The Impact of Undergraduate Science Course Innovations on Student Learning

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End of Year Event
Science Education Initiative
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Traditional Science Classes
Innovations

What works in undergraduate science education?
What is meta-analysis?
Meta-Analysis

• Systematic approach to the synthesis of research findings
• Pooling existing evidence
• Summing up:
  ▫ Innovations implemented
  ▫ Evidence of success
What is needed?

- Gather empirical evidence
- Metric for computing effects of studies with different outcome measures?

Effect Size: \[ ES = \frac{\bar{X}_T - \bar{X}_C}{SD_C} \]
Gathering of Empirical Evidence
What was included?

Four criteria:

1. focus on undergraduate education in biology, chemistry, engineering & physics;
2. include one or more instructional strategies considered to be an innovation;
3. refer to actual classrooms, rather than controlled conditions; and
4. be reported in article published in 1990 or later. (Suter & Narayanan, 2006; Beichner, 2009)
Study Search Methods

Word of Mouth

Journal Search

Validate Keywords

Comparative Studies
- Biology = 82
- Chemistry = 18
- Engineering = 23
- Physics = 74

Classify
- Classify papers as either:
  - Background
  - Synthesis
  - Descriptive
  - Comparative

Expanded Search
All Innovation Papers
n = 868

Comparative Studies
n = 210

Biology
Include 54%
Exclude 46%

Chemistry
Include 77%
Exclude 23%

Engineering
Include 58%
Exclude 42%

Physics
Include 48%
Exclude 52%
Effect Size Distribution

Included Comparative Studies

n = 166

ES from -1.06 to 2.57

Mean = 0.47

SD = 0.54

83% Positive Effect Size
Biology
Mean = 0.54 (0.66)

Chemistry
Mean = 0.27 (0.41)

Engineering
Mean = 0.08 (0.58)

Physics
Mean = 0.59 (0.37)
Factors Explaining Variability?
## Innovation Type

<table>
<thead>
<tr>
<th>Innovation Combination</th>
<th>Number of Studies</th>
<th>Mean Effect Size (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology</td>
<td>30</td>
<td>0.35 (0.39)</td>
</tr>
<tr>
<td>Conceptually Oriented Tasks + Collaborative Learning</td>
<td>42</td>
<td>0.56 (0.41)</td>
</tr>
<tr>
<td>Conceptually Oriented Tasks + Technology</td>
<td>18</td>
<td>0.41 (0.61)</td>
</tr>
<tr>
<td>Conceptually Oriented Tasks + Collaborative Learning + Technology</td>
<td>38</td>
<td>0.46 (0.50)</td>
</tr>
</tbody>
</table>
Importance of Outcome Measure

- Outcome measure item format
  - Multiple-choice (mean ES=0.56)
  - Open-ended (mean ES=0.35)

- Alignment of the outcome measure to the innovation

In one particular report:
  - Force and Motion Conceptual Evaluation (ES = 1.36)
  - Open-ended traditional problem solving (ES = -0.62)
The Issue of Assignment

- 88% of studies do not have random assignment of individuals to treatment and control
- Pretest scores are essential to evaluate/adjust for group differences
- For those studies that do, when taken into account:
  - Mean effect size is much larger
Conclusions

• Innovations have a positive effect on student learning

• Things to consider:
  ▫ Providing sufficient empirical data
  ▫ Importance of outcome measure
  ▫ Pretest administration

• Next steps – Case studies of effective innovations
Thank You

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