Comparing a “Flipped” Instructional Model in a Calculus III Course

Nick Wasserman, Scott Norris, Thomas Carr
Southern Methodist University
Technology

- In recent years, technology has drastically transformed the educational landscape. In particular, it has expanded the classroom walls.
“Flipping” the classroom

- Lage, Platt, & Tregalia (2000) describe an “inverted” classroom model as: events that typically take place inside the classroom now take place outside the classroom and vice versa.

- Bergman & Sams (2008) popularized an analogous approach that has come to be known as the “flipped” classroom.
Instruction

Two aspects of instruction are:
1) Transmission of content (e.g., lecture)
2) Assimilation (e.g., practice)

Adaptation of Bloom’s Taxonomy
Anderson & Krathwohl (2001)

Higher Order Thinking Skills
- Creating
- Evaluating
- Analysing
- Applying
- Understanding
- Remembering

Lower Order Thinking Skills

Cognitive Load
Instruction

Adaptation of Bloom’s Taxonomy
Anderson & Krathwohl (2001)

Assimilation

Transmission

Higher Order Thinking Skills
- Creating
- Evaluating
- Analysing
- Applying
- Understanding
- Remembering

Cognitive Load
Traditional Approach

Adaptation of Bloom’s Taxonomy
Anderson & Krathwohl (2001)

- Transmission
- Assimilation
- Higher Order Thinking Skills
  - Creating
  - Evaluating
  - Analysing
  - Applying
  - Understanding
  - Remembering

Lower Order Thinking Skills
Cognitive Load
Traditional Approach

Traditional Approach
Potential Problem

Accessibility of help

Assimilation

Transmission

Adaptation of Bloom’s Taxonomy
Anderson & Krathwohl (2001)

Higher Order Thinking Skills
- Creating
- Evaluating
- Analysing
- Applying
- Understanding
- Remembering

Lower Order Thinking Skills
Cognitive Load
“Flipped” Approach

Adaptation of Bloom’s Taxonomy
Anderson & Krathwohl (2001)

Cognitive Load
Transmission
Assimilation
Accessibility of help

Potential Solution

Higher Order Thinking Skills
- Creating
- Evaluating
- Analysing
- Applying
- Understanding
- Remembering

Lower Order Thinking Skills
Instructional Models

Traditional Instruction

- Lecture Content
- Practice Problems
- Lecture Content
- Practice Problems
- Lecture Content
- Practice Problems
Instructional Models

Traditional Instruction

Lecture Content  Practice Problems  Lecture Content  Practice Problems  Lecture Content  Practice Problems

“Flipped” Instruction

Lecture Content  Practice Problems  Lecture Content  Practice Problems  Lecture Content  Practice Problems
Theoretical Model

Procedural questions: those that primarily require carrying out a standard mathematical procedure or algorithm (e.g., calculate the partial derivative of a function)

Conceptual questions: those that primarily require explanation/generalization of mathematical concepts or application of procedures in non-standard settings (e.g., interpret the partial derivative of \( T=f(x,y,z) \) with respect to \( z \)
Other Research

• While the theoretical idea of “flipping” the classroom is compelling, there is actually very little conclusive research about its impact on student performance.

• From Bergman & Sams (2008)
  - Chemistry class
  - 2006-2007, traditional
  - 2007-2008, flipped
  - Same tests

Checking the Results

<table>
<thead>
<tr>
<th>Exam</th>
<th>2006-07</th>
<th>2007-08</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 2</td>
<td>78.7%</td>
<td>78.7%</td>
</tr>
<tr>
<td>Unit 3</td>
<td>84.5%</td>
<td>86.8%</td>
</tr>
<tr>
<td>Unit 4</td>
<td>81.6%</td>
<td>80.7%</td>
</tr>
<tr>
<td>Unit 5</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Sem 1</td>
<td>67.9%</td>
<td>66.2%</td>
</tr>
<tr>
<td>Unit 6</td>
<td>75.1%</td>
<td>74.1%</td>
</tr>
<tr>
<td>Unit 7</td>
<td>89.0%</td>
<td>81.2%</td>
</tr>
<tr>
<td>Unit 8</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Final</td>
<td>73.9%</td>
<td>71.7%</td>
</tr>
</tbody>
</table>
Other Research

- Gannod, Burge, & Helmick (2008), in an undergraduate software engineering course, used pre- and post-testing to demonstrate that students did learn using a flipped approach. No control group.

- Los Altos school district, using Khan Academy, showed some improvements for 7th graders on state test scores; suggestive, but not conclusive.

- Deslauriers, Schelew & Wieman (2011), in two large enrollment physics courses, demonstrated large gains for students in one class from just one week of “flipped” instruction. Not entire course.
Research Questions

Does “flipping” the instructional delivery in an undergraduate Calculus III course:

- Impact students’ overall performance, or their performance on procedural or conceptual mathematics problems (compared to a more traditional delivery that covers the same content)?
- Impact students’ opinions and perceptions about the course regarding in-class and out-of-class interactions with the content and the professor?
Partially “Flipped” Model

Traditional Instruction

- Class
- Out of Class
- Class
- Out of Class
- Class
- Out of Class

“Flipped” Instruction

- Lecture Content
- Practice Problems
- Lecture Content
- Practice Problems
- Lecture Content
- Practice Problems
- Lecture Content
- Practice Problems

Our Conceptualization: Partially “Flipped”

- Lecture Content
- Practice Problems
- Lecture Content
- Practice Problems
- Lecture Content
- Practice Problems
- Lecture Content
- Practice Problems
## Conceptualization

### Traditional

<table>
<thead>
<tr>
<th>Content</th>
<th>Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Lecture</strong></td>
<td><strong>Homework</strong></td>
</tr>
<tr>
<td>(primarily writes notes on board, minimal student interaction)</td>
<td>Problems</td>
</tr>
</tbody>
</table>

### Flipped

<table>
<thead>
<tr>
<th>Content</th>
<th>Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Procedural Lecture Content</strong></td>
<td><strong>Homework</strong></td>
</tr>
<tr>
<td>~20 min. instructor video</td>
<td>Problems</td>
</tr>
<tr>
<td><strong>Conceptual Lecture Content</strong></td>
<td>(whole-class/small group discussions, using additional lecture notes or HW problems)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assign Same HW Problems</th>
<th><strong>Some HW problems</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Turned into class activities</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cover Same Lecture Notes</th>
<th><strong>Rest of HW problems</strong></th>
</tr>
</thead>
</table>

### Goal:
Make the process of “flipping” as simple as possible.
Example of “Flipping” a HW problem

- HW problem:

Calculate \( \frac{dz}{dt} \) if \( z = \sin A \cos B \)
\[
A = t + s \\
B = t^2 - s^2
\]
Example of “Flipping” a HW problem

• HW problem “Flipped”:

With a partner, one of you calculate \( \frac{\partial z}{\partial A} \), the other calculate \( \frac{\partial z}{\partial B} \)

\[
\begin{align*}
  z &= \sin A \cos B \\
  A &= t + s \\
  B &= t^2 - s^2 
\end{align*}
\]

Discuss the meaning of each partial derivative. Together, calculate \( \frac{dz}{dt} \).

Reflection Question:
1. What happens if A or B is just a function of S (e.g. \( A = s \))?
2. Why do you think: \( \frac{dz}{dt} = \frac{dz}{dA} \frac{dA}{dt} + \frac{dz}{dB} \frac{dB}{dt} \)?
**Methodology**

Fall 2012. Two Calculus III courses. Two Instructors.

<table>
<thead>
<tr>
<th></th>
<th>Class A, Instructor A</th>
<th>Class B, Instructor B</th>
</tr>
</thead>
<tbody>
<tr>
<td>N=41</td>
<td>Traditional</td>
<td>Traditional</td>
</tr>
<tr>
<td>1st third</td>
<td>Traditional</td>
<td>Traditional</td>
</tr>
<tr>
<td>2nd third</td>
<td>Traditional</td>
<td>Flipped</td>
</tr>
<tr>
<td>3rd third</td>
<td>Traditional</td>
<td>Flipped</td>
</tr>
</tbody>
</table>

Students’ performance was similar when both professors used a traditional instructional model.

NOTE: Demographic backgrounds of both classes of students were similar along: Gender, Age, Ethnicity, Major, Class, Calculus II grades, SAT Math Scores
### Measures

<table>
<thead>
<tr>
<th>Exams</th>
<th>Traditional</th>
<th>Flipped</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Professors collaborated to write each Exam</td>
<td>• Professors gave the same Exam</td>
<td></td>
</tr>
<tr>
<td>• Professors gave the same Exam</td>
<td>• Professors split the grading, so that one professor graded the same questions for both sections</td>
<td></td>
</tr>
<tr>
<td>• Professors split the grading, so that one professor graded the same questions for both sections</td>
<td>• Questions were determined to be more procedural or conceptual; sub-scores for each category were calculated</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Participation</th>
<th>Attendance</th>
<th>HW completion</th>
<th>Attendance</th>
<th>HW completion</th>
<th>Blog post about video</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Exam Findings

- Test 1 Scores
Exam Findings

• Test 2 Scores

![Graph showing the relationship between Test 2 scores and percent rank. The graph includes data points for different classes, such as Flipped and Traditional.](image)
Exam Findings

- Test 2 Scores
Exam Findings

- Test 2 Scores
Exam Findings

- Test 3 Scores
Exam Findings

- Test 3 Scores
Exam Findings

- Test 3 Scores
Exam Findings

- Procedural and Conceptual Problems
  Test 2
Exam Findings

• Procedural and Conceptual Problems
  Test 3
Exam Findings

• RQ1: Based on the findings, there was no statistically significant differences between the two groups overall.
• However, the effect of “flipping” instruction seems to be potentially promising for: 1) lower-achieving students; and potentially impactful for: 2) performance on more conceptual problems.
• There were no significant differences or visual trends between classes that depended on students’ Gender, Age, Ethnicity, Major, Class, Calculus II grades, SAT Math Scores, or Participation
Survey Findings

TIME SPENT OUTSIDE OF CLASS

• Based on the results from 3 survey questions, there were no differences in students perception of time spent outside of class.
  • **Q4:** Compared to other math courses, I spent about the same amount of time outside of class completing assignments and studying.
  • **Q12:** The work required for this course outside of class was more demanding than I am accustomed to doing for other courses.
  • **Q31:** In a typical week, how many hours outside of class did you devote to this course?
Survey Findings

COURSE SATISFACTION/PREFERENCE

• Traditional students reported the traditional method as more effective use of class time
  • Q3: Our class stays busy and doesn’t waste time
  • Q14: The time during class was used effectively for learning the course material

• Overall, flipped students’ responses about satisfaction with the course were much more varied.
Limitations

• Implementation of “Flip” may have some limitations
• Video creation
• Facilitating in-class problems & discussions
• Consistency between Courses
• Interpretation/Emphasis on Notes
• Reviews for exams
• Sample
• Different professors & students
• Size
Conclusions

• Overall, despite small sample, and not enough statistical power to infer significant differences, the findings indicate some potential hypotheses worth exploring related to low-performing students and conceptual problems.

• Currently, implementing a second iteration of the study
Discussion

• Any thoughts about the characterization of the partially “flipped” model?
• Any thoughts about the experimental design for isolating the impact that Traditional vs. Flipped instructional delivery (of same content) has on student performance?
• Any other suggestions? Questions? Comments?