ASEE's 123rd Annual • Conference & Exposition • New Orleans, LA • June 26-29, 2016


Paper ID #14804

# Comparison of On-Campus and Distance Learning Outcomes in a Flipped Materials Science Course

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## Abstract

Student performance in a flipped materials science course is assessed using pre- and posttests as well as a survey of student preferences and perceptions. Both on-campus and at-a-distance learners are included in the study. The general structure of the course and associated learning aids and outcomes is presented. Previous iterations of the course have included comparing flipped and traditional sections of the same course as well as changing requirements on topic quizzes/learning gates associated with recorded material in the flipped structure. In general, students in the flipped version of the course have performed better as measured by pre- and posttests than those in the traditional format. Students who were required to achieve a certain level of performance on topic quizzes reported spending more time with the material but did not necessarily demonstrate a marked improvement on the posttest compared to those who were only required to attempt the quizzes. In the current iteration, two variables are considered, 1) the effect of place for on-campus students (traditional classroom vs. SCALE-UP classroom), and 2) the effect of changing the format of discussion materials for distance students. Results show mixed outcomes with results to gains from pretest to posttest, but distance students tended to score higher on the pretest and show somewhat larger gains from pretest to posttest. Distance students tended to self-report higher confidence on the pretest than their on-campus peers. Their gains were smaller in this area and final reported confidence levels lower than on-campus students. Little effect of classroom setup was evident on performance or reported confidence between the two groups of on-campus students.


## Introduction

Much recent educational research has focused on the advantages and challenges of the flipped course structure relative to other pedagogies. Flipping in this context implies that classroom time, rather than being spent conveying basic knowledge, is used for higher level interactions such as problem solving, discussions, and investigation. The foundational knowledge necessary for effective problem solving, etc., must be acquired by the students prior to arriving in class. This is typically achieved through the use of assigned readings or recorded lectures with accompanying quizzes or other assessments to guarantee participation. Investigators have compared flipped courses to traditional, lecture-style courses and to more active-learning pedagogies. They have also explored variations on the flipped model, comparing student outcomes when course requirements, learning tools, and activities are modified[1]. Investigators who have looked at the amount of content coverage in flipped courses[1-6] universally conclude that more material can be covered in the flipped format. It is equally clear, however, that increased content coverage does not always lead to better learning outcomes.

Recent literature related to flipping classes covers a variety of engineering disciplines and course levels including freshman-level design courses[2-4], sophomore-level mechanics[2] and circuits courses[5], and a variety of upper-level engineering courses[2,6-8]. Results have shown that the

efficacy of the flipped format can vary as much as for any other pedagogy style. For example, Cavalli *et al*.[2] found positive correlations with respect to student performance for an upper-level materials science course but neutral to negative correlations with respect to student performance for a freshman design course and a freshman programming course. Maarek and Kay[9] compared the results from two biomedical freshman-level courses and found good acceptance (and corresponding gains in outcomes) in once course and poor acceptable and lower performance in the other. Saterbak *et al*.[3,4] reported the implementation of the flipped format in a freshman design course but the assessment is ongoing and conclusions are not yet clear. Swift and Wilkins[5] reported both student performance and student satisfaction increased in a partially flipped course for sophomore circuits compared to the previous course structure. Clemens *et al*.[6] reported mixed results for students in a flipped upper-level materials science course while Mason *et al*.[8] found student performance increased through implementation of a flipped class in an upper-level controls course. Mason also reported, however, that students in the same course reported doubts about freshmen and sophomore students possessing the maturity needed to succeed in the flipped format. Prust *et al*.[10] reported student enthusiasm for the flipped model but few tangible gains in performance. They hypothesize this is due to a lack of student engagement with the required materials outside of class.

SCALE-UP classrooms are the outgrowth of the Student-Centered Activities for Large Enrollment Undergraduate Programs Project, funded by the National Science Foundation and various commercial partners[11,12]. SCALE-UP classrooms are configured into group workstations, typically including whiteboards, displays, and circular or oval tables. Students come to class having completed preparatory learning and ready to work with their peers on in-class assignments. Research has shown SCALE-UP classroom and teaching methods to be effective in classes of various types and enrollments.

The ME 301 – Materials Science course has been taught in a flipped format to varying degrees and with varying teaching aids for several years. The course typically consists of two on-campus sections, each paired with a section of at-a-distance students. Assessment has been performed to determine relative advantages of class format and pedagogies throughout the evolution. In Fall 2013, one section each of distance and on-campus was taught in the flipped format and one section each was taught in a traditional lecture-style[2]. For the flipped section, students were expected to watch ~45-80 minute pre-recorded lecture segments (in 10-20 minute chunks). Class-time was used for focused discussion. Knowledge gains over the course of the semester (as measured by pre- and post-tests) were higher in the flipped section than in the traditional section.

The recorded lecture segments were further refined into 5-10 minute chunks for the Fall 2014 semester. All sections were taught in the flipped format. Adobe Captivate was used to create a learning module for each class session. Within each learning module, video segments were followed by concept quizzes ('learning gates'). Each quiz required students to answer three questions on the material just viewed (typically drawn from a random pool of 5-10 questions from each segment)[13]. Comparisons were made between students who were required to achieve a minimum score (80%) on the learning gates to receive credit for completing the modules and those who simply needed to view the module (as recorded by Blackboard). In general, students with the score requirement reported spending more time with the course material and higher

confidence in their mastery of the material at the end of the semester. However, knowledge gains as measured by pre- and post-tests were mixed with no clear advantage for one group over the other.

## Method

All sections of ME 301 were taught in the flipped format for Fall 2015. There were 77 on-campus and 28 distance students enrolled. Of the on-campus students, 34 were in a section that met in a SCALE-UP classroom and 43 were in a section that met in a traditional classroom (rows of tables bolted to the floor). Figures 1 and 2 shows one of collaboration stations in the SCALE-UP classroom and a view of the traditional classroom setup, respectively.

**Figure 1: Example of a student collaboration station in the SCALE-UP classroom. There were six such stations throughout the room plus an instructor computer station.**

Approximately 20% of the course grade was assigned to participation in class discussions and successful completion of the learning quizzes within the learning modules. All students were required to achieve a grade of 80% or higher on the quiz for each module to receive credit. Failure to complete a module resulted in a loss of ¼ of the participation points. Completion of both the pre- and posttest was considered part of the participation grade. Students who completed the end-of-class survey were given the option to receive full credit for one homework assignment (12 assignments throughout the semester, approximately 15% of the course grade) or two learning modules. This option was announced at the beginning of the last week of class.

At the start of each class period, the instructor asked the class for any conceptual questions that had arisen from the pre-class recordings. Those questions were addressed and discussion sheets distributed. A typical discussion sheet consisted of 5-10 questions related to the topics for the

day. In small groups, students discussed the questions, sometimes asking the instructor for clarification. The class then discussed their responses, with the instructor asking additional questions or providing additional information as deemed appropriate. The discussion session for one on-campus section was recorded and made available for distance students to view. Distance students were required to complete at least as much of the discussion sheet as was covered by the on-campus students and to submit it electronically to document "attendance" and participation.

**Figure 2: View of the traditional classroom setup. Tables are bolted in place but chairs are moveable.**

A pretest and posttest were administered to determine the initial knowledge of each group (on-campus vs. distance, SCALE-UP vs. traditional) and any changes over the course of the semester. Ten questions were multiple choice or true/false related to specific technical information covered over the course of the semester. Three additional questions were included on the pre- and posttest related to students' perceptions about their understanding of the concepts and their comfort in discussing course material with their peers or instructors.

In addition, a survey was administered at the end of the semester regarding student's general opinion of the flipped course format and their perceptions of the value of various aspects of the course on their learning as well as the perceive value of the course for their careers. Students were encouraged to participate in the survey by being allowed to drop low homework or participation scores in exchange for survey completion.

## Results

*Pre- and Posttest Results*

Tables 1-3 summarize the results of the pre- and posttests. Results are grouped according to whether students are on-campus (OC) or distance (DEDP) and, if on-campus, the type of classroom in which they met (traditional or SCALE-UP). Table 3 shows any changes in responses from the pretest to the posttest. Positive changes from pretest to posttest ≥ 20% are indicated by green highlighting. Negative changes from pretest to posttest are indicated by red highlighting. The total number of student completing each test is indicated in column 'N'. Several students completed either the pretest or the posttest but not both. These responses were removed from the data. The resulting response rates were 87.0% for on-campus students and 85.7% for distance students.

**Table 1: Percent of correct pretest responses (technical questions) by delivery method and performance requirement.**

| DEDP/OC | N | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | Avg Score | STD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DEDP | 24 | 58.3% | 50.0% | 41.7% | 16.7% | 62.5% | 45.8% | 58.3% | 41.7% | 91.7% | 20.8% | 48.8% | 21.4% |
| OC - Traditional | 37 | 54.1% | 18.9% | 24.3% | 32.4% | 54.1% | 45.9% | 62.2% | 35.1% | 64.9% | 10.8% | 40.3% | 18.7% |
| OC - SCALE-UP | 30 | 50.0% | 36.7% | 20.0% | 16.7% | 56.7% | 10.0% | 46.7% | 26.7% | 70.0% | 16.7% | 35.0% | 20.1% |

**Table 2: Percent of correct posttest responses (technical questions) by delivery method and performance requirement.**

| DEDP/OC | N | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | Avg Score | STD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DEDP | 24 | 95.8% | 54.2% | 62.5% | 50.0% | 91.7% | 91.7% | 83.3% | 54.2% | 95.8% | 41.7% | 72.1% | 21.5% |
| OC - Traditional | 37 | 94.6% | 37.8% | 43.2% | 48.6% | 81.1% | 78.4% | 62.2% | 24.3% | 89.2% | 21.6% | 58.1% | 26.8% |
| OC - SCALE-UP | 30 | 90.0% | 60.0% | 36.7% | 56.7% | 80.0% | 80.0% | 80.0% | 23.3% | 83.3% | 26.7% | 61.7% | 25.0% |

**Table 3: Change in correct responses (Pretest % - Posttest %) by delivery method and performance requirement.**

| DEDP/OC | | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | Avg Score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DEDP | | 37.5% | 4.2% | 20.8% | 33.3% | 29.2% | 45.8% | 25.0% | 12.5% | 4.2% | 20.8% | 23.3% |
| OC - Traditional | | 40.5% | 18.9% | 18.9% | 16.2% | 27.0% | 32.4% | 0.0% | -10.8% | 24.3% | 10.8% | 17.8% |
| OC - SCALE-UP | | 40.0% | 23.3% | 16.7% | 40.0% | 23.3% | 70.0% | 33.3% | -3.3% | 13.3% | 10.0% | 26.7% |

Tables 4-6 present the same information from Tables 1-3 but with students grouped simply as on-campus or distance.

**Table 4: Percent of correct pretest responses (technical questions) by delivery method only.**

| DEDP/OC | N | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | Avg Score | STD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DEDP | 24 | 58.3% | 50.0% | 41.7% | 16.7% | 62.5% | 45.8% | 58.3% | 41.7% | 91.7% | 20.8% | 48.8% | 21.4% |
| OC | 67 | 52.2% | 26.9% | 22.4% | 25.4% | 55.2% | 29.9% | 55.2% | 31.3% | 67.2% | 13.4% | 37.9% | 17.9% |

**Table 5: Percent of correct posttest responses (technical questions) by delivery method only.**

| DEDP/OC | N | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | Avg Score | STD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DEDP | 24 | 95.8% | 54.2% | 62.5% | 50.0% | 91.7% | 91.7% | 83.3% | 54.2% | 95.8% | 41.7% | 72.1% | 21.5% |
| OC | 67 | 92.5% | 47.8% | 40.3% | 52.2% | 80.6% | 79.1% | 70.1% | 23.9% | 86.6% | 23.9% | 59.7% | 25.5% |

**Table 6: Change in correct responses (Pretest % - Posttest %) by delivery method only.**

| DEDP/OC | | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | Avg Score |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DEDP | | 37.5% | 4.2% | 20.8% | 33.3% | 29.2% | 45.8% | 25.0% | 12.5% | 4.2% | 20.8% | 23.3% |
| OC | | 40.3% | 20.9% | 17.9% | 26.9% | 25.4% | 49.3% | 14.9% | -7.5% | 19.4% | 10.4% | 21.8% |

For the non-technical pre- and posttest questions, students were asked to respond to the following statements on a scale of 1-5 with 1 being 'Strongly Disagree' and 5 being 'Strongly Agree'.

- Q11 – I can select the best material for a design based on the design requirements and an understanding of material behavior.
- Q12 – I feel confident discussing material behavior with my peers.
- Q 13 – I feel confident discussing material behavior with my instructors.

Tables 7 and 8 summarize the results.

**Table 7: Changes in student-reported confidence and perceptions by delivery method and performance requirement.**

| | Q11 | | | Q12 | | | Q13 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pre | Post | Delta | Pre | Post | Delta | Pre | Post | Delta |
| DEDP | 3.54 | 3.75 | 0.21 | 3.08 | 3.83 | 0.75 | 2.92 | 3.42 | 0.50 |
| OC - Traditional | 2.89 | 4.14 | 1.24 | 2.70 | 4.19 | 1.49 | 2.62 | 3.84 | 1.22 |
| OC - SCALE-UP | 2.60 | 4.00 | 1.40 | 2.57 | 4.13 | 1.57 | 2.43 | 3.67 | 1.23 |

**Table 8: Changes in student-reported confidence and perceptions by delivery method only.**

| | Q11 | | | Q12 | | | Q13 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Pre | Post | Delta | Pre | Post | Delta | Pre | Post | Delta |
| DEDP | 3.54 | 3.75 | 0.21 | 3.08 | 3.83 | 0.75 | 2.92 | 3.42 | 0.50 |
| OC | 2.76 | 4.07 | 1.31 | 2.64 | 4.16 | 1.52 | 2.54 | 3.76 | 1.22 |

*Class Survey Results*

The end-of-class survey asked students to identify their delivery method (on-campus vs. distance). On-campus students were further asked to identify the type of classroom in which their section met. Sixty-four campus and 15 distance students completed the survey, response rates of 83.1% and 53.6%, respectively. Students were asked to report their average hours per week spent on a variety of class-related activities including homework, exam prep, class discussions, completing discussion questions on the class handouts that were not covered during classtime, viewing the learning modules, and a required term paper. The results of the survey are summarized in Table 9.

**Table 9: Student-reported hours spent per week on categories of class-related activities.**

| | DEDP | OC - Traditional | OC - SCALE-UP |
|---|---|---|---|
| Homework | 3.57 | 2.62 | 2.34 |
| Class Discussion | 2.90 | 2.38 | 2.50 |
| Additional Discussion Q's | 1.83 | 1.08 | 0.98 |
| Exam Prep/Review | 2.97 | 3.38 | 2.95 |
| Learning Modules | 3.17 | 2.95 | 3.18 |
| Term Paper | 3.77 | 3.77 | 2.95 |

Next, students were asked to rate the value of each area of required activity to their learning of the material. Responses ranged from 1 ('Very Unhelpful') to 5 ('Very Helpful'). Results are summarized in Table 10.

**Table 10: Student-perceived value of each area of required effort for learning course material.**

| | DEDP | OC - Traditional | OC - SCALE-UP |
|---|---|---|---|
| Homework | 3.87 | 3.03 | 3.16 |
| Class Discussion | 4.20 | 4.42 | 4.84 |
| Additional Discussion Q's | 3.80 | 3.45 | 3.42 |
| Exam Prep/Review | 4.20 | 4.36 | 4.55 |
| Learning Modules | 4.93 | 4.52 | 4.68 |
| Term Paper | 3.80 | 3.48 | 3.48 |

Students were then asked to rate their confidence in understanding the material in each of several broad topics areas as well as their confidence in applying their knowledge of materials behavior in each of those topic areas. Responses ranged from 1 ('Not at all confident') to 5 ('Extremely confident'). Results for confidence in understanding and application are summarized in Tables 11 and 12, respectively.

**Table 11: Student-reported confidence in understanding concepts from class topic areas.**

| | DEDP | OC - Traditional | OC - SCALE-UP |
|---|---|---|---|
| Mechanical Properties: Microstructure | 3.00 | 3.15 | 3.00 |
| Mechanical Properties: Testing | 3.60 | 3.21 | 3.13 |
| Electrical Properties | 3.27 | 2.97 | 3.03 |
| Optical Properties | 3.20 | 2.88 | 3.10 |
| Magnetic Properties | 3.20 | 2.97 | 3.10 |
| Thermal Behavior: Thermal Properties | 3.53 | 3.30 | 3.06 |
| Thermal Behavior: Binary Phase Diagrams | 2.80 | 3.21 | 3.39 |
| Thermal Behavior: Phase Transformations | 2.80 | 3.12 | 3.06 |

**Table 12: Student-reported confidence in applying concepts from class topic areas.**

| | DEDP | OC - Traditional | OC - SCALE-UP |
|---|---|---|---|
| Mechanical Properties: Microstructure | 3.27 | 2.88 | 2.94 |
| Mechanical Properties: Testing | 3.60 | 3.15 | 3.10 |
| Electrical Properties | 3.20 | 2.84 | 3.16 |
| Optical Properties | 3.07 | 2.58 | 2.93 |
| Magnetic Properties | 3.27 | 2.85 | 3.03 |
| Thermal Behavior: Thermal Properties | 3.47 | 3.21 | 3.23 |
| Thermal Behavior: Binary Phase Diagrams | 3.00 | 3.09 | 2.84 |
| Thermal Behavior: Phase Transformations | 2.93 | 3.00 | 2.81 |

Student were also asked to specify whether or not they would prefer to take another course in the flipped format. Comparisons between the responses of the two on-campus sections are shown in Table 13. Students in the SCALE-UP classroom were generally more in favor of additional flipped courses. However, a sizable portion of both groups specified 'it depends'. Comments provided by students implied that their perceived effectiveness of the flipped format depends strongly on the course and the instructor. Some gave examples of previous experiences with courses that were claimed to be 'flipped' by the instructor that were perceived to be poorly organized while other pointed to experiences in other classes that had gone quite well. About 36% of the students in the SCALE-UP group had taken at least one other class in the flipped format and about 46% of the traditional classroom group had done so.

**Table 13: Student-reported preference with regards to taking another course in the flipped format**

| | OC - Traditional | OC - SCALE-UP |
|---|---|---|
| Strongly Prefer | 9.1% | 12.9% |
| Prefer | 21.2% | 29.0% |
| Ambivalent | 6.1% | 12.9% |
| Prefer Not | 18.2% | 12.9% |
| Strongly Prefer Not | 3.0% | 0.0% |
| It Depends | 42.4% | 32.3% |

## Discussion and Conclusions

Tables 1-3 show improvement of student performance from pretest to posttest with the exception of Question 8 for both on-campus cohorts. This may indicate confusing wording in the question itself; however, the positive gains for the distance students argue against it. Question 8 related to whether or not carburization is a steady-state diffusion process, which would fall under the thermal topics category (Tables 11 and 12). Distance students reported less confidence with this material and yet demonstrated higher mastery and larger gains over the course of the semester.

Both on-campus groups reported lower initial confidence with respect to applying concepts from the class. By the end of the semester, however, the confidence level of on-campus students surpassed that of distance students. No significant difference was apparent between performance or confidence levels reported by on-campus students in the two different classroom settings.

Distance students reported spending at least as much time, if not more, in each of the reported areas of effort with the exception of exam prep. Despite being only required to complete the same portion of the discussion handouts as completed by on-campus students, distance students reported spending slightly more time on this activity. It is not clear if this also includes load time, etc. associated with accessing the session recordings remotely. They also reported spending significantly more time completing homework assignments than their on-campus peers. This is consistent with the reported value of each area of effort – distance students valued homework significantly higher than on-campus students. All students reported a high value to the pre-class learning modules.

Results from Table 13 are most interesting for what the numbers don't report – the comments in the 'It Depends' category. Most comments reflected a general skepticism by students regarding courses that are presented as being 'flipped'. Much of this seemed to be based on experiences with poorly structured flipped courses that left unfavorable impressions. Students seemed to approve of the flipped implementation in ME 301 and, on that basis, tended to be willing to consider subsequent courses in this format. Unfortunately, few details were provided regarding flipped courses that didn't work.

As reported previously by Cavalli[13], there seems to be a disconnect between student ability and student perceptions/confidence, particularly in the distance cohort. Previous work has shown that both expectations and achievement can be quite different between on-campus and distance students. Goodson *et al*.[14] showed that there can be different learning outcomes in the same course between on-campus and distance students. These outcomes can depend on the both class structure and content. They can also depend strongly on student preconceptions about student/faculty interactions according to Mackey and Freyberg[15].

Considine[16] emphasized the importance of active learning techniques even for distance learners. Despite gains relative to previous iterations of the course, additional work appears to be required to help the distance cohort realize the potential gains of this class format. This is the single biggest area for potential future work: what is the most effective way to incorporate the discussion/problem solving portion of the flipped class into an asynchronous distance course setting? A multitude of tools exist for collaboration in the synchronous distance environment. But there does not yet seem to be an effective method for replicating these person-to-person interactions for asynchronous class structures.

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