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Comparison of Learning Gate Completion Requirements in a Flipped Classroom

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Abstract

Previous work by the author has investigated the implementation of a flipped course structure for a junior-level materials science course. The basic structure of the course includes 1) topical learning modules to be viewed by students before class, 2) discussion/active learning activities during each class meeting and 3) an in-depth term paper and associated presentation on a materials science topic of each student's choosing. Each module nominally corresponds to 1-1.5 hours of lecture material broken into 5-10 minute chunks. Results showed that students in flipped sections of the course demonstrated larger gains in learning over the semester compared to students in a traditional classroom setting. The current work investigates additional details of the flipped structure. Pre-recorded course materials ('learning modules') include lecture segments and short learning assessments ('learning gates'). One cohort of students is required to achieve a minimum score on the learning gates for them to be counted as complete (>80%). A second cohort of students is required only to attempt the learning modules for them to be counted as complete. Both cohorts have the option take the assessments as many times as they desire. This paper compares student performance between the two cohorts throughout the course as well as student impressions of the course format.

Introduction

Inverted ('flipped') learning is currently an area of active interest for engineering educational research. In the flipped classroom, course material is typically pre-recorded by the instructor and students are required to view the recordings prior to class. In theory, this allows class-time to be spent answering questions and delving deeper into concepts than would otherwise be possible. A universal conclusion[1-6] seems to be that more material can be covered in the flipped format. This does not always appear to lead to improved student learning or mastery of the material, however.

A variety of recent publications have reported efforts in flipping classes ranging freshman-level design courses[1,2], to sophomore-level mechanics[1] and circuits courses[3], to a variety of upper-level engineering courses[1,4-6]. Results of the flipped format implementation have been mixed. For example, Cavalli *et al*.[1] 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. Saterbak *et al*.[2] reported the implementation of the flipped format in a freshman design course but have not yet presented results. Swift and Wilkins[3] reported gains in both student performance and student satisfaction through the implementation of a partially flipped course for sophomore circuits. Clemens *et al*.[4] found that the flipped format seemed to benefit some students and not others in an upper-level materials science course. Mason *et al*.[6] reported gains in student performance through implementation of a flipped class in an upper-level controls course. But, students in the same course reported doubts about freshmen and sophomore students possessing the maturity needed to succeed in the flipped format.

The current work reports on continuing efforts to implement the flipped format into an upper-level materials science course. Pre-recorded class materials were accompanied by concept quizzes. Some students were required to achieve specific scores on the concept quizzes and some were not. The purpose of the study is to ascertain if requiring a demonstration of a certain level of mastery on the material prior to the in-class discussions leads to overall gains in student understanding and performance.

Method

During the Fall 2013 semester one section of ME 301 – Materials Science was taught in a flipped format to on-campus students. Typical 50 minute lecture periods were replaced with ~45-80 minute pre-recorded lecture segments (in 10-20 minute chunks) and in-class discussions. For the Fall 2014 semester, these lecture segments were further sectioned into 5-10 minute chunks. Material for each class meeting was collected into a single file ('learning module') using Adobe Captivate. Within each learning module, each video segment was followed by a concept quiz ('learning gate') in which students were required to answer three questions on the material just viewed (from a random pool of 5-10 questions from each segment).

All ME 301 students experienced the flipped class structure for Fall 2014. This included both on-campus and distance students. There were 71 on-campus and 31 distance students enrolled. Approximately 20% of the course grade was assigned to participation in class discussions and successful completion of the learning quizzes within the learning modules. Distance students received credit for discussion participation via posts made to a weekly set of discussion board topics. Similar topics were covered during in-class discussion for on-campus students. Non-completion of any learning module or non-participation in a discussion session resulted in a loss of ¼ of the participation points for the semester. Students were divided approximately in half, with one group (comprising half of the on-campus and half of the distance students) required to achieve a score of 80% on the learning modules (aggregate of all quiz questions) to receive credit. The other group just had to attempt the modules to receive credit. Students were not aware prior to the first day of class which section had the 80% requirement.

A pretest and posttest were administered to determine the relative initial knowledge of each group (on-campus vs. distance, 80% required vs. 80% not required) 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. The pretest and posttest were administered electronically (using Blackboard) for both on-campus and distance cohorts.

In addition, a survey was administered electronically at the end of the semester regarding student's general opinion of the flipped course format. 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 whether or not they were required to achieve a score of 80% on each learning module to receive credit. 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'. On-campus response rates for the pre- and posttests were 98.6% and 100%, respectively. In contrast, the distance response rates were 87.1% and 58.1%.

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

DEDP/Campus	80 Req/Not Req	N	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Avg Score	STD
DEDP	Req	13	76.9%	46.2%	61.5%	46.2%	84.6%	76.9%	53.8%	76.9%	92.3%	30.8%	64.6%	20.7%
DEDP	Not Req	14	57.1%	42.9%	71.4%	35.7%	78.6%	57.1%	78.6%	7.1%	92.9%	42.9%	56.4%	16.0%
OC	Req	30	53.3%	6.7%	20.0%	13.3%	46.7%	43.3%	60.0%	33.3%	43.3%	16.7%	33.7%	13.5%
OC	Not Req	40	47.5%	20.0%	27.5%	20.0%	50.0%	35.0%	52.5%	47.5%	55.0%	22.5%	37.8%	15.6%

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

DEDP/Campus	80 Req/Not Req	N	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Avg Score	STD
DEDP	Req	7	85.7%	71.4%	71.4%	71.4%	71.4%	85.7%	100.0%	28.6%	85.7%	42.9%	71.4%	22.7%
DEDP	Not Req	11	100.0%	72.7%	81.8%	90.9%	100.0%	81.8%	81.8%	72.7%	100.0%	36.4%	81.8%	16.0%
OC	Req	31	90.3%	38.7%	38.7%	32.3%	93.5%	77.4%	77.4%	48.4%	83.9%	6.5%	58.7%	16.9%
OC	Not Req	40	80.0%	37.5%	57.5%	30.0%	72.5%	70.0%	72.5%	32.5%	80.0%	20.0%	55.3%	16.6%

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

DEDP/Campus	80 Req/Not Req		Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Avg Score	STD
DEDP	Req		8.8%	25.3%	9.9%	25.3%	-13.2%	8.8%	46.2%	-48.4%	-6.6%	12.1%	6.8%	2.0%
DEDP	Not Req		42.9%	29.9%	10.4%	55.2%	21.4%	24.7%	3.2%	65.6%	7.1%	-6.5%	25.4%	0.0%
OC	Req		37.0%	32.0%	18.7%	18.9%	46.9%	34.1%	17.4%	15.1%	40.5%	-10.2%	25.0%	3.4%
OC	Not Req		32.5%	17.5%	30.0%	10.0%	22.5%	35.0%	20.0%	-15.0%	25.0%	-2.5%	17.5%	1.0%

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/Campus	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Avg Score	STD
DEDP	66.7%	44.4%	66.7%	40.7%	81.5%	66.7%	66.7%	40.7%	92.6%	37.0%	60.4%	18.2%
Campus	50.0%	14.3%	24.3%	17.1%	48.6%	38.6%	55.7%	41.4%	50.0%	20.0%	36.0%	14.7%

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

DEDP/Campus	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Avg Score	STD
DEDP	94.4%	72.2%	77.8%	83.3%	88.9%	83.3%	88.9%	55.6%	94.4%	38.9%	77.8%	18.6%
Campus	84.5%	38.0%	49.3%	31.0%	81.7%	73.2%	74.6%	39.4%	81.7%	14.1%	56.8%	16.7%

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

DEDP/Campus	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Avg Score	STD
DEDP	27.8%	27.8%	11.1%	42.6%	7.4%	16.7%	22.2%	14.8%	1.9%	1.9%	17.4%	0.4%
Campus	34.5%	23.7%	25.0%	13.8%	33.1%	34.7%	18.9%	-2.0%	31.7%	-5.9%	20.8%	2.0%

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		
DEDP/Campus	80 Req/Not Req	Pre	Post	Delta	Pre	Post	Delta	Pre	Post	Delta
DEDP	Req	3.00	4.43	1.43	2.00	3.00	1.00	2.77	3.43	0.66
DEDP	Not Req	2.93	4.18	1.25	2.21	4.09	1.88	1.93	3.64	1.71
OC	Req	2.83	4.03	1.20	2.53	4.10	1.56	2.33	3.71	1.38
OC	Not Req	3.10	3.90	0.80	2.78	4.08	1.30	2.68	3.58	0.90

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

	Q11			Q12			Q13		
DEDP/Campus	Pre	Post	Delta	Pre	Post	Delta	Pre	Post	Delta
DEDP	2.96	4.28	1.31	2.11	3.67	1.56	2.33	3.56	1.22
Campus	2.99	3.96	0.97	2.67	4.08	1.41	2.53	3.63	1.11

Class Survey Results

The end of class survey asked students to identify their delivery method (on-campus vs. distance) as well as whether or not they were required to achieve 80% on the learning modules. Fifty three campus and 23 distance students completed the survey, response rates of 74.6% and 74.2%, 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, 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.

	OC - 80% Req	OC - 80% Not Req	DEDP - 80% Req	DEDP - 80% Not Req
Homework	2.94	2.54	3.80	3.42
Class Discussion	2.62	2.20	2.20	2.04
Exam Prep/Review	2.70	2.54	3.60	2.58
Learning Modules	3.14	2.76	3.80	3.50
Term Paper	3.02	3.12	4.10	2.73

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.

	OC - 80% Req	OC - 80% Not Req	DEDP - 80% Req	DEDP - 80% Not Req
Homework	3.48	3.68	4.10	4.08
Class Discussion	4.48	4.43	3.10	3.00
Exam Prep/Review	4.08	4.32	4.00	3.46
Learning Modules	4.40	4.75	4.10	3.69
Term Paper	3.32	3.36	3.60	2.92

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.

	OC - 80% Req	OC - 80% Not Req	DEDP - 80% Req	DEDP - 80% Not Req
Mechanical Properties: Microstructure	3.12	2.96	3.10	2.38
Mechanical Properties: Testing	3.20	3.61	3.40	3.08
Electrical Properties	3.04	2.89	2.70	2.77
Optical Properties	3.08	2.89	2.90	2.92
Magnetic Properties	2.88	2.75	3.00	2.77
Thermal Behavior: Thermal Properties	3.44	3.32	3.30	3.31
Thermal Behavior: Binary Phase Diagrams	3.20	3.32	2.80	2.46
Thermal Behavior: Phase Transformations	3.12	3.25	3.10	2.31

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

	OC - 80% Req	OC - 80% Not Req	DEDP - 80% Req	DEDP - 80% Not Req
Mechanical Properties: Microstructure	2.96	2.86	3.20	2.38
Mechanical Properties: Testing	3.21	3.46	3.40	3.00
Electrical Properties	2.92	2.89	3.22	2.85
Optical Properties	2.92	2.79	2.89	3.08
Magnetic Properties	2.88	2.82	3.00	2.85
Thermal Behavior: Thermal Properties	3.40	3.25	3.10	3.08
Thermal Behavior: Binary Phase Diagrams	3.16	3.14	3.20	2.46
Thermal Behavior: Phase Transformations	3.12	3.18	3.30	2.46

Discussion and Conclusions

Tables 1-3 show a general improvement of student performance from pretest to posttest with a few exceptions. Three of the four groups (on-campus 80% required, on-campus 80% not required, distance 80% required, distance 80% not required) did worse on question ten which is related to the definition of a slip system. This may indicate poor/confusing wording in the question. Three of the four groups showed significant gains on question five which is related to primary and secondary atomic bonding. The exception was the distance 80% required group. This group also did worse on questions eight and nine, related to diffusion and corrosion, respectively.

Of the four student groups, the distance 80% required group showed the smallest gains in average score from the pretest to the posttest, with worse performance on three out of 10 questions. It should be noted, though, that only about half of their original cohort completed the posttest resulting in a significantly different sample size from pretest to posttest. The distance 80% not required and on-campus 80% required groups showed the greatest gains in average score with increases of about 25%. When considered as complete cohorts, the on-campus group showed slightly more improvement in average score from pretest to posttest, but more variation in score on individual questions with some actually decreasing on the posttest. Changes in score on all questions were positive for distance students.

With regards to the non-technical questions on the pre- and posttests, distance students showed larger gains by the end of the semester. This trend was not consistent when broken down by required score on the learning modules.

Distance students required to achieve 80% on the learning modules reported more time spent on all aspects of the course than their counterparts in the distance cohort. They also placed higher value on each of the course activities than distance students not required to achieve 80%. For on-campus students, those required to achieve 80% reported spending more time on all but one aspect of the course (term paper). However, their reported valuation of the course activities did not show a clear trend compared to the rest of the on-campus students.

Similar results were observed in the end of class survey. Distance students required to achieve 80% on the learning modules tended to report higher confidence in both their understanding and ability to apply concepts from the course than distance students who did not have to achieve 80% scores. There was not a clear trend between the two groups of on-campus students.

The results of this study showed that the student group most likely to benefit from a performance requirement on the learning modules was the distance cohort when viewed from the lens of student perceptions and confidence. When assessed by gains from pretest to posttest, on-campus students actually demonstrated increased knowledge. Distance students with a performance requirement actually demonstrated the smallest gains in pre- to posttest scores of any group. Thus, 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. For example, Goodson *et al.*[7] showed that within the same course there can be different learning outcomes (or areas of learning strength) between on-campus and distance students. Such outcomes can depend on the both class content and structure. The outcomes can also depend strongly on student preconceptions about student/faculty interactions, as reported by Mackey and Freyberg[9]. Considine[8] stressed the importance of focusing on active learning techniques even in distance education. The discussion participation of the distance students in this study was relatively passive (posting to a discussion board with little interaction). It is possible that increase interactions between the instructor and distance students or distance and on-campus students on the discussion boards would increase the gains of distance students in general. Additional work appears to be required to help the distance cohort realize the potential gains of this class format.

The results of this work leave somewhat unresolved the question of the relative importance of the learning gates in the preparatory material and the content/format of the discussion questions/active learning sessions during class on student learning. For example, it became clear partway through the semester that starting the discussion session for on-campus students with a short 5-10 minute period for any questions to be asked to clarify concepts from the learning modules seemed to improve overall understanding of the material and performance on the discussion questions. However, these sessions were not recorded for the benefit of the distance students. Similarly, while the general format of the discussion sessions followed the same basic questions for both on-campus and distance students, additional material was sometimes introduced organically by the instructor during the course of a discussion in response to specific student questions. Distance students did not have the benefit of these deviations/additions. Thus, conclusions about relative importance of class components for on-campus and distance students should be drawn with care and may be unique to this class setting.

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