122nd ASEE Annual Conference & Exposition
June 14 - 17, 2015
Seattle, WA
Making Value for Society
Paper ID #11261

How do you like your course - Blended or Flipped?: A Preliminary Comparison

Dr. Renee M Clark, University of Pittsburgh

Renee Clark serves as the Director of Assessment for the Swanson School of Engineering at the University of Pittsburgh. She received her PhD from the Department of Industrial Engineering, where she also completed her post-doctoral studies. Her research primarily focuses on the application of data analysis techniques to engineering education research studies as well as industrial accidents. She has over 20 years of experience in various engineering, IT, and data analysis positions within academia and industry, including ten years of manufacturing experience at Delphi Automotive.

Prof. Autar Kaw, University of South Florida

Autar Kaw is a professor of mechanical engineering at the University of South Florida. He is a recipient of the 2012 U.S. Professor of the Year Award from the Council for Advancement and Support of Education and Carnegie Foundation for Advancement of Teaching. The award is the only national program to recognize excellence in undergraduate education. Professor Kaw received his BE Honors degree in Mechanical Engineering from Birla Institute of Technology and Science (BITS) India in 1981, and his degrees of Ph.D. in 1987 and M.S. in 1984, both in Engineering Mechanics from Clemson University, SC. He joined University of South Florida in 1987. Professor Kaw's main scholarly interests are in engineering education research, open courseware development, bascule bridge design, fracture mechanics, composite materials, and the state and future of higher education. Funded by National Science Foundation (2002-16), under Professor Kaw's leadership, he and his colleagues from around the nation have developed, implemented, refined and assessed online resources for an open courseware in Numerical Methods (http://nm.MathForCollege.com). This courseware annually receives more than a million page views, 900,000 views of the YouTube lectures, and 150,000 visitors to the "numerical methods guy" blog. Professor Kaw has written more than 85 refereed technical papers and his opinion editorials have appeared in the Tampa Bay Times, Tampa Tribune and Chronicle Vitae. His work has been covered/cited/quoted in many media outlets including Chronicle of Higher Education, Inside Higher Education, U.S. Congressional Record, Florida Senate Resolution, ASEE Prism, and Voice of America.

Dr. Mary E. Besterfield-Sacre, University of Pittsburgh

Dr. Mary Besterfield-Sacre is an Associate Professor and Fulton C. Noss Faculty Fellow in Industrial Engineering at the University of Pittsburgh. She is the Director for the Engineering Education Research Center (EERC) in the Swanson School of Engineering, and serves as a Center Associate for the Learning Research and Development Center. Her principal research is in engineering education assessment, which has been funded by the NSF, Department of Ed, Sloan, EIF, and NCIIA. Dr. Sacre's current research focuses on three distinct but highly correlated areas – innovative design and entrepreneurship, engineering modeling, and global competency in engineering. She is currently associate editor for the AEE Journal.

Dr. Andrew Scott, Alabama A&M University

Andrew Scott has been a faculty member with the Department of Electrical Engineering and Computer Science at Alabama A&M University, Huntsville, since 2002. He has a strong background in high-performance scientific computing, including algorithms and numerical analyses on parallel and distributed systems. He has expertise in the following areas: Field Programmable Gate Arrays for reconfigurable computing applications, software development for heterogeneous computing environments, domain decomposition, process mapping and data structuring techniques for distributed platforms, and finite element analysis. He holds both BS and MS degrees in mechanical/aerospace engineering from the University of Missouri, Columbia, and PhD in computer science and engineering from the University of Missouri, Kansas City.

How Do You Like Your Course - Blended or Flipped?: A Preliminary Comparison

Renee M. Clark, Autar Kaw, Mary Besterfield-Sacre, and Andrew Scott
rmclark@pitt.edu, kaw@usf.edu, mbsacre@pitt.edu, andrew.scott@aamu.edu

Index Terms – Flipped classroom, Blended instruction, Numerical Methods, Mechanical Engineering.

1. Introduction and Literature Review

The traditional lecture is not highly effective in engaging students and supporting them in practicing the higher order thinking skills, such as critical analysis. When topics are complex, students require more in-depth engagement activities to fully construct an understanding of the topic [1]. Blended learning has emerged in higher education as a means to provide more engaging, quality-driven experiences for learners. It aims to optimally integrate face-to-face oral communications with online learning, which often contains a written component [1,2,3]. With blended learning, aspects of face-to-face classroom learning are replaced or augmented by appropriate online or technology-based experiences, such as simulations, labs, tutorials, and assessments [1].

An NSF grant allowed us to experiment with alternative teaching modes in a numerical methods course, and we began a formal comparison of blended vs. flipped instruction in 2014. This is one of the first studies we are aware of (after a search of the literature) that compares blended versus flipped instruction in a STEM course. This required course is taken by approximately 130 junior and senior mechanical engineering students each year at the University of South Florida (USF) and covers numerical methods for the topics of differentiation, nonlinear equations, simultaneous linear equations, interpolation, regression, integration, and ordinary differential equations. The spring 2014 course was taught in a blended fashion and consisted of in-class lectures, clicker questions, and exercises. In addition, there was a 24-hour online discussion board, digital audiovisual lecture videos, and automatically-graded online quizzes for students. This course aligned with the *supplemental* model of blended instruction, which retains the structure of the traditional class but adds technology-driven activities outside of class to enhance student engagement and experiences and provide additional resources [4]. The instructor had extensive prior experience in teaching this course in a blended manner.

There is evidence that blended learning can be more effective than a traditional classroom approach, and there is certainly intuitive appeal to combining the strengths of face-to-face (synchronous) and web-based (asynchronous) activities [5]. With support from the Pew Charitable Trusts, an instructional redesign program for achieving quality enhancements was conducted by Rensselaer Polytechnic Institute. This grant program encouraged higher education institutions to redesign their instructional approaches using technology. In the first round of ten redesign projects involving a range of arts and sciences courses undertaken by schools including

Penn State, University of Central Florida (UCF), Wisconsin-Madison, and Virginia Tech, five of the ten projects reported improved learning outcomes, four reported equivalent achievement, and one was not conclusive. Some of the improvement techniques included computer-based assessment and feedback, online student discussion groups and learning communities, computer-lab group work (with faculty present) in lieu of a lecture, and online, self-paced interactive tutorials with assessment checks [6]. The University of Central Florida (UCF) has been a large adopter of the blended learning model and is a recognized leader in this area, having offered blended courses since 1997 [3,7].

Blended learning has been advocated or implemented in other mechanical engineering courses, in which online experiments, web-based simulations, or remote labs have been used [8,9,10,11]. For example, a remote experiment for measuring mechanical properties of materials was used in a blended learning fashion in a laboratory course. The students could perform the online experiment either before or after the in-person lab session to prepare or review [9]. In a mandatory "Computer Science in Mechanical Engineering" course taken by 1,000 students a year at a German university, a blended learning approach was used to help meet the challenge of educating a large number of students with diverse initial backgrounds. This blended course included face-to-face lectures and project work as well as internet-based lecture videos, a student discussion forum, and a library of complementary enrichment e-learning units, including a C++ unit [10]. At South Dakota State University, a blended approach was used for an introductory mechanical engineering course in material science. This course employed multi-media online resources, such as video clips and discussion forums, to enhance, replace, and/or supplement in-class face-to-face lectures [11].

Our numerical methods instructor at the University of South Florida soon developed an interest in flipping his numerical methods course. The flipped classroom enables in-class, face-to-face time for application and demonstration of skills with the instructor present for as-needed support. This is typically accomplished by having students watch online videos containing lecture content outside of class, thus freeing class time for higher-engagement activities such as mentored problem solving [12,13,14]. The instructor's primary goals were to promote higher order thinking and metacognitive skills on the part of his students. In addition, he wanted to drive student responsibility for learning, albeit using fully guided instruction. With fully guided instruction, students are presented with all essential information versus being asked to "discover" or "construct" necessary information on their own. This full, explicit instructional guidance, which can be provided via live lectures, videos, etc., is followed by practice of skills and feedback [15]. Therefore, in the summer 2014 course, the instructor "mixed it up" and covered half of the topics in a "flipped" mode; the other half continued to be taught in a blended fashion. This also allowed him to pilot and "ease into" fully-flipped instruction in the fall semester.

In the flipped sessions in the summer term, students watched video lectures and/or read the textbook before class. In addition, prior to class, they took an online, auto-graded quiz and responded to an online open-ended question about difficult or interesting topics. During class, the students worked in groups on exercises or applications and used clickers. Micro-lectures were employed as necessary, and the online discussion board was also available. The video lectures were developed as part of previous NSF-funded work in which comprehensive numerical methods courseware was developed. This open courseware, known as Holistic

Numerical Methods (HNM), includes resources for the topics of introductory computing, differentiation, nonlinear equations, simultaneous linear equations, interpolation, regression, integration, ordinary differential equations, partial differential equations, optimization, and Fast Fourier transforms [16]. Between 2009 and 2012, 328 videos were developed and recorded for this open courseware initiative, with an average length of about nine minutes.

The benefits of an active learning approach such as flipped instruction are numerous. Flipping requires students to be actively involved in their education and reduces the amount of passive participation [17,18]. Studies have shown that active or interactive learners exhibit significantly higher results and gains compared to passive learners in problem solving, time to mastery, and conceptual understanding [18,19]. A recent meta-analysis of studies comparing active learning to traditional lecturing indicated that student test performance increased by about half a standard deviation on average in active-learning STEM courses. Also, average failure rates were 22% with active learning compared to 34% with traditional lecturing [20]. In addition, top educators have stressed that genuine learning occurs when students become involved in activities such as discussion, analysis, application, problem solving, and design [21]. Inverted instruction also leads to benefits such as increased student-teacher interaction, student collaboration, accommodation of different skill levels via individualized help, self-paced video "pause and rewind" capability, multiple information sources, increased problem examples, and flexibility for those who cannot attend class due to legitimate reasons, such as a job interview. These types of benefits have also been noted in the literature [22,23].

The flipped classroom has been implemented with other mechanical engineering courses, including introductory mechanical design, statics and mechanics, numerical methods, and electronics instrumentation, as discussed in the literature [24,25,26,27,28]. In the results section, we will compare our experiences in this course to others in the literature. As detailed in these articles, two institutions that have used online statics materials in an inverted and blended fashion are Carnegie Mellon University and Miami University of Ohio [24, 25]. These web-based statics materials were developed as part of the Carnegie Mellon Open Learning Initiative (OLI) [29].

To assess and evaluate progress and outcomes, we developed a comprehensive plan consisting of direct and indirect assessment. These assessments included course-specific assessments (i.e., exam questions), interviews and discussions with the instructor, student perception surveys, and a student demographics survey. For the summer semester containing some flipped instruction, a formative course evaluation survey was administered. Our course evaluation survey was modeled upon the work of Leicht, Zappe, and colleagues in their flipped classroom research and was expanded upon based on our own research questions and interests [12,14].

2. Methods

In this section, we discuss in greater detail the assessment methods we utilized. We distributed our various perception surveys during the last week of class to enable the most comprehensive view and understanding of the course. The students were offered extra credit for completing the surveys. We used final exam scores to directly assess and compare learning with blended versus flipped instruction in numerical methods.

2.1 Demographics Survey

The demographics survey, which we developed specifically for this research, consisted of questions regarding age, gender, race/ethnicity, Pell grant status, transfer status, work and credit hours, and pre-requisite course grades. The pre-requisite courses consisted of calculus 1-3, ordinary differential equations, introductory programming, and physics 1. We also accounted for the possible fulfillment of these requirements through Advanced Placement (AP) test credits. These grades were used to calculate a numerical methods pre-requisite GPA for each student to be used as a covariate or control variable in the analysis of covariance of the blended vs. flipped approach. The students were asked to provide a personal code when completing this survey, which allowed us to match the student's exam performance with his/her demographic characteristics. This enabled us to evaluate various demographic segments of our population. The demographic segments of interest within our research were the following:

1. Age Group: {22 or under, over 22}
2. Gender: {male, female}
3. Under-Represented Minority: {yes, no}
4. Transfer Status: {admitted to engineering as a freshmen, transferred to engineering from a community college with an associate's degree, other transfer status}
5. Pell Grant Recipient: {yes, no}
6. Combined Work and Credit Hours/Effort: {under 40, 40-65, over 65}

The age categories reflect our interest in traditional vs. non-traditional engineering students, with the traditional student starting college at age 18. The students in this course were juniors and seniors. The under-represented minority students consisted of Hispanic, American Indian, Black/African American, or Hawaiian/Pacific Islander students. The work and credit hours were combined by multiplying the credit hours by 3 and adding the weekly work hours. For the summer term, we used a slightly different multiplier. Sixty-five combined hours (65) corresponded to a full-time student taking 15 credits and also working a 20-hour-per-week work study or other job, which would be reasonable for a student. The boundaries associated with this field (i.e., field 6 above) also resulted in a reasonable number of students in each of the three categories.

2.2 Flipped Classroom Evaluation Survey

The course evaluation survey for use with the flipped classroom was adapted from previous work and used for both formative and summative assessment purposes. Specifically, our survey was modeled upon those of Leicht et al. and Zappe et al., who used student perception instruments in a flipped course taken by undergraduates with sixth-semester standing in architectural engineering at Penn State [12,14]. We employed questions from this prior work pertaining to preferences for flipped instruction and in-class active learning as well as video usage behavior. We added specific questions about online, auto-graded homework, applicability to one's future career, perceived learning gains, peer interaction, and student motivation with the flipped classroom. We also asked two open-ended questions on perceived benefits as well as drawbacks and suggestions regarding the flipped classroom. Based upon a content analysis of the responses, these benefits and drawbacks were identified using two coders [30].

2.3 Direct Assessment

The final exam contained 14 multiple choice questions that were identical between the spring and summer semesters. The multiple choice questions were designed to test the lower-level skills in Bloom's taxonomy [31]. In addition, there were four open-ended, free-response questions that remained the same from term to term. These were intended to measure the higher-order skills in Bloom's taxonomy, such as synthesis. The comparisons between the spring and summer semesters were done using an analysis of covariance, with the pre-requisite GPA serving as a covariate. Since the summer term sample size was less than 20, we also ran a non-parametric analysis of covariance, known as Quade's test [32,33].

3. Results

In this section, we will present a comparison of the final exam results for blended versus flipped instruction, including for various demographic segments of our population. We will also provide the results from the flipped-classroom evaluation survey.

3.1 Direct Assessment of Learning

In the spring semester, the multiple-choice topics were taught using only the blended method of instruction. In the summer, however, eight of the multiple-choice questions were based on material taught in the flipped mode, and six were based on material taught in a blended manner. We therefore compared the composite result of the eight questions for each semester to determine the impact of flipping the material. We made the comparisons for each demographic segment of interest, based upon the goals of our research grant. For example, we asked the following question: "For females, is flipped instruction better than blended instruction in terms of achievement?"

The *p*-values from the parametric and non-parametric analyses of covariance were generally in agreement, as shown in Table 1. Based upon the non-parametric results, we uncovered significant improvements ($p \leq 0.001$) on the result of the eight questions from the spring to the summer terms for each of the male, non-under-represented, and medium-effort (40-65 hours/week) segments of our population. These would be significant at $\alpha = 0.05$ even when considering Bonferroni's adjustment for multiple comparisons [34]. Not considering Bonferroni's adjustment, there were also significant improvements for the 22-and-under ($p = 0.004$), admitted-to-engineering-as-freshmen ($p = 0.019$), Pell-grant-recipient ($p = 0.034$), and non-Pell-grant-recipient ($p = 0.048$) segments of the population. The small sample size in the summer term potentially influenced the levels of significance.

We calculated both adjusted and non-adjusted effect sizes based on Cohen's *d* [35]. The effect size represents the extent of the difference between two groups. Cohen defined effects as small (d=0.20), medium (d=0.50), or large (d=0.80) [35]. The effect sizes associated with the above-mentioned significant differences were all large (i.e., *d* between 0.92 and 1.17), except for those associated with the Pell grant segments of the population, which were of medium (*non-Pell grant recipient*) and small (*Pell grant recipient*) size. Each of the eight questions was worth one point, and the adjusted mean of the eight questions is shown in Table 1. The means were "adjusted" by the SPSS software using the mean value of the covariate, as is typically done. Females were the only segment that did not experience an improvement in performance from the spring to the summer term; however, there were only two female students during the summer term.

Table 1: Comparison of Eight Questions – Blended (Spring) vs. Flipped (Summer)

Multiple Choice 8 Q's	Difference Blended vs. Flipped		Adjusted Mean		Sample Size	
	Parametric ANCOVA *p*	Non-Parametric ANCOVA *p*	Spring	Summer	Spring	Summer
Gender						
Male	0.001	<0.0005	4.99	6.45	64	15
Female	0.354	0.662	5.11	4.00	9	2
Age Group						
<= 22	0.007	0.004	5.19	6.45	41	12
> 22	0.706	0.848	4.74	5.08	32	4
Transfer Status						
Freshman Admit to Engineering	0.034	0.019	5.33	6.69	34	7
CC Transfer with Associates	0.056	0.074	4.67	5.86	33	9
Other	0.723	0.801	4.94	5.39	6	1
Effort (hours/week)						
< 40	0.902	0.569	5.61	5.72	17	5
40-65	0.002	0.001	4.70	6.32	44	10
> 65	0.109	0.095	5.16	7.03	12	2
Under Represented Minority						
Yes	0.839	0.691	4.66	4.85	13	4
No	0.002	0.001	5.07	6.49	60	14
Pell Grant						
Yes	0.024	0.034	4.86	6.30	29	7
No	0.090	0.048	5.10	6.07	44	10

Although these significant improvements with the eight "blended vs. flipped" questions are promising, an additional interesting outcome is a contrast of these results with those of the remaining six questions that were taught solely in a blended fashion during both terms. Across the 14 demographic segments, there was only one significant improvement in the outcome of these six questions - for the community college transfers with associates degrees ($p = 0.044$). Note that this is not a highly-significant result and would not be significant at $\alpha=0.05$ if applying Bonferroni's adjustment; however, adjusted Cohen's *d* was high at 0.82. Thus, the spring and summer results for the six questions were essentially statistically equivalent. Thus, there was equivalent achievement in the spring versus summer terms on material taught in a blended fashion both times (as one might expect). However, there was evidence of statistically better achievement on material taught in a flipped manner in the summer term compared to the same material taught in a blended manner in the spring term. This suggests a positive impact of flipping the numerical methods coursework, as opposed to presenting it solely in a blended fashion. With the six "blended only" questions, there were also three demographic segments that showed a decrease in performance from the spring to the summer terms– females, admitted-to-engineering-as-freshmen, and high effort (>65 hours/week) students. However, the summer term was associated with a small sample size.

We conducted additional analyses of covariance with several other dependent variables, including the free-response score and the final exam total score (determined by a combination of the multiple choice and free response scores). Across the 14 demographic segments, there were 10 and 13 increases (spring to summer) in these two dependent variables, respectively. Of these, there were only two significant differences – in the final exam total score – but the p-values were not highly significant at $p=0.02$ and would not be significant if adjusted for multiple comparisons using Bonferroni's adjustment. The effect sizes were medium (*males*) and large (*CC transfers with associates*), however. Thus, there were not significant changes from the spring to the summer terms in higher-order thinking skills as evidenced in the free-response items. The free response items that the higher order skills were based upon were taught in both the blended and the flipped modes in the summer term.

3.2 Flipped Classroom Evaluation Survey

The students evaluated the flipped portion of the summer course via the formative evaluation survey, with approximately 67% of the students in the class responding. One third of the respondents preferred the flipped classroom to the usual method of instruction in the course, which was the blended instructional method. Another 44% were unsure of their preferences, and 23% did not prefer flipped instruction to the usual method. When asked to compare the use of class time for problem solving with the instructor present versus listening to a lecture, 61% preferred the former, as shown in Figure 1. In comparison, Zappe et al. found somewhat lower student preference for active learning in the classroom, with 48% agreeing or strongly agreeing that they preferred problem solving versus lecture during class time [14].

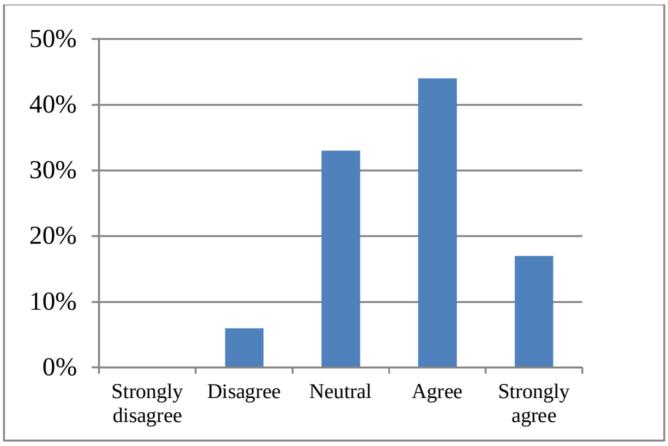

Figure 1: Prefer Using Class Time for Problem Solving vs. Lecture

In terms of required effort, over 60% of respondents reported that the flipped classroom required more or much more effort compared to the usual method of instruction in the class (i.e., blended), and 78% felt it placed more or much more responsibility on them. The respondents felt the online, auto-graded, multiple-attempt homework problems were valuable (83% agreement or strong agreement), as was the discussion board (78% agreement or strong agreement). However, they were not enthusiastic about other aspects of the flipped classroom. Only one-third agreed or strongly agreed that the learning gains were better in the flipped classroom versus the usual method of instruction in the class (i.e., blended). Only 39% agreed or strongly agreed that interaction with other students in the flipped classroom was valuable. Only 28% thought the flipped classroom led to valuable experiences for their future careers. Finally, only 39% felt the flipped classroom enabled them to develop better computer programs for numerical methods problems.

3.2.1 Content Analysis of Benefits

In an open-ended question in the evaluation survey, we asked the students what they liked about the flipped classroom and the benefits they perceived. The frequencies associated with the categories in our coding framework are shown in Table 2. Seventeen students provided responses. Interestingly, the most frequently perceived benefits related to enhanced learning or learning processes as well as preparation, engagement, and professional behaviors, as described in Table 2. Thus, the students perceived the top benefits that we were hoping to drive. These results were based on a content analysis and consensus coding by two coders. One coder was the assessment analyst for the project, and the second was a junior-level engineering student. If they disagreed on a particular code, they discussed until agreement was reached. Nonetheless, their first-time inter-rater reliability score based on Cohen's Kappa of $\kappa = 0.73$ showed agreement beyond chance [34]. The coding framework was developed based on prior flipped classroom research [36].

Table 2: Summary of Open Ended Responses to Benefits

Frequency	% of Respondents	Category	Description
9	53%	Enhanced Learning or Learning Process	Better understanding; less confusion Enhanced learning/effectiveness/depth/ability Subject matter retention Multiple sources/resources for understanding Reinforcement and review Multiple attempts
8	47%	Preparation, Engagement & Professional Behaviors	Engaged during class; paid attention; not bored Enjoyed class Arrived to class prepared Ability to learn on one's own Drove motivation and accountability
5	29%	Video/Online Learning	Re-watch videos Work at one's own pace; pause video Flexibility, convenience, own preferences Modularization of topics

Frequency	% of Respondents	Category	Description
4	24%	No Benefit or Neutral Result	No benefits perceived Did not like flipped instruction Videos not used Instructional differences not noticed
3	18%	Alternative Use of Class Time	In-class active learning, problem solving, clickers In-class support and questions In-class group time for projects Student interactivity and peer support
2	12%	Specific to Course or Course's Videos	Videos concise Videos had a good pace Overall work time less Videos had relevant content (e.g., demo or examples) or were of high quality

3.2.2 Content Analysis of Suggestions and Drawbacks

In a second open-ended question in the evaluation survey, we asked the students what drawbacks they perceived with the flipped classroom and their suggestions for improvement. The frequencies associated with the categories in our coding framework are shown in Table 3. Fifteen students provided responses. The most frequent suggestions or drawbacks related to the use of in-class time, followed by the perceived load, burden, or stressors on the students. These results were obtained using a content analysis and consensus coding by the same two coders discussed in the previous section. Their first-time inter-rater reliability score based on Cohen's Kappa of $\kappa = 0.79$ showed strong agreement beyond chance [34].

Table 3: Summary of Open Ended Responses to Suggestions/Drawbacks

Frequency	% of Respondents	Category	Description
9	60%	In-Class Time	Increase time for active learning or problem solving Increase effectiveness or relevancy of problems; grade them Provide appropriate amount of lecture or content review Have more instructor-types during class to assist Synchronize class activity and video content
6	40%	Load, Burden, Stressors	Insufficient time to complete out-of-class activities Increased work load Increased time burden Concerns over grades or impacts to the grade Accountability quizzes (including surprise)

Frequency	% of Respondents	Category	Description
3	20%	Prepare, Equip & Incentive Students To Flip	Prepare students for the flipped learning style Incentivize students, including video quizzes Clarify/emphasize expectations, including video watching Provide video "lecture" notes Ensure videos available in advance for students
3	20%	Specific to Course or Course's Videos	Include more examples or problems in the videos Videos needed editing or bug/technical fixes Videos were too long Videos were not sufficiently described Videos were dry or boring Videos did not have an appropriate pace Videos repeated information Video material was too complex
2	13%	Approach Differently	Do not flip courses in general; use traditional teaching Do not flip this course in particular Provide students with a choice on flipping Flip only a portion of the class periods
1	7%	No Drawbacks or Neutral Result	No drawbacks or suggestions
1	7%	Student Learning	Lesser understanding or learning Difficulty learning from a video
0	0%	Video/Online Learning	Students unable to ask questions during a video Instructor unable to sense student understanding in a video Distractors to viewing videos in a non-classroom setting Less motivation to attend class

We asked the summer-term students to report the percentage of videos they watched. The average percentage reported was 57%. However, the videos were not the only resource available for learning the material; students were also directed to the book chapters. These book chapters were in both online and hardcopy format. In fact, 72% of survey respondents reported using a combination of the videos and the book chapters for their out-of-class learning. No students reported using only the videos. In a post-course interview, the instructor felt that students took responsibility for the self-learning aspect. At Michigan Tech, in a pilot of a blended course for first-year engineering students that used pre-class videos, the students who reported having prepared for class likewise used a combination of available readings and videos to do so. The authors concluded that providing students with a variety of options for their preparation was a desirable feature to maintain in the course [37].

4. Discussion and Conclusions

In comparisons of blended versus traditional or fully-online learning in the literature, blended learning has shown success, including in the initial round of the Pew Trusts' redesign program discussed in the introduction, in which the improved outcomes included significantly higher grades and exam performances[6,7]. Comparisons of flipped to traditional instruction in mechanical engineering have shown mixed results, including at the University of North Dakota (UND), where a series of undergraduate mechanical engineering courses was flipped [26]. At the University of Puerto Rico (Mayaguez), an inverted classroom was implemented for several sections of a statics course in the fall 2009 [28].

A blended as well as flipped approach to teaching a required mechanical engineering course in numerical methods was taken at USF beginning in the spring of 2014. A fully-blended approach was used in the spring, followed by a partially-flipped/partially-blended approach in the summer. This allowed a comparison of blended versus flipped instruction for numerical methods. This paper is believed to be one of the first such comparisons within engineering education. The instructor has been teaching this course in a fully-guided, blended fashion for many semesters and transitioned to a fully-flipped format in the fall 2014. Flipped instruction enables an instructor to incorporate active learning and problem solving in the classroom while still exposing students to necessary content. With flipped instruction, students apply and practice foundational concepts and skills initially obtained outside the classroom, oftentimes by video lectures but also by readings or other resources. This active learning can promote increased involvement and engagement in one's education, better understanding and achievement, and a deeper experience, particularly with the higher order skills in Bloom's taxonomy [17, 18, 19]. Blended instruction of this course involved maintaining the traditional in-class lecture format supplemented by online and technology-based resources including clickers, online quizzes, a discussion board, and a library of videos (i.e., Holistic Numerical Methods Open Courseware).

To directly compare these two methods of instruction, we used the results of final exam questions, which were identical for the two semesters. Eight multiple-choice questions were based on topics taught in a flipped mode in the summer and a blended mode in the spring. However, six other questions served as a comparison, as they were based on topics taught in a blended fashion during both terms. One of the goals of our research was an investigation of blended versus flipped instruction of numerical methods for certain demographic segments of our student population. When analyzed for these various demographic segments, such as females or under-represented groups, there were highly significant improvements from the spring to the summer terms in the composite outcome of the eight multiple-choice questions but not in the composite outcome of the six "blended-only" questions. This suggests that flipped instruction may be better than blended instruction within numerical methods for achievement of Bloom's lower-order skills. In a post-course interview, the instructor noted particularly good conceptual questions being asked by the summer students when they submitted their comments on interesting or difficult topics. Other results were analyzed, including the free-response and overall outcomes on the final exam. There were only two significant improvements from the spring to the summer terms in these outcomes across the various demographic segments; however, there was typically an upward change between the spring and summer term for the various segments. This provides additional preliminary evidence that the use of flipped instruction may lead to enhanced outcomes in numerical methods.

Based on the students' evaluation of the summer term's flipped component, one-third of the respondents preferred flipped instruction to blended instruction, with another 44% unsure of their preferences. However, over 60% of the students preferred using class time for active learning with the instructor present versus listening to a lecture, indicating that the students realized value in flipped instruction. In addition, in an open-ended question to the students, the most frequently-stated benefits of flipped instruction were enhanced learning or learning processes as well as the promotion of preparedness, engagement, and professional behaviors. Based on these preliminary results as a whole, we believe that flipped instruction is a valuable method for teaching numerical methods. Our ongoing research in this area will enable us to add to these initial findings.

Acknowledgment

This material is based upon work supported partially by the National Science Foundation under Grant Number 1322586, and the Research for Undergraduates Program in the University of South Florida (USF) College of Engineering. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. We wish to thank Anita Jain, an undergraduate engineering student at the University of Pittsburgh, who provided invaluable assistance in coding the open-ended student responses. We would also like to thank undergraduate assistants Benjamin Rigsby and Humberto Isaza of the University of South Florida for compiling the demographics and final examination data.

References

[1] Garrison, D., & Vaughan, N. (2008). *Blended Learning in Higher Education: Framework, Principles, and Guidelines*. San Francisco, CA: John Wiley & Sons, Inc., 4-8.

[2] Bourne, J., Harris, D., & Mayadas, F. (2005). Online Engineering Education: Learning Anywhere, Anytime. *Journal of Engineering Education*, *94*(1), 131-146.

[3] Dziuban, C., Hartman, J., Juge, F., Moskal, P., & Sorg, S. (2006). Blended Learning Enters the Mainstream, In C. Bonk, & C. Graham (Eds.), *The Handbook of Blended Learning: Global Perspectives, Local Designs* (195-206), San Francisco, CA: John Wiley & Sons, Inc.

[4] Twigg, C. (2003). Improving Learning and Reducing Costs: New Models for Online Learning. *Educause Review, 38(*5).

[5] Garrison, D., & Kanuka, H. (2004). Blended Learning: Uncovering its Transformative Potential in Higher Education. *The Internet and Higher Education*, *7*(2), 95-105.

[6] Twigg, C. (2003). Improving Learning and Reducing Costs: Lessons Learned from Round I of the PEW Grant Program in Course Redesign. *Center for Academic Transformation, Rensselaer Polytechnic Institute, Troy, NY*.

[7] Cavanagh, T. (2011). The Blended Learning Toolkit: Improving Student Performance and Retention. *Educause Quarterly Magazine, 34(*4).

[8] Cortizo, J., Rodríguez, E., Vijande, R., Sierra, J., & Noriega, A. (2010). Blended Learning Applied to the Study of Mechanical Couplings in Engineering. *Computers & Education*, *54*(4), 1006-1019.

[9] Restivo, M., Mendes, J., Lopes, A., Silva, C., & Chouzal, F. (2009). A Remote Laboratory in Engineering Measurement. *IEEE Transactions on Industrial Electronics*, *56*(12), 4836-4843.

[10] Henning, K., Bornefeld, G., & Brall, S. (2007). Mechanical Engineering at RWTH Aachen University: Professional Curriculum Development and Teacher Training. *European Journal of Engineering Education*, *32*(4), 387-399.

[11] Hu, Z., & Zhang, S. (2010). Blended/Hybrid Course Design in Active Learning Cloud at South Dakota State University. *2nd International Conference on Education Technology and Computer (ICETC), IEEE.*

[12] Leicht, R., Zappe, S., Litzinger, T., and Messner, J. (2012). Employing the Classroom Flip to Move 'Lecture' Out of the Classroom. *Journal of Applications and Practices in Engineering Education, 3*(1).

[13] Strayer, J. (2012). How Learning in an Inverted Classroom Influences Cooperation, Innovation and Task Orientation. *Learning Environments Research*, *15*(2), 171-193.

[14] Zappe, S., Leicht, R., Messner, J., Litzinger, T., and Lee, H. (2009). "Flipping" the Classroom to Explore Active Learning in a Large Undergraduate Course. *Proceedings of the ASEE Annual Conference and Exposition, Austin, TX.*

[15] Clark, R., Kirschner, P., & Sweller, J. (2012). Putting Students on the Path to Learning: The Case for Fully Guided Instruction. *American Educator*, 36(1), 6-11.

[16] Kaw, A., Yalcin, A., Lee-Thomas, G., Nguyen, D. T., Hess, M., Eison, J., & Owens, C. (2012). A Holistic View on History, Development, Assessment, and Future of an Open Courseware in Numerical Methods. *Proceedings of the ASEE Annual Conference & Exposition, San Antonio, TX.*

[17] Prince, M. (2004). Does Active Learning Work? A Review of the Research. *Journal of Engineering Education, 93*(3), 223-231.

[18] Chi, M. (2009). Active-Constructive-Interactive: A Conceptual Framework for Differentiating Learning Activities. *Topics in Cognitive Science*, *1*(1), 73-105.

[19] Hake, R. (2001). Interactive Engagement vs. Traditional Methods: A Six-Thousand Student Survey of Mechanics Test Data for Introductory Physics Courses. *American Journal of Physics, 66,* 1, 64-74.

[20] Freeman, S., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active Learning Increases Student Performance in Science, Engineering, and Mathematics. *Proceedings of the National Academy of Sciences*, 201319030.

[21] Bonwell, C., and Eison, J. (1991). Active Learning: Creating Excitement in the Classroom. *ASHEERIC Higher Education Report No. 1*, George Washington University, Washington, DC.

[22] Bergmann, J., & Sams, A. (2012). *Flip your Classroom Reach Every Student in Every Class Every Day*. Eugene, OR: International Society for Technology in Education.

[23] Rosenberg, T. (2013 October 23). In "Flipped" Classrooms, a Method for Mastery. *New York Times*.

[24] Dollar, A. & Steif, P. (2009). A Web-Based Statics Course Used in an Inverted Classroom. *Proceedings of the ASEE Annual Conference and Exposition, Austin, TX.*

.

[25] Steif, P. & Dollar, A. (2012). Relating Usage of Web-Based Learning Materials to Learning Progress. *Proceedings of the ASEE Annual Conference and Exposition, San Antonio, TX.*

[26] Cavalli, M., Neubert, J., McNally, D., & Jacklitch-Kuiken, D. (2014). Comparison of Student Performance and Perceptions Across Multiple Course Delivery Modes. *Proceedings of the ASEE Annual Conference and Exposition, Indianapolis, IN.*

[27] Connor, K., Newman, D., & Morris Deyoe, M. (2014). Flipping a Classroom: A Continual Process of Refinement. *Proceedings of the ASEE Annual Conference and Exposition, Indianapolis, IN.*

[28] Papadopoulos, C., & Roman, A. (2010). Implementing an Inverted Classroom Model in Engineering Statics: Initial Results. *Proceedings of the ASEE Annual Conference and Exposition, Louisville, KY.*

[29] Steif, P., & Dollár, A. (2009). Study of Usage Patterns and Learning Gains in a Web-based Interactive Static Course. *Journal of Engineering Education, 98*(4), 321-333.

[30] Neuendorf, K. (2002). *The Content Analysis Guidebook*. Thousand Oaks, CA: Sage Publications.

[31] Wiggins, G., & McTighe, J. (2005). *Understanding by Design*. Upper Saddle River, NJ: Pearson Education, Inc., 339-340.

[32] Quade, D. (1967). Rank analysis of covariance. *Journal of the American Statistical Association, 62*(320), 1187-1200.

[33] Lawson, A. (1983). Rank analysis of covariance: alternative approaches. *The Statistician*, *32*(3), 331-337.

[34] Norusis, M. (2005). *SPSS 14.0 statistical procedures companion*. Upper Saddle River, NJ: Prentice Hall, 152, 183.

[35] Salkind, N. (ed.), 2010, *Encyclopedia of Research Design*, *Vol. 1*, Sage Publications, Thousand Oaks, CA.

[36] Clark, R., Norman, B., & Besterfield-Sacre, M. (2014). Preliminary Experiences with 'Flipping' a Facility Layout/Material Handling Course. *Proceedings of the Industrial and Systems Engineering Research Conference, Montreal*.

[37] Hamlin, A., Kemppainen, A., & Fraley, M. (2014). Extended Abstract – Is Student Preparedness and Performance Improved by Using Pre-Lesson Videos?. *Proceedings of the First Year Engineering Experience (FYEE) Conference, College Station, TX.*