 

# Can "Flipping the Classroom" Improve the Educational Experience in Construction Management Courses: A Case Study in Teaching HVAC Psychrometrics

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"Flipping the classroom" is gaining acceptance in university-level education as a way of improving teaching by freeing class time from the lecture and replacing it with active learning exercises. This paper will address whether this type of teaching is an effective tool in the construction science and management classroom. Two sections of the same course were taught using two different teaching models. The first used a traditional model that primarily included lectures during class hours with homework completed at home. The flipped model inverted the material so that lectures were recorded and viewed outside of class, leaving classroom time available for other active learning exercises. This paper shows the effectiveness of a flipped construction management classroom using student surveys and quantitative learning assessments. Specifically, this paper uses the teaching of psychrometrics as a case study to highlight the barriers and potential solutions to improve the educational experience in a construction management class using the flipped classroom model.

**Key Words**: Flipped Classroom, Pedagogy, Active Learning, Psychrometrics

## Introduction

A recent study conducted at the University of British Columbia tested the effectiveness of "research-based instruction" on large-enrollment physics classes (Deslauriers, Schelew & Wieman, 2011). In the experiment, two sections of the same course were taught by two different instructors. Both sections had approximately 270 students. The first instructor, who received high student evaluations, was an expert in the subject matter and had taught the course many times before. The second section was taught by inexperienced but well-coached teaching assistants using modern best practices in pedagogy. These best practices included pre-class reading, small-group tasks, student-to-student discussions, and in-class instructor feedback. Notably, there were no formal in-class lectures. The study found that the section using the best practices performed twice as well on the end exam as the control section (Deslauriers et al., 2011).

Although the study at the University of British Columbia did not use the term specifically, the model used is commonly referred to as the "flipped classroom." The flipped classroom is a teaching model born in the digital age that is gaining widespread acceptance in the university system (Berrett, 2012; Brame, 2013; Educause, 2012; Rogers & Tingerthal, 2013). The most simplistic application of the flipped classroom is when the time and place in which students engage in homework and lectures are "flipped" (Bennett, Kern, Gudenrath & McIntosh, 2012). The flipped classroom is contrasted with the traditional teaching approach in which the instructor is responsible for lecturing and then following up with homework done outside of class (Bennett et al., 2012; Educause, 2012). With the class time freed from lectures, active learning exercises that are essential to reaching Millennial students can be used (Lee, 2011; Roehl, Reddy & Shannnon, 2013; Walvoord & Anderson, 2010; Wilson & Gerber, 2008). Though the model gets its name from the order in which content is presented and assessed; flipping the classroom is less about how content is delivered and more about a philosophy of teaching and learning (Roger & Tingerthal, 2013). For members of the Associated Schools of Construction (ASC), it is ultimately about having students reach our learning objectives so they are prepared for a successful career in construction. This paper shows the results of a study that tested the effectiveness of the flipped classroom in a typical construction management (CM) class. The effectiveness was measured against a different section of the same course in which the traditional teaching model was used. The students in both sections completed a survey to evaluate their perceptions of the approach used in their class. Homework, quizzes and exams were given to qualitatively assess how much the students had learned

after specific learning exercises. Barriers to the flipped classroom are identified with recommendations on how to use it to improve CM courses.

## The Experiment

To evaluate the effectiveness of the flipped classroom model, two sections of an environmental systems course were used in the study. The first section used a traditional approach where lectures were given during class time and homework assigned. The second section was flipped. Lectures were recorded and posted on the class website. This section used class time for assignments, peer-to-peer teaching, and project-based learning. The traditional section and flipped section had 23 and 18 students respectively. The learning objectives for both sections were identical. All physical material such as PowerPoint files, homework, in-class assignments, quizzes, and the cumulative exam were exactly the same. This environmental systems course focused on HVAC and plumbing systems, but this particular study only observed the portion of the class addressing psychrometrics. This particular subject matter was selected because it is fairly specialized and not commonly covered in general education or other CM classes. The intention was that all of the course material was "new knowledge," negating any advantages obtained through previous courses.

The course met twice a week, and the psychrometric module was taught over a 4-week period. Assignments, quizzes, and in-class assignments made up 25% of the grade, with exams making up the remaining 75%. The learning objectives during this portion of the class were as follows:

1. Understand how heat flows.
2. Understand what psychrometrics is and how to read a psychrometric chart.
3. Introduce the properties of air and what affects thermal comfort.
4. Understand how air can be manipulated to achieve thermal comfort.
5. Comprehend how the properties of air can affect HVAC equipment size and energy consumption.

Over the four-week period that psychrometrics was taught the class met seven times. Table 1 provides a chart outlining the learning objective and specific activities for the two sections. In addition to the activities provided in the table, both sections were required to view web links provided by the instructor (primarily from YouTube) but without assessments tied directly to them. There were also three recorded videos, each with a short online quiz, presented through the Mechanical Service Contractors of America's HVAC101 webinar series (www.mscastar.org/hvac_101/) that the students were required to watch.

## Traditional Section Activities

The instructor lectured on course material most days the class met in the traditional section (see Table 1). A PowerPoint presentation accompanied the lecture which the students had access to at least two days in advance. The lecture generally took 60 minutes of a 75-minute class. Lecture quizzes were commonly given. The lecture quiz assessed how well the students understood/retained the information just presented. The quiz only addressed the material from the lecture that immediately preceded the quiz. About half of the classes had homework assigned. The homework was completed individually. A short practice exam was given the class period before the exam (Class #6).

A survey was given to the students that addressed how they felt about different aspects of the class (see Table 2). A five-point Likert scale evaluated how much a student disagreed or agreed with a question. A score of 1 indicated they strongly disagreed whereas a 5 indicated they strongly agreed with the statement. Table 2 presents the mean results of the survey. A statistical t-test ($p<5\%$) indicating that questions 3, 8, and 10 were not statistically significant enough to make any inferences from them. The limited sample size of the class made firm conclusions difficult but did still allow for insightful interpretations of the data. The students in the traditional section generally liked the traditional teaching style, rating it 4.1 out of 5 (Q1–6). When asked whether they would prefer to go to the flipped model, the majority of the students in that section answered that they would not (2.5, Q11) citing in part that they preferred live over recorded lectures (2.3, Q7).

## Flipped Section Activities

As shown in Table 1, the flipped section had a very different approach than the traditional section. At the beginning of the course, students were made aware that their section would be taught using the flipped model. At the end of the study, the students were asked about their experience using the flipped approach. The students did not have a strong opinion either way on how effective it was at teaching the material and responded with a rating of 3.4 (Q11). The traditional section students, who had not been taught using the flipped model, demonstrated an initial resistance to it (2.5, Q11). Based on the survey, it appears that students are initially uncomfortable with the flipped classroom approach but with familiarity they seem to appreciate it more.

### *Recorded Lectures*

One key difference between the two sections is that the in-class instructor-led lecture had almost completely been removed from the flipped section. In its place were recorded lectures on the class website. The same PowerPoint presentation files used in the traditional section were used in the flipped section. The students moderately preferred recorded over live lectures (3.7, Q7) citing in part a preference in using class time for homework and other learning exercises (3.4, Q11). Several students provided written comments on the survey that the recorded lectures would be better for less advanced topics or reviews, but that difficult new concepts should be taught with live lectures.

The learning management system BlackBoard, which has the ability to track if and when students access the recorded files, was used in the class. To assess how effective the recorded lectures were at transferring the material, lecture quizzes were given during the first 15 minutes of class. The instructor found that getting students to watch the recorded lectures was difficult. Physical attendance in both sections was consistently above 94%; however, on average only 61% of the students actually watched the recorded lectures before class. The percentage of students who watched it before the cumulative exam only marginally improved to 68%. As you would expect, the mean scores of the lecture quizzes from the flipped section were lower than those of the traditional: 74% compared to 79% (see Table 3). However, if you remove the students who didn't watch the recorded lecture from the average, the flipped section received an average of 78%, as compared to 79% on the lecture quizzes. Based on these scores it appears that recorded lectures are just as effective as live lectures at conveying information. For this course the value of the live lectures was not in the quality of information provided but in the participation from a larger percentage of the class.

An advantage to recorded lectures is that students can go back and rewatch lectures again to prepare for exams or other assessments. However, students didn't appear to appreciate the value of this. When asked whether they "actively" watch the recorded lectures by taking notes and rewatching difficult topics a second time, the students only slightly agreed that they did (3.5, Q9). However, only 17% of the students accessed the recorded lectures a second time prior to the exam. One possible explanation for this is that the lectures were provided as one continuous video. Students may not have thought it a good use of time to re-watch a whole lecture to better understand a few concepts. A better practice may be to divide the lecture videos by topics or provide audio on each individual slide of the PowerPoint presentation.

### *Homework*

The same homework assigned in the traditional section was assigned in the flipped section. However, with the lectures recorded, there was time available to complete most, if not all, of the homework in class. Completing homework in class allowed the students to ask the instructor questions that may not have occurred to them when watching the lecture. The survey could not statistically support that the students preferred this activity (not significant, Q3). However, the students seemed to understand the material better when it was done in class. The flipped section outperformed the traditional section on their homework assignments by a mean score of 94% to 85% (see Table 3). Based on the students' higher grades this does appear to be an effective technique.

### *Project-Based Learning*

Project-Based Learning is a teaching technique that engages students through investigation. Students pursue solutions to real world problems by asking refining questions, debating ideas and creating predictions (Blumenfeld, Soloway, Marx, Krajcik, Guzdial & Palincsar, 1991). In Class #2, the students were broken up into small groups

and given a list of discussion questions. The questions were ordered so they built towards how actual engineers calculate the impact of infiltration and ventilation on a building's energy load. The students were instructed to put themselves in the shoes of the mechanical engineer. As the students were discussing the questions, the instructor would walk around the class and listen passively. As they moved closer to the solution, the instructor would encourage additional discussion on that topic. If the conversation started to move away from the solution, the instructor would gently nudge the discussion back on track. Initially, the students were told that they weren't expected to know exactly how to do the calculation but to first identify what they would need to know "if" they were the engineer and making the calculation. As the students identified factors, such as delta temperatures, the instructor would provide reasonable values for the factors. The students were ultimately able to think through the process and make the calculation using formulas that they had learned from previous classes. This project-based activity received lackluster feedback from the students, who rated it 3.3 (Q2).

*Peer-to-Peer Learning*

Peer-to-peer learning was an active learning technique used in Classes #1 and #6. For Class #1, volunteers were solicited before class to participate in an undisclosed class assignment. Four volunteers were asked to meet the instructor before class. The instructor used the time to tutor the volunteers on the material covered in the recorded lecture. The intent was that with one-on-one tutoring, the volunteers would be "content experts" and could help the other students when divided into small groups. The instructor passively walked from group to group further clarifying points when asked by students. The flipped section students didn't have a strong opinion when asked if this was a better way of learning than an instructor-led lecture, rating it 3.0 (Q1).

Another peer-to-peer active learning technique was used for an exam review in Class #6. Again, student volunteers met with the instructor for a 1- to 2-hour tutoring session. The same PowerPoint presentation used in the traditional section to review for the exam was shown to the volunteers. The tutoring sessions were tailored to the volunteers, with extra time given to the topics that the volunteers indicated were difficult. Copies of the PowerPoint presentation were given to the volunteers so they could use it in their study groups. They were also encouraged to come up with material on their own that they could share with their group. The students overwhelmingly did not like this technique, rating it 2.3 (Q5). Half of the write-in comments specifically addressed this as a poor way to learn material when compared to an instructor-led lecture. Comments such as "Teach us yourself" and "My group leader didn't help me at all" articulate the theme of the comments well.

**Activities Shared by Both Sections**

As demonstrated in Table 1, there were many differences between the two sections; however, there were also some similarities. First, it is important to highlight that the learning outcomes and content presented were exactly the same. All PowerPoint presentations, homework questions, lecture quizzes, and in-class assignments were identical. Teaching styles and philosophies were very different, but the content was the same.

*Sling Psychrometer Lab*

Class #4 was an outside lab activity completed by both sections. The students were given a sling psychrometer and asked to record the dry bulb and wet bulb temperatures in the classroom, directly outside the building, and next to a cooling tower. The students then used the skills learned from previous classes and solved for other properties of air (RH, h, W, V, & DP) manually. Students then download psychrometric software which calculated these values automatically. An instructor-led discussion "dissected" the three air samples, and the class talked about "why" the samples had the properties they did. This activity was overwhelmingly well received by both sections, which scored it 4.1 and 4.6 (Q4). The lab was specifically addressed in the survey with several write-in comments all affirming the value of the exercise.

*Exam*

At the end of the module, a cumulative exam was given to both sections. The first 25% of the exam dealt with non-analytical principles. The questions did not involve any calculation or abstract thinking. Essentially, a student could have done well simply by memorizing the PowerPoint slides. Another 60% of the exam was an assessment of the process. The students needed to "understand" what was taught in the course. This 60% included calculations that

were very similar to what they had seen on homework and class examples. There was some variation in the exam questions from the homework and other class examples, but the questions were similar enough for students to do moderately well by knowing only the process and not the concept behind it. The last 15% of the exam contained applied analytical questions. Students needed to know how and where these concepts could be used to do well on these questions.

## Overall Understanding of Material

The student's comprehensive understanding of psychrometrics was measured with a practice exam and a cumulative exam. The practice exam was a six-question quiz that was to be completed in 20 minutes; however, it very closely mirrored the exam in content and level of difficulty. Neither section did well on the practice exam, but what was notable was how close the scores were. The traditional section (35%) outperformed the flipped section (31%) by only four percentage points (see Table 3). The cumulative exam was a 19-question, multiple choice, fill-in-the-blank, short answer, and calculation-based assessment of all material covered. Similar to the practice exam, the two sections performed nearly as well as each other; traditional earning 83% (Median = 84%, SD = 12%) and flipped 81% (Median = 84%, SD = 14%) (see Table 3). The very close scores between the two sections in both the practice exam and the cumulative exam do not support that either teaching style was superior to the other. The question of "why" will be addressed shortly.

### *Practice Exam and Exam Delta*

A notable observation was that both sections did very poorly on the practice exam (35% and 31%) but were able to improve their overall grasp of the material significantly within 2 days for the cumulative exam (83% and 81%). The instructor randomly selected 10 students to have an informal discussion as to why there was such a difference. The lead questions were "Did the class lectures and material teach you only 35% of the content?" and "Did you really learn 48% (83%–35%) in 2 days on your own?" The consensus of the group was that there was more than 35% value to the lecture and other activities, but they didn't really "learn it" until they studied. One student said, "It was all rolling around in my brain, but until I started to study, I never put it together." Based on the conversation with the group, the students didn't really "study," which the word "learn" could be substituted for, until there was an exam pending. More frequent exams could be a good tool to get students to study/learn the material more in step with when it is presented.

### *Higher Level of Understanding*

Proponents of the flipped model contend that flipped students will have a higher level understanding of the subject matter. According to this argument, students' self-discovery of the material will lead not just to learning the steps to solve a problem but to understanding the principles behind it. This contention was tested with the exam. The last three problems of the exam (weighted 15% of total graded) were higher-level analytical questions. Of the 15 points possible, the traditional section earned 9.09 (60.6%) compared to 9.39 (62.6%) from the flipped section. Based on this observation, this study could not validate the claim that the flipped classroom led to a significantly higher analytical understanding of the covered material.

## Lessons Learned

The flipped classroom has been used very effectively in universities across the country. There are obvious benefits of inverting the lectures and assignments. In the modern world with readily accessible multimedia, there is no reason why information passed to the student has to come through a live person in a classroom. In fact, the students (via the survey) largely agreed that recorded lectures were just as effective at transferring information. This was supported by nearly identical averages on lecture quiz results. The other element of the flipped model is doing homework during class hours, which allows students to ask questions as they solve difficult calculations. This aspect of the model was largely supported by the students, as evidenced by a positive score on the survey and higher homework grades when compared to the traditional section. Ultimately, however, the students performed nearly identically on the exam, which was the best evaluation of overall understanding. The question at hand is *why*. Why did a well-documented pedagogical model not improve students' overall understanding of psychrometrics?

### *Recorded Lectures*

 

The recorded lectures in the flipped section had two major shortcomings. First, the number of those who watched the lectures or "virtual attendance" was too low. On average, only 68% of the class watched them. The other 32% of the students had no educational value from the lectures. To improve the flipped approach in this course, more aggressive incentives to watch the lectures could be imposed. The second shortcoming in the recorded lectures was the failure to make the distinction between information transfer and "learning." This could be addressed in two ways. First, the instructor could help the student change the way they perceive the lectures from just a conduit of information to tool to learn difficult concepts. To teach difficult concepts with recorded media, the students can't just be passive observers. They need to be active participants. Another way the recorded lecture could be used successfully is by not using them to teach difficult concepts at all. They could be used for basic information transfer only. They could cover only basic definitions, simple explanations, and review material allowing more class time for more difficult material. More difficult concepts that require students to be more engaged could be reserved for the live lectures.

### *Peer-to-Peer Learning*

Peer-to-peer learning should be used cautiously in a flipped class. For peer-to-peer learning to be effective, the leader needs to have a solid understanding of the material. In this study, the student volunteers were generally not comfortable with the material. This, coupled with the other students' expectation of "being taught" with loose concepts still "rolling around in [their] brain," led to an ineffectual active learning exercise. If peer-to-peer learning is to be used, students who have demonstrated a higher understanding of the material should be tapped to lead the groups. Assignments preceding the peer-to-peer activity may also help engage the student's not leading the group.

### *The Point of Engagement*

An important observation was the dramatic improvement in grades from the practice exam to the cumulative exam. Both sections had extremely low scores on the practice exam (35% & 31%). Within 2 days, however, they were able to improve their understanding enough to earn scores of 83% and 81%. After speaking with a sample of students, the unanimous explanation was that they hadn't studied until after the practice exam. They had remembered nebulous concepts, but it wasn't until they had a sizable portion of their grade at stake that they tried to bring them into focus. Stated another way, it wasn't until their grade was at stake that they went from passive absorbers of information to active learners of concepts. More exams with shorter durations between them would reduce the amount of material taught but not really digested by the student. Additional study in this area is recommended.

## Conclusions

The flipped classroom approach to teaching represents more than the order in which material is presented—it is a tool to support active learning. This study used two sections of the same Environmental Systems course to evaluate the effectiveness of this approach with construction management students. The effectiveness of active learning activities was measured through student surveys and quantitative assessments. The study found that for the flipped model to be successful, students needed to be highly incentivized to watch the recorded lectures. It also found that recorded lectures are a poor choice to "teach" difficult concepts. Recorded lectures are better suited for basic concepts in which passive observation of the information is sufficient. Peer-to-peer learning can be effective but is highly dependent on the students, especially the student leaders. The study also found that in general, students only learned (the students used the word "study") immediately before a high-point-value examination. To shorten the time between when material is taught and learned, more frequent examinations are recommended.

Table 1
*Psychrometric Lesson Plan Summary*

| Class | Learning Objectives | Traditional Section Activities | Flipped Section Activities |
|---|---|---|---|
| 1 | 1 | • In-class lecture<br>• Lecture quiz<br>• Homework assigned | • Recorded lecture assigned<br>• Lecture quiz<br>• "Homework" completed in-class |

 

| | | | |
|---|---|---|---|
| | | | • Peer-to-peer learning exercise |
| 2 | 1 | • In-class lecture | • Abridged in-class lecture<br>• Active learning class discussion |
| 3 | 2, 3 | • In-class lecture<br>• Lecture quiz<br>• Homework assigned | • Recorded lecture assigned<br>• Lecture quiz<br>• "Homework" completed in-class |
| 4 | 2, 3, 4 | • Sling psychrometer lab | • Sling psychrometer lab |
| 5 | 3, 4, 5 | • In-class lecture<br>• Lecture quiz<br>• Homework assigned | • Recorded lecture assigned<br>• Lecture quiz<br>• "Homework" completed in-class |
| 6 | 1, 2, 3, 4, 5 | • Instructor-led exam review lecture<br>• Short practice exam | • Peer-led exam review study group<br>• Short practice exam |
| 7 | 1, 2, 3, 4, | • Cumulative Exam | • Cumulative Exam |

Table 2
*Survey Results*

| | Question* | Traditional | Flipped | T-test @ 5% |
|---|---|---|---|---|
| 1 | Class #1 – A student-led study group was more effective than a traditional class. | 4.1** | 3.0 | Significant |
| 2 | Class #2 – An interactive discussion in combination with a short lecture was more effective than a traditional class. | 4.1** | 3.3 | Significant |
| 3 | Class #3&5 – A recorded lecture and the homework done in class was more effective than a traditional class. | 4.1** | 3.8 | Not Significant |
| 4 | Class #4 – An outside lab with a sling psychrometer was more effective than a traditional class. | 4.1 | 4.6 | Significant |
| 5 | Class #6 – A peer-led exam review was more effective at preparing me for the exam than a traditional class. | 4.1** | 2.3 | Significant |
| 6 | I feel that the instructor and the class activities prepared me very well for the exam. | 3.9 | 3.4 | Significant |
| 7 | Bearing in mind that recorded lectures could be watched over and over again, I prefer to have the lectures recorded instead of watching them live. | 2.3 | 3.7 | Significant |
| 8 | Watching live lectures is much more interesting than recorded lectures and holds my attention longer. | 4.1 | 3.5 | Not Significant |
| 9 | I always "actively" watched the recorded lectures by taking notes, backing up and re-watching parts of the lecture I didn't understand, and writing down questions to ask the instructor in class. | 2.7 | 3.5 | Significant |
| 10 | I always "actively" watch live lectures in my classes by taking notes and asking the instructor questions on things I don't understand. | 3.8 | 4.1 | Not Significant |
| 11 | Overall, I prefer to learn under the flipped model where lectures are recorded and class time is used for homework or other learning activities as opposed to the traditional model where class time is used for lectures and homework is done at home. | 2.5 | 3.4 | Significant |

* Questions abridged for brevity.
** As the traditional section didn't have this active learning exercise they were asked to rate how effective an in-class lecture with homework assigned was at learning the material.

 

Table 3
*Mean Score of Assessment*

| | Assessment | Class #1 | Class #3 | Class #5 | Class #6 | Class #7 | Average |
|---|---|---|---|---|---|---|---|
| Lecture Quiz | Traditional | 93%<br>89% | 82%<br>69% | 62%<br>63% | | | 79%<br>74% (78%*) |
| Homework | Traditional | 89%<br>99% | 94%<br>98% | 73%<br>84% | | | 85%<br>94% |
| Practice Exam | Traditional | | | | 35%<br>31% | | 35%<br>31% |
| Cumulative Exam | Traditional | | | | | 83%<br>81% | 83%<br>81% |

* Score excluding students who did not watch recorded lectures

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