Evaluating the Effect of Flipped Classroom on Students' Learning in Dynamics

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Evaluating the Effect of Flipped Classroom on Students' Learning in Dynamics- Relative Velocity and Instantaneous Centers of Zero Velocity

Abstract

Flipping the classroom is an instructional approach where students learn about a topic outside of classroom and then use class time for active learning. Our control-impact study design paired two sequential rigid-body motion topics in Engineering Mechanics: Dynamics to test the effect of flipped vs. traditional lecture on both student learning and engagement. We alternated instructional methodology (traditional lecture + flipping) between the two sections of Dynamics in spring 2018. The traditional lecture sessions were taught with hand-written note lectures (with limited active learning) and completed two typical numerical homework problems per topic. For the flipped sessions, students watched instructional lecture videos prior to class, worked through a hands-on in-class activity, and completed analytical questions related to the in-class activity which substituted for 1 of the 2 homework problems on each topic. Paired multiple choice pre- and post-assessments were completed by all students and related mid-term exam question were evaluated. Additionally, as part of the post-assessment, several feedback questions evaluated how students felt about the experience and in which classroom method (i.e., traditional or flipped) they felt that they learned better. In general, we found that participating in the traditional lecture or flipped classroom did not significantly affect the performance of students on the paired pre- vs. post-assessments nor on related exam questions. Related to student preference, 38% of students expressed a preference for solely traditional lectures and 48% of students expressed a preference for mostly traditional lectures with a few (~5 sessions per semester) being flipped.

Introduction

While Engineers are pioneers in world's technological advancement, engineering education is evolving (often slowly) to meet the latest findings in the science of learning. The methods by which engineering educators prepare future engineers to solve problems and communicate solutions vary widely, but often fall back on the traditional lecture-based techniques which have dominated higher education for most of the 20th and 21st centuries. To engage students, fundamentals must be tied to engineering practice, through practice-oriented examples, and through relevant hands-on activities. Developing a practical engineering perspective through relevant engineering activities can help in building strong engineering fundamentals and judgment.

One way to facilitate more hands-on activities for engineering students is to flip the classroom. Traditional lecture + homework teaching consists of students learning a new concept in the classroom and then reinforcing their understanding by solving homework problems after class time. However, in a flipped classroom activity, students learn a new concept by being introduced to the topics before class and then reinforcing their understanding with hands-on activities in the classroom, plus appropriate levels of post-class assignments. The flipped classroom shifts instruction from an instructor-centered method to a learner-center method.

Flipping the classroom is not a new concept. Bishop et al. [1] summarizes 24 studies utilizing flipped classroom and reported that across studies students' perceptions were positive generally; however, there were a few students in each study who strongly opposed the method. Students often choose flipped classrooms over traditional lecture. Wendell [2] evaluated a case study on a flipped classroom for an undergraduate manufacturing class. Students watched a recorded lecture prior to class and during class students participated in answering a series of guided questions targeting critical thinking about the content. At the end of semester, students were asked to evaluate their experience about flipped classroom. Students strongly preferred flipped classroom (averaged 6.4 out of 7 on a Likert Scale) over traditional classroom. Mithun and Evans [3] concluded that flipped classroom method improved students' performance, motivation, and engagement when evaluating the use of a flipped classroom in an introductory class in computer information technology program. In the same study, students who participated in flipped classroom had an average on high *C+* in compare to a solid *C* for students on the traditional classroom.

Lee et al. [4] compared students' learning in two sections of Mechanics of Materials using a flipped and traditional classroom methods. They concluded that students attended flipped classroom scored 8 % higher than students attended traditional classroom after correcting for prior academic achievements and initial levels of content-specific achievements. This and other evidence looked promising, so we concluded to set up an experiment to test the efficacy of flipping the classroom in Dynamics.

Methodology

This study was conducted in Engineering Mechanics: Dynamics (hereafter "Dynamics") in the Spring semester of 2018. Dynamics is a required course for Civil, Environmental, Mechanical, and Biomedical Engineering students. Most students take Dynamics in the fourth semester of their engineering coursework. Two sections of Dynamics were offered in the spring semester of 2018 with a total of 210 registered students.

We selected the topics of Relative Velocity and Instantaneous Centers of Zero Velocity (ICZV's) for multiple reasons. First, the topics are in the middle of the 2D rigid body kinematics (motion) chapter of Dynamics, which traditionally is the most challenging chapter in the course. Secondly, the topics are sequential and fundamentally different ways of solving kind of problems. Relative Velocity is covered first as it is the basis for both topics. Relative Velocity requires a moderate amount of vector algebra to complete problems, whereas by using ICZV's you can opt to use scalar/spatial tools to solve. We hoped that hands-on activities would provide a better conceptual understanding of both topics, resulting in greater elevated capacity to solve relative motion problems for rigid bodies.

The study design consisted of alternating the instructional methodology (traditional vs. flipping) between the two sections and across the two topics (see Table 1). The traditional lecture sessions used lecture-based instruction (with < 10% active learning during the class session) and two related homework problems per topic. For the flipped sessions, students watched recorded lectures before class. Each topic had a <20 minute overview video plus an example video which were recorded lectures from the same instructor and then edited to present online. Students were minimally introduced to the in-class activity before dividing into 2-4 person groups to create Mindstorms Lego systems to manipulate and evaluate rigid-body motion systems. Two teaching assistants and one grader helped students during Section A flipped session and the instructor and a teaching assistant answered students' questions during Section B flipped session. As part of the in-class activity, each student was required to answer analytical questions related to the Lego activity which were turned in as a substitute for 1 of 2 homework problems assigned on each topic. Most students did not have time to complete the in-class analytical questions during the 50-minute class period and worked to complete the remainder after class.

Table 1 – Alternating design of traditional and flipped sessions.

	Section A	**Section B**
Relative Velocity	**Traditional**: In-Class Lecture + Full Homework (92 students)	**Flipped**: Pre-Video + In-class Activity + Limited Homework (37 students)
Instantaneous Centers of Zero Velocity (ICZV)	**Flipped**: Pre-Video + In-class Activity + Limited Homework (92 students)	**Traditional**: In-Class Lecture + Full Homework (37 students)

We also delivered identical pre- and post- assessments to assess learning across each methodology. These assessments consisted of multiple-choice questions covering the two topics, plus the previous topic covered (fixed axis rotation of a rigid body). All sections received the same pre- and post- assessment questions. As part of the post-assessment, several survey questions evaluated how students felt about the experience and in which classroom method (i.e., traditional or flipped) they felt that they learned better. Finally, we evaluated mid-term exam question, given ~3 weeks after the experiment, which specifically addressed each topic.

Thus, students' learning in flipped vs traditional methodologies were evaluated with the following metrics:

1. The difference (post – pre) of students' perceived knowledge on each topic (evaluated with paired t-tests)
2. Student responses to: "Given the choice would you:" (A) Prefer the flipped delivery method for MOST class sessions, (B) Prefer the flipped deliver method for HALF of class sessions (~20 per semester), (C) Prefer the flipped deliver method for A FEW class sessions (<5 per semester), or (D) Prefer the standard lecture delivery method for ALL class sessions;
3. Compare students' learning on flipped vs. traditionally methodology in the short-term by analyzing the post-assessment responses within one week of the experiment (evaluated with paired t-tests); and
4. Compare students' learning on flipped vs. traditional taught topics in the long-term by analyzing students' grades from mid-term exam questions across the two topics (evaluated with paired t-tests).

Results and Discussion

A total of 92 (of 144 enrolled) students participated in the ICZV’s flipped session and 37 (of 33 enrolled) students participated in Relative Velocity flipped session. Student attendance for the flipped sessions was self-reported as part of the post assessment, hence the data showing 37 students participating on the Relative Velocity flipped day when only 33 were enrolled could be either student error in self-reporting attendance or students from Section A deciding to attend the smaller Section B. Forty-nine (49) of the total enrolled students did not participate in either flipped session. This included 22 online students, plus others who were absent the day of experiment.

Metric 1: Students’ Perception of Learning

Students were asked to evaluate how knowledgeable they feel with topics that they participated in the flipped classroom or traditional classrooms. For ICZV’s, students who participated in flipped classroom felt they are slightly less knowledgeable in comparison with students who participated in the traditional lecture for the same topic, though the difference was not significant at the 0.05 level (p=0.231). (Table 2). For Relative Velocity, students who participated in the flipped classroom felt they are more knowledgeable in comparison with students who participated in the traditional classroom. Results in this case was statistically significant (P-value = 0.039) (Table 3).

This difference between two responses can be due to the quality of the student experience between classes as a function of the ratio of available assistants to students during the flipped classroom. For ICZV’s, there were a total of three learning assistants for 92 students providing one learning assistant per 30.7 students. Based on teaching assistant observation in flipped classroom for ICZV’s there were several students who did not get the help as soon as they requested which resulted in lower engagement level of those students during 50 minutes of activity. For Relative Velocity there were two learning assistants for 37 students providing one learning assistant for each 18.5 students. More support provided in the flipped classroom for Relative Velocity resulted in more student engagement.

Table 2: Perception of students from learning of ICZV’s.

<table>
<tr><th>On the scale of 1 to 10, how knowledgeable do you feel with the ICZV’s?</th><th>Average</th><th></th></tr>
<tr><td>All students</td><td>6.06</td><td>P-value=0.231</td></tr>
<tr><td>I watched the standard lectures and did NOT attend either Lego In-class Activity</td><td rowspan="2">6.17</td><td rowspan="3">Not Statistically Significant</td></tr>
<tr><td>I participated in the Relative Velocity flipped classroom</td></tr>
<tr><td>I participated in the ICZV’s flipped classroom</td><td>5.98</td></tr>
</table>

Table 3: Perception of students from learning of Relative Velocity.

On the scale of 1 to 10, how knowledgeable do you feel with the Relative Velocity?	**Average**	
All students	5.8	P-value=0.0392
I watched the standard lectures and did NOT attend either Lego In-class Activity	5.7	**Statistically Significant**
I participated in the ICZV's flipped classroom		
I participated in the Relative Velocity flipped classroom	6.19	

Metric 2: Student Preference/Enjoyment

After participating in the flipped classroom experiment, students were asked how many flipped classroom sessions would they like to experience during a semester (Table 4). Only 38.4 % of students did not prefer to take any flipped classroom for their course while approximately half of students (48%) preferred to experience a few (5 sessions per semester) flipped classrooms during a semester. One in ten students preferred half of classes to be performed as flipped classrooms. These results suggest that most students enjoyed the hands-on flipped classroom experience.

Table 4: Students' response to "Given the choice would you:"

Answer Options	**Number of Students**	**Percentage (%)**
Prefer the flipped deliver method for A FEW class sessions (5 per semester).	85	48.0%
Prefer the flipped deliver method for HALF of class sessions (~20 per semester).	17	9.6%
Prefer the flipped delivery method for MOST class sessions.	7	4.0%
Prefer the standard lecture delivery method for ALL class sessions.	68	38.4%
Total	177	100%

Metric 3: Student short-term learning

The results from the multiple choice post-assessment for each student group is shown in Table 5. Students who participated in flipped classroom for ICZV's earned a higher average grade on the assessment in comparison with students who participated in traditional classroom for the same topic. However, students who participated in traditional classroom averaged higher for Relative Velocity questions in comparison with students who participated in flipped classroom. This result is counterintuitive in contrast to the Relative Velocity (Metric 1) result of students reporting higher perceived learning under the flipped method. It is further confounded by the much lower average scores on the Relative Velocity related problems and the fact that students who participated in the Relative Velocity flipped classroom had lower average on exams prior to experiment in comparison with students who participated in ICZV's flipped classroom experiment (data not shown). However, results for both comparisons were not statistically significant.

Table 5: Assessment of students score in post-assessment survey took one week after the experiment (short-term learning).

Topic	**Students who participated in:**	**Grade (%)**	**P-value**
ICZV's	ICZV's traditional lecture	77.7	0.21
	ICZV's flipped classroom	80.1	
Relative Velocity	Relative Velocity traditional lecture	55.2	0.37
	Relative Velocity flipped classroom	53.6	

Metric 4: Student long-term learning

Specific questions were included on the subsequent midterm covering both Relative Velocity and ICZV's approximately four weeks after the experiment. For consistency, both questions were graded by a single grader. The average of grades for each student group is shown in Table 6. Students who participated in flipped classroom for ICZV's got 5.4 % higher average score in compare to students who participated in traditional lecture for problem from ICZV's. The average score of students who participated in the flipped classroom and traditional classroom were approximately the same for question from Relative Velocity. These results again can be due to the better implementation of the flipped classroom for ICZV's rather than Relative Velocity based on the number of students per learning assistant.

Table 6: Assessment of students score in the following exam from the topical questions (long-term learning).

Topic	**Students who participated in:**	**Grade (%)**	**P-value**
ICZV's	ICZV's traditional lecture	71.8	0.19
	ICZV's flipped classroom	77.2	
Relative Velocity	Relative Velocity traditional lecture	70.3	0.76
	Relative Velocity flipped classroom	69.2	

Conclusions

The effect of flipped classroom method on students' perception and learning was evaluated in this study across two sections of Engineering Mechanics: Dynamics course. Two subsequent topics from rigid body motion were picked while the instructional methodology (traditional lecture + flipping) was alternated between the two sections. The following conclusions were drawn from this study:

- Across both groups, 38% of students preferred traditional lectures for all classes in the semester and 48% of students preferred flipped classroom for a few classes (≤5 sessions) in each semester;
- There was a statistically significant perception by students in the flipped Relative Velocity group that they learned the topic better than students who participated in the traditional lecture of the same topic. However, the same perception did not hold for the flipped section focused on Instantaneous Centers of Zero Velocity.
- Post-assessment results suggested no statistically significant difference between learning of students participated in the flipped classroom and traditional classroom from short-term learning perspective;
- Analysis of grades from related question in the following exam suggested there was no statistically significant difference between students who participated in flipped classroom and traditional classroom. However, students participated in flipped classroom for ICZV's scored 5 % better than students participated in traditional classroom. Average scores for the Relative Velocity were approximately the same; and
- General trends of students' responses and measured learning suggest that the flipping method was more successful when there was a lower students to learning assistant ratio.

References

[1] Bishop, J. L., and Verleger, M. A. (2013). The flipped classroom: A survey of the research. *120th ASEE Annual Conference & Exposition*, Atlanta, GA.

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[3] Mithun, S. and Evancs, N. (2018). Impact of the flipped classroom on students' learning and retention in teaching programming. *125th ASEE Annual Conference & Exposition*, Salt Lake City, UT.

[4] Lee, L. S., Hackett, R. K., Estrada, H. (2015) Evaluation of a flipped classroom in Mechanics of Materials. *122th ASEE Annual Conference & Exposition*, Seattle, WA.