The Impact of a Flipped Math Course on Peer Learners

Dr. Gianluca Guadagni, University of Virginia

PhD in Mathematics University of Virginia

Lecturer, Applied Mathematics, Department of Engineering and Society, School of Engineering and Applied Sciences, University of Virginia.

Dr. Bernard Fulgham, University of Virginia

Bernard Fulgham received his PhD in Mathematics in 2002, writing his thesis in the field of non-associative algebras with advisor Kevin McCrimmon. He began teaching Applied Mathematics at the University of Virginia in August 2004 and became a full-time Lecturer in 2006.

The impact of flipped Math course on Peer Learners

Why we wanted to change

Passive learning was not working anymore in class; students were missing lectures at a higher rate, their attention level in class was decreasing proportionally to the availability of external resources, such as Youtube videos, on line lectures etc.

Our feeling, as instructors, was that the deluge of material outside class was diminishing the value of lecture-time as the unique time to get an understanding of the material, and many of our students were falling to the temptation of procrastinating their study: "I'll google it, and study later this afternoon".

The diffusion of new tools such as laptops and cell phones increased the level of distraction as well. Even if computers were brought to class with the purpose of taking notes, or access class material, too many students were using theirs for activities not related to the lecture (e.g. surfing the web, checking emails, instant messaging, etc.). We knew we were not alone, as many of our colleagues were facing the same issues, but this was of little avail. [1,2]

What we did

In 2013 we received a grant from our institution to "flip the classroom" and we decided to use it for our 4 credit course in Ordinary Differential Equations. The main reasons were 1) both of us had been teaching the course for several semesters, and 2) the natural structure of the lecture:

model of differential equation → solution method → examples

could be easy to implement into a flipped course; 3) while we would teach two sections of the flipped course every semester, other four sections would be still taught in the passive manner, and we could have a direct comparison.

The following is the structure of the flipped course we started in academic year 2013/2014.
- All lectures are posted on the class website (*Collab*) at the beginning of the semester. Students are instructed to read each lecture before coming to class. Class begins with a mini-lecture (10-20 min) covering the material of the day; afterwards students tackle a worksheet in groups of 3-4 for the rest of the class time. The instructor and two undergraduate students, peer learners (PL), roam the classroom answering students' questions.
- Workgroups are chosen via CATME-TEAM MAKER [catme.org]: students enter categorical information at the CATME.org website (gender, race, GPA, weekly schedule, etc.). The *Team-maker* algorithm creates optimal groups based on students' information and instructor's preferences. Our primary emphasis is on GPA: ideally, a group has one student from each of the 4 quartiles.
- About 35 Worksheets (created by BF) are available for the entire course, almost one for each lecture and solution keys are provided after the corresponding class. Worksheets are closely integrated with the comprehensive set of class notes posted on the class website and with homework assignments.

We use WeBWorK, an open-source online homework system funded by NSF & MAA [webwork.maa.org] for homework assignments and online tests. There are also video solutions of sample problems in the Media Gallery in the course website.

Peer learners (PLs) are chosen by the instructors from our best students. They must have already taken the class, so they know the drill, must be enthusiastic and have great communication skills. They are the bridge connecting teacher to student: often students do not feel comfortable asking "simple" or "supposed to be known" questions to instructors, instead they're more likely to talk to one of their peers. They also know PLs have no part in grading.

Results

After the first academic year, we had a grant for an evaluation by the department of education at our institution. Unfortunately the grant was only for one year and we were not able to repeat the evaluation. The following table summarizes the combined results of two semesters, Fall 2013 [*GG*] and Spring2013 [*GG*].

Post-Questionnaire Hybrid Questions 2013/2014		
1=Strongly Disagree 2=Disagree 3=Neutral 4=Agree 5=Strongly Agree	**Mean**	**Std. Dev.**
The in-class activities used in this course helped me master the course material and learn.	4.00	0.947
The lecture notes posted on (*name-here*) helped me master the course material and learn.	4.21	0.78
The digital resources used in this course helped me master the course material and learn.	3.90	0.851
The structure of this course encouraged me to interact with my fellow students.	4.48	0.67
The structure of this course encouraged me to interact with my instructor and teaching assistants.	4.15	0.76
After my experience in this course, I am enthusiastic about using digital resources in my courses.	3.42	0.87
After my experience in this course, I will intentionally seek out courses that use digital and/or online resources.	2.94	0.93
The digital and online resources used in this course helped me explore the content in more varied and meaningful ways.	3.27	1.01
Compared to my experiences in other courses, in this course I received more frequent feedback on my progress towards course objectives.	3.52	1.06
Compared to my experiences in other courses, in this course I received more opportunities to assess my own understanding and learning.	3.88	0.99
Compared to other courses, the technology allowed more interaction with the instructor(s).	3.33	1.05
Compared to my experiences in other courses, in this course I experienced more interaction with my fellow students.	4.33	0.85

Feedback

Students' reaction was very diverse. Many of our students never took a flipped class, and did not expect to be in one of them, probably because our school never had flipped class. Below we report some of the comments after the first academic year.

TOTALLY NEGATIVE

- *I could not learn from the instructor in class because he barely taught anything. I learned the material on my own.*

- *Did not enjoy the "flipped" class structure. The lack of lecture on subject matter meant I had to learn only from looking at paper notes of equations, without the complementary explanations.*
- *I did not like the experimental setup of the course. I believe it hindered my learning of the material.*
- *The reversed teaching method (worksheets in class/learning outside of) really ruined the course for me.*
- *- Awful. Just plain awful. [...] [The instructor] couldn't even help on the worksheets he made us do. [...]*
- *This was absolutely, without a doubt, the worst class I have ever taken.*

SKEPTICAL

- *At first I was hesitant about the new learning style with the group worksheets. However, over time I actually came to prefer the group worksheets as the main way of learning.*
- *When I found out the course was not taught in the traditional lecture format I wanted to switch sections, but I stuck with it and it turned out to be very effective for my learning. I felt well prepared for all the exams because of the number of practice problems I was exposed to in class and in the homework assignments.*

POSITIVE & VERY POSITIVE

- *I loved doing the worksheets with groups because it helped me to understand the information better and have a few students to explain it in a different way if I didn't understand the material.*
- *The setup of this course was extremely effective. Keep using this style for later sessions of this course. Try applying it to Calculus 1,2, and 3 courses if possible.*
- *I absolutely loved the structure of the course: a brief lecture followed by group work on the math problems we had just discussed. Learning and then immediately practicing was so helpful to my understanding of the course material as was having the chance to explain things to peers (or learn from them). All around I felt like the information stayed with me better. Definitely my favorite class this semester!*
- *I learned most of the material from the TA's and working in groups. I think having the groups was very effective.*
- *Great class- used new method of teaching with the in class worksheets. I thought they were extremely effective.*
- *I think the lecture/worksheet teaching method was very helpful. I'm a student who gets easily distracted when teachers just lecture, then teach the material to myself before the tests. Needing to complete worksheets kept me involved in the class and required me to learn the material with the pace of the class.*
- *I really liked how we did worksheets during class to learn the material, instead of just listening to a lecture. I learned much more from completing the worksheet than I did from the 15 min lecture at the beginning of class.*
- *I really enjoyed the way this class was structured. The in class worksheets effectively taught me the lecture material every single class period.*

It should be noticed that we did not get “moderately negative” feedback. Few students (2-3) dropped the class after few weeks and moved to other sections with a standard lecture structure. Students with learning disabilities find the flipped class more challenging and are likely to move to a standard lecture model. Unfortunately, we do not have feedback from students who dropped the course.

Remedies

In this section we report the changes we introduced after the first year.

- The dynamics of in class groups is very unpredictable, there are often 1-2 dysfunctional groups where one student does all the work, or students do not collaborate as expected. The introduction of two or three evaluation forms, usually after midterms and at the end of the semester, is usually enough to discourage hitchhikers and couch potatoes in each team. Some semester we changed groups every four weeks.

- We have also tried changing the weight of parameters in the Team-maker algorithm. At first we wanted to get groups as gender diverse as possible, but given the 1/3 of female to male student ratio, we always ended up with groups with one female and two male students. While this has worked for many of the groups, there were cases where the female student was not participating as actively as expected in the group discussion. As an alternative, we set up groups with at least two females, and those groups have performed very efficiently.

- Some times students were not able to complete the worksheet in class, and we let them work on it at home. Quite often students will not complete it, or just one student would do it but without group work. Therefore we started to grade the worksheets, some classes once a week, some only one worksheet per week randomly selected, some even every worksheet. With the worksheet being graded, in-class participation increased, as well as group involvement in completing the worksheet off class.

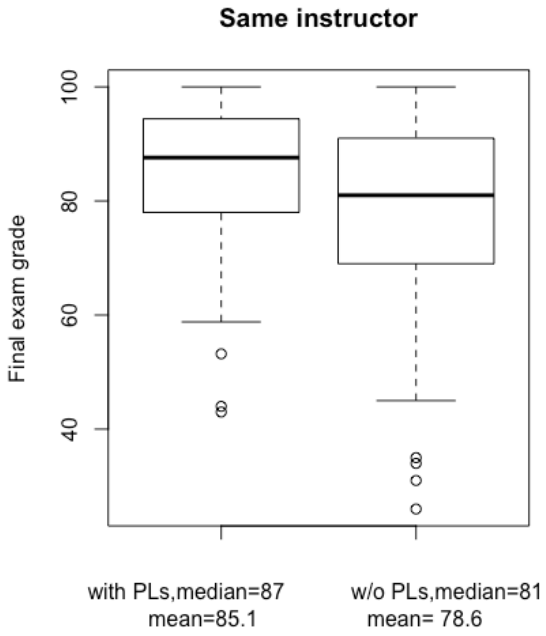
- Pre and Post assignments were added to most of the classes. One of us (BF) has post assignments; the other one (GG) has both pre and post. They are administered on WebWork as the Homework, and are open 24hr before and 24hr after class, respectively. Usually is it only one question, which reinforced lecture material right after class. The pre question is intended to encourage students to actually read the notes before coming to class. On average students do not like Pre assignments and consider them a waste of time, but find Post assignments quite useful.

What are the results: analysis with R.

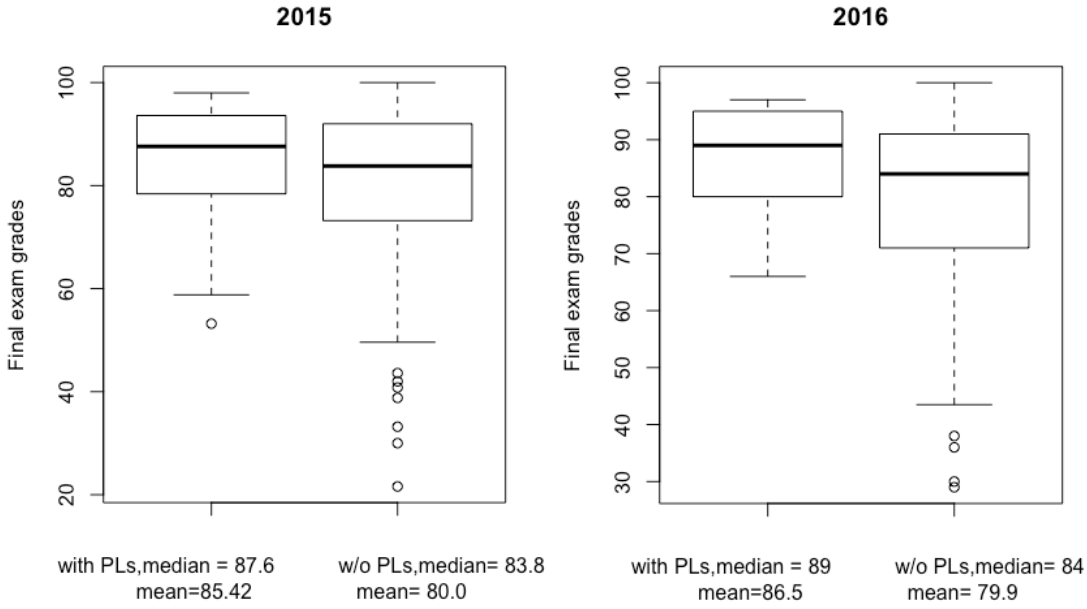
After three academic years we have a set of grades we could look into. We condensed the results in three sets of boxplots.
The first set represents the class score of one of us for his classes from 2010 to 2016, with the intent to show the improvement AFTER the introduction of the flipped course in one instructor's teaching method. "with PLs" means Spring of 2014-2015-2016 with Peer Learners and flipped course, "w/o PLs" means Spring of 2010-2011-2012-2013 without Peer Learners and standard lecture format. We computed the Welch Two Sample t-test for the two samples:

data: same instructor "with PLs" and "w/o PLs"
t = 5.7973, df = 501.94, p-value = 1.193e-08
mean of x mean of y
85.08109 78.60119

A very low p-value suggests rejecting the null hypothesis H_0: two samples ("with PLs" and "w/o PLs") have same mean; the result is in support of our claim that with PLs our class performance is superior.



The second and the third sets represent final exam scores of flipped courses and non-flipped ones for 2015 and 2016. The “w/o PLs” represents grades of four sections taught with the standard lecture model without PLs, “with PLs” represents grades of two sections flipped and with PLs. All sections of Ordinary Differential Equations take the same final exam, so we thought this parameter could be a significant measure in order to compare flipped and non-flipped courses. In these sets we are comparing sections taught by different instructors.



Even in comparison with other sections of the same course, taught by colleagues, there is statistical support for rejecting the null hypothesis that "with PL's" and "w/o PL's" are samples from the same distribution:

Welch Two Sample t-test
data: 2015 withPLs, 2015 w/oPLs
t = 3.2639, df = 219.98, p-value = 0.001274
mean of x mean of y
85.42439 80.03192

Welch Two Sample t-test
data: 2016 withPLs, 2016 w/oPLs
t = 2.9981, df = 29.285, p-value = 0.005493
mean of x mean of y
86.52273 79.85283

In conclusion the flipped class with Peer Learners is more effective than the standard lecture model by increasing the mean grade by 5 points (out of 100) or more.

Peer Learners

The introduction of peer learners (PL) in our course has been possible not just because we were aware of the reported improvements [3,4,5], but mostly because we already had the budget for them. Each of our courses gets two undergraduate graders, their duty is to grade homework. Since we switched the homework to WebWork we could use our graders as PLs. Our Chair was not aware of the new setting until it was too late, and, at that point, we already had evidence of the improvements. While this is a practical explanation of why we have two PLs in our class, indeed this number seems to be fine. There are between 12 to 16 groups in each class, and three people (including the instructor) roaming the class are usually enough.

How PLs are selected

We select PLs out of a list of undergraduate graders who submitted their requests to our program (*Applied Mathematics*). We receive several requests from students who have taken the class and are excited about becoming PLs, but it is not easy to combine their schedule with our class time, so quite often we have to recruit six different PLs for 4 lectures a week. This is positive for PLs, since we are able to expose many of them to this practice, but it may not be so good for students who see their PLs change every day of the week. Sometimes we actively reach out to (particularly good) former students to check whether they are interested in working as PLs. Not surprisingly, many do not even think they would be capable, and are very honored by the call, and end up taking the job very seriously.

What PLs do

Peer Learners sit in the back of the class while the instructor lectures for the first 10-20 minutes; afterwards they walk in the classroom waiting for students to call them. We want PLs to engage with groups even if students do not ask for questions yet, but some PLs are a bit shy and do not engage with students right away. We provide PLs with solutions of worksheets and ask them to guide students through the solution. From the feedback we receive, this is often the case, but not always.
We received very few feedback like the following.
- Some PL's were better than others

- Sometimes they didn't know how to explain the steps to the solutions to us they would only give us the answer which was frustrating

A regular class experience would see PLs answer a question, or provide an explanation, and, in case, a hint, but not the solution, then move to another group and later go back to the previous groups to how check they are progressing.

What we learn from our Peer Learners.

In a sort of serendipity, we got more than we were expecting. The first batch of PLs was a little skeptical, they had never taken a class with PLs and now they were expected to be one of them.
-Took Differential Equations in a traditional classroom format and had a good experience.
- Had lukewarm experiences with different kinds of experimental classrooms in the past.
For every subsequent semester, PLs had taken the class this style and had clearer expectations.
- I think it helped a lot that we are all students ourselves, so we were in their shoes just a year ago
- Students were hesitant at first, but much more engaged as the semester progressed. Later in semester, asked not about just Diff Eqs, but about college and classes in general
- Questions were intimidating at first. Not sure our answers would be as clear as we wanted. Soon realized our explanations were helpful because we had very similar perspectives on the material having taken the class so recently
- Remembering what helped me understand the material when it was new to me was the key to helping students succeed.

We realized something very specific to PLs: students and PLs had a "*connection*" that they could not get with Graduate Teaching Assistants [6]: being both students they could understand each other better, and students felt more comfortable asking questions to PLs than instructors. Besides age proximity, another possible reason of this special *connection* is that PLs are not involved in the grading process. This makes students more relaxed when interacting with PLs.

PLs give us feedback about the class during the semester; we do not have to wait for class evaluations at the end of the semester.

What PLs take from their class experience.

PLs' experience in this program was overwhelmingly positive. For them it was a personal development process not just a job, and the little empowerment that comes with the position does contribute to their growth as young individuals. For several of them this was the first opportunity to lead a group of peers on a technical project where they are expected to be the expert.
All of them report that

- Ability to explain mathematical concepts improved greatly;
- Different kind of understanding was required to teach a subject than to be in a class;
- Students were asking challenging questions forcing the PLs to think deeply about the material.

But also they gained/had

- More confidence in their knowledge and skills related to course content, which reflected in other advanced courses they were taking while being PLs;

- The opportunity to *peer behind the curtain*: find out what is means to teach "*it has helped me foster a new appreciation for the work professors put in outside of class to prepare lecture and grade assignments*";
- More creativity and engagement: a PL created a video on a topic that several students had trouble with so that they could have an additional resource to study and review.

On the personal side, PLs report

- Increased interpersonal skills to meet students' expectations and to deal with peers almost their age, sometimes even friends.
- A social status "*Many students knew me by name and would recognize me outside of the classroom which felt rewarding*".
- Leadership and problem solving skills.

We have seen PLs who started quite intimidated at the beginning of the semester and then constantly grow their confidence during the semester. This has been more common for female PLs. When we ask them to become PLs because they have performed very well in the class, some are a bit cautious, afraid of not being up for the task. At the end of the semester they all report a boost in their confidence.

Conclusion and Future of the PLs program

The program has a certified beneficial impact on both our students and our PLs, who are our students too. Since we started in Fall 2013 more courses in our program are shifting to the adoption of PLs in their classrooms. For instance some Calculus and Statistics sections now include PLs in their class activities.

Despite the success, there are improvements and fixes that we need to address.
Sometimes a worksheet is too long or the lecture needs to be more detailed, and we need to be able to gauge more effectively between lecture and worksheet.

In terms of PLs, the main issue is that they rely on their knowledge on "how to teach" and have no experience besides what they have seen in their courses.

Our school has recognized the importance of PLs and will support a teaching training for them. A one credit hour course for STEM PLs will be created next Fall in collaboration with the pan-university "center for undergraduate education" (*Center for Teaching Excellence)*. PLs will learn about classroom teaching methodologies, strategies on how to engage students, how stimulate their learning, and how to handle challenging situations. This class will become a prerequisite for our PLs, and will add more quality to the PL experience.

In collaboration with the Dean's Office we are creating a special program that will encourage minority and female students to become PLs, either through a fellowship or some other form of support. We believe the PL experience will help our growingly diverse student population become more successful.