Flipping Forward: Improving Student Experiences in *Process Calculations* and Following Its Effect on Performance in Subsequent Chemical Engineering Courses

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Abstract

Flipping is an appealing method to engage students for meaningful and active learning. However, students are notoriously resistant to this shift in learning culture, which puts the responsibility for learning more squarely on their shoulders. In this paper, ideas are provided to manage student expectations of the flipped course, and essential elements for increased student satisfaction and participation are presented. In addition, qualitative and quantitative assessment data are used to begin addressing the question "How does flipping affect student performance in required downstream courses?" With this information, further improvements in the flipped experience can be suggested to maximize the impact of this active learning technique.

Keywords

Flipped classroom; course improvement; assessment

Introduction

Process Calculations, which serves as the course example in this paper, is a prime candidate for flipping. As the first required chemical engineering (ChE) course, sophomores are primarily learning how to approach and solve ChE problems. It meets 3 times a week for 50-minute periods and covers material that forms the foundation for all subsequent, required ChE courses. It also provides opportunities for students to meet and work with others who will be progressing through the ChE curriculum over the next three years.

The instructor has been teaching the lecture-based form of this course, with class sizes of 25-30 students, since Fall 2008. In 2011, she also began facilitating the web-based form of this course,[1] offered only in the spring and summer sessions, with an average of 13 students per year. Since Fall 2013, she has implemented a flipped version of the course,[2] with class sizes of 45-55 students.

In this flipped version of the course, students use the textbook and at least one other mode of content delivery (lecture capture, screencasts,[3] and/or the web lessons) to gain the needed concepts prior to coming to class. An on-line quiz is used to identify concepts that need to be clarified further in the class period. In class, students engage in individual warm-up exercises before going to the whiteboards with their assigned teams to work more complex problems.

The instructor could see the benefits that the students were accruing during the flipped classes, including: engagement in more problem-solving exercises, immediate feedback on erroneous work, less instances of academic misconduct, less reluctance to ask questions, and better preparation before class. However, were the benefits worth the increased work for her and her students? In addition, the ChE advisory board was skeptical that the flipped version was effective and wanted support for its efficacy after students complained, during the annual interview process, that they did not like flipped courses. Thus, the instructor enlisted assistance from the university's Assessment Coordinator to begin a more systematic and longitudinal assessment of the success and impact of the flipped version of the course. Results of student surveys and institutional data correlation are being used to improve the student experience in each rendition of the flipped course.

Managing Student Expectations

It is not surprising when students verbalize a preference for lectures over active learning; the phenomenon is well documented (e.g., see Rich Felder's comments[4,5]). After all, flipping is effectively changing the rules to the educational game to which they have grown accustomed. Students are now responsible for their own learning, and the objective is mastery, not coverage, of course content. However, this shift in learning culture is consistent with the goal to develop lifelong learners, and the shift will become easier for the students as they encounter more courses with significant active-learning components. Some students are now entering college having had flipped courses in high school. In the College of Engineering at the University of Iowa, students are likely to have had multiple flipped courses within their first 3 semesters since several of the core courses have flipped sections (e.g., *Engineering Problem Solving II*, *Statics*, and *Electrical Circuits*). For the *Process Calculations* flipped cohorts in Fall 2013 and Fall 2014, 70% had at least one other flipped course besides *Process Calculations*. As students matriculate through these flipped courses, they provide pointers and explanations to those students who follow so that there is not such a big surprise about what to expect in a flipped course.

In the meantime, providing students with an explanation of what to expect and what is expected in a flipped course is crucial to managing their initial responses to being in a flipped course. In the very first class period, the instructor overviews what a flipped class entails (i.e., swapping the lecture and out-of-class activities) and why flipping benefits them (e.g., focus on application of concepts and achievement of higher levels of learning), as well as demonstrating the various content delivery modes. After this overview, she has the students answer two questions in a minute paper: (1) "Why are you excited about flipping *Process Calculations*?" and (2) "What questions do you have about flipping *Process Calculations*?" She collates and discusses these responses in the next class period.

Students in both cohorts listed similar top benefits: problem-solving in class, being able to watch lectures any time, and being able to review content they did not understand the first time they saw it. Common concerns (i.e., listed by >15% of the students) included: being disciplined enough to learn the material outside of class, additional time required for a flipped course, getting used to flipping, and whether or not they would learn as well teaching themselves. The instructor answered each concern in class and posted the answers on the course website for future reference. For example, her response to the discipline concern is:

> Yes, you will need to be disciplined to review the required content outside of class as directed. However, you always needed to be disciplined to do your homework outside of class. Here, you're switching the activity to which you apply the discipline. You can

also set up accountability with other students. For example, if you like the lecture capture, pick a time when you all can watch it together and take notes. I'll remind you at the end of each class what you are expected to cover, and the ICON quiz is an incentive for you to keep the pace. If you don't keep up, you won't learn as much during the in-class problem-solving sessions. An added benefit to keeping the prescribed pace is that you won't have to cram for the exams!

Again, students will need to understand how the paradigm shift will affect their study habits. They may be used to waiting until the night before a weekly homework is due to start it. In a flipped course, they cannot procrastinate because the "homework" is due each lecture period.

The time concern is also an interesting issue. Sophomores especially may not be used to the rigor required for engineering major courses. Thus, the amount of time they will need to spend in a flipped course may seem excessive, when in reality it is what is needed for the advanced classes – they can no longer coast by on what they have learned in high school. The instructor reminds them on the first day (and in the syllabus) that they are expected to spend at least 2-3 hours in outside preparation for every hour in class.[6] End-of-course surveys show that the students were averaging 6-7 hours of studying per week as is reasonably expected (see Figure 1).

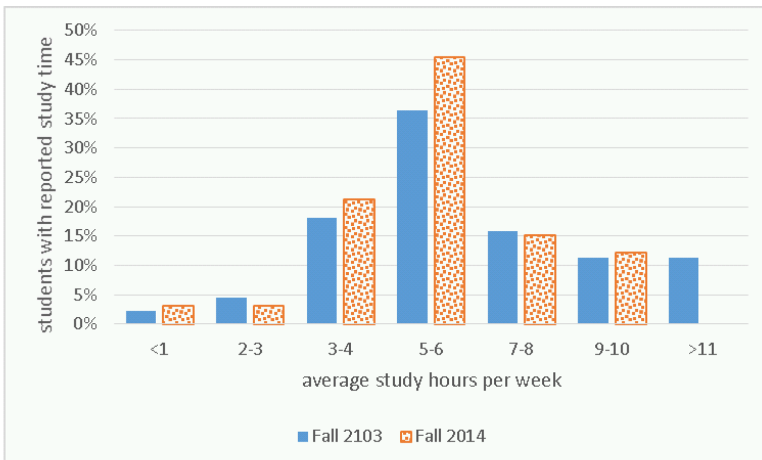

Figure 1. Students in the flipped version of *Process Calculations* reported studying for class an average of 6.6 hours/week in Fall 2013 and 5.5 hours/week in Fall 2014.

Getting used to flipping takes time, and the first week or two can be rough as the students adjust to the new culture. It is helpful during this transition time to keep a regular schedule of activities in class so that the students can acclimate to the more active nature of the class period. Instead, the instructional team can focus on soliciting the behaviors needed for success in active learning: preparedness for class activities, engagement in problem-solving activities, courage to ask their questions often and soon, and willingness to answer questions of their peers.[2] Once students have made the transformation from passive bystander to active participant, the flipping becomes much more enjoyable for all.

Listening to student feedback

At the end of each semester, the instructor provides in-class time for the students to complete a course survey, which the students submit anonymously. These responses are used to improve the next offering of the course, as well as to manage student expectations in that next offering. Based on the student responses regarding how much time they spent outside of class studying (Figure 1), there was not a concern that the instructor was expecting too much of the students as far as out-of-class activities. However, at least 40% of the students reported that they felt that they spent more time on the flipped class as they did for other engineering classes they were taking the same semester (see Figure 2). Again, this result is important for management of student expectations – <u>it is not because the class is flipped that they may be spending more time on the class</u>, but that the class is the first of their major courses, which will take more focus than the introductory engineering classes.

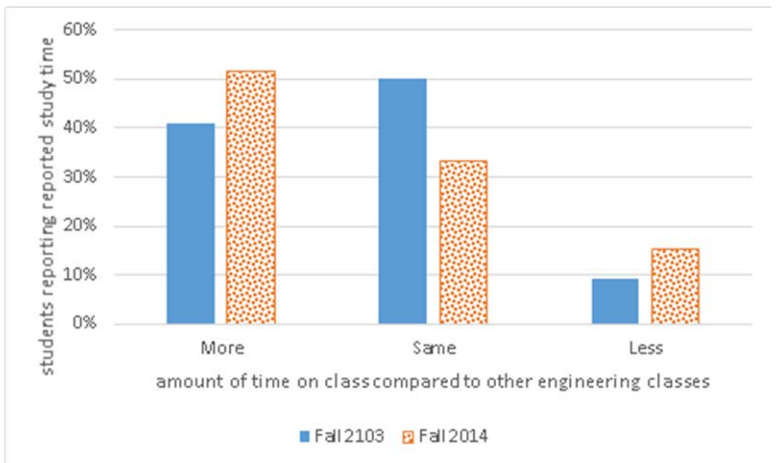

Figure 2. Over 40% of students in the flipped version of *Process Calculations* thought that they spent more time studying for the class than their other engineering classes.

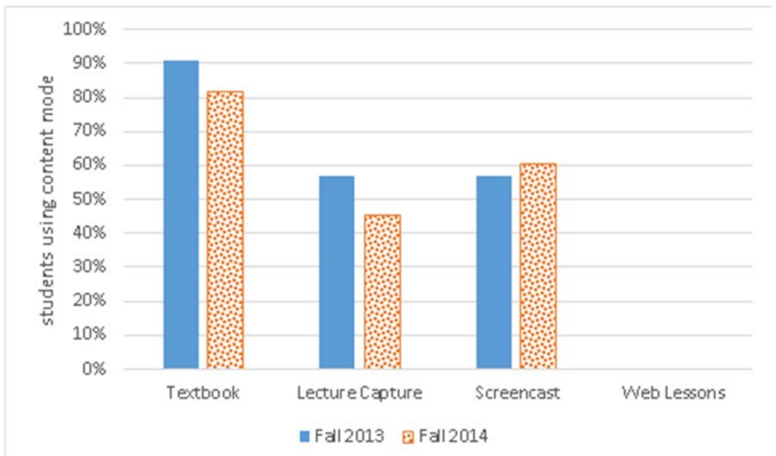

Figure 3. Most students used the textbook (as required) and supplemented content delivery with either lecture capture or screencasts.

The usefulness of the content delivery modes is important to monitor as well. Over 80% of the students were using the textbook as required with supplementation split between lecture capture and screencast (see Figure 3). This split is good news for instructors who may not have time to create a set of screencasts prior to flipping their course – many students are still satisfied (comfortable) with the lecture mode. Students who preferred the lecture captures liked that they followed the textbook more closely, provided more detail, and were similar in structure to what they were used to having in a traditional classroom. Students who preferred the screencasts liked that they were short and focused on application of the principles. One possible area for improvement in this regard would be to develop a problem-solving glossary from the lecture capture files so that it is easier for students to find example problems of a certain type as they work to master a specific skill.

The students in Fall 2013 and Fall 2014 overwhelming reported that the most valuable aspects of the flipped class were working problems in teams and getting their questions answered as they had them during class. These benefits can be used as testimonials at the beginning of future flipped classes. For the Fall 2013 class, the aspect that they most wanted changed is the number of instructors available during class. In that semester, there was one faculty member or teaching assistant for every 5-6 teams of 3 students. It was difficult to circulate the room to answer questions quickly, and some teams waited a while or did not get their questions answered before the end of class. Because departmental budgets are tight, adding another ¼-time graduate teaching assistant was not an option; however, it was possible to hire an hourly undergraduate teaching assistant to be a part of the in-class instructional team. This solution worked very well for the Fall 2014 class in which there was one faculty member or teaching assistant for every 3-4 teams of 3 students. It was much easier to answer questions immediately, and not one student mentioned instructor number as an issue in that semester's survey. Instead, the Fall 2014 cohort most often requested more time to work the problems that they had started in class instead of finishing them at home. For most of the semester, there was not a class in the classroom after *Process Calculations*, and students enjoyed staying later with one of the instructional team members to get their work done while it was fresh in their minds. This issue is a little more difficult to tackle since the university has specific course time slots, and the instructor is working to get the class offered 3 times a week for 70-minute periods. The first 50 minutes would be class as usual, and the last 20 minutes would be considered a help or recitation session; thus, there would not be additional content added to the class.

Reflecting as the instructor

The instructional team is a critical aspect of the flipping experience. As discussed in the previous section, the instructor-to-student ratio greatly impacts student satisfaction and learning. This ratio depends on the types of activities in the flipped classroom and may need some trial and error to perfect. In addition, teaching assistants may need special training to be effective in a flipped classroom. They may need to be coached in the Socratic method – asking a question when asked a question instead of giving an easy answer. They may also need to be encouraged to look for students/teams needing help instead of waiting to be asked (especially at the beginning of the semester when students tend to be more hesitant to ask questions) and to be persistent in offering help when it is obvious the students are misunderstanding a key concept.

Cultivating cooperative learning among the students is also key. Students are often concerned about working in a team due to shyness or due to others not pulling their fair share. Karl Smith provides multiple suggestions on cooperative learning techniques[7] that are helpful in promoting positive interdependence and individual accountability. Role interdependence (each team member has a role like reader, recorder, or question asker) and resource interdependence (each team member has a piece of information to share with the others) have been helpful in team activities in the flipped *Process Calculations* classes. One idea for implementation in this next offering of *Process Calculations* is to assign each team member a different marker color so that participation can be visually judged from the whiteboard work of each team during (and after) class. Instructor attentiveness plays a role in encouraging cooperative learning. When students are seen left out or hanging back from the team work at the board, instructors must intervene and draw those students into the midst of the team activity.

Although having multiple modes of content delivery is good for students with different learning styles, students are sometimes overwhelmed with options. It is important that they identify the mode that best suits their learning preferences and use the others to supplement as needed (e.g., extra example problems for a difficult concept). Many students are loathe to compare the different modes side-by-side because of the time required. Here, a jigsaw (resource interdependence) activity could be helpful. Each student would be assigned a content delivery mode and must report out to the rest of the team its perceived pros and cons. Students could make a more informed selection of mode without spending extra time going through each one individually.

Querying student later perceptions

In order to gain a better understanding of students' perceptions of the flipped *Process Calculations*, we conducted a research study to examine the attitudes of students who took flipped *Process Calculations* and were now in a downstream course. We identified two downstream courses for this study: *Chemical Process Safety* (junior ChE course) included students who had taken *Process Calculations* in Fall 2013, and *Engineering Flow & Heat Exchange* (sophomore ChE course) included students who had taken the most recent iteration of *Process Calculations* in Fall 2014. All of our research procedures for this study were approved by the Institutional Review Board (IRB). The surveys were administered toward the end of the Spring 2015 semester. We recruited 36 students who had taken *Process Calculations* in Fall 2014 and 33 students who had taken the course in Fall 2013. We computed descriptive statistics in order to examine the overall distribution of the survey items. We then computed independent sample t-tests to assess the differences in the survey responses by the two cohorts.

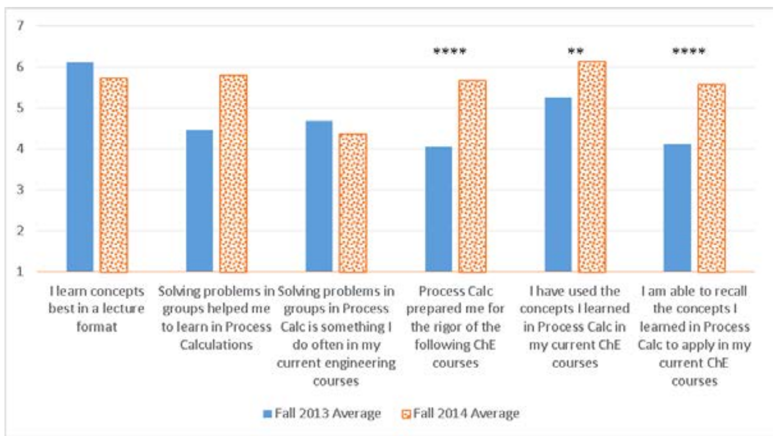

Figure 4. Students' responses to items about the effectiveness of *Process Calculations* (by cohort). Agreement Scale: 1 = Strongly Disagree, 7 = Strongly Agree. $p < .01$ **, $p < .0001$****

The students in the Fall 2014 cohort were more likely to believe that elements of the course design were helpful for their learning, and these results seem to provide evidence that the second iteration of flipped *Process Calculations* was an improvement (see Figure 4). There were major differences between the two groups on two of the items that assessed students' perceptions of how much their in-class activities were useful to their learning. Compared with students in the

Fall 2013 cohort, students in the Fall 2014 cohort, on average, more strongly believed that solving problems with others in class was helpful for their learning, $t(64) = 4.46$, $p < .0001$, and more strongly believed that writing problems out on the whiteboard was helpful for their learning, $t(48.56) = 5.49$, $p < .0001$.

The findings of this small-scale survey suggest that students in the second iteration of the flipped course were more likely to perceive a benefit in their downstream courses. There was no statistically significant difference in the level of agreement between the two cohorts for the survey item, "I learn concepts best in a lecture format," ($p < .11$) and "Solving problems in groups in Process Calculations is something I do often in my current engineering courses," $p < .47$. Thus, there was no evidence to suggest that these two cohorts had different attitudes toward learning in a traditional, lecture-based format, and no difference in their perception of how often they engaged in collaborative learning in their current engineering courses. However, students in the Fall 2014 cohort who participated in this study were more likely to believe that participating in collaborative learning activities helped them to learn in *Process Calculations*, $t(55.397) = 3.31$, $p < .01$. Students in the Fall 2014 cohort who participated in the study were also, on average, more likely to agree that they were able to recall concepts learned in *Process Calculations* in downstream ChE courses, $t(47.49) = 4.24$, $p < .001$; more likely to agree that they had used the concepts they learned in *Process Calculations* downstream courses, $t(44.81) = 2.82$, $p <.01$; and more likely to believe that *Process Calculations* prepared them for the rigor of downstream engineering courses, $t(67) = 4.26$, $p < .0001$. These results (shown in Figure 2) are heartening because they suggest that the improved iteration of *Process Calculations* had a beneficial effect on students even after the semester in a downstream course.

Following student downstream progress

In addition to surveying students who had progressed from *Process Calculations* to other ChE courses, we conducted a separate set of procedures to examine the academic outcomes of these students with institutional data. Many research studies delve into the effectiveness of active learning in general (for review, see Ref 8) and outcomes in Active Learning Classrooms in particular.[9,10] According to one of most comprehensive reviews of research on the benefits of active learning in undergraduate STEM education, active learning methods resulted in an average gain in exam performance of one half a standard deviation.[8] However, one important question we asked was whether students who completed *Process Calculations* in a flipped instructional setting performed as well in other courses in the curriculum. Again, we used *Chemical Process Safety* and *Engineering Flow & Heat Exchange*, which follow *Process Calculations* in the curriculum, and these courses have been consistently taught by the same instructor since at least Spring 2012. This instructional consistency was an excellent situation for a statistical analysis of the outcomes of groups of students who took *Process Calculations* at different times. Specifically, we asked the following research questions:

1. After we controlled for prior learning, did students who completed the Fall 2014 or Fall 2013 sections of *Process Calculations* earn a higher final course grade than students who completed the course in Fall 2012?

2. Did students who completed the Fall 2014 and Fall 2013 versions of *Process Calculations* earn higher grades in *Engineering Flow & Heat Exchange* than Fall 2012 students after we controlled for the outcomes in *Process Calculations?*

3. Did students who completed the Fall 2013 version of *Process Calculations* earn higher grades in *Chemical Process Safety* than Fall 2012 students after we controlled for the outcomes in *Process Calculations?*

All of our research procedures were approved by the IRB. We collected anonymized demographic data, course-level outcomes, and GPA for students who were enrolled in *Process Calculations* in Fall 2012, 2013, and 2014. The data set included the outcomes in downstream courses that we could use to answer our research questions. We computed descriptive statistics to gain an understanding of the distribution of variables, such as the outcomes in courses and students' grade point averages. We then used analysis of covariance to estimate the effect of the flipped version of *Process Calculations* on final grades. All statistical procedures were conducted in SAS 9.4.

There was some evidence that the Fall 2014 cohort of *Process Calculations* had a lower level of prior learning. The results of an ANOVA with a Tukey adjustment for multiple comparisons indicated that the difference (Fall 2014 – Fall 2013) was -0.31, 95% CI [-0.58, -0.02]. For this reason, we adjusted for UI GPA when we examined whether students in the flipped version of *Process Calculations* achieved higher grades than students in the Fall 2012 version of the course. The results of the analysis of covariance indicated that, after controlling for UI GPA, students in Fall 2014 cohort earned a final grade that was 0.47 points greater than students in Fall 2012. This difference was statistically significant at the alpha .05 level. (We did not find any evidence that the Fall 2013 cohort earned higher grades than the students in Fall 2012, $p < .20$.) Thus, to answer our first question, we did find evidence that students in the Fall 2014 section of *Process Calculations* achieved higher grades than students in the traditional section. In addition, we found that in Fall 2012, 11.1% of students earned a failing grade and 7.4% of the students withdrew from the course. In Fall 2014, however, 6.7% of the students failed, and 4.4% withdrew.

Table 1 includes the summary statistics of students' outcomes in the downstream courses of *Chemical Process Safety* and *Engineering Flow & Heat Exchange.* The Fall 2013 cohort had the highest average grades in each class, but these figures are unadjusted. Because the downstream courses were taught by the same faculty member, we combined the sections of each course in a given semester to ensure that there were enough students from the different cohorts of *Process Calculations* for the regression analyses. For example, there were two downstream sections of *Chemical Process Safety*, but we combined them into one to make the analysis more efficient.

Table 1. Average Grades in Downstream Courses for Different Cohorts of PC

	Fall 2012			Fall 2013			Fall 2014		
	n	mean	std. dev.	n	mean	std. dev.	n	mean	std. dev.
Safety	16	2.71	0.79	41	3.01	0.72			
Flow	21	2.87	1.05	48	3.15	0.92	37	2.96	1.02

After adjusting for students' grade in *Process Calculations* in an analysis of covariance, we did not find any statistically significant difference among the outcomes in *Engineering Flow & Heat Exchange* according to the cohort of *Process Calculations*. In addition, although the Fall 2013 PC cohort had an average grade in *Chemical Process Safety* that was 0.31 points higher than the average for the Fall 2012 cohort, this difference was also not statistically significant at the alpha .05 level. It is important to note that the 2013 and 2014 cohorts of *Process Calculations* were twice the size of the 2012 cohort, so it is a positive finding that the larger flipped cohorts were doing just as well in these two downstream courses, on average.

Conclusion

Flipping can be an effective active learning technique, especially for courses with intensive problem-solving components. However, students often require convincing, as well as significant coaching from an appropriately sized instructional team, to embrace this change in learning paradigm. Activities in flipped courses help develop requisite problem-solving and teaming skills without requiring an unreasonable amount of preparation outside of class. Using both qualitative and quantitative data analysis from the course example in this paper, flipping was shown to manage successfully substantial increases in course enrollments without sacrificing outcomes in the course and its downstream counterparts. Continued assessment and improvement of the flipping experience will further enhance student satisfaction and performance, as well as garner support from other important constituencies involved, such as engineering colleagues and advisory boards.

References

1 Scranton, A.B., Russell, R.M., Basker, N., Jessop, J.L.P., Scranton, L.C., "Teaching Material and Energy Balances on the Internet," ASEE National Conference Proceedings CD-ROM edition, June 1999.
2 Jessop, J.L.P., "Flipping Without the Cold Turkey," ASEE North Midwest Section Conference Proceedings on-line edition, October 2014.
3 University of Colorado Boulder (n.d.). Learn ChemE: Material and Energy Balances. Retrieved May 28, 2015, from the World Wide Web: http://www.learncheme.com/screencasts/mass-energy-balances.
4 Felder, R.M., Brent, R. (n.d.). Navigating the Bumpy Road to Student-centered Instruction. Retrieved May 28, 2015, from the World Wide Web: http://www4.ncsu.edu/unity/lockers/users/f/felder/public/Papers/Resist.html.
5 Felder, R.M., "Sermons for Grumpy Campers," Chemical Engineering Education, 41(3), 2007, 183-184.
6 College Parents of America (2015). Is Your College Student Investing in Enough Time Studying? Retrieved May 28, 2015, from the World Wide Web: http://www.collegeparents.org/members/resources/articles/your-college-student-investing-enough-time-studying.
7 Smith, K.A. (n.d.). Cooperative Learning. Retrieved May 28, 2015, from the World Wide Web: http://personal.cege.umn.edu/~smith/docs/Smith-CL%20Handout%2008.pdf.
8 Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., et al., "Active learning increases student performance in science, engineering, and mathematics," Proceedings of the National Academy of Sciences, 111(23), 2014, 8410-8415.
9 Baepler, P., Walker, J. D., & Driessen, M., "It's not about seat time: Blending, flipping, and efficiency in active learning classrooms," Computers & Education, 78, 2014, 227-236.

10 Brooks, D. C., "Space matters: The impact of formal learning environments on student learning," British Journal of Educational Technology, 42, 2010, 719-726.

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