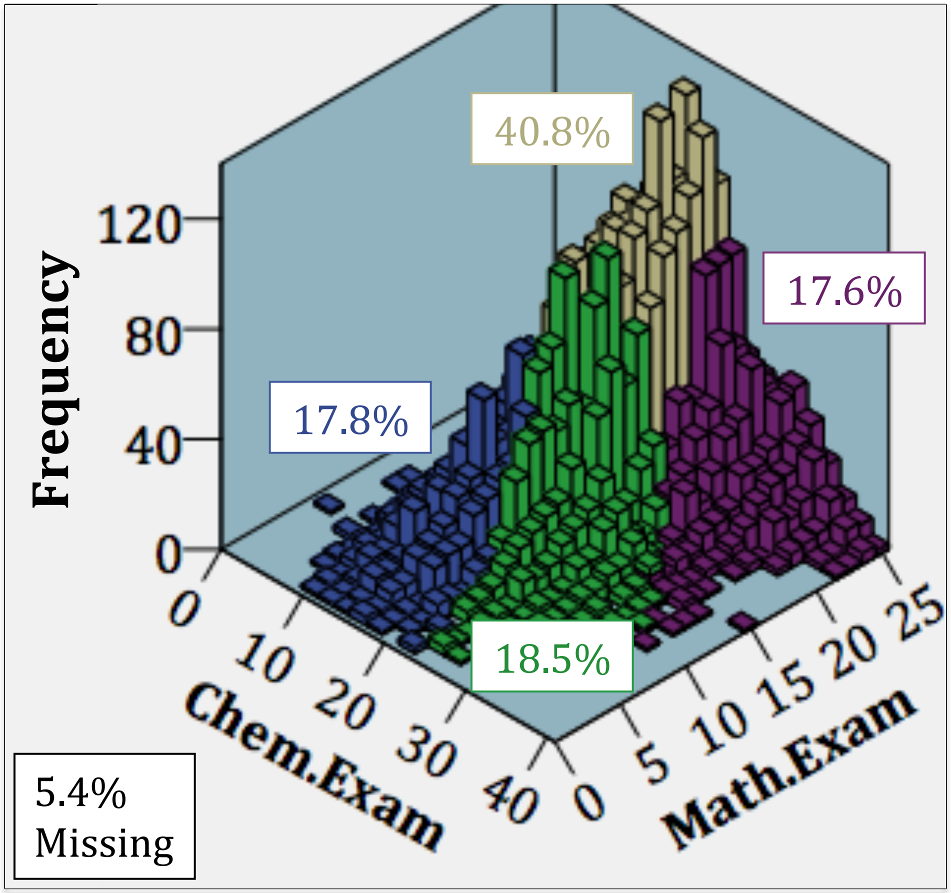
Chemistry Placement Exam /40



Grouping Students by K-Means Cluster Analysis

Mathematics Placement Exam /25

Chemistry Placement Exam /40

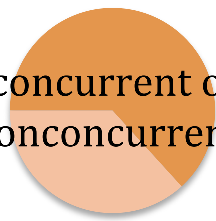


	% Conc.	% Non-Conc.
0	15.6	21.7
1	18.7	18.1
2	43.8	35.5
3	17.9	17.0
Missing	4.1	7.7

Predictor Variables Used in Regression Models

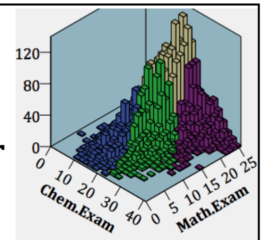
Final Grades in the Lecture	Withdrawal Rate from the Lecture
Linear Regression	Binary Logistic Regression
$y = b_1 \cdot x_1 + b_2 \cdot x_2 + b_3 \cdot x_3 + b_4 \cdot x_4 + b_5 \cdot x_5 + a$	$\log(\text{odds}) = b_1 \cdot x_1 + b_2 \cdot x_2 + b_3 \cdot x_3 + b_4 \cdot x_4 + b_5 \cdot x_5 + a$

Five Predictor Variables

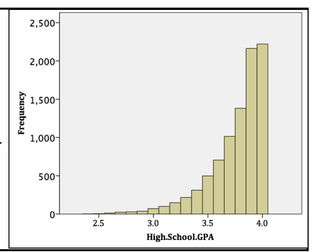


concurrent or nonconcurrent?

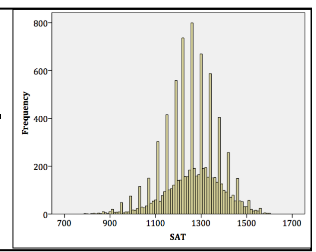
cluster number



high school GPA



comp. SAT



interaction of enrollment (C or NC)and cluster number

CHEMISTRY

Results of Regression Models

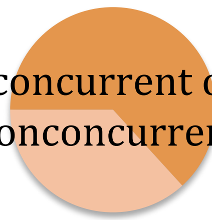
Results: Final Grades in the Lecture

Linear Regression

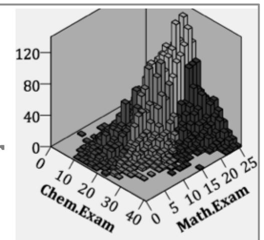
$y = \mathbf{0.19} \cdot \boldsymbol{x_1} + 0.27 \cdot x_2 + 0.86 \cdot x_3 + 0.00 \cdot x_4 + -0.04 \cdot x_5 - 2.4$

p = 0.00 for all predictors at 95% CI $R^2 = 0.32$

1 concurrent or nonconcurrent?

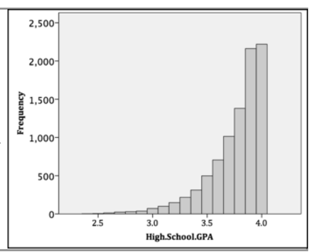


cluster number



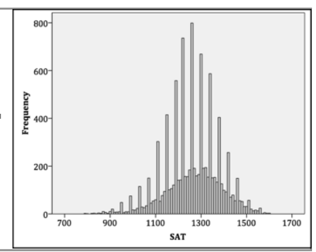
2

high school GPA



3

comp. SAT



4

interaction of enrollment (C or NC)and cluster number

5

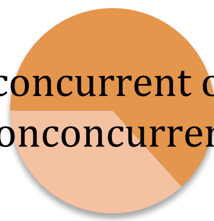
Results: Final Grades in the Lecture

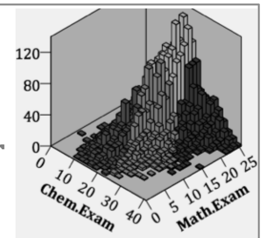
Concurrent enrollment positively affects students' final grades by up to 0.19 points!

Linear Regression

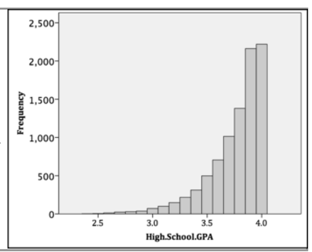
$$y = \mathbf{0.19} \cdot \boldsymbol{x_1} + 0.27 \cdot x_2 + 0.86 \cdot x_3 + 0.00 \cdot x_4 + -0.04 \cdot x_5 - 2.4$$

p = 0.00 for all predictors at 95% CI $R^2 = 0.32$

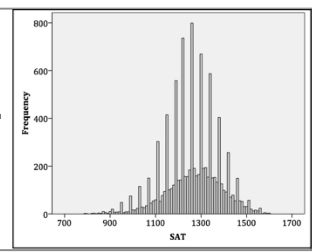
1


cluster number


2

high school GPA


3

comp. SAT


4

interaction of enrollment (C or NC)and cluster number
5

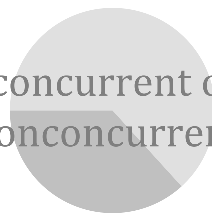
Results: Final Grades in the Lecture

Linear Regression

$$y = 0.19 \cdot x_1 + 0.27 \cdot x_2 + 0.86 \cdot x_3 + 0.00 \cdot x_4 + \mathbf{-0.04 \cdot x_5} - 2.4$$

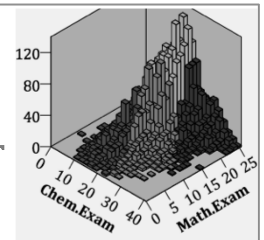
$p = 0.00$ for all predictors at 95% CI $\qquad R^2 = 0.32$

1



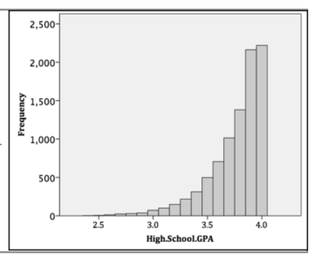
concurrent or nonconcurrent?

cluster number

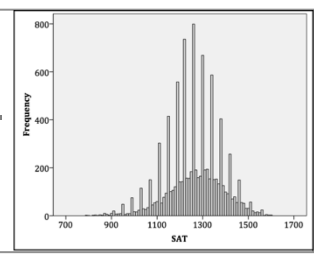


2

high school GPA



comp. SAT



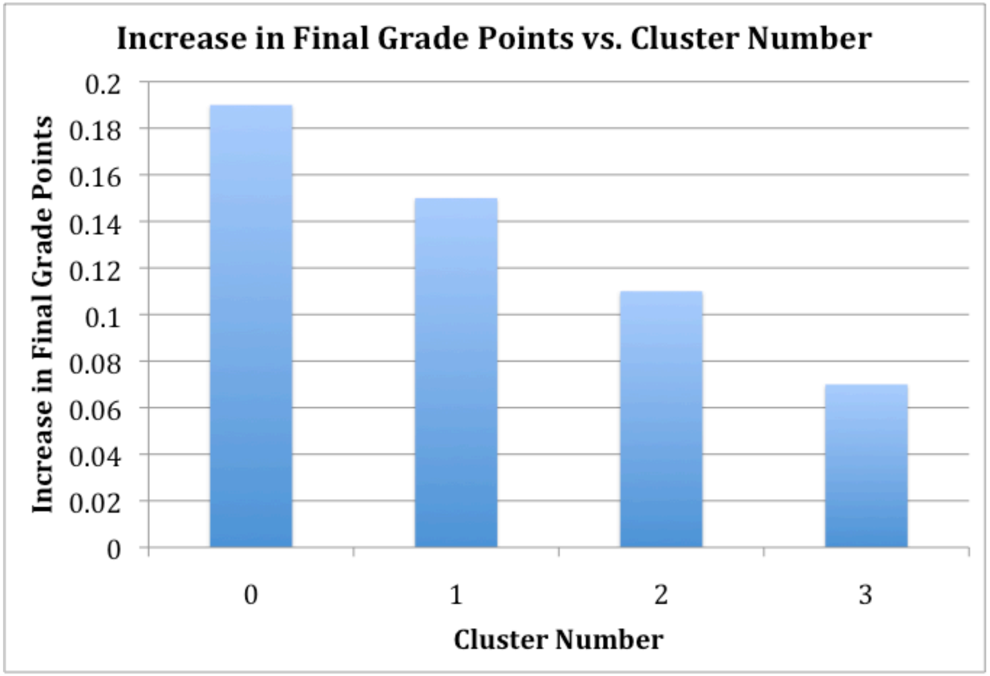
interaction of enrollment (C or NC)and cluster number

3 4 5

Results: Final Grades in the Lecture

Linear Regression

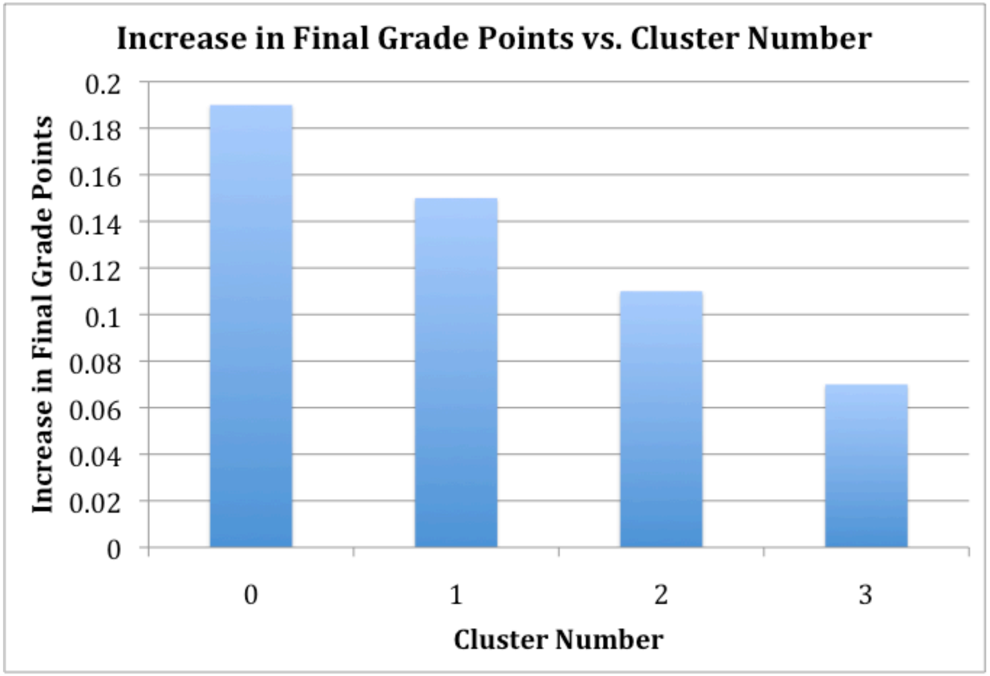
$y = 0.19 \cdot x_1 + 0.27 \cdot x_2 + 0.86 \cdot x_3 + 0.00 \cdot x_4 + \mathbf{-0.04 \cdot x_5} - 2.4$



Results: Final Grades in the Lecture

The lowest-scoring students receive the most benefit from concurrent enrollment in terms of final grades!

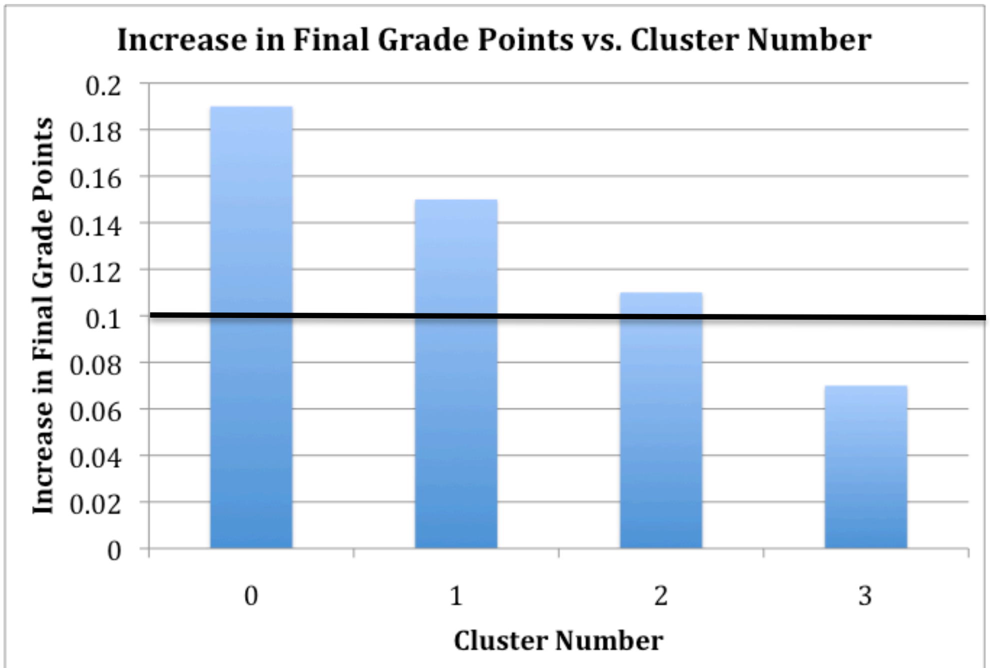
$$y = 0.19 \cdot x_1 + 0.27 \cdot x_2 + 0.86 \cdot x_3 + 0.00 \cdot x_4 + \mathbf{-0.04 \cdot x_5} - 2.4$$



Results: Final Grades in the Lecture

Prediction bias modeling reveals that concurrent enrollment may not be exclusively responsible for the final grade increases observed for clusters two and three.

$$y = 0.19 \cdot x_1 + 0.27 \cdot x_2 + 0.86 \cdot x_3 + 0.00 \cdot x_4 + \mathbf{-0.04 \cdot x_5} - 2.4$$



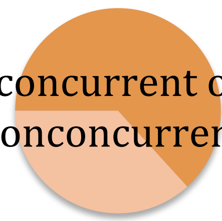
Results: Withdrawal Rate from the Lecture

Binary Logistic Regression

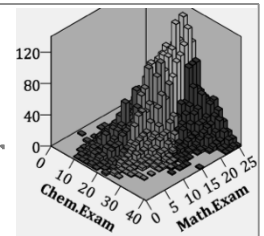
$\log(\text{odds}) = \mathbf{0.79} \cdot \boldsymbol{x_1} + 0.70 \cdot x_2 + 0.94 \cdot x_3 + 0.00 \cdot x_4 + 0.19 \cdot x_5 + a$

p = 0.00 for all predictors at 95% CI except #5 $R^2 = 0.19$ **Exp(b_1) = 2.19**

1 concurrent or nonconcurrent?

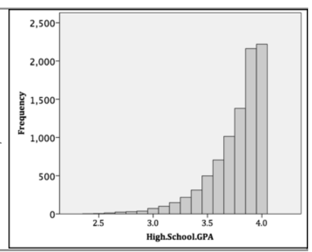


cluster number



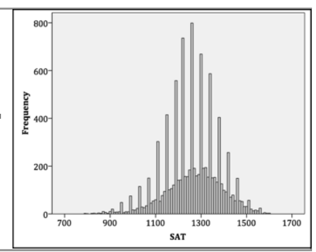
2

high school GPA



3

comp. SAT



4

interaction of enrollment (C or NC)and cluster number

5

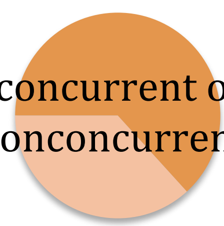
Results: Withdrawal Rate from the Lecture

The odds of a concurrent student being retained in the lecture are 2.2 times higher than for a nonconcurrent student!

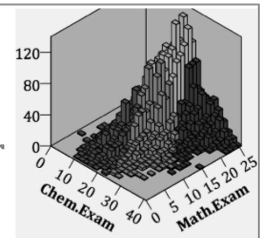
$$\log(\text{odds}) = \mathbf{0.79 \cdot x_1} + 0.70 \cdot x_2 + 0.94 \cdot x_3 + 0.00 \cdot x_4 + 0.19 \cdot x_5 + a$$

p = 0.00 for all predictors at 95% CI except #5 $R^2 = 0.19$ **Exp(b_1) = 2.19**

1

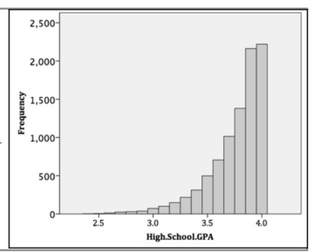


cluster number

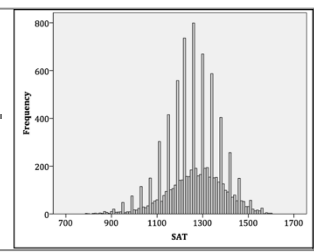


2

high school GPA



comp. SAT



interaction of enrollment (C or NC)and cluster number

3 4 5

Results: Studio-Style Course Format

	Studio vs. Nonstudio	Studio vs. Nonstudio (concurrent only)
Withdrawal Rates	No difference	No difference
Final Grades	+0.23 for studio	+0.13 for studio

Results: Studio-Style Course Format

	Studio vs. Nonstudio	Studio vs. Nonstudio (concurrent only)
Withdrawal Rates	No difference	No difference
Final Grades	+0.23 for studio	+0.13 for studio

Studio

35%	Exams
30%	Group projects
20%	Lab reports
10%	Homework
5%	Participation

Nonstudio Lecture & Laboratory

50%	Exams
30%	Lab reports & presentations
10%	Quizzes
5%	Homework
5%	Participation

CHEMISTRY

Results: Studio-Style Course Format

	Studio vs. Nonstudio	Studio vs. Nonstudio (concurrent only)
Withdrawal Rates	No difference	No difference
Final Grades	+0.23 for studio	+0.13 for studio

Studio

35% Exams

30% Group projects

20% Lab reports

10% Homework

5% Participation

Nonstudio Lecture & Laboratory

50% Exams

30% Lab reports & presentations

10% Quizzes

5% Homework

5% Participation

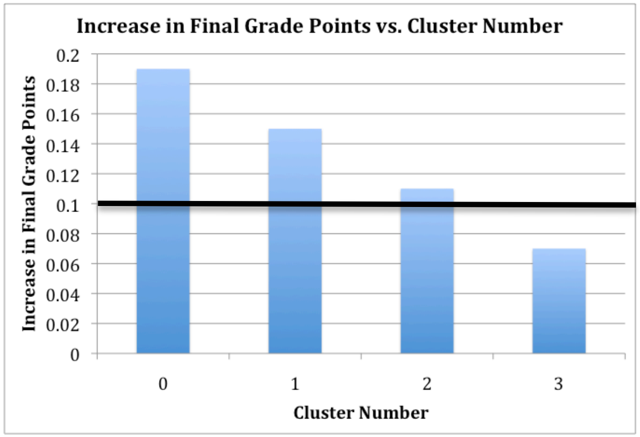
Due to uncertainty about "equality" of grading procedures in studio vs. nonstudio, we find no benefit to enrollment in studio over concurrent enrollment in a nonstudio format based on these metrics.

CHEMISTRY

Key Findings and Potential Implications

Key Findings

The students who score lowest on university placement exams receive the most benefit from concurrent enrollment in terms of final grades



The odds of a concurrent student being retained in the lecture are 2.2 times higher than for a nonconcurrent student

CHEMISTRY

Collaborative Work in the Laboratory: A Possible Reason for the Findings

Benefits of Collaborative Work

better student learning

development of interpersonal skills

promoting enjoyment of courses

Collaborative Aspects of the Laboratory Course

team lab reports

team discussion presentations

peer evaluations

CHEMISTRY

Cooper, M. M., Cox, C. T., Nammouz, M., Case, E., & Stevens, R. (2008). Journal of Chemical Education, 85(6), 866-872.
Cooper, M. M., & Kerns, T. S. (2006). Journal of Chemical Education, 83(9), 1356-1361.
Tien, L. T., Roth, V., & Kampmeier, J. A. (2002). Journal of Research in Science Teaching, 39(7), 606-632.

Potential Implications

Curriculum advisors

Other chemistry courses (organic)

Other disciplines (biology and physics)

CHEMISTRY

Acknowledgements

Ed Rothman (CSCAR)

Joe Krajcik (Education)

Brad Orr (Physics)

Banaszak Holl Group

Department of Chemistry

Graduate Assistance in Areas of National Need (GAANN) Fellowship

CRLT Investigating Student Learning Grant