Heat Transfer - Student Response to an Inverted Format

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Introduction

Heat Transfer is one of the foundational courses for engineering students studying both Mechanical and Chemical Engineering. At Worcester Polytechnic Institute (WPI), there are no prerequisite classes for the Heat Transfer course, resulting in a wide variety of background knowledge in the students who take the course. Historically, the course has been taught in a traditional lecture style to an ever-increasing size class. Teaching methods are slow to change for a foundational course such as this one. Some changes have occurred in the corresponding textbooks, which, over recent years, have moved towards being more engaging by including examples that are more applicable and realistic to the world students know. And yet the students can still struggle with mastering the key concepts within the course.

In order to address this, the format of the heat transfer course was converted from a more traditional lecture to an inverted format. The specific inverted (also referred to as flipped) format that was selected was set up with the following structure; 1) outside of class time, students watched short lecture videos and solved one or two simple problems related to the concept presented in the video. 2) During class time the simple problems were passed in and any student questions were answered. 3) A more complex problem on the same concept was distributed and the students worked in teams to solve it while the professor and TAs moved around the room, addressing their questions.

Rationale

Educational research is now providing the data that backs a belief that many professors have held based on instinct – students learn better when they are engaged in their learning. The traditional lecture class that has students sitting passively and receiving information, even if broken up with questions for students to answer about the material, is not engaging for all[1]. 'Flipped classes' which are starting to be used in engineering classes[2, 3, 4] is an attempt to address this concern. The premise for flipping is that the student come to the class meeting time with enough background information to actively engage in deeper discussions and work related to the material[5, 6]. An advantage of this format is that when the students are mentally wrestling with more complex issues, and functioning at higher levels of Bloom's Taxonomy, they have the immediate support of an expert in the field. The guidance the expert can provide in how to address the issue can reduce the frustration that students feel when trying to overcome challenges on their own. Having the guidance from an expert while addressing challenging concepts is an advantage for any course, not just Heat Transfer. The instructor chose to try this method with Heat Transfer to compare the results of student learning with prior years of teaching this course.

It is common to assign readings from the textbook to the students, with the intent that they will read it in advance of attending a lecture. However, students rarely read their reading assignments since there is no incentive associated with completing the readings. Partly this is

due to the fact that they believe it is a waste of time since the lecture will provide them the same information, and partly it is due to their inability to critically and comprehensively read technical resources. Inverted classes tend to utilize formats besides textbook readings that can be completed outside of class to assist students in gaining the related knowledge. With the easy access to computers, tablets, and smartphones, video is becoming one of the predominant choices. The video format provides multiple advantages. Videos can either be created as original screencasts, a whiteboard type presentation with voice over by the professor, or come from existing resources such as TED Talks or the Kahn Academy. Students can pause and rewind videos, stopping to think through a concept or to repeat it over again as many times as necessary. This is not an option during lecture where students may miss key points as they are trying to capture the ideas being presented[7]. One consideration with videos is that they should not just be a capture of the full, traditional lecture. It is important to cover the key aspects within a 10-15 minute long video. Preliminary studies show shorter videos are more effective[8, 9].

Resulting Course Structure

The traditional format for the heat transfer course at WPI is to meet four times a week for lectures or tests and one meeting that is an option recitation section for the students. In previous years, when Dr. Cyr taught the course, weekly sets of homework problems were assigned and a weekly quiz tested the related knowledge.

In the new inverted format, the general concept of materials leading up to a weekly quiz was still the general approach that was followed. Three major variations were made in the inverted format. The first one was that instead of covering the content by giving lectures during class meeting time, the professor created screencast videos. A screencast captures writing, similar to writing on a white board, with voice over providing the explanations. The videos were created using the Explain Everything™ app and ranged in length from 8 – 22 minutes in length. Each one captured a foundational concept, explaining the types of situations where the concept is applied, any governing relationships, and providing an example of how to solve a problem that includes the concept. These videos were made by the professor and did not require any technical assistance to create. Once the professor completes the screencast of the concept, the Explain Everything™ iPad app does all of the technical work to convert that into the desired video format. This course used the MP4 video format. The videos were made available to students on a daily basis, through the course Blackboard site. The daily information posted on the course site included a description of which sections in the textbook were related to the same foundational concept, along with the newest video. In addition, a foundational level homework problem related to the concept was also posted.

A screen shots from the Fin video is shown in Figure 1. These screencasts have the ability to include the handwritten component along with imported images from the textbook or other sources.

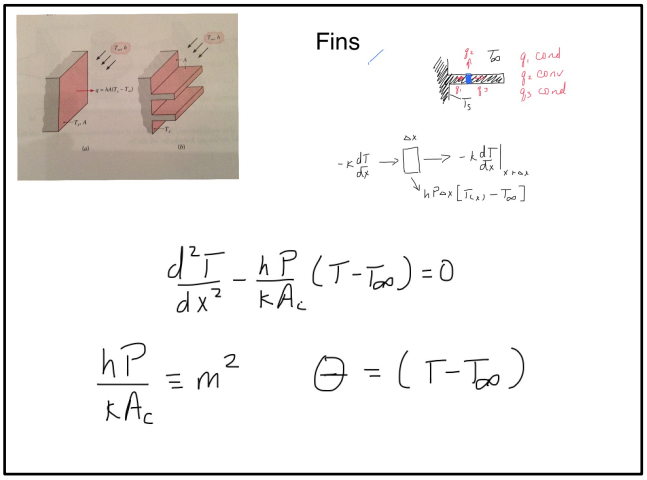

Figure 1
Screen capture from the Fin Video

The second major variation from previous years is that the foundational problem was a daily assignment and not part of a weekly problem set. Students passed in individual solutions to the daily problem as they arrived for class. After collecting the problems, the first 5 minutes of class time was spent addressing any questions that the students had about the concept. These daily problems were a way of ensuring that the students had an experience with the foundational concept prior to coming to the class. Having already tried to work through the problem, whether successful or not, provided them with a basic level of knowledge or a set of questions to ask about what they didn't understand. The remainder of the class time was spent with the students working in self-assigned teams to solve a more complex version of the problem. This is the third major variation, the structure of in-class time. As the students worked in teams, discussing the approach and solution, the professor and TAs circulated about the class, assisting the groups. Each student was responsible for turning in his or her own solution. These could be passed in as they left class that day, or turned in at the start of the next class meeting time.

Three out of the four weekly class meetings were spent in this format. The fourth meeting time was devoted to a weekly quiz that was taken individually by the students.

Challenges

There were two significant challenges associated with changing the course over to the inverted format. One was the large size of the class. 90 students were originally enrolled, forcing the classroom environment to be a static, fixed row lecture hall. This made it difficult to circulate and assist the students as they did in class problem work. On top of that, there was a large volume of assignments to grade. With the required out of class foundational problem, along with the in-class problem, 180 assignments were generated three times a week. This could have resulted in an excessive amount of grading time. The strategy employed to minimize this was to implement a 0-1-2 grading system that quickly assessed the level of work. If a problem had the correct solution and with a quick glance it appeared that the correct approach had been used, it was graded with a '2'. Problems that had an incorrect answer but the correct approach, or, a correct answer and an incorrect approach, were graded with a '1'. This was done because both a

correct approach and a correct solution are required to show mastery of a concept. Problems with neither a correct answer nor a correct approach received a '0'.

The other challenge was associated with the conversion from during class lectures to the creation of screencast videos, which were not just a transferred version of the 50-minute lecture. This required taking the time to determine what the primary foundational concept was for the day, a relevant example problem, and creating the video that presented them. The Explain Everything™ software was easy to use, and effortlessly created versions to upload to the course Blackboard site. The intent of the flipped structure has the students learning the foundational concepts outside of class time, and then building more complex concepts onto the foundational knowledge during class time. Because of this split nature in the learning process, only the basic concepts had to be included in the videos. The more complex parts of the concepts were discussed during class time as the students worked on the in class problems. The combination of the two components allows for complete coverage of all the concepts. The effort and time for this challenge was in rethinking how to present the material in order to separate the foundational concepts from the complexities that build on those concepts.

There is the potential for pitfalls in the inverted classroom if the course structure is not carefully planned. Two of the common pitfalls are that the professor still acts as 'sage on the stage' instead of the expert who guides students as they work through challenging problems, and students opting not to attend class time because the relevant resources can be found on-line. Both of these were successfully addressed for this Heat Transfer course. The professor made a conscious effort to limit the amount of time spent addressing the full class, holding it to 5 minutes at the most. Student attendance was not an issue, in part due to the daily assignments that were due at the start of each class meeting, and partly due to their opportunity to complete the in-class assignment during the class time. Sensibly thinking through the pitfall and determining an appropriate course of action in advance can manage several of the other potential pitfalls. Some of these potential pitfalls include; professors not recognizing the amount of preparation for the in-class work, assigning too much work to the students, not explaining to the students why the new course format is being used, and students not completing the work assigned for outside of the class time.

Study Results

At the end of the course, students were offered the opportunity to take an online survey and provide feedback on the course structure. The full survey is shown in Appendix A. As incentive to complete this survey they were told those who completed the survey would receive a bonus 2 points towards their final grade. This required that the survey not be anonymous, which may have skewed the data. But Dr. Cyr believes that a high level of trust had been built between herself and the students, and based on the shared comments it was clear that the students were not hesitant to share negative comments as well as the positive ones.

Ninety students were initially enrolled and participating in the course and 88 completed the full class. Of these, 64 filled out the end of course survey. The gender break down of respondents was 72% male and 28% female, which correlated almost identically to the gender break down of the course completers, which was 73% male and 27% female.

Using the videos for the inverted teaching format was new for this course, and is still relatively new at WPI, with less than six undergraduate courses following a similar approach. Because of this we were interested in gathering data about how and when the videos were utilized. Figure 2 shows when the students typically watched the videos. The predominant response, with 75% of the students selecting it, was 'immediately before working on the assigned problem.'

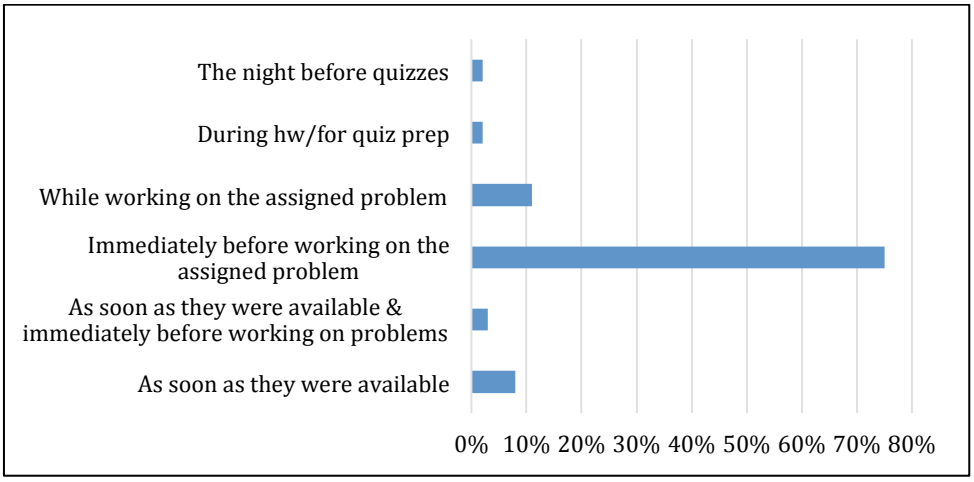

Figure 2
Most common time videos were typically viewed.

Videos have several advantages, including providing students the opportunity to watch them on demand. They can also be watched at varying speeds, paused, and rewound. Figure 3 shows the typical playback rate that students used while watching the videos, and Figure 4 shows how often the videos were typically paused or rewound.

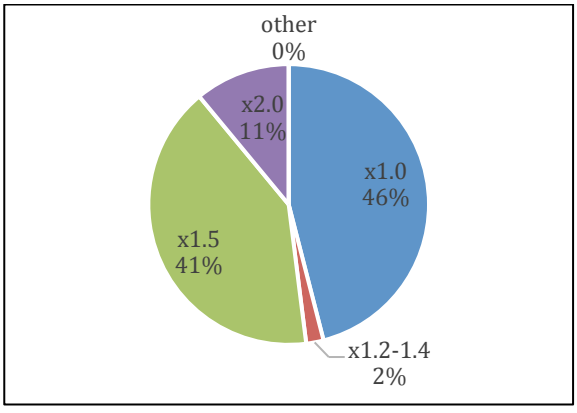

Figure 3
What speed did you typically use for playback of the videos?

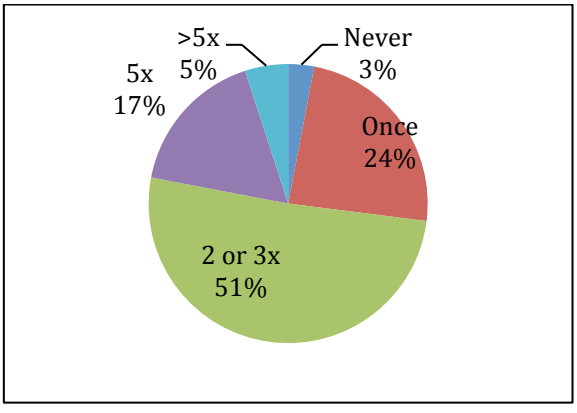

Figure 4
How often did you typically pause or rewind the videos?

When asked why they did pause or rewind the videos, the most common response was to take notes, as shown in Figure 5. However, it is interesting to note their awareness of not staying focused had a 36% response. For this question, students were not limited to one response.

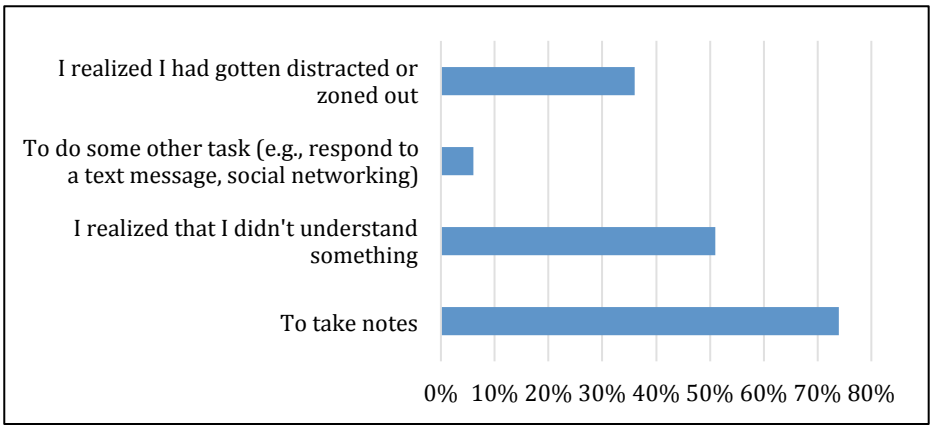

Figure 5
When you did pause or rewind, what was usually the reason?
(More than one option could be selected)

With the course intending to improve content understanding by problem solving in teams for the in-class problem work, we were curious to see what size groups they worked with outside of class time, and if they watched the videos alone or in groups. 75% of the students watched the videos alone. Figure 6 shows the group sizes, with just over a third of the students choosing to work alone outside of class time and slightly more than half of the students working in groups of 2 or 3.

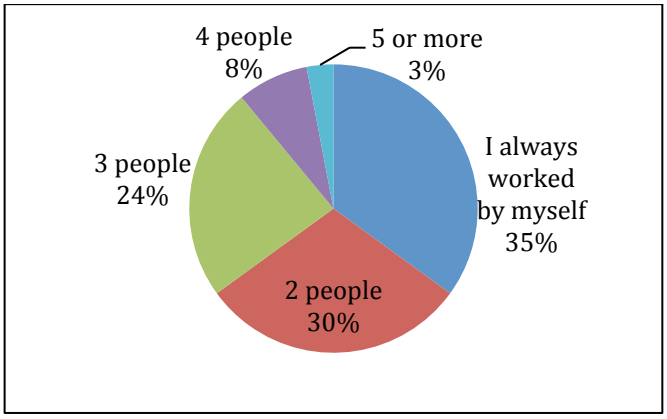

Figure 6
Size of student groups when working outside of class

Up to this point, the data has all been about facts on the students, their group work, and how they used the videos. Moving from that to the student opinions about the inverted course and use of videos provided another set of useful information. When asked "Would you prefer more classes where you had video lectures as opposed to readings?" only 13% responded no, they prefer to read the material they are learning. Figure 7 shows the full break down on this question, where a majority indicated that they preferred the use of video lectures. Figure 8 looks at their attitudes toward the video lectures.

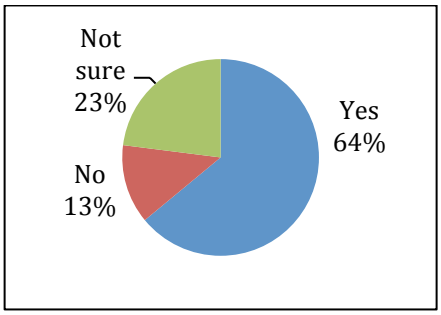

Figure 7
Would you prefer more classes where you had video lectures as opposed to readings?

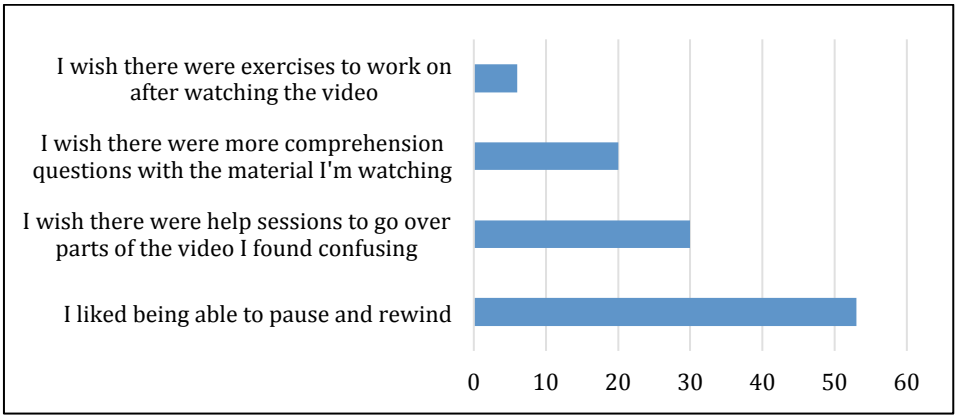

Figure 8
Which of these describes your attitude toward video lectures?
(More than one option could be selected)

The students were also asked to provide written responses that provided feedback for future modification of the course. The first of these was "*What advice would you have for how this class is run the next time it is offered? (This is the most important feedback you can provide!)*" All 64 students provided feedback to this question. The most common general response indicated a desire to have a 10-15 minute review of the video each day by the instructor that would review the concepts and set up the in class problem. Other than that, there were a good

variety of comments. Many suggested staying with the videos, but adding a time that the professor would be available for an online session to answer questions. 11% of the student responses essentially indicated that they thought the class should be run with a traditional lecture.

The second one was *"Do you have any advice for what to do during class time the next time this course is offered?"* And again, all 64 students provided feedback to this question. The most common general response was to hold a blended version of lecturing and guiding through the in class problem.

In addition to the student survey, a quick analysis was conducted on overall student grades for the most recent inverted offering of Heat Transfer and all the offerings in prior years for the same course by Dr. Cyr. Figure 9 shows that significantly more students received either an A or B in comparison to any prior year.

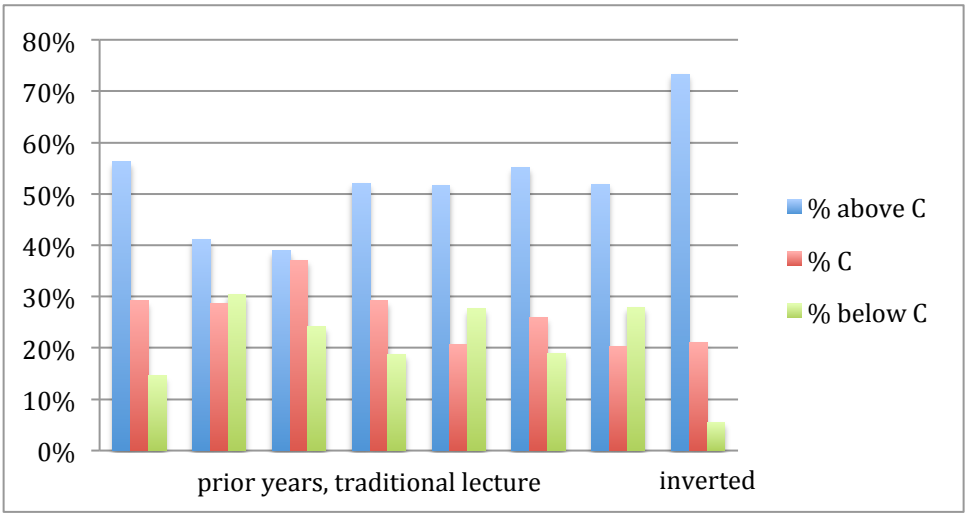

Figure 9
Student grades in Heat Transfer

Conclusion

The student survey responses show that the students respond well to this format for the course. Their responses specifically indicated that they would prefer to have more courses that provide videos instead of reading material from the textbook for learning outside of the class time. The simple grade analysis over all the offerings of Heat Transfer show overall increases in the grade based on performance of the students when the inverted format was used. A personal observation of the students during the class indicated that it took five class meetings before they became comfortable with the in-class group problem solving instead of sitting and listening passively. Once they had passed that point, the class time became lively and engaging for both the students and the professor. All of the positive outcomes from this change in format outweighed the challenges of making the inverted format work for a large undergraduate course.

Bibliography

1. Bligh, D.A., *What's the use of lectures?*. San Francisco, CA, Jossey-Bass, 2000.

2. B. Morin, K. M. Kecskemety, K. A. Harper, P. A. Clingan, "The Inverted Classroom in a First-Year Engineering Course," 120th ASEE Conference & Exposition, June 23-26, 2013, Atlanta.

3. G. S. Mason, T. R. Shuman, K. E. Cook, "Comparing the Effectiveness of an Inverted Classroom to a Traditional Classroom in an Upper-Division Engineering Course," *IEEE Transactions on Education*, Vol. 56, No. 4, November 2013.

4. Bishop, J.L. and M.A. Verleger. *The Flipped Classroom: A Survey of the Research*. in *2013 ASEE Annual Conference*. 2013. Atlanta, GA: American Society for Engineering Education.

5. Lage, M.J., G.J. Platt, and M. Treglia, *Inverting the Classroom: A Gateway to Creating an Inclusive Learning Environment.* Journal of Economic Education, 2000. **31**(1): p. 30-43.

6. Roehl, A., S.L. Reddy, and G.J. Shannon, *The Flipped Classroom: An Opportunity To Engage Millennial Students Through Active Learning.* Journal of Family and Consumer Sciences, 2013. **105**(2): p. 44-49.

7. "7 Things You Should Know About Flipped Classrooms, " *EDUCAUSE Learning Initiative*, 2012. Web. 20 May 2013. <http://net.educause.edu/ir/library/pdf/ELI7081.pdf>.

8. C. Savage, B. Ruedlinger, "Does Length Matter? It Does For Video: 2K12 Edition" Wistia.com, Retrieved January 30, 2015, http://wistia.com/blog/does-length-matter-it-does-for-video-2k12-edition

9. P. Guo, "Optimal Video Length for Student Engagement", www.edx.org, Retrieved January 30, 2015, https://www.edx.org/blog/optimal-video-length-student-engagement

Appendix A

Survey questions

Survey for ES 3003

* Required

1. **What is your name?** *

   .....

2. **What is your date of birth?** *

   .....

3. **What is your prior background in thermo-fluids?**
   Check all that apply.

   - [ ] I have previously taken at least one fluid mechanics course
   - [ ] I have previously taken at least one thermodynamics course
   - [ ] I have previously taken a heat transfer course
   - [ ] I have not take any prior courses in fluids, thermodynamics or heat transfer.

4. **What is your English language proficiency?**
   Mark only one oval.

   - ◯ Native speaker
   - ◯ Fluent
   - ◯ Good
   - ◯ Still learning

5. **Are you male or female?**
   Mark only one oval.

   - ◯ Female
   - ◯ Male

6. **When did you typically watch the videos?** *
   Mark only one oval.

   - ◯ As soon as they were available
   - ◯ Immediately before working on the assigned problem.
   - ◯ While working on the assigned problem
   - ◯ The night before quizes
   - ◯ The day of quizes
   - ◯ I did not watch the videos
   - ◯ Other: .....

7. **What speed did you typically use for playback on the videos?**
Mark only one oval.

- ◯ x2.0
- ◯ x1.5
- ◯ x1.0
- ◯ x0.5
- ◯ Other: _____

8. **How often did you typically pause or rewind the videos?**
Mark only one oval.

- ◯ Never
- ◯ Once per video
- ◯ Two or Three times per video
- ◯ About five times per video
- ◯ More often than five times per video

9. **When you did pause or rewind, what was usually the reason?**
Check all that apply.

- ☐ To do some other task (e.g., respond to a text message, social networking)
- ☐ To take notes
- ☐ I realized I had gotten distracted or zoned out
- ☐ I realized that I didn't understand something

10. **What device did you typically use to watch the videos?**
Mark only one oval.

- ◯ A PC or laptop
- ◯ A tablet
- ◯ Cell phone
- ◯ Other: _____

11. **Where did you watch the videos?**
Mark only one oval.

- ◯ Your dorm room
- ◯ Your home or apartment
- ◯ The library
- ◯ Other: _____

12. **Did you ever watch the videos in a group?**
Mark only one oval.

- ◯ Yes
- ◯ No

13. **If you worked on problems in groups, how large was your group size?**
Mark only one oval.

- ◯ 5 or more
- ◯ 4 people
- ◯ 3 people
- ◯ 2 people
- ◯ I always worked by myself.

14. **Would you prefer more classes where you had video lectures as opposed to readings?**
Mark only one oval.

- ◯ Yes. I prefer video lectures.
- ◯ Not sure
- ◯ No. I prefer reading material that I'm learning.

15. **Which of these describe your attitude towards the video lectures? (You can select more than one.)**
Check all that apply.

- ☐ I liked being able to pause and rewind
- ☐ I wish there were more comprehension questions with the material I'm watching
- ☐ I wish there were exercises to work on after watching the video
- ☐ I wish there were help sessions to go over parts of the video I found confusing
- ☐ Other: _____

16. **What advice would you have for how this class is run the next time it is offered? (This is the most important feedback you can provide!)** *

_____

_____

_____

_____

_____

17. **Do you have any advice for what to do during class time the next this course is offered?** *

_____

_____

_____

_____

_____

18. **Are there features on myWPI you wish had been used in this class? If so, what feature and why?** *

19. **Any other comments?**

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