Concurrent Enrollment in Lecture and Laboratory Enhances Student Performance and Retention

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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

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

Introduction

Laboratories are also expensive to staff and run

- Budget restrictions
- Safety concerns
- Standardized exam scores
Concurrent vs. Nonconcurrent Enrollment
Many Universities Offer Nonconcurrent Enrollment For Introductory Science Courses

<table>
<thead>
<tr>
<th>University</th>
<th>Biology</th>
<th>Chemistry</th>
<th>Physics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C</td>
<td>NC</td>
<td>C</td>
</tr>
<tr>
<td>Indiana University</td>
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<td></td>
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<tr>
<td>Michigan State University</td>
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<td>Purdue University</td>
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<tr>
<td>University of Wisconsin</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
</tbody>
</table>

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

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
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
General Chemistry At University of Michigan

- Regular lecture
  - Regular lab
  - Concurrent
  - Nonconcurrent

- CSP lecture
  - Regular lab
  - Concurrent
  - Nonconcurrent

- Studio lecture
  - Studio lab
  - Concurrent

- Regular Lecture: 91.4%
- CSP Lecture: 4.9%
- Studio Lecture: 3.7%
Concurrent vs. Nonconcurrent Enrollment in General Chemistry

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

- Concurrent: 63.2%
- Non-Concurrent: 36.8%
Concurrent vs. Nonconcurrent Enrollment in General Chemistry

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

- Concurrent: 62.5%
- Nonconcurrent: 37.5%

- Concurrent: 49.8%
- Nonconcurrent: 51.2%
- Studio lecture: 100%
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

<table>
<thead>
<tr>
<th>Final Grades in the Lecture</th>
<th>Withdrawal Rate from the Lecture</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear Regression</td>
<td>Binary Logistic Regression</td>
</tr>
</tbody>
</table>
Methodology: Regression Model for Final Grades

Final Grades in the Lecture  Withdrawal Rate from the Lecture

Linear Regression  Binary Logistic Regression

\[ y = b \cdot x + a \]

![Depression Score vs. Internet Use](chart)

- \( y = 1.66x + 13.45 \)
- \( R^2 = 0.76 \)

Methodology: Regression Model for Withdrawal Rate

Final Grades in the Lecture | Withdrawal Rate from the Lecture

Linear Regression | Binary Logistic Regression

\[ y = b \cdot x + a \] \hspace{1cm} \log(\text{odds}) = \log(\frac{p}{1-p}) = b \cdot x + a

Predictor Variables Used in Regression Models

Final Grades in the Lecture

Linear Regression

\[ y = b_1 \cdot x_1 + b_2 \cdot x_2 + b_3 \cdot x_3 + b_4 \cdot x_4 + b_5 \cdot x_5 + \frac{a}{c} \]

Withdrawal Rate from the Lecture

Binary Logistic Regression

\[ \log(\text{odds}) = b_1 \cdot x_1 + b_2 \cdot x_2 + b_3 \cdot x_3 + b_4 \cdot x_4 + b_5 \cdot x_5 + a \]

Five Predictor Variables

- concurrent or nonconcurrent?
- cluster number
- high school GPA
- comp. SAT
- interaction of enrollment (C or NC) and cluster number
Predictor Variables: High School GPA and SAT

High School GPA

- Mean = 3.8
- Std. Dev. = 0.25
- N = 8,938 (95%)

SAT Score

- Mean = 1261
- Std. Dev. = 120
- N = 9,346 (99%)

Grouping Students by K-Means Cluster Analysis

Mathematics Placement Exam
/25

- Mean = 18
- Std. Dev. = 5.3
- N = 8,869 (94%)

Chemistry Placement Exam
/40

- Mean = 19
- Std. Dev. = 5.5
- N = 8,598 (91%)
Grouping Students by K-Means Cluster Analysis

Mathematics Placement Exam /25

Chemistry Placement Exam /40
Grouping Students by K-Means Cluster Analysis

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Grouping Students by K-Means Cluster Analysis

Mathematics Placement Exam
/25

Chemistry Placement Exam
/40

<table>
<thead>
<tr>
<th>Conc.</th>
<th>% Conc.</th>
<th>% Non-Conc.</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>15.6</td>
<td>21.7</td>
</tr>
<tr>
<td>0</td>
<td>18.7</td>
<td>18.1</td>
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<tr>
<td>1</td>
<td>43.8</td>
<td>35.5</td>
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<tr>
<td>2</td>
<td>17.9</td>
<td>17.0</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Missing</td>
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Predictor Variables Used in Regression Models

Final Grades in the Lecture

Linear Regression

\[ y = b_1 \cdot x_1 + b_2 \cdot x_2 + b_3 \cdot x_3 + b_4 \cdot x_4 + b_5 \cdot x_5 + a \]

Withdrawal Rate from the Lecture

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\[ \log(\text{odds}) = b_1 \cdot x_1 + b_2 \cdot x_2 + b_3 \cdot x_3 + b_4 \cdot x_4 + b_5 \cdot x_5 + a \]

Five Predictor Variables

- concurrent or nonconcurrent?
- high school GPA
- comp. SAT
- interaction of enrollment (C or NC) and cluster number
- cluster number

Final Grades in the Lecture

Linear Regression

\[ y = b_1 \cdot x_1 + b_2 \cdot x_2 + b_3 \cdot x_3 + b_4 \cdot x_4 + b_5 \cdot x_5 + a \]
Results of Regression Models
Results: Final Grades in the Lecture

Linear Regression

\[ y = 0.19 \cdot x_1 + 0.27 \cdot x_2 + 0.86 \cdot x_3 + 0.00 \cdot x_4 + -0.04 \cdot x_5 - 2.4 \]

\[ p = 0.00 \text{ for all predictors at 95\% CI} \quad R^2 = 0.32 \]
Results: Final Grades in the Lecture

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

Linear Regression

\[ y = 0.19 \cdot x_1 + 0.27 \cdot x_2 + 0.86 \cdot x_3 + 0.00 \cdot x_4 - 0.04 \cdot x_5 - 2.4 \]

\( p = 0.00 \) for all predictors at 95% CI \hspace{1cm} R^2 = 0.32
Results: Final Grades in the Lecture

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Results: Final Grades in the Lecture

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

\[ y = 0.19 \cdot x_1 + 0.27 \cdot x_2 + 0.86 \cdot x_3 + 0.00 \cdot x_4 + -0.04 \cdot x_5 - 2.4 \]
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.

\[ y = 0.19 \cdot x_1 + 0.27 \cdot x_2 + 0.86 \cdot x_3 + 0.00 \cdot x_4 -0.04 \cdot x_5 - 2.4 \]
Results: Withdrawal Rate from the Lecture

Binary Logistic Regression

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

\[p = 0.00\] for all predictors at 95% CI except #5  \[R^2 = 0.19\]  \[\text{Exp}(b_1) = 2.19\]
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!

\[
\text{log(odds)} = 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
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\(p = 0.00\) for all predictors at 95% CI except #5 \(R^2 = 0.19\) \(\text{Exp}(b_1) = 2.19\)
# Results: Studio-Style Course Format

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## Results: Studio-Style Course Format

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### 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

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**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.*

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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.
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


Potential Implications

Curriculum advisors

Other chemistry courses (organic)

Other disciplines (biology and physics)
Acknowledgements

Ed Rothman (CSCAR)
Joe Krajcik (Education)
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Banaszak Holl Group

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