Increase student learning outcomes with flipped classrooms - a collection of empirical evidences

Jen-Mei Chang, Ph.D.
California State University, Long Beach
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Flipped Learning is a New Fad in Education

will it last???

1. Learn Independently (before class)
   videos, books, web resources

2. Benchmark Understanding (before class)
   online quizzes (e.g., Learning Management System)

3. Active Learning (in class)
   group quizzes
   due at the end of class

4. Written/Online Homework (after class)
   WebAssign/textbook problems
Institutional Background

what works here might not work elsewhere …

- Part of the 23-campus California State University System
- Large urban and comprehensive campus with ~ 37,500 students (Fall’15 data)
- ~90% commuters
- Nearly 2/3 qualifies for financial aid
- A Hispanic-Serving Institute
(Guinea Pig) Class #1
MATH 247: Introduction to Linear Algebra

Active learning classroom

Mostly CS and math

Tablet Computer + Panopto screen capture
(Guinea Pig) Class #2
MATH 113: Pre-Calculus Algebra

Non-majors

iPad + Doceri screen capture + YouTube
Why? why torture myself with more work (& more from students)?

I was mainly not satisfied with math students’ abilities to
1. Communicate
2. Write
3. Teamwork

I was even more disturbed by the ineffectiveness of timed “exams” – are exams, even when written with extreme care, truly measuring students’ faithful understanding of the content?

Food for thought:

Q: Construct a matrix $A$, not equal to the identity matrix, such that $Ax = b$ is consistent for all $b$. Be sure to justify why your example works.

\[
\begin{bmatrix}
1 & 2 \\
3 & 4
\end{bmatrix}
\]

\[
\begin{bmatrix}
10 \\
0
\end{bmatrix}
\]

\[
\begin{bmatrix}
5 & 10 \\
0 & 2
\end{bmatrix}
\]

\[
\begin{bmatrix}
5 \\
0
\end{bmatrix}
\]

\[
\begin{bmatrix}
0 \\
0
\end{bmatrix}
\]

Student response #1: Let $A = \begin{bmatrix} 5 & 10 \\ 0 & 2 \end{bmatrix}$. Then $\det(A) = 5 \cdot 2 - 10 = 10 \neq 0$. Since $A$ is a triangular matrix, it is invertible and through the Invertible Matrix Theorem, $A$ is onto. Hence, $Ax = b$ is consistent for all $b$.

Student response #2: Let $A = \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix}$. Then $\text{rank}(A) = 2$, so $A$ is onto and $1$-1, which is consistent for all $b$ in $Ax = b$. 

Student response #2: Let $A = \begin{bmatrix} 5 & 10 \\ 0 & 2 \end{bmatrix}$. Then $\det(A) = 5 \cdot 2 - 10 = 10 \neq 0$. Since $A$ is a triangular matrix, it is invertible and through the Invertible Matrix Theorem, $A$ is onto. Hence, $Ax = b$ is consistent for all $b$.
Desired Student Learning Outcomes (SLOs)

why fix it if it ain’t broken?

[SL01.] Improved **math verbal & written communication skills** — leads to **mastery of content** beyond the basic levels of Bloom’s Taxonomy

[SL02.] Increased **depth of understanding on key concepts** — leads to better **retention** of course materials

[SL03.] Improved **attitudes towards mathematics** — key to **persistence** through a rigorous STEM curriculum

[SL04.] Improved **(interpersonal) skills in collaborative environment** — prepares students for real-world **work place**
Observed SLO1
Improved math verbal & written communication skills

Q: Find a basis for each eigenspace of $A$.

Non-Flipped, highest exam grade

Flipped, highest exam grade
Observed SLO 1
Improved math verbal & written communication skills

Q: Construct a non-standard basis of $\mathbb{R}^3$ and justify why your construction works.

Non-Flipped, highest exam grade

Flipped, highest grade
Q: Construct a non-standard basis of $\mathbb{R}^3$ and justify why your construction works.

Let the set

$$S = \left\{ \begin{bmatrix} 1 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}, \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix} \right\} \subseteq \mathbb{R}^3.$$  

Since $A = [v_1, v_2]$ and since $v_1 \neq v_2$ are not linear combinations of one another, they are linearly independent. Since they are linearly independent and $x_3 = 0$ for both vectors, they span the $x_1x_2$-plane and are a two-dimensional subspace of $\mathbb{R}^3$. 

Non-Flipped, lowest exam grade

Flipped, lowest exam grade
### Observed SLO2
*Increased depth of understanding on key concepts [2]*

<table>
<thead>
<tr>
<th>Final Exam (150 possible)</th>
<th>Flipped (n = 32)</th>
<th>Traditional (n = 34)</th>
<th>Percent Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>101</td>
<td>88</td>
<td><strong>8.6%</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(=(101-88)/150)</td>
</tr>
<tr>
<td>Median</td>
<td>111</td>
<td>79</td>
<td><strong>21.3%</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(=(111-79)/150)</td>
</tr>
<tr>
<td>Pass Rate (C or higher)</td>
<td>53.1%</td>
<td>8.8%</td>
<td><strong>44.3%</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(=53.1%-8.8%)</td>
</tr>
</tbody>
</table>

*Final exam grade distribution in the introductory Linear Algebra class.*
### Observed SLO2

*Increased depth of understanding on key concepts [1]*

<table>
<thead>
<tr>
<th>Final Exam (100 possible)</th>
<th>Flipped (n = 74)</th>
<th>Hybrid (n = 132)</th>
<th>Percent Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mean</strong></td>
<td>63.3</td>
<td>57.5</td>
<td><strong>5.8%</strong> (63.3%-57.5%)</td>
</tr>
<tr>
<td><strong>Median</strong></td>
<td>63.5</td>
<td>56.5</td>
<td><strong>7%</strong> (63.5%-56.5%)</td>
</tr>
<tr>
<td><strong>Pass Rate (C or higher)</strong></td>
<td>35.1%</td>
<td>25.8%</td>
<td><strong>9.3%</strong> (35.1%-25.8%)</td>
</tr>
</tbody>
</table>

#### Final Exam Grade Distribution

- **A's**: Flipped 4, Hybrid 11
- **B's**: Flipped 8, Hybrid 18
- **C's**: Flipped 20, Hybrid 15
- **D's**: Flipped 30, Hybrid 17
- **F's**: Flipped 35, Hybrid 56

*Final exam grade distribution in the Pre-Calculus Algebra class (Semester 1).*
Observed SLO2
*Increased depth of understanding on key concepts [1]*

<table>
<thead>
<tr>
<th></th>
<th>Flipped (T/TH 2PM)</th>
<th>Flipped (M/W 11AM)</th>
<th>Hybrid (M/W 8AM)</th>
<th>Hybrid (M/W 12:30PM)</th>
<th>Hybrid (Special Cohort)</th>
<th>Percent Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>N (Census)</strong></td>
<td>109 (116)</td>
<td>152 (172)</td>
<td>113 (149)</td>
<td>124 (148)</td>
<td>77 (82)</td>
<td></td>
</tr>
<tr>
<td><strong>Attrition</strong></td>
<td>6.03</td>
<td>11.63</td>
<td>24.16</td>
<td>16.22</td>
<td>6.10</td>
<td>-0.06</td>
</tr>
<tr>
<td><strong>Mean</strong></td>
<td>69.27</td>
<td>62.17</td>
<td>59.96</td>
<td>62.38</td>
<td>63.05</td>
<td>6.22</td>
</tr>
<tr>
<td><strong>Median</strong></td>
<td>74</td>
<td>64</td>
<td>62</td>
<td>64.5</td>
<td>66</td>
<td>8</td>
</tr>
<tr>
<td><strong>Pass Rate</strong></td>
<td>58.72%</td>
<td>35.10%</td>
<td>32.74%</td>
<td>39.52%</td>
<td>41.56%</td>
<td>17.16%</td>
</tr>
</tbody>
</table>

*Final exam grade distribution in the Pre-Calculus Algebra class (Semester 2).*
Observed SLO2
Increased depth of understanding on key concepts [1]

Final exam grade distribution in the Pre-Calculus Algebra class (Semester 2).
Observed SLO3
Improved attitudes towards mathematics [2]

- Asked students to agree/disagree with statements on a Likert scale of
  1 = Strongly Disagree to 5 = Strongly Agree

- 45 statements in 4 categories [3, 4]:
  1. Confidence in learning mathematics (e.g., “I think I could handle advanced mathematics.”)
  2. Mathematics usefulness (e.g., “I will need mathematics for my future work.”)
  3. Beliefs about mathematics (e.g., “Math problems have one and only one right answer.”)
  4. Learning with others (e.g., “Talking with others about math problems helps me understand better.”)

- Administered to classes at beginning & end of term
Observed SLO3
Improved **confidence** towards mathematics [2]

**Positive Statement(s)**

Q2: I am sure I could do advanced work in math.
Desirable change with regards to increased confidence in mathematics

<table>
<thead>
<tr>
<th>Median (Mean)</th>
<th>Flipped</th>
<th>Traditional</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Q2</strong> Post</td>
<td>4(4.18)</td>
<td>2(1.79)</td>
</tr>
<tr>
<td><strong>Q8</strong> Post</td>
<td>2(2.5)</td>
<td>1(1.8)</td>
</tr>
<tr>
<td><strong>Q11</strong> Pre</td>
<td>4(3.94)</td>
<td>1.5(1.85)</td>
</tr>
<tr>
<td><strong>Q12</strong> Pre</td>
<td>1.5(1.85)</td>
<td>1(1.35)</td>
</tr>
</tbody>
</table>

Paired Sample Diff. in Means

<table>
<thead>
<tr>
<th>Diff. in Means</th>
<th>Flipped</th>
<th>Traditional</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Q2</strong></td>
<td>0.2326</td>
<td>-0.1395</td>
</tr>
<tr>
<td><strong>Q8</strong></td>
<td>-0.1395</td>
<td>0.6824</td>
</tr>
<tr>
<td><strong>Q11</strong></td>
<td>0.6824</td>
<td>0.5263</td>
</tr>
<tr>
<td><strong>Q12</strong></td>
<td>0.5263</td>
<td>0.008</td>
</tr>
</tbody>
</table>

**P-value**

<table>
<thead>
<tr>
<th>Flipped</th>
<th>Traditional</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.038</td>
<td>0.037</td>
</tr>
<tr>
<td>0.011</td>
<td>0.008</td>
</tr>
</tbody>
</table>

**Negative Statement(s)**

Q8: I don’t think I could do advanced mathematics.
Desirable change with regards to decreased negative confidence in mathematics

Q11: Most subject I can handle OK, but I have a knack for messing up in math.

Q12: Math has been my worst subject.
Undesirable change with regards to decreased confidence in mathematics

[2] Results generated by the Wilcoxon signed rank test
Observed SLO3
Improved beliefs towards mathematics [2]

Positive Statement(s)

Q26: There are often several different ways to solve a math problem.

Q27: Time used to investigate why a solution to a math problem works is usually time well spent.

Desirable change with regards to increase in positive beliefs about mathematics

<table>
<thead>
<tr>
<th></th>
<th>Flipped</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median (Mean) Q26</td>
<td>Q27</td>
</tr>
<tr>
<td>Post</td>
<td>5(4.42)</td>
</tr>
<tr>
<td>Pre</td>
<td>4(4.25)</td>
</tr>
<tr>
<td>Paired Sample Diff. in Means</td>
<td>0.093</td>
</tr>
<tr>
<td>P-value</td>
<td>0.035</td>
</tr>
</tbody>
</table>

Negative Statement(s)

Q31: Math problems have one and only one answer.

Desirable change with regards to decrease in negative beliefs about mathematics

[2] Results generated by the Wilcoxon signed rank test
Observed SLO3

*Increased enjoyment *learning with others* [2]*

**Positive Statement(s)**

Q40: Math is more interesting when I work in a group with other people.

Q38: I prefer to work with other students when doing math assignments or studying for tests.

Desirable change with regards to increased enjoyment learning with others

<table>
<thead>
<tr>
<th>Positive Statement(s)</th>
<th>Flipped</th>
<th>Traditional</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q40: Math is more interesting when I work in a group with other people.</td>
<td>Post: 4(3.79)</td>
<td>Pre: 4(3.77)</td>
</tr>
<tr>
<td>Q38: I prefer to work with other students when doing math assignments or studying for tests.</td>
<td>Post: 3(3.27)</td>
<td>Pre: 2.5(3.12)</td>
</tr>
<tr>
<td>Paired Sample Diff. in Means</td>
<td>0.2558</td>
<td>0.4737</td>
</tr>
<tr>
<td>P-value</td>
<td>0.037</td>
<td>0.43</td>
</tr>
</tbody>
</table>

14. My in-class discussions with peers and the instructor help me learn.
15. The class time is structured effectively for my learning.
17. The structure of this flipped class supports my learning in and out of class.
19. Having to communicate mathematics in class help me learn the concepts better.
20. I enjoyed learning in this flipped class.

[2] Results generated by the Wilcoxon signed rank test
Concluding Remarks

It sounds tempting, but is it worth it?

- When a class is organized effectively and efficiently, deeper learning can be accomplished through various means of active learning strategies (even in a lecture-based or hybrid class). Strayer [5] noted, and was reaffirmed here, that students can be resistant to the change to their work and study habits brought by the flipped format. Increased predictability and organization can help ease the transition and empower students to find a rhythm that works for them.

- When running a flipped class, there is not a one-size-fits-all bucket list of must-dos. Do what works for your teaching style and your institution, as suggested by [2, 6].

- Designing a full-blown flipped class requires a lot more preparation time; therefore an interested instructor should be cautious and gauge their familiarity with the technology, mastery of the content, the expected student learning outcomes, and the program learning outcomes before embarking on this endeavor.
References


