The efficient classroom: How team-based learning and lecture video acceleration affect the learning efficiency and effectiveness of a first-year engineering course

by

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ABSTRACT

This paper researches the impact of the team-based learning (TBL) pedagogy and video lecture viewing strategies on an introductory engineering course. Teaching an introductory engineering course is a complex task because the students vary greatly in ability and experience. As the demand for engineers grows, emphases are placed on introductory engineering courses to effectively and efficiently educate the student in order to prepare them for their future engineering coursework and career. TBL, especially with the use of video lectures, has shown promise as an educational tool for a broad variety of students, but more research is needed. This paper describes three studies that provide more insight into whether the TBL pedagogy with video lectures is sufficient to provide the flexibility, performance, and preferential environment needed for introductory engineering classes.

The first study compares two semesters of the TBL pedagogy to two semesters of the traditional pedagogy in a first-year Industrial Engineering course. This comparison demonstrated that students perform slightly better in the TBL pedagogy, students have a strong preference for the TBL classroom, and TBL provides a more engaging and interactive environment. The second study surveyed both first-year engineering students and the general university student population to understand the lecture video viewing habits of students. The study showed that approximately 45% of the students sampled accelerate video lectures to 1.25X or 1.5X normal speed and another 45% of students watch them at normal speed. Less than 10% of the students accelerate videos faster than 1.5X normal speed. The third study investigated the trade-off between video acceleration and video comprehension and how practice watching accelerated videos impacts that trade-off. The results show that video acceleration up to 2X normal speed may be warranted

if full comprehension of the video is not required and time is a priority. Together, these three studies show that the TBL classroom has the ability to provide a more efficient and effective learning environment that students prefer.

CHAPTER I: INTRODUCTION

This paper contains three studies that are focused on finding best practices to educate and retain undergraduate engineering students. It strives to determine if the team-based learning (TBL) pedagogy with the use of video lectures is more efficient and effective[1] than a traditional lecture for introductory engineering courses. The education and retention of undergraduate engineering students has been a focus of the National Science Board, National Science Foundation, and President's Council because there is currently a global shortage of engineers. (Holdren & Lander, 2012; Marra, Rodgers, Shen, & Bogue, 2012).

Focus Area

The focus is on a first-year introductory engineering course because the attrition rate for first-year engineering students is about 25%; half of the overall engineering attrition rate (Besterfield-Sacre, Atman, & Shuman, 1997; Holdren & Lander, 2012). The introductory engineering course may be the first and only major impression of the engineering discipline that the student has in the first year. Most of the curriculum during the first-year of engineering is on general classes, such as Calculus, Physics, and Chemistry, that don't expose the student to their specific engineering discipline. Thus, the introductory engineering course has the burden (or opportunity) to provide an environment that the student prefers in order to engage and retain the student in engineering.

Currently, engagement is very low in traditional lecture courses; 59% of university students find at least half of their classes boring, which causes 75% of the students to daydream

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[1] Effectiveness and efficiency are terms that will be used throughout this paper and are further defined here: effectiveness is measured by the student's ability to comprehend and retain the subject content and efficiency is how quickly the student can learn the required information.

to cope with the boredom (Mann & Robinson, 2009). In fact, a student typically loses focus for a period of time 10 to 18 minutes into a lecture (Middendorf & Kalish, 1996). Boredom can cause a loss of learning and “is one of the most frequently identified causes for students leaving school temporarily or permanently” (Mann & Robinson, 2009). Thus, an engaging and preferred classroom environment is very important to curb boredom and potentially increase retention.

The challenge is that besides being engaging, introductory engineering courses must also prepare the student for the rigors of the remainder of their engineering curriculum. However, it is now more difficult to adequately prepare every student. With the increased focus on recruitment in the STEM fields and increased global mobility in general, the number of engineering students has grown. This has led to greater variability in student ability (Smaill, Rowe, Godfrey, & Paton, 2012). This ability gap is the most prevalent in first-year students because they have yet to take any engineering classes together that would standardize their knowledge. Thus, the introductory course must effectively *prepare* the student for future coursework, provide a *preferential* environment that engages and retains them, and offer *flexible* resources that can efficiently teach the large variety of students.

TBL was chosen as the pedagogy because it has been shown to provide an interactive classroom environment that uses peer collaboration and instructor resources for feedback and support. This helps students learn more effectively and efficiently than they would on their own (Michaelsen, Knight, & Fink, 2002). Video lectures were chosen as the main learning resource because its flexibility provides multiple advantages over a typical lecture hall, including the ability to change the pace of the video as well as the ability to pause or watch the videos at any time. The main question of this paper is: are these features enough? Does the TBL pedagogy that employs video lectures achieve the three criteria of performance, preference, and flexibility? All three studies in this paper will work to answer this question.

Thesis Overview

Study 1: *Transformation to TBL* focuses on the transformation of an introductory Industrial Engineering course from a traditional lecture-based pedagogy to a team-based learning (TBL) pedagogy. TBL is an active learning approach that uses class time for groups of students to work on problems with the instructor acting as an aid (Michaelsen et al., 2002). In this study, video lectures and a textbook were the main resources for out-of-class learning. The question that Study 1 will answer is: Did the transformation from a traditional lecture-based model to a TBL model increase student performance or preference for the course?

Study 2: *Video-Speed Preference* analyzes student accountability for learning outside of class. One of the big changes for students in TBL is the out-of-class learning experience. The vast majority of first-year undergraduate students have not been exposed to TBL because it is mainly established in undergraduate and graduate coursework, not in primary or secondary education (Michaelsen, et al., 2002). In the traditional model, which is predominantly used in secondary education, the accountability was on the student to show up to class and learn passively; the instructor had to teach the material and supervise the students' attention (Freeman Herreid & Schiller, 2012). Now, the accountability is on the student to actively use the video, textbook, or other outside resources to learn the material without supervision. Study 2 surveyed the students to understand what learning resources they were using and how frequently they were using them; in other words, how accountable were they and to which resource? A focus was placed on the video resources because they were a new resource to students who were accustomed to textbooks in the traditional model. This focus included studying how much students accelerate the video lectures because that feature is not present in traditional lectures. Thus, the other questions that Study 2 answers are: Are students accountable, are they using the lecture videos, and if so, how are they using them?

Study 3: *Video-Speed Experiment* arrives back at the original focus of performance and preference, but instead of analyzing the pedagogy, the analysis will be done on the video lectures. There is evidence that students accelerate video lectures and video software already includes video acceleration as a feature of their product. For example, YouTube videos can be accelerated to two times (2X) their normal speed, so the videos can be watched in half the time. Another term for video acceleration is video compression (Galbraith, Liu, Ausman, & Kirby, 2003); both terms will be used interchangeably throughout this paper. While accelerating videos is very efficient, analysis is needed on how video acceleration affects student performance, especially when watching lecture videos for long periods of time. The questions Study 3 will analyze are: what is the trade-off between video acceleration and video comprehension and how does practice watching accelerated videos affect this trade-off? Study 3 will also analyze the question: when should video acceleration be encouraged and when should it be discouraged?

A summary of the three studies and their research focus is below in Table 1.

Table 1. Summary of Three Research Studies

Study	Title	Description
1	Transformation to TBL	Transformation of a lecture-based introductory engineering course to team-based learning pedagogy
2	Video-Speed Preference	Surveys covering the benefit of video lectures and how students used them
3	Video-Speed Experiment	Analysis of how practice impacts students’ comprehension and engagement of accelerated videos

Benefit

This paper will analyze multiple aspects of a freshman engineering course for efficiency and effectiveness. The TBL pedagogy will be compared against a traditional pedagogy to provide a recommendation and explanation for which pedagogy should be used. The utility of lecture videos will also be determined to inform educators who are considering using lecture videos. Finally, the rate at which students watch lecture videos will be analyzed for its impact on students' comprehension of and preference for lecture videos. In summary, this paper will provide insight into whether these alternatives to the traditional lecture-style model are beneficial to the student.

Thesis Structure

This paper encompasses three studies, so the structure of the paper is not standard. An overview of the structure is provided here to guide the reader. The next chapter will cover the literature review, which provides a background for the research in all three studies. Then, Chapter III will cover the methods, results, and discussion for Study 1. Chapter IV will cover the methods, results, and discussion for Study 2 and Chapter V will do the same for Study 3. Chapter VI is the conclusion, which will provide a summary of all three studies' findings, along with their implications and future work.

CHAPTER II: LITERATURE REVIEW

Backgrounds in many areas of study are necessary to understand the questions posed in the introduction, which were:

1. Did the transformation from a lecture-based model to TBL increase student performance or preference for the course?
2. Are students accountable in the TBL pedagogy, are they using the lecture videos, and if so, how are they using them?
3. What is the trade-off between video acceleration and video comprehension and how does practice watching accelerated videos affect this trade-off? Also, when should video acceleration be encouraged or discouraged?

The first section of this chapter will focus on the first-year engineering student, which relates to all three studies. Then, TBL and a similar concept, the flipped classroom, will be reviewed to understand what disciplines have successfully implemented this pedagogy and how the implementation of TBL has impacted student engagement, performance, and retention, among other metrics. Next, audio-speed will be explored to determine how the rate of information affects student comprehension and perception. Finally, research on video-speed will show how information dissemination is affected by increasing the rate of speed of both the audio and visual channels.

Variability and Retention of the First-Year Engineering Student

The attrition rate for engineers has hovered around 50% for the last 60 years with about half the attrition occurring during the freshman year (Besterfield-Sacre et al., 1997; Geisinger & Raman, 2013), although recent years have shown that attrition rates may be dropping to draw closer to other disciplines (Marra et al., 2012). The engineering attrition rate at Iowa State

University (ISU), where the three studies occurred, is similar to these national levels. After the first year of engineering study, 23.2% of students leave the ISU College of Engineering and 45.8% of the students that start in the ISU College of Engineering do not graduate as engineers (*Key Performance Indicators (KPIs)*, 2015). Lowering the engineering attrition rate is important because in the U.S. there will be a shortage of one million college graduates in the Science, Technology, Engineering, and Mathematics (STEM) fields in the next decade (Holdren & Lander, 2012). Engineering shortages are also a global problem. There is a shortage of 2.5 million engineers in Africa in order to ensure that basic needs are met, and other developing countries have similar engineering needs (Geisinger & Raman, 2013).

There are six main variables that have a strong impact on engineering students leaving their discipline: "classroom and academic climate, [low course] grades and conceptual understanding, self-efficacy and self-confidence, high school preparation, interest and career goals, and race and gender" (Geisinger & Raman, 2013, p. 922). Since low performance causes high attrition rates due to low grades, self-efficacy, and self-confidence, it is important to create introductory courses where students can perform well despite their variable high school preparation (Smaill et al., 2012). A sense of belonging is also very important to retention and a positive academic climate. A Harvard study has shown that interactive classrooms have increased the feeling of openness in the classroom and have led to lower attrition rates (Marra et al., 2012; Watkins & Mazur, 2013). TBL provides an interactive classroom that could help mitigate this problem, if students can perform well with TBL.

Team-Based Learning & Flipped Classrooms

The team-based learning (TBL) pedagogy began with the doctoral dissertation of Wayne Wilson (1982) and was popularized by Larry Michaelsen (2002). A pedagogy on its own, TBL can also incorporate the flipped classroom pedagogy. The following research review will focus on the structure of these pedagogies and how these instructional methods have impacted student performance and engagement.

One of the main goals of TBL is to employ a team of students to be able to solve complex problems more effectively and thus, enables students to learn and do more than if they were working individually. In order to incorporate the TBL pedagogy, a course must be able to meet "two conditions:

1. The course contains a significant body of information and ideas (i.e., the content that students need to understand), and
2. One of the primary goals for the course is for students to learn how to apply or use this content by solving problems, answering questions, resolving issues, etc." (Michaelsen et al., 2002, p. 7)

The majority of introductory engineering courses satisfy these two conditions, including the course that will be discussed in this paper.

The format of the TBL classroom follows the structure of Table 2 below.

Table 2. Sequence of TBL.

	Preparation		**Practice and Application of Concepts**					**Assessment**	
In-Class:		Readiness Assurance Process	Lab - Simple Concepts		Homework -Complex application		Repeat previous steps as necessary	Review	Exam
Out-of-Class:	Lecture Videos and/or Readings			Lab (if not completed in-class)		Homework (if not completed in-class)		Review	
Approximate Level of Concept Understanding:	40%	50%	60%		80%			90-100%	

Note. **Adapted from Beyond small groups: Harnessing the extraordinary power of learning teams. In *Team-Based Learning: A Transformative Use of Small Groups in College Teaching*, p. 13, by L. D. Fink, 2004, Virgina: Stylus Publishing.**

The first activity in Table 2 is ‘Lecture Videos and/or Readings’. This is where the initial learning of the subject occurs, which is done out-of-class. Approximately 40% of the subject’s content should be understood after this outside learning activity. Learning the subject outside of class is also known as a flipped or inverted classroom pedagogy (Bergmann & Sams, 2012).

The Readiness Assurance Process (RAP) begins after the student has done their initial out-of-class study of the material. The RAP starts with an individual multiple-choice test, known as a Readiness Assurance Test (RAT). Once completed, the same RAT is done as a team. Teams are created by the teacher, so that the member resources are distributed evenly and there are 5-7 students per team (Michaelsen et al., 2002). As the teams select answers on the RAT, they are given immediate feedback as to whether or not they have answered the question correctly by using Epstein Educational Enterprise’s Immediate Feedback Assessment Technique (IF-AT®) answer forms. The team will continue to answer each question on the RAT until they answer each question correctly. Following the RATs, the instructor gives a mini-lecture, which explains the correct answers to the questions that the teams missed. Since the teams know all the correct answers by the end of the team RAT, they are able to appeal the correct answer through a written appeal process. The written appeal provides reasoning for which alternative answer the team believes should be accepted. The instructor then reviews the appeal and determines if the team will be given full points for the alternative answer.

After the RAP, the teams work on basic and then challenging applications of the content in their teams. As the teams work on these applications, the instructor answers questions so that students get frequent feedback. The out-of-class learning, RAP, and application activities can be repeated as many times as needed until the students are ready for the section’s cumulative project or exam. At this point, a review of the content is done and the students are assessed through a project or exam that can be done as an individual or as a team depending on the instructor's wishes. The students are held accountable to their teams through peer evaluations which are given periodically throughout the course, typically after the exam or project (Michaelsen et al., 2002).

TBL helps at-risk students continue and complete their course work, partially because of its ability to allow the instructor to develop much stronger relationships with his/her students (Michaelsen & Sweet, 2008). It has been used effectively in a variety of disciplines including introductory and regular STEM classes (Dinan, 2002; Garrett, 2008; Herreid, 2002; McInerney & Fink, 2003), first-year veterinary courses (Hazel, Heberle, McEwen, & Adams, 2013), medical school (Koles, Stolfi, Borges, Nelson, & Parmelee, 2010; Shankar & Roopa, 2009), accounting (W. R. Wilson, 1982), and pharmacy (Beatty, Kelley, Metzger, Bellebaum, & McAuley, 2009).

TBL has also been shown to: be preferred over traditional classrooms (Dinan, 2002; Hazel et al., 2013; Herreid, 2002; McInerney & Fink, 2003), enhance learning (Beatty et al., 2009; Dinan, 2002; Garrett, 2008; Koles et al., 2010), increase teamwork and accountability to peers (Beatty et al., 2009; Bray & Levine, 2008; Dinan, 2002; Hazel et al., 2013; Shankar & Roopa, 2009), and increase student retention in the course (Freeman Herreid & Schiller, 2012; Hazel et al., 2013).

Similarly, the flipped classroom has been effective in many areas including introductory courses in Statistics, Computer Science, and Microsoft Excel, and upper-level Engineering courses (Amresh, Carberry, & Femiani, 2013; Davies, Dean, & Ball, 2013; Mason, Shuman, & Cook, 2013; S. G. Wilson, 2013). Flipped classrooms have led to higher performance and enhanced learning (Amresh et al., 2013; Mason et al., 2013; Talley & Scherer, 2013; S. G.

Wilson, 2013) and are more scalable than traditional classrooms (Bergmann & Sams, 2012; Davies et al., 2013).

Finally, there have been a few instances where both pedagogies have been combined effectively for engineering courses (Demetry, 2010; Ghadiri, Qayoumi, Junn, Hsu, & Sujitparapitaya, 2013). One study showed that combining these two pedagogies increased the passage rate from 59% to 91% compared to the traditional pedagogy.

With these summarized results, the TBL and flipped classroom pedagogies have been shown to be promising methods to increase student performance and preference for the course. However, the use of one important aspect of these pedagogies still needs to be investigated; the resource that is used for out-of-class learning: videos.

Video-Speed Experiment

This section of the literature review is focused on lecture videos and how well students can comprehend them. There are many types of lecture videos: moving images (Harrigan, 2000), still images (Pastore, 2012), writing on a black background (Khan, 2012), and multiple screens of still and moving images (Potter & Jacobson, 2015), among many others. Lecture videos may differ in type, but they are all comprised of both visual and audible sources of information. Thus, the next section investigates how audio-speed and speed-reading (visual-speed) affect a person's ability to acquire knowledge. Later, video-speed will be introduced for a few of the lecture video types mentioned.

Audio-Speed & Speed-Reading Capability

The speed of audio can be increased via multiple methods; for example, removing audio at a rate of "10 times per second or more" (Foulke & Sticht, 1969, p. 51). This is known as audio acceleration, audio compression, or compressed speech (Foulke & Sticht, 1969). Similarly, words can be shown on a screen at an accelerated pace to speed up a reader (Benedetto et al., 2015). Information dissemination from both of these accelerated sources (audio or visual) will be explored. Topics include the cognitive speed model, the comprehension metric, training effects, retention, and speed-reading. Finally, simultaneous processing of information through both audio and visual channels will be explored.

Cognitive Speed Model

In a 2001 paper by Fulford, the model of cognitive speed was introduced. The model discussed how quickly people under the age of 60 can process information. The model was introduced because it was discovered that the maximum speed at which an untrained person can process information is the same for both audio and visual channels (Foulke & Sticht, 1969; Fulford, 2001; Hausfeld, 1981; Janet & Louis, 1982; Thompson, 1985). Research studies on listening to compressed speech and speed-reading, "have shown 250-300 words per minute (wpm) to be the average rate for comprehending traditional learning materials and classroom lectures" (Foulke & Sticht, 1969; Fulford, 2001, p. 33; Hausfeld, 1981; Janet & Louis, 1982; Thompson, 1985) This comprehension rate, or cognitive capacity, of 250-300 wpm is twice the speed of the average person's speaking rate (Fulford, 1992). During conversations 125-150 wpm is an ideal rate of speech because the person listening needs to utilize half of their cognitive capacity to listen to the external conversation and the other half to prepare a response. However, in traditional lectures, the response is not necessary so half of the student's cognitive capacity is available. Some students use their available cognitive capacity to actively question and comprehend the lecture with their internal dialogue, but the extra capacity can also be used to daydream or switch off to another subject. Daydreaming or switching off can then fully distract the student, which causes 100% of the lecture material presented to eventually be ignored (Mann & Robinson, 2009).

This cognitive speed model demonstrates a gap in learning efficiency that occurs in the traditional classroom. The information spoken from the lecturer occupies about 50% of the student's cognitive capacity while the other 50% may be used for purposes that ultimately distract the learner (Fulford, 2001).

Comprehension & Intelligibility

To measure the capability of students to learn from audio, text, and ultimately video, a distinguishing metric must be used. Traditionally that has been done via two metrics: intelligibility and comprehension (Foulke & Sticht, 1969).

Intelligibility is "the ability to repeat a word, phrase, or short sentence accurately" after hearing or reading it (Foulke & Sticht, 1969, p. 52). However, this metric has been highly variable as seen by the following studies. One study found that when words were compressed by 1.5 times (1.5X), only 60% of the words were intelligible (Klump & Webster, 1961). However, another found that compression by 2.5X resulted in 90% of the words being intelligible (Garvey, 1953). Yet another study found that compression by 7.5X resulted in 57% of the words being intelligible (Fairbanks & Kodman, 1957). Due to the fine level of detail required to understand a single word, the results depend on the words being tested and the method of compression (Janet & Louis, 1982). Since intelligibility is a highly variable metric and the intelligibility of unique words is not a practical measure of how well a lecture of thousands or hundreds of thousands of words are understood, the study of comprehension became the standard metric.

Comprehension is the ability to recall facts or instructions from the audio, video, or text selection and is measured by a comprehension test (Foulke & Sticht, 1969). This definition should not get confused with “Comprehension” in Bloom’s Taxonomy. Comprehension as used in the field of cognitive speed is very similar to the “Knowledge” level in Bloom’s Taxonomy because it requires the recall of previously learned information (Anderson & Sosniak, 1994).

Comprehension has been much less variable as a metric compared to intelligibility. Many studies have shown that acceleration of audio up to two times the normal rate of speech (250-300 wpm) does not significantly impact the comprehension of the material. In terms of words per minutes (wpm), the results of various studies can be seen in Table 3.

Table 3. Comprehension of Various Audio-Speeds.

Audio-speed (artificially accelerated)	Comprehension (compared to normal speed)	Source
325 wpm	80%	Orr, Friedman, & Williams, 1965
290 wpm	100%	Hausfeld, 1981
282 wpm	90%	Fairbanks & Kodman, 1957
275 wpm	100%	Foulke & Sticht, 1969
250 wpm	100%	Janet & Louis, 1982

Another study by Heiman, Leo, Leighbody, & Bowler (1986) found that comprehension slowly deteriorates from 1X to 2X normal speed acceleration (175 wpm to 350 wpm), and then comprehension quickly declines above 2X normal speed (350 wpm). Due to the low variability in the comprehension metric and its practical nature in education, comprehension is frequently used as the metric for information dissemination from an audio or visual sources.

Speed-Reading

While some speed-readers claim to be able to read upwards of 1,000 words per minute, studies have shown that these readers actually read 250-300 words per minute. They are simply skimming the content and extrapolating from the words they pick out from the various sections

(Thompson, 1985). Another study (Carver, 1982) specifically showed that reading beyond 300 wpm resulted in reduced comprehension.

Retention

While retention of learned information will not be tested in this study, it is important to know that the retention of information is equal for both high and normal audio-speeds (Foulke & Sticht, 1969; Orr et al., 1965). In these studies, retention was tested at various speeds between 225 and 280 wpm. If students were able to comprehend the information initially, the increased speed did not affect their ability to retain the information.

Trainability of Comprehending Accelerated Audio

Multiple studies have shown that training increases the ability to comprehend accelerated audio past the 300 wpm level[2]. One study showed that after 8-10 hours of listening to accelerated audio varying between 325 and 475 wpm comprehension over a four-week period, participants' comprehension significantly increased (Orr, Friedman, & Williams, 1965). The participants comprehended audio better at 325 wpm post-training than at 175 wpm pre-training and were able to comprehend audio at 475 wpm twice as well post-training as pre-training (Orr, Friedman, & Williams, 1965). However, hours of listening to accelerated audio may not be necessary for an improvement in comprehension to occur. Voor and Miller (1965) found that there was a significant improvement in audio comprehension at 380 wpm after seven minutes (or ~2,700 words) of practice listening at 380 wpm. This improvement resulted in no significant loss of comprehension compared to the normal speed (190 wpm).

Besides comprehension, three studies found that preference also shifted after training. Lass, Foulke, Nester, & Comerci (1974) found that preferences shifted towards faster audio-

[2] The maximum level of comprehension according to the Cognitive Speed model (Fulford, 2001)

speed over a six-week study where participants were exposed to audio starting at 225 wpm and increasing towards 350 wpm. Beasley and Maki (1976) also found that after 30 minutes of exposure to time-compressed speech, participants' preference again shifted towards the faster speed. Blind adults who make up for their visual handicap through accelerated speech also have a preference for faster rates. Arons (1992) show that blind subjects have a preference for speech in the range of 236-275 wpm while sighted subjects prefer speech at 175 wpm.

Studies with blind users have also shown that audio can be comprehended far faster than normal. A study by Gordon-Salant & Friedman (2011) showed that older blind adults could comprehend audio at 512 wpm better than older sighted adults, regardless of whether the blind adult was born blind or developed blindness. Another study by Moos & Trouvain (2007) demonstrated that blind participants were able to understand speech at 792 wpm much better than sighted adults. The blind users in this study had at least two years of daily practice with an audio synthesizer, which read text at an accelerated pace. Thus, years of practice might have tremendous impact on the comprehension of accelerated audio.

However, daily practice may not be the only reason that blind adults can listen faster than sighted adults. For example, congenitally blind adults are not able to listen as fast as those who lose their blindness after the age of two even though they have daily practice (Moos & Trouvain, 2007; Hertrich, Dietrich, & Ackermann, 2013). In studies, fMRI scans have shown that blind adults that had vision for a period of time can re-wire the visual part of their brain to understand ultra-fast audio. Congenitally blind adults, on the other hand, never developed the visual part of the brain, so they cannot re-wire it to comprehend ultra-fast audio (Hertrich et al., 2013, Moos et al, 2008). This demonstrates that using the audio plus visual parts of the brain may allow sighted adults to also understand faster audio since a larger portion of the brain would be used.

Dual Channel Learning

Incorporating dual channel learning by reading and listening at the same time has shown to increase the rate at which we can comprehend information. A study done by Vemuri, DeCamp, Bender, & Schmandt (2004) had participants listen to audio while reading from different types of transcription. A test done with a “perfect” human constructed transcript resulted in an 80% comprehension score at 350 wpm. The highest comprehension score was 95% at 300 wpm and tests were done all the way from 200 to 700 wpm. Another study (Thames & Rossiter, 1972) showed that listening and reading at 304 wpm actually increased comprehension after training compared to just reading or listening at a normal speed (125-175 wpm).

Video-Speed

Comprehension

There have been a limited number of studies done on comprehension with video compression, but they have similar results. A study by Harrigan (2000) showed that comprehension declined significantly in the 225-300 wpm range and participants rarely accelerated past the 250 wpm range. This is much lower than the maximum comprehension rates that occurred through audio compression. Harrigan’s (2000) theory is that channel switching occurs when audio and moving images are combined. Thus, the participants could not switch channels fast enough for effective comprehension to occur if the video had been significantly accelerated.

Instead of moving images, a study by Pastore (2012) used audio and still images with very little text to test how multi-media principles affected comprehension of accelerated videos. Pastore (2012) similarly demonstrated that “50% [video] compression (2X; 328 wpm) is too fast for learning to take place” because cognitive load increased and post-test comprehension scores decreased substantially (p. 502). However, these impacts were not seen at 25% compression (219 wpm) (Pastore, 2012). Therefore, 25% compression (1.5X; <225 wpm) does not appear to have any negative effect on the comprehension of videos.

Preference for Accelerated Videos

Media, especially commercials, have used accelerated video for years due to its ability to save time and media storage as well as its favorable effect on viewers' preferences (Gutenko, 1995). Viewers perceive people in accelerated media as having higher confidence and credibility compared to those in normal media (Gutenko, 1995). Thus, acceleration elicits favorable effects for persuasion. Media typically compresses videos 5-10%, but sometimes goes as high as 20% because video compression up to 20% can go unnoticed by viewers (Gutenko, 1995). Research also shows that faster speaking rates can be up to two times as engaging as normal speaking rates (Guo, Kim, & Rubin, 2014). A study by Simonds, et al. (2006) demonstrated that students had higher affective learning when listening to speech at 213 wpm compared to 116 wpm. Higher levels of affect lead to higher engagement (Titsworth, 2001). Other studies have shown quantitatively (Gutenko, 1995) or qualitatively (Galbraith, 2004) that students' attention and engagement improve with accelerated video because the increased speed forces them to focus. Also, shorter videos, especially those under six minutes, are more engaging than longer videos (Guo et al., 2014). Thus, accelerated videos may have the ability to raise student engagement and preference.

CHAPTER III: TRANSFORMATION TO TBL

This chapter is comprised of the methods, results and discussion sections for Study 1: *Transformation to TBL*. Study 1 analyzed the implementation of the team-based learning pedagogy in an introductory engineering course that was comprised of mostly first-year students. The study tested whether students could perform as well or better than with the traditional lecture-based model. It also tested whether the students preferred the TBL pedagogy to the traditional pedagogy. Study 2 and 3, which focus on student accountability and the video resource, will follow in the consecutive chapters.

Methods

Research Objective

The purpose of Study 1 is to understand how the change in pedagogy from a traditional lecture-style course to a TBL course impacted the students' performance and preference for a first-year Industrial Engineering course.

Course Overview[3]

The first-year engineering course in the Industrial and Manufacturing Systems Engineering (IMSE) Department at Iowa State University (ISU) includes engineering fundamentals, problem solving, and communication; flowcharting and algorithms; fundamentals of programming; Excel; Access; Visual Basic for Applications (VBA); decision support systems; HTML; and website development. Student mastery is evaluated through homework, labs, quizzes, projects, and exams. There is a required textbook that students use as a resource to supplement class instruction or the video lectures (Eksioglu, Seref, Ahuja, & Winston, 2011).

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[3] Many subsections of Study 1's methods section, including the Course Overview, are adapted from: Potter, L., & Jacobson, B. (2015). Lessons Learned from Flipping a First-Year Industrial Engineering Course. In *ISERC*.

The instructor and the teaching assistant co-teach the course; both are in the classroom with each section. The class meets for two hours twice per week.

Hypotheses

Study 1 has two main hypotheses:

- H_1: TBL will result in higher performance compared to the traditional lecture-based model.
- H_2: TBL will result in higher student preference for the pedagogy compared to the traditional lecture-based model.

Independent Variables

There is one independent variable in this study: *Pedagogy* (TBL vs. traditional lecture-based).

Pedagogy. The traditional lecture-based pedagogy was taught in Fall 2013-Spring 2014. The TBL pedagogy was taught in Fall 2014-Spring 2015. The differences in course structure between the two pedagogies can be seen in Table 4.

Table 4. Transformation in Course Structure from Traditional (Fall 2013–Spring 2014) to Team-Based Learning (Fall 2014–Spring 2015)

Traditional Lecture-Based	Team-Based Learning
Lecture in Class	Technical Lecture Videos out of class
	Professionalism Lectures in class
Quizzes in class (individual)	RATs in class (individual and team^)
Q&A in class (if time)	Q&A in class
Lab in/out of class	Lab[x] in class
Homework out of class	Homework[x] in/out of class
^Teams assigned at beginning of semester	
[x]Lab/Homework done individually or in teams	

Dependent Variables

There were two dependent variables in Study 1: *performance* and *preference* for the course. They were measured with the following metrics as shown in Table 5.

Table 5. The metrics for the dependent variables - Study 1

Variables	Metric	Measurement (Unit)	Frequency	Data Type	
Performance	Exam Grades	Percentage	Twice each semester	Objective	Continuous
	Lab Grades	Percentage	10 times each semester	Objective	Continuous
	ABET Results	Points	Once each semester	Objective	Ordinal
Preference	Preference	Likert Scale 1-5	Once for last two semesters	Subjective	Ordinal
	Qualitative Response	Clustered Themes	Once for last two semesters	Subjective	Ordinal

Performance. The metrics for performance focus largely around grades. The first two exams will be analyzed, which covered the first two-thirds of the course and were graded by the same individuals across the four semesters. The first two-thirds of the course did not change in terms of content for the four semesters in this study. Thus, these two exams provide a consistent comparison between pedagogies. All of the exams were curved as part of the class, but the curves were taken out for the analysis in order to compare the effect of the two pedagogies.

There were 10 labs that also covered the first two-thirds of the course and had the same grader through all four semesters. Lab #5 was the only lab that changed considerably between pedagogies, so it will be excluded from the analysis.

ABET assessments also demonstrate student performance. As part of ABET accreditation, the process for which has been in place in the IMSE Department at ISU since 2003, outcome items are assigned to courses for assessment each semester. Outcome item (k) [An ability to use the techniques, skills and modern engineering tools necessary for engineering practice] was assigned to this course from Fall 2013 through Spring 2015. The rubric used to make end-of-semester assessments for 20 randomly chosen students each semester is shown in Table 6. Outcome item (k) has been split into three parts for assessment, including an ability to use the following: (k1) information technology, (k2) engineering equipment, and (k3) engineering methods.

Table 6. ABET assessment rubric for outcome item (k): an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

Item	Exemplary 5-6	Acceptable 3-4	Poor 1-2	Score
Ability to use information technology	Integrates sets of hardware and software as needed for problem formulation and solution	Understands computer hardware and software. Applies them correctly for subtasks in problem formulation and solution	Does not understand computer hardware and software. Application is incorrect	
Ability to use engineering equipment	Equipment is utilized for problem solving in an efficient, effective, and safe manner	Understands how equipment works and uses it correctly	Does not understand how the equipment works. Use is incorrect	
Ability to use engineering methods	Methods are selected and utilized effectively and efficiently	Understands the methods. Methods are applied correctly.	Does not understand methods. Incorrect application	
Total				

Preference. The Preference metric was measured through three questions on a post-semester survey, which can be seen in Appendix A. This survey was given to the students in the last two semesters of the study, i.e. the students that took the IE 148 course when it was taught with the TBL pedagogy. The first question is: *How does the IE 148 TBL framework and video lectures compare to the other classes that you are taking that are more traditional lecture-style* *classes?* The students could answer on a five-point scale, with one being “much worse” and five being “much better”. The second question is: *Why did you answer the way you did?* The third question is: *What comments do you have about the videos or their speed?*

Participants

The number of students per semester can be seen in Table 7. A total number of 106 students took this course with the traditional format and 110 students took this course with the TBL format. While there are 216 students in this study, only 80 students are participants in the ABET assessments because 20 students are randomly selected to be assessed each semester.

Table 7. The number of students and sections per semester and pedagogy.

Pedagogy	Semester	Number of Students	Number of Sections
Traditional	Fall 2013	71	2
Traditional	Spring 2014	35	1
TBL	Fall 2014	63	2
TBL	Spring 2015	47	2

The course is almost entirely comprised of first-year students (freshman or transfer) because it is the only course in the Industrial Engineering Department that does not have a prerequisite and the department’s academic advising team heavily encourages students to take it their first year. The only exception is students who re-take the course their second year, which occurs to less than 5% of the students. Thus, the participants in this study represent first-year engineering students.

Procedure

<u>Traditional Pedagogy</u>

Using a traditional classroom format in the Fall 2013 and Spring 2014 semesters, students were informed prior to class of the chapters/topics that would be covered, and were encouraged to read the book ahead of time. Classroom material was delivered via PowerPoint and

Excel/VBA/Access examples, which were projected in the front of the classroom using a dual monitor computer with dual projection and sound, along with a document projector. Summative quizzes were given each non-exam Thursday for the previous two days' material, covering technical and professionalism material. Weekly homework and lab assignments were given, and students had time to work on these during class, but often had less than twenty minutes of work time per class. Three exams were given based mainly on the material covered during the four weeks prior to each exam.

TBL Pedagogy

Using a TBL format in the Fall 2014 and Spring 2015 semesters, students were expected to watch lecture videos that contained the technical content (engineering basics, Excel, Visual Basic for Applications programming) of the course, which was approximately 75% of the information covered. A flipped format was used the first 10 of the 15 weeks that the class met. The students could also learn the technical course content from the textbook, but watching the lecture videos was highly recommended. The balance of the content covered was about professionalism and communication. This was covered in-class through lecture and activities.

To facilitate student preparation, students were placed on RAT teams the first day of class. Teams were determined by students' prior Excel and programming knowledge; experience was equally distributed among teams. Each non-exam week, formative multiple-choice RATs were given: ten questions with five choices per question. These RATs were taken individually first by circling the correct answer on a sheet of paper. Afterwards, students would take the RAT with their team using the Epstein Educational Enterprise Immediate Feedback Assessment Technique (IF-AT) answer forms.

Once all teams submitted their answer forms, the instructors reviewed with the class all the questions that were missed on the team RAT. All students had the opportunity for a second round of questions and answers (Q&A). If there was professionalism material to cover, it was then taught in a traditional setting with instructors and students face-to-face. When this was complete, students worked on their labs, homework, and project assignments.

The progression of student responsibilities each week starts with preparation outside the class, individual and then team formative RATs, laboratory exercises introducing basic concepts, and then homework with complex problems. Each of the three exams is preceded by four weeks of this process, with the fifth week including review and then the exam.

The last five weeks focused on two projects, some of which reviewed the technical information that occurred in the first 10 weeks of class. Thus, little new technical content was covered in the last five weeks. This is different from the traditional model where new topics (Access, SQL, and HTML) were taught. Besides project work time, class time was used to discuss problem solving, engineering communication, professional skills, and background information on different areas of Industrial Engineering. These topics were taught in class because the material allowed for students to engage directly in the exchanges, ask questions, and interact with each other through in-class activities.

Class Environment

The environment was the same for both the traditional and TBL semesters. The classroom had 22 dual monitor computers with 44 seats facing the front of the room and 3 computers with 6 seats facing the rear. Each computer could only be controlled by one student at a time. Some students brought their own laptops, which included Windows or Mac platforms, but the course was taught using a Microsoft Windows 7: Excel 2013 platform. Students worked on their own or together in groups of twos or threes. These groups were not assigned and were dynamic. For example, students could work on their own for one assignment, work in a group of two or three for the next assignment, and then change groups for the third assignment. The labs and homework were done on the lab computers or on the students' laptops.

Students used the university-supported Panopto software to watch the videos. The Panopto videos showed three screens: PowerPoint, Excel/VBA, and the presenter. An example of the Panopto video screen is in Figure 1. The video of the computer screen (VBA and PowerPoint) is in the upper right hand corner. The video of the speaker is in the upper left hand corner.

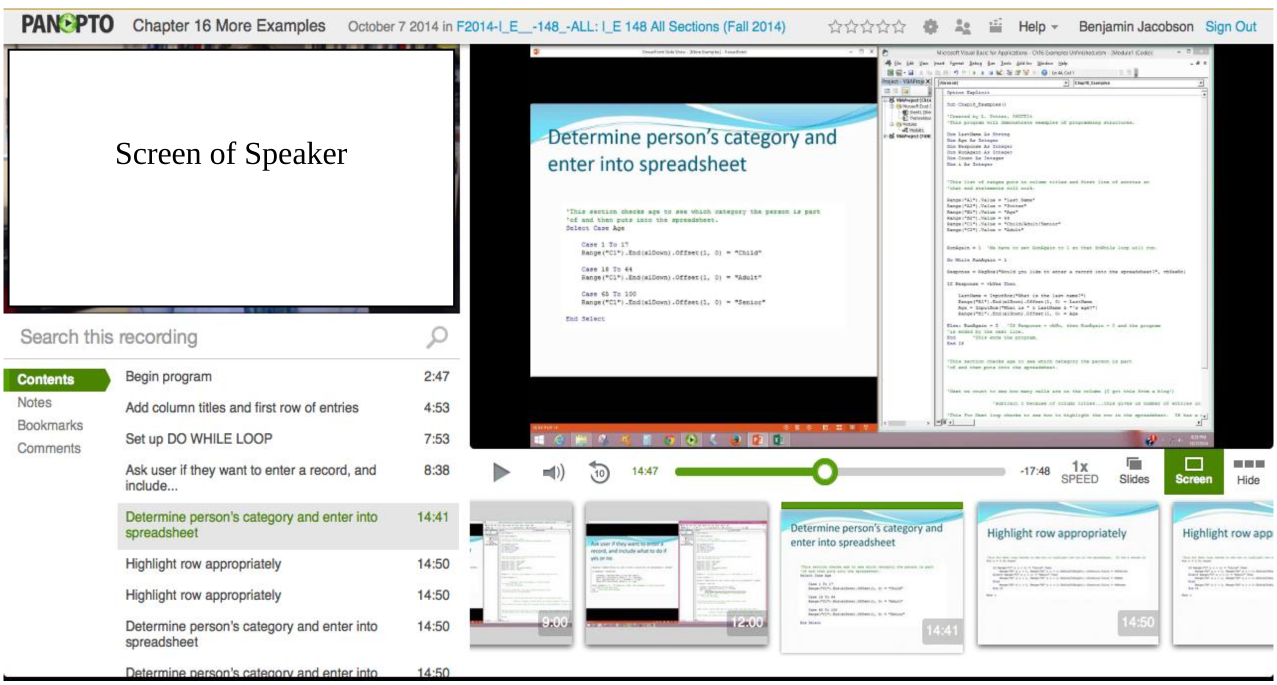

Figure 1. Example of Panopto Video Screen.

The use of PowerPoint indexes the videos, allowing students to navigate by concept easily, which results in higher learner performance and satisfaction (Zhang, Zhou, Briggs, & Nunamaker, 2006). The Panopto software also allows viewers to enlarge any screen, change video speed from .5X to 2X normal speed by increments of .25X, rewind/fast-forward, and pause/resume the video. The Panopto software generates video links and these links were posted in “preparatory documents,” with additional relevant information included in each document each week. These preparatory documents were posted on Blackboard, and only students enrolled in the course had access to the video. The videos were available to students 24/7 through Blackboard.

Data Analysis

For all the results in Study 1, an alpha level of .05 is considered significant and an alpha level of .10 is considered marginally significant.

Exam and lab grades and ABET assessment data were collected as part of the normal assessment process. The exam grades were aggregated and averaged for each semester. The lab grades were also aggregated and averaged. For the ABET results, outcome item (k) was assessed for all four semesters that the instructors taught the course. ABET assessments were based on student assignments, projects, and exam scores as well as instructor observation, interaction, and confirmation of peer evaluations. Data for 20 random students was collected each semester for ABET.

Bar charts of the grades and ABET assessment results will provide a visual assessment of the data. Student’s t tests will compare the Fall 2013-Spring 2014 semester (traditional format) to the Fall 2014-Spring 2015 semester (TBL format). A descriptive analysis will be done to demonstrate the students’ preferences for TBL or the traditional model based on their answers to the post-experiment survey. A qualitative analysis on the reasoning for the students’ preferences will be done to codify the responses and cluster them along common themes. A similar analysis will be done for students’ thoughts on the videos and video-speeds.

Limitations and Assumptions

The major limitation of this study was the length of the study and the inability to counterbalance. The study was done over a two-year period, but the pedagogy was switched from one year to the next. Since the pedagogies were not counterbalanced, there are numerous confounding variables that may have impacted the performance of the students. For example, the instructors' knowledge of the material and their teaching ability most likely improved with an extra year of experience, the ability of the tutors or peer mentors may have changed from one year to the next, and the online resources may also have changed with time.

The metrics for performance are also a limitation because the questions on the labs and exams had to change from semester to semester to dissuade cheating. The instructors did work diligently to ensure that the difference in difficulty across these metrics of performance would not change significantly, but it cannot be guaranteed that the difficulty did not change.

The final limitation is that the preference for the TBL or traditional pedagogy was not compared directly. Students that took the IE 148 course when it was taught with the TBL pedagogy answered whether they preferred the TBL pedagogy in the IE 148 course compared to other courses they had taken that used a traditional pedagogy. This is an indirect comparison because the other courses may have been better or worse than the IE 148 for reasons other than the pedagogy, which could have had a confounding impact on each student's answers. However, students were told to focus on the pedagogy when responding with their preference. Also, the free response answers about their preference related to the pedagogy, so it can be assumed that this indirect comparison provides some evidence of students' pedagogical preference.

Results

Performance

After a year of teaching each type of pedagogy, an analysis was done on the students' exam grades, lab grades, and ABET outcome k to determine how the transformation to the TBL course affected the students' performance in the class.

Exam Grades

Exam #1 and Exam #2 were averaged to compare the performance on exams across pedagogies and semesters. There was no significant difference between the two pedagogies of TBL or Traditional. The comparisons of the pedagogies can be seen below in Figure 2.

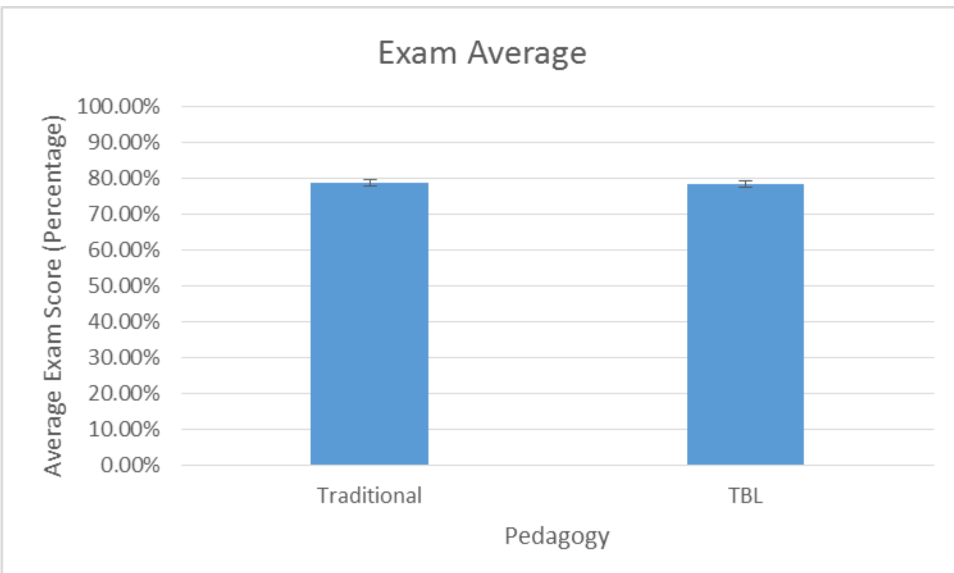

Figure 2. Exam Averages across Pedagogies; n=216. Note:*=significant difference, m=marginal difference

Lab Grades

Lab #5 was excluded from the study because the lab problems changed significantly after the Spring 2014 semester. The other nine labs were aggregated to create the lab average for each semester. The lab grades show that the TBL pedagogy was significantly higher than the

Traditional pedagogy (*F*(1,214)=6.00, *p*=.015, *d*=.33). The comparisons of the pedagogies is shown in Figure 3.

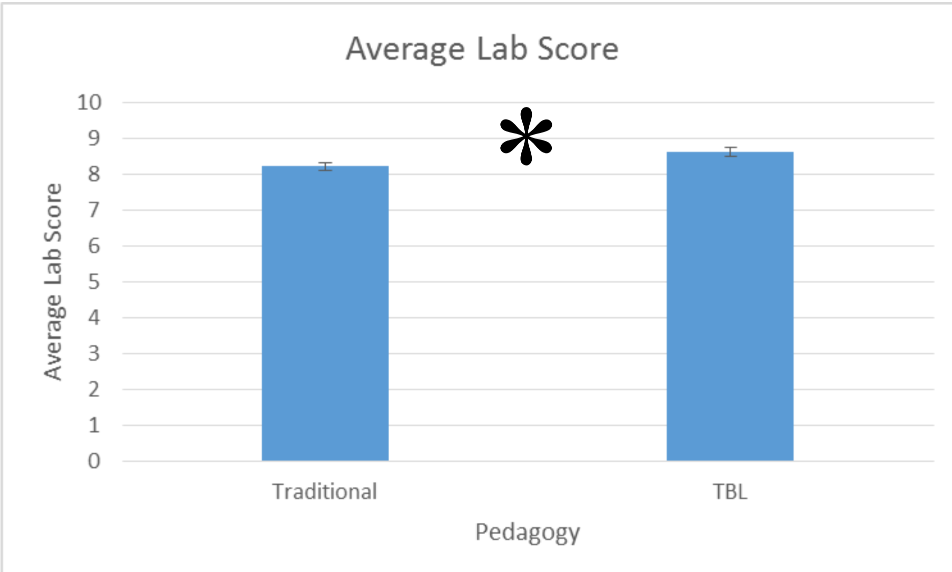

Figure 3. Average Lab Score by Pedagogy; n=216. Note: *=significant difference, m=marginal difference

<u>ABET Results</u>

The ABET results can be seen in Figure 4 comparing the performance of the Traditional pedagogy to the TBL pedagogy. There was not a significant difference between the Traditional and TBL semesters.

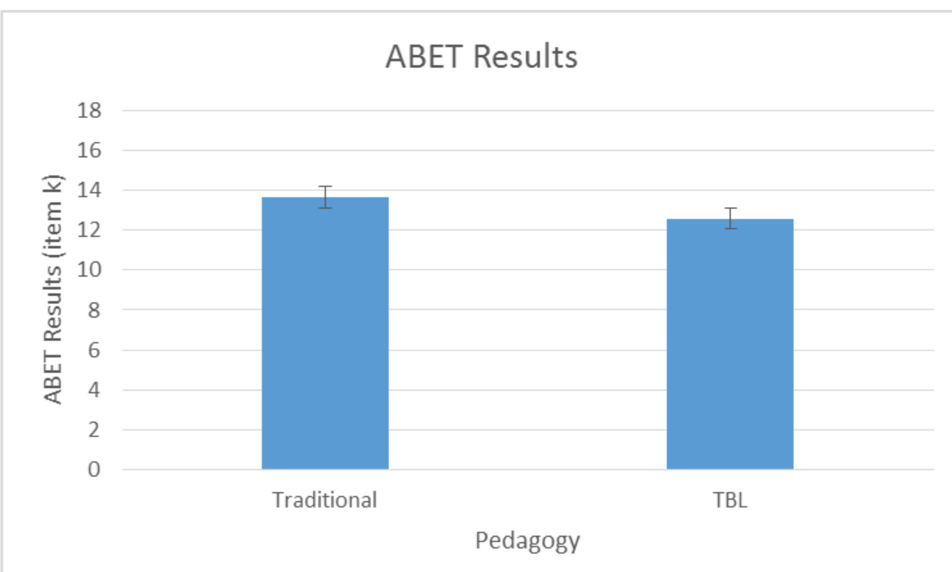

Figure 4. ABET Results across Pedagogies; n=80. Note:*=significant difference, m=marginal difference

Please note that n=40 students for each pedagogy for this metric. This is much smaller than the sample sizes for the earlier metrics. This smaller sample size results in a lower significance level.

Preference

Besides performance, preference for the pedagogy type was also measured. The responses to the question: *How does the IE 148 TBL framework and video lectures compare to the other classes that you are taking that are more traditional lecture-style classes?* on the post-semester survey demonstrated that the students did prefer the TBL pedagogy of IE 148 to the traditional pedagogy of their other classes[4]. In the Fall 2014 semester 42 out of the 52 students (80.7%) agreed that the TBL framework was “somewhat better” or “much better” than the traditional lecture-style framework. On the Likert Scale with 1 being “much worse” and 5 being “much better”, the Fall 2014 students averaged 4.09 with a standard deviation of 1.07. In the Spring 2015 semester 31 out of the 37 students (83.8%) agreed that the TBL course framework was “somewhat better” or “much better” than the traditional lecture-style framework. On the Likert Scale, the Spring 2015 students averaged 4.22 with a standard deviation of 0.85. Figure 5 shows the overall student response to this first question: ‘How does TBL with video lectures compare to traditional lecture-style classes’.

[4] This survey was only given to the students who had IE 148 as a TBL class; this question was not asked of students who took IE 148 when it was taught through traditional lecture.

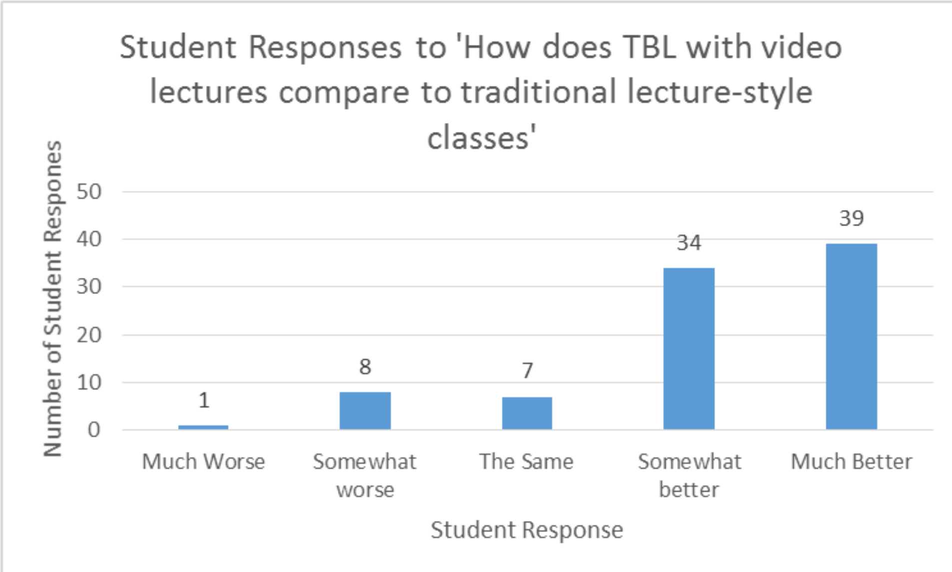

Figure 5. Student Responses to 'How does TBL with video lectures compare to traditional lecture-style classes' (n=89)

There were a variety of reasons that students preferred the TBL or traditional pedagogy, according to the student responses on the second question. These reasons were codified into common themes and Table 8 below displays the themes and how many students listed them as reasons:

Table 8. Reasons for Pedagogy Preference (n=68)

Number of students	Preference	Reason
20	TBL	Videos are flexible; can watch any time and any pace
10	TBL	Time to ask questions of instructors
7	TBL	Teamwork and interactive classrooms
7	TBL	Learned more/faster
7	TBL	Engaging/easier to focus during
5	Traditional	TBL is too time-consuming
4	TBL	Structured/easy to stay on task
4	TBL	Entertaining
2	Traditional	Not accustomed to learning from video lectures
2	TBL	Productive Class time

The following bullets are some examples of students' quotes:

Pro-TBL:

- "Flexibility in when we can learn, ability to go over examples and stop the videos to work through them"
- "Learning is faster and more efficient"
- "Collaboration makes tough stuff go faster"
- "Easier to get help and more engaging learning"
- "More organized, more personal, and more resources"

Pro-Traditional:

- "Not a fan of watching videos for long periods of time"
- "Was new to prep videos and did not know how to go about watching them to obtain information efficiently"

Another question on the post-semester survey asked the students for their thoughts on the videos and the video-speeds. 30 students answered the question and below are some examples of student responses:

- "Loved ability to watch videos fast" (response from four students)
- "Sometimes 2X speed is easy to understand because [it helps me] focus more"
- "At times, I ran out of time so I had go through [the videos] faster"
- "[Videos are] fine since I can adjust [speed]"
- "At times videos were slow"
- "The option to change speed was very nice"
- "Faster is better"

Discussion

The results provided some evidence that the transformation from the traditional pedagogy to the TBL pedagogy had a significant impact on student performance. The exam grades and ABET results did not show a significant difference between the two pedagogies, but the lab grades showed that the students in the TBL pedagogy performed better than with the traditional method. For this reason, Hypothesis #1: *TBL will result in higher performance compared to the traditional lecture-based model* is partially supported. This slight increase in performance may be caused by the students' accountability to their peers or their preference for the course, which will be discussed next.

Students reported that they have a preference for the TBL course over the traditional classroom based on their responses to the post-semester survey. Over 80% of the students preferred the TBL pedagogy to the traditional model. Their preference for TBL came from the flexibility of the lecture videos, the interactivity with both peers and instructors during the class (and the relationships that followed), and the increased engagement, focus, and learning efficiency that occurred with the TBL classroom that used lecture videos. Thus, there is support for Hypothesis # 2: *TBL will result in higher student preference for the course compared to the traditional lecture-based model*.

With these results, the instructors of this course (including this author), suggest that a transformation to TBL with lecture videos for first-year engineering courses can be successful, especially if there is a focus on technical content. The instructors recommend having students learn the technical content outside of the class and any non-technical (i.e. "soft" or professionalism) skills in the classroom. For educators who would like to transform their courses to TBL, the instructors recommend networking with fellow faculty or teachers to understand what resources are available at your university or school for TBL. If lecture videos will be created, the school's IT group should also be consulted about which video software programs they support. Previous or current students of the course should be asked for feedback and ideas about the proposed transformation. This will help get buy-in from future students who know that past students' opinions were incorporated into the transformation decisions. The instructors also recommend that educators consider how strong their grasp of the material is because there will be much more time for individual Q&A in TBL versus the traditional lecture, so the quantity and variety of questions will be much higher. The educator should also consider how much time they have available because this transformation does require a serious investment in time, especially if the transformation includes creating lecture videos[5]. However, even without lecture videos, creating in-class activities requires a large investment of time because they must promote both learning and team development (Michaelsen et al., 2002). One method to make the transformation easier is to spread out the investment in time across several semesters by changing the course to TBL one section at a time. Further recommendations are in Appendix B for educators who want to switch to the TBL pedagogy.

With only slight evidence of improvement in performance, there may be a question as to why this transformation is recommended. The following paragraphs will highlight the reasons for making this transformation to TBL and why the transformation should include lecture videos.

Since the videos were recorded, the instructors were able to review the content for mistakes and change the videos if they (or the students) noticed an error. Due to this, the content delivery was much more consistent and correct across instructors and semesters. The two

[5] A typical 10-minute video typically took the author 40 to 80 minutes to create depending on the complexity and the author's experience with the topic.

instructors also felt they had much stronger relationships with their students with the TBL pedagogy. About half of the in-class time was work time on labs, homework, or projects, so the instructors were able to engage with individual students and small groups much more than in the traditional pedagogy. This allowed instructors to understand what aspects of the class students were struggling with.

With the help of TBL, students had the motivation to do well, not only for themselves, but for their teammates. There was social pressure to study the material so students would not disappoint their teammates with inadequate knowledge of the RAT's subject. TBL also helped create an environment of critical thinking and communication. Students not only had to decide on solutions to the RATs and the different aspects of the group project, but they also had to defend and support their solutions to their teammates. The students also had to listen to and critically think about other students' ideas to decide the best course of action. The responses to the post-semester survey demonstrated that students prefer the video lectures to regular lectures, appreciate engaging with the instructors and their peers, and believe they are getting more out of the TBL pedagogy (more learning, more productive, more structured, and more entertaining). The only negative reasons against the TBL pedagogy were that students were not used to it and that it was too time-consuming. However, lecture videos may be the answer to the time-consuming complaint of TBL. By accelerating the videos, the students would save time compared to traditional lectures. Thus, video acceleration is one of the many reasons why students preferred the videos.

The lecture videos gave the students flexibility and control over their learning environment. The students were able to watch the videos at whatever time of day they preferred. They could also speed up, slow down, or re-watch the videos based on their experience with the content and their learning ability. Almost all of the responses to the third question about the videos and video-speed demonstrated appreciation for the ability to accelerate the video. The next sections in this paper will determine whether this control over the lecture videos was a useful and positive outcome of the pedagogy used in IE 148: TBL with video lectures.

CHAPTER IV: VIDEO-SPEED PREFERENCE

Based on responses from students in the last study, Study 1, there was a strong preference for the lecture videos and their flexibility, especially in the ability to speed up the video. The instructors also considered recording the lecture videos to be the most significant time investment in preparation for TBL. The importance of the video resource predicated the following study, Study 2: *Video-Speed Preference*, to analyze how many students were using the lecture videos and the speed at which they watched them.

Methods

Overview

Study 2 involves two separate surveys to investigate the video-watching habits of two different populations: the students in the first-year engineering course, IE 148, and the general university population. The first survey: *IE 148 Weekly Survey* was given to the students weekly throughout the first 10 weeks (excluding exam weeks) of the IE 148 course. A second survey: *General University Population Survey* was distributed to the Engineering and Liberal Arts and Sciences students at Iowa State University to get a better understanding of the video-watching habits of the general student population.

IE 148 Weekly Survey

Research Objective

The purpose of the IE 148 Weekly Survey is to understand if the IE 148 students watched the lecture videos and if they did watch them, whether they accelerated or decelerated the video-speed. It also seeks to understand if these habits changed over time throughout the semester.

Participants

All of the 49 students (39 male, 10 female) of the Spring 2015 IE 148 class could have taken this survey. However since this survey was weekly and optional, the number of students that took it varied from 30 to 47. The students were all in the Industrial Engineering major and the vast majority of them were first-year students. They ranged in age from 18 to 31 years old.

Independent Variables

The only independent variable is *time*. The dependent variables will be measured throughout the semester to discover if there were any significant changes with time.

Dependent Variables

There are two dependent variables for this survey: *Videos watched* and *video-speed preference.* The dependent variables and their metrics are represented in Table 9.

Table 9. Dependent Variables for IE 148 Weekly Survey

Variables	Metric	Measurement (Unit)	Frequency	Data Type	
Videos Watched	Percentage of Video-Watched	Percentage (Likert Scale 1-5)	Weekly	Objective	Ordinal
	Resource Used	Survey: Four options	Weekly	Objective	Ordinal
Video-Speed Preference	Video-Speed	Survey: Four options	Weekly	Objective	Ordinal

The utility of the video resources can be judged by how many videos were watched. This is composed of two factors: The percentage of the videos that the students watched and the main resource that the students used to learn the content: Textbook, Video, Both, or Neither. The video-speed preference was determined by the video-speed that the students watched the videos at each week.

Survey Instrument

The IE 148 Weekly Survey was attached to the end of the weekly RAT that the students took the first ten weeks of the course. When the RATs were collected the surveys were detached and compiled. The survey consisted of three questions:

1. What percentage of this week's videos did you watch:
   [0%, 1-33%, 34-67%, 68-100%, >100% (Watched multiple times)
2. Did you mainly read the textbook, watch the videos, do both, or do neither to study for this RAT?
   [Textbook, Videos, Both, Neither]
3. If you watched the videos, on average, what speed did you watch the videos at?
   [0.5 x speed, Normal speed, 1.5 x speed, 2.0 x speed]

Limitations and Assumptions

The data for this survey was self-reported by students without any formal verification. The students were encouraged to answer honestly and they were told that their responses to the IE 148 Weekly Survey would have no impact on their final grade or their relationship with either of the instructors. The students were also told that their responses would be immediately separated from their RATs, would be stored in separate locations, and would not be analyzed until later in the semester.

Results

Average Responses to the IE 148 Weekly Survey. This first subsection of the results section analyzes the average responses of the three questions across the ten weeks of the survey. First, the average response for question #1 can be seen in Figure 6.

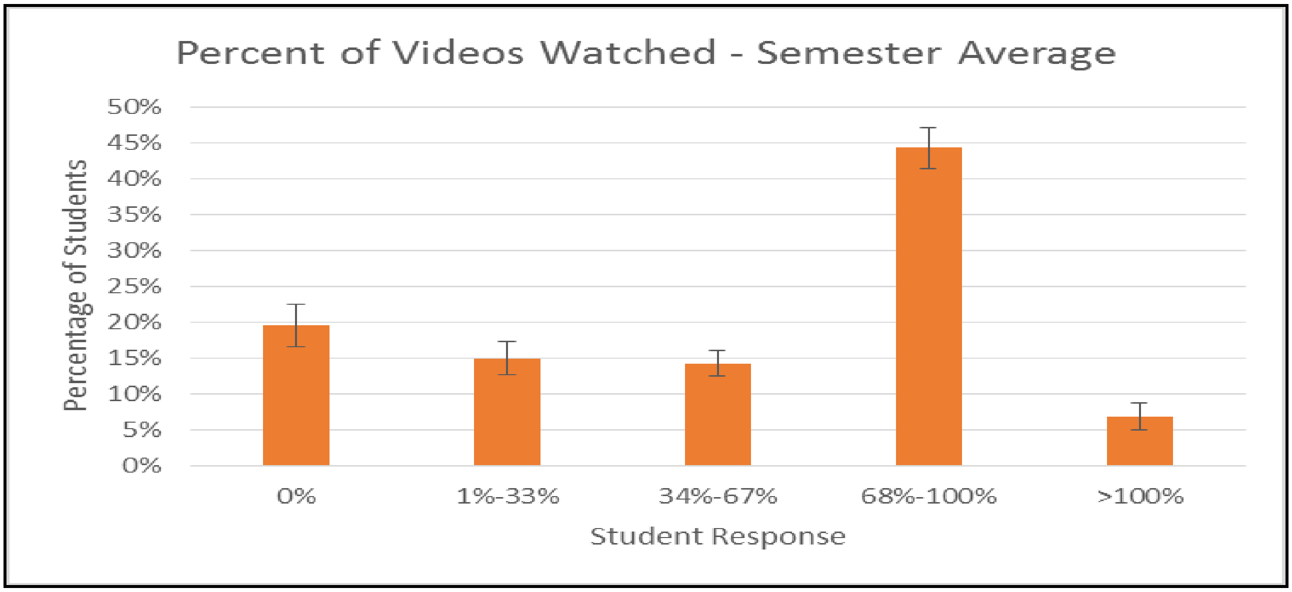

Figure 6. Student Response about Percent of Videos Watched - Semester Average (n=367; 30-46 students for 10 weeks)

These results show that the majority of the class is watching at least two-thirds of the video throughout the semester. However, an average of 20% of the class watched none of the videos.

Next, Figure 7 shows the average response to which main resource the students used throughout the semester.

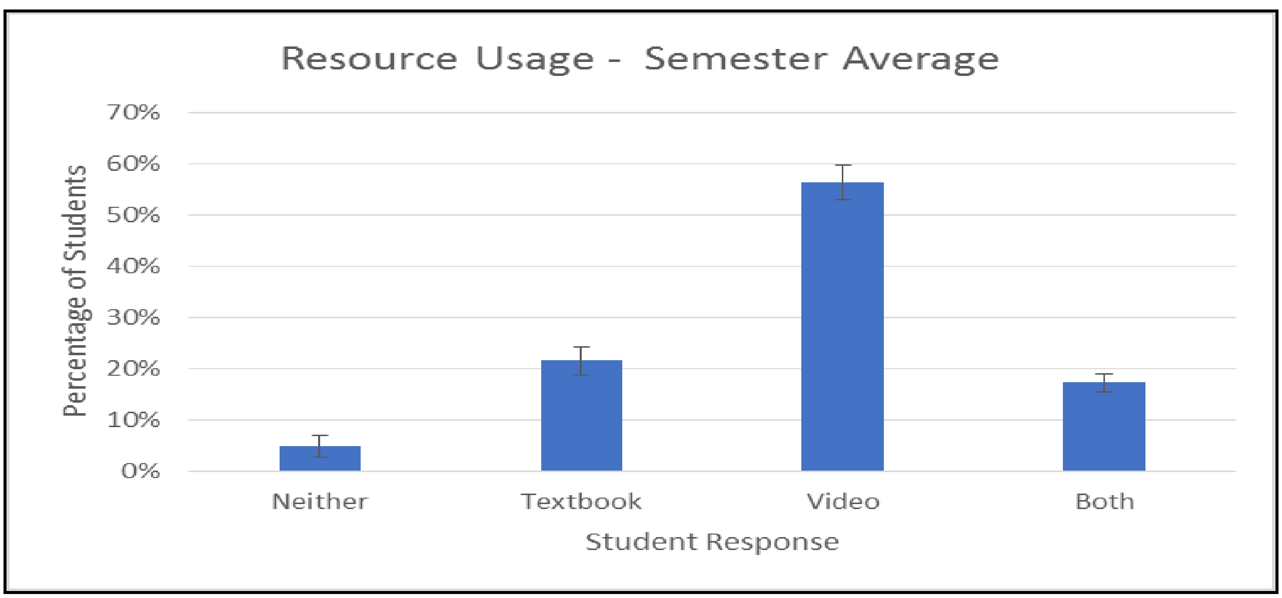

Figure 7. Student Response about Resource Usage - Semester Average (n=365; 30-47 students for 10 weeks)

This figure shows that 73% of the students watched the lecture videos (56% responded “Videos”, 17% responded “Both”) throughout the semester, 39% of the students read the textbook (22% responded “Textbook”, 17% responded “Both”), and only 5% percent of the class did not use either of the course recommended resources. The weekly variation was fairly small as shown by the standard deviation. In comparison, 35% of the students that took IE 148 when it was taught traditionally did the 2-4 hours of reading that was needed for pre-class preparation(Potter & Jacobson, 2015), which is similar to the levels seen in these results.

Figure 8 below demonstrates the semester average for the speeds at which students watched the lecture videos.

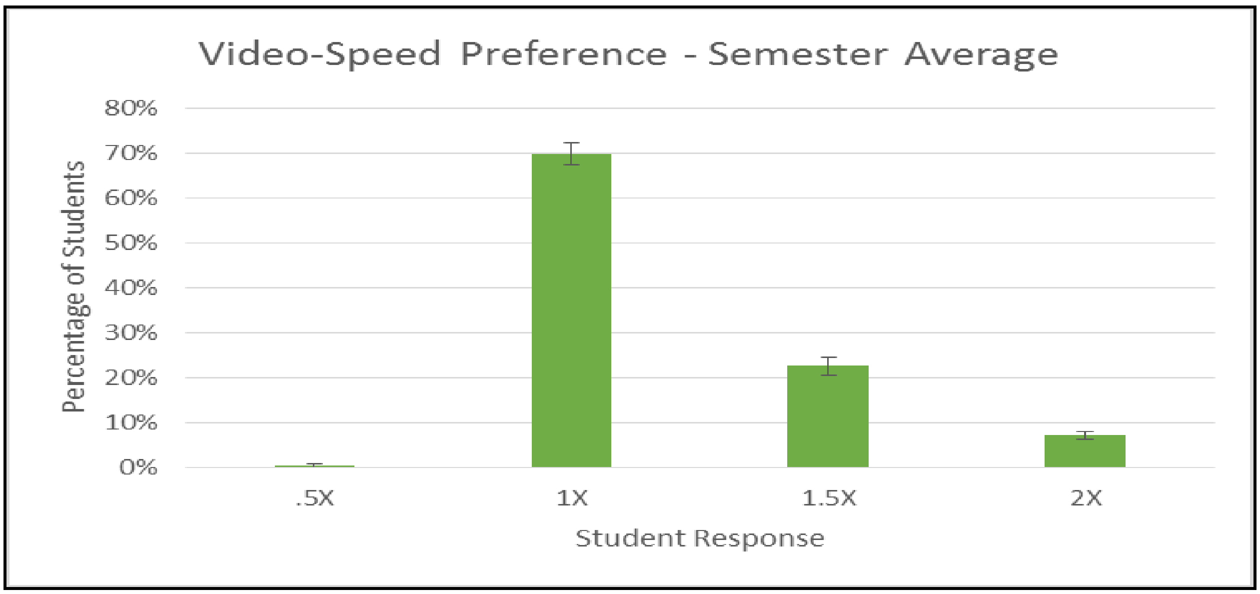

Figure 8. Student Response about Video-Speed Preference - Semester Average (n=292; 19-40 students for 10 weeks)

This figure shows that the majority of students watched videos at the 1X speed, but an average of 30% of the class did accelerate the videos throughout the semester. The weekly variation throughout the semester is also pretty small, thus showing that the video-speed preferences were fairly stable.

Weekly Trends of Responses to the IE 148 Weekly Survey. This second of two subsections demonstrates how the responses to the three survey questions changed over the first ten weeks of the semester. First, the percentage of the videos that were watched by the students are shown in Figure 9.

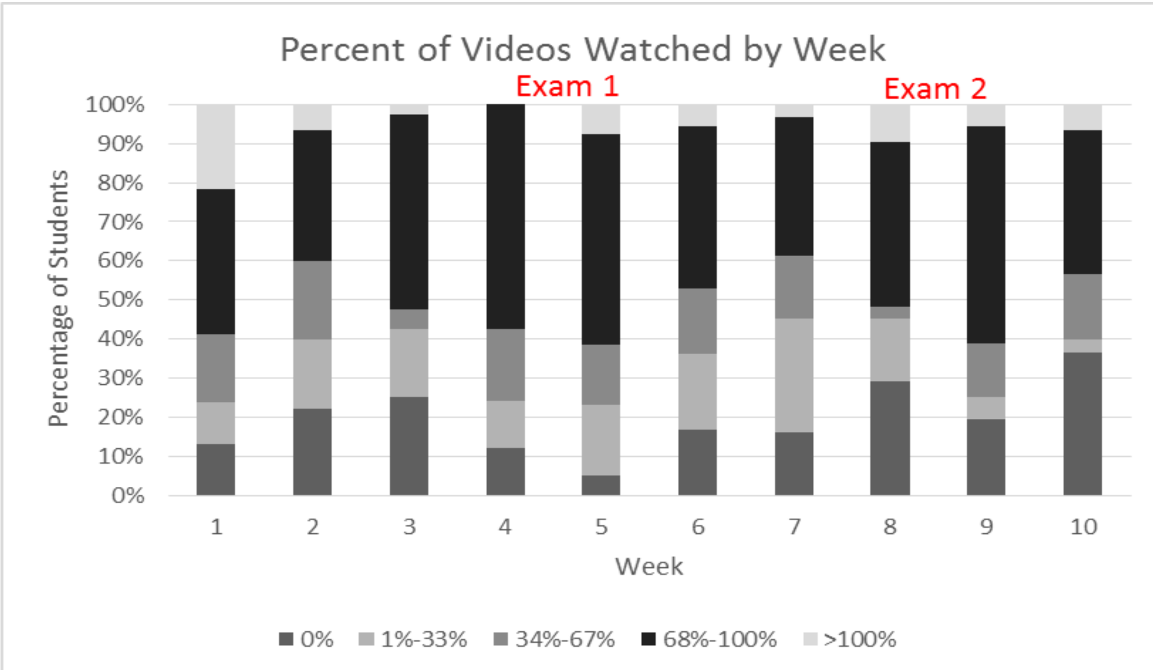

Figure 9. Percentage of the videos that were watched across the Semester (n=367; 30-46 students for 10 weeks)

This figure shows that the videos tend to be watched more around exam time and less in between exams and at the very end of the class. The class averaged 51% of the students watching at least two-thirds of the videos throughout the semester.

Next, Figure 10 below shows the Resource Usage across the semester:

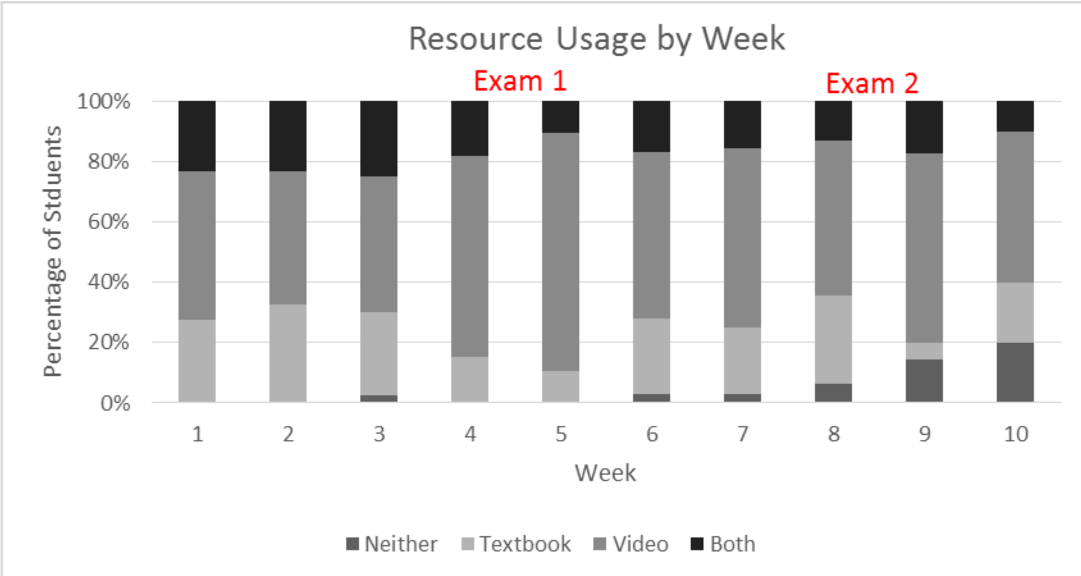

Figure 10. Usage of Course Materials across the first 10 weeks of the semester (n=365; 30-47 students for 10 weeks)

Figure 10 shows that anywhere from 60% to 90% of the students mainly used “Videos” or “Both Videos and Textbooks” depending on the week. The video usage is highest directly after the two exams and lowest the week before Exam 2 and the last week.

Last, Figure 11 shows the students’ video-speed preferences on a weekly basis.

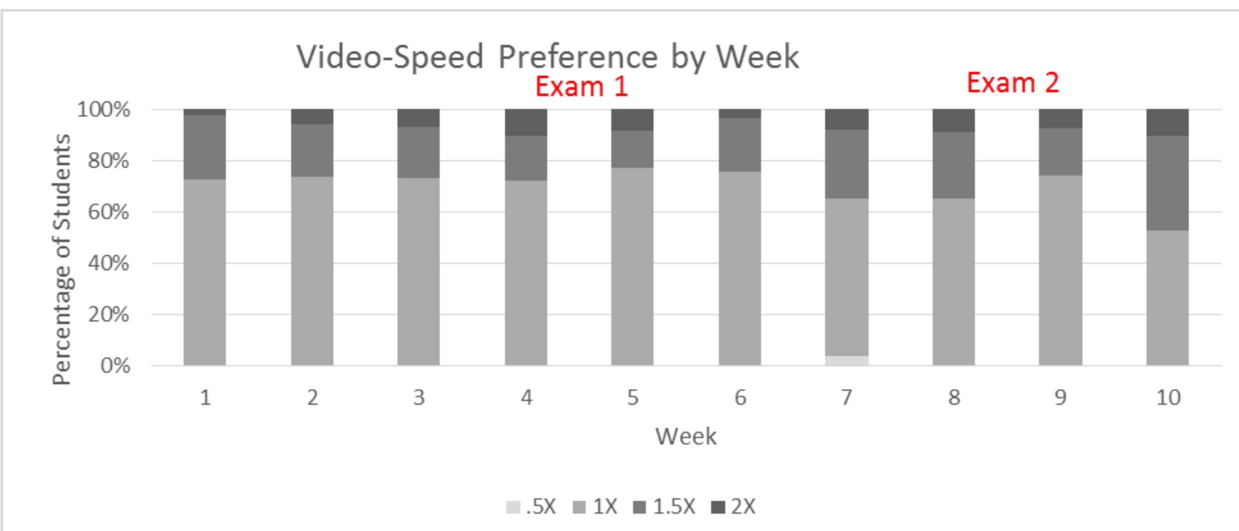

Figure 11. Video-speed Preferences across the Semester (n=292; 19-40 students for 10 weeks)

The Video-Speed Preferences did increase in between the first and second exam and in week 10. The class averaged 30% of the students accelerating videos throughout the semester, but at the end of the class 47% of the students were accelerating videos.

General University Population Survey

Research Objective

The General University Population Survey will provide an overview of the video-speed preferences for the general university population in terms of what percentage of general students accelerate videos and how frequently they accelerate videos when given the option. The results will also be compared to the first-year students' results to provide a better understanding of any differences between the two populations.

Participants

The General University Population Survey surveyed two groups of students. The first group was comprised of online undergraduate and graduate Engineering and Liberal Arts & Sciences (LAS) students through the Engineering-LAS Online Learning department. The survey was e-mailed to instructors at Iowa State University who teach online sections of undergraduate and graduate courses in the Engineering and LAS colleges. These instructors then forwarded the survey to their students and asked them to complete it. From this sample population 80 students completed the survey. The second group was comprised of 65 students who took the survey as part of the experiment for Study 3. This second group consisted of 47 undergraduate students in the Industrial Engineering department at Iowa State University who were participants in Study 3 and 18 other miscellaneous Iowa State students, who completed the pilot test version of Study 3. A Student's t-test was performed on the video-preference results for these two groups and no significant differences were found. Thus, the groups' results were aggregated.

When the two groups were combined there were a total of 145 participants (98 male and 47 females). The participants had a mean age of 23.8, median age of 21, and a range of 18 to 61. 83% of the respondents were native English speakers and 17% of the respondents were not. 71% of the respondents were White, Non-Hispanic, with the next largest ethnicities being Asian Pacific Islander (7.6%) and Black, Non-Hispanic (4.8%). The class rank of the respondents varied with approximately 30 respondents for each class (freshman through graduate student), except for the sophomore class, which only had 19 respondents. The GPA of the respondents had a mean of 3.11 and a standard deviation of .59. These participants represent general university students.

Independent Variable

The one independent variable is *student type* (first-year vs. general). First-year students will be gauged from the IE 148 Weekly Survey while general will be measured from the General University Population Survey.

Dependent Variable

There are two dependent variables: *video-speed preference* and *frequency of video acceleration.* The dependent variables and their metrics are represented in Table 10.

Table 10. Dependent Variables for General University Population Survey

Variables	Metric	Measurement (Unit)	Frequency	Data Type	
Frequency of Video Acceleration	Frequency	Frequency (Likert Scale 1-5)	Weekly	Objective	Ordinal
Video-Speed Preference	Video-Speed	Survey: Five options	Weekly	Objective	Ordinal

Video-speed preference will be measured by what video-speed students in the general university population watch videos. Frequency of video acceleration will be measured by how frequently students in the general university population accelerate videos.

Survey Instrument

The survey contains 12-questions about the students' demographics and video-speed preferences. The full survey can be seen in Appendix C. The three questions that pertain to video-speed preference are:

1. At which rate do you normally speed up the videos you watch? [1.25x, 1.5x, 1.75x, 2.0x,]
2. How recently have you watched a video at a faster than normal speed? [Less than a day, Less than a week, Less than a month, More than a month]
3. When you watch videos that can be sped up, how frequently do you speed them up? [Never, Rarely, Sometimes, Most of the time, Always]

The other nine-questions of the survey focused on the demographics of the survey participants. Those results were summarized in the 'Participants' subsection. The general Engineering-LAS students that were contacted through ELO completed the survey through the Qualtrics medium. The survey was also hosted on Blackboard, which is where the group of Study 3 participants and pilot testers took the survey.

Data Analysis

For all the results in Study 2, an alpha level of .05 is considered significant and an alpha level of .10 is considered marginally significant.

Descriptive statistics and a bar chart will be used to describe the video-speed preferences and frequency of video acceleration habits of the general student population. A Student's t test will be used to determine whether the video-speed preferences of the first-year students and the general student population are significantly different.

<u>Results</u>

The 145 survey results from the general university population were analyzed to summarize their video-speed preferences and the frequency at which they accelerate videos.

Video-Speed Preference. Figure 12 provides the distribution of results from the students in the general student population.

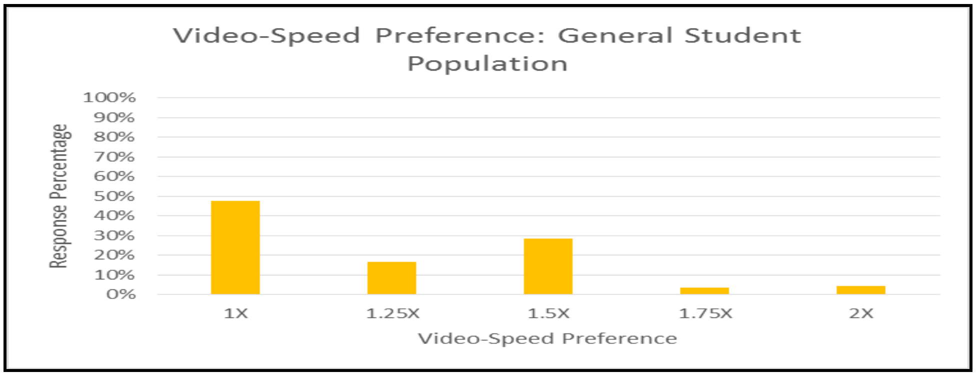

Figure 12. Video-Speed Preference - General Student Population (n=145)

An almost equal number of the general students surveyed watch videos at normal speed or at 1.25X/1.5X normal speed (47.6% and 44.8% respectively). Only 7.6% of the students surveyed watch videos at 1.75x/2X normal speed. No one surveyed watched videos at less than normal speed. The average video-speed preference from the student responses is 1.25X normal speed.

Figure 13 compares the video-speed preferences of the general student to the IE 148 first-year student.

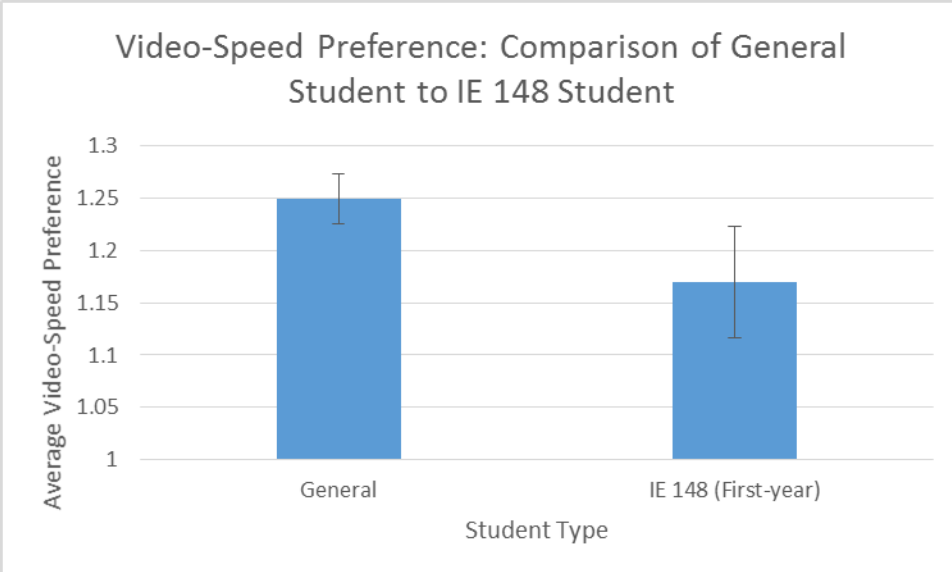

Figure 13. Video-Speed Preference by Student Type (n=174; General: 145, IE 148: 29)

The results show there is no significant difference in video-speed preference between the general student and the first-year student.

Frequency of Video Acceleration. Out of the 145 students that took the survey only 83 students responded to how frequently they accelerate lecture videos. Presumably, the majority of these respondents were the ones who accelerate lecture videos. From this subsample of the 145 students, 45% of the students surveyed rarely or never sped up videos, 41% sometimes sped up videos, and 13% of the students surveyed sped up videos all or most of the time. The distribution of results can be seen in Figure 14.

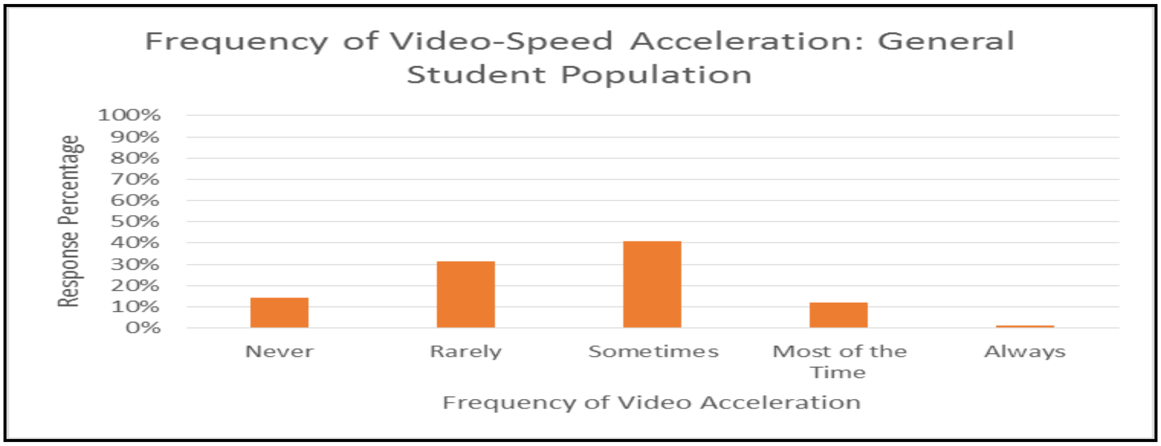

Figure 14. Frequency of Video-Student Acceleration: General Student Population (n=145)

Discussion

The video resource is used by about three-quarters of the students on average and it was used the most after the two exams; most likely because the students do not have homework after the exams, so they would have more time to watch the videos. The video resource is also heavily favored over the textbook resource with at least twice as many students mainly watching the videos compared to reading the textbook. The percentage of students who used the textbooks did not change between the traditional and TBL semesters. When students used the video resource, about half watched at least two-thirds of the videos.

The video-preference results show that on average about a quarter of the first-year students preferred accelerating videos throughout the semester. However, by the end of the semester, almost half of the students were accelerating the videos. Since around half of the general student population also accelerates videos, this provides evidence that students begin accelerating videos more as they progress through their first year.

The general student results demonstrate that about half of students speed up lecture videos. Some students reported that they chose to accelerate the video because it reduces the time it requires to complete the video-watching task. However, the half that watches videos at normal speed do so because they are worried they will miss something important in the video, especially if the student chooses to take notes. Some also believe the expectation is to watch the video at normal speed since that is the default setting for the video.

For the students that did accelerate videos, half did so sometimes or most of the time. However, students almost never watch the videos faster than 1.5x normal speed. The hesitancy to accelerate the videos beyond a certain point occurs for three reasons. First, there is again the concern that accelerating the video will cause the student to miss something. Second, sighted adults have a preference for 175 wpm, which is about 1.25/1.5X the normal speaking rate (Arons, 1992). Third, research has shown that 1.5X normal speed does not reduce comprehension, but 2X normal speed does (Pastore, 2012). Thus, people are hesitant to accelerate the video past 250 wpm, which is about 1.75X the normal speaking rate (Harrigan, 2000).

In Study 1, students described why they liked the video lectures as part of the TBL pedagogy. In Study 2, the surveys demonstrated that approximately half of the general student body prefers to accelerate lecture videos. However, the students are not pushing the limits of their cognitive speed model. There is an opportunity with video acceleration to watch lectures in half the time or less, so the questions are: How quickly can students reasonably speed up lecture videos and under what conditions should they? These questions will be investigated in the next chapter: *Video-Speed Experiment*.

CHAPTER V: VIDEO-SPEED EXPERIMENT

The previous two studies, Study 1: *Transformation to TBL* and Study 2: *Video-Speed Preferences* demonstrated that students: are accelerating video lectures, enjoy having the ability to accelerate videos, and are saving time because of this acceleration. Since only half of the students watched at least two-thirds of the lecture videos (most likely due to time constraints based on the student feedback from Study 1), a final study was created to understand whether video acceleration could be a solution for the time constraints without sacrificing performance. Thus, this final study, Study 3: *Video-Speed Experiment,* was done to provide objective results about the trade-off between video acceleration and student comprehension of video lectures. Study 3 was also done to demonstrate how practice watching accelerated videos affects this comprehension/acceleration trade-off as well as students' preferences for watching accelerated videos.

Methods

Research Objective

The purpose of this experiment is to understand how video acceleration impacts student comprehension and whether university students' comprehension of accelerated videos can be improved through practice. The experiment will also explore how video-speed preference is impacted by practice watching accelerated video-speeds. Finally, the experiment aims to provide recommendations about when accelerated videos should be encouraged or discouraged.

Hypotheses

In total, two hypotheses were developed for this experiment. These two hypotheses are:

- H_1: Initially, video acceleration will result in lower comprehension and higher cognitive workload. The decrease in comprehension and increase in workload will both increase in magnitude as the increase in video-speed increases
- H_2: After 18 minutes or less of practice watching accelerated videos, comprehension of accelerated videos will increase from its initial levels and preference for higher video-speeds will also increase.

Participants

This experiment consisted of 47 participants (33 male, 14 female) with a mean age of 20 (range: 18-31 years old). Each participant only attended one experiment session. The participants were a mix of students from two undergraduate Industrial Engineering courses that completed the experiment to gain extra credit in their respective courses. These participants represent undergraduate university students studying in a STEM field.

Tasks

The participant's task consisted of watching a video at a pre-selected video-speed via headphones. The participant could not manipulate the controls of the video in any way (fast-forward, rewind, change video-speed, etc.), except to change the volume. The participants were also not allowed to take notes during the task. Participants watched the video in full screen mode using the Google Chrome Browser. An overview of the videos will be covered in the next few paragraphs.

The participants were asked to watch six videos at various video-speeds. The six videos were all standardized to be as similar as possible in terms of content, speaker, and presentation of information. The videos all came from the Khan Academy® website, so that the videos would have the same speaker (Sal Khan) and the same method of presenting information (writing/drawing on the screen). Sal Khan also has a clear voice and even though he has a slight accent, preliminary experiments showed that native vs. non-native English speakers were able to understand him equally. This demonstrates that his accent was easy enough for even non-native English speakers to understand. Khan Academy was selected because it has proven to be a very effective educational resource. With 10 million students worldwide, 3,400 lecture videos, and multiple million dollar investments from groups like Google and the Bill and Melinda Gates foundation, Khan Academy is becoming a very extensive, yet simple resource for educators to use in flipped classrooms (Khan, 2012; Noer, 2012). The selected videos are aimed at high school or introductory university students, so the complexity of the information presented was at or below the skill level of the university students that served as participants. Preliminary experiments were done with 18 students to ensure that the videos were as isomorphic[6] as possible.

Even though the same speaker teaches each video, each video had different video-speeds, varying from 154 to 188 wpm (*M*: 169 wpm, *SD*: 11.4 wpm). Thus, the video-speed needed to be standardized and 179 wpm was chosen as the standard normal speed. 179 wpm could then be accelerated to 358 wpm (2X) or 573 wpm (3.2X).

The videos were modified by downloading the videos from Khan Academy's® website and then converting the audio and video streams to the required speed by using FFmpeg®. The converted .mp4 file was then uploaded to Blackboard to be used in the experiment. When watched at the standard normal speed, the videos had a mean time of nine minutes, a standard

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[6] Isomorphic in this context refers to the similarity and standardization of the complexity, delivery, and overall feel of the video.

deviation of 42 seconds and a range of 7:39 to 9:49. The links to the six videos can be found in Appendix D.

After watching the video, each participant's task was to take a seven-question multiple-choice quiz that tested each participant's comprehension of the content of the video. The quiz did not have a time limit and it was taken through the Blackboard learning management system.

Independent Variables

There were two independent variables in this study: *practice speed* (1X, 2X, 3X) and *trial number* (Baseline: T1, Practice: T2-T5, Test T6).

Practice Speed Group. Participants conducted trials T2 through T5 at one of three speeds: 179 wpm, 358 wpm, and 573 wpm. These three video-speeds were chosen based on three criteria: 1. The speaking rate of 179 wpm is the most preferred rate of speech. 2. The video-speed of 358 wpm pushes the capacity of the cognitive speed model, yet this rate of speech has been shown to be trainable with audio comprehension. 3. In the preliminary experiment there was not a difference between the comprehension scores at 179 wpm and at 358 wpm. A third standard video-speed, 573 wpm, was added to ensure that there would be a practice speed that resulted in different comprehension levels than the other two practice speeds.

Trial Number. There were six trials that all the participants completed: Baseline (T1), Practice Trials (T2-T5), and Test (T6). Trial 1 was the baseline and was conducted at 179 wpm. The Practice Trials T2 through T5 were conducted at the practice speed that the participant was assigned. Finally, the Test Trial (T6) was conducted at 573 wpm.

Dependent Variables

The dependent variables were *comprehension level, video-speed acceleration, practice effect, cognitive workload, learning efficiency, video-speed preference,* and the *perceived practice effect.* They are described in Table 11.

Table 11. The metrics for the dependent variable - Study 3

Variables	Metric	Measurement (Unit)	Frequency	Data Type
Comprehension Level	Comprehension Quiz Score	Points	After each trial	Objective
Video-Speed Acceleration	Quiz Score (T6 – T5)	Points	Once	Objective
	Quiz Score (T2 – T1)	Points	Once	Objective
Practice Effect	Quiz Score (T5 – T2)	Points	Once	Objective
Learning Efficiency	Comprehension Quiz Score per Minutes of Video	Points/Minute	After each trial	Objective
Cognitive Workload	TLX Subscale Mental Demand	Scale 0 - 10	After Trials 1, 5, 6	Subjective
	TLX Scale	Scale 0 - 60	After Trials 1, 5, 6	Subjective
Video-Speed Preference	Comfort	Likert Scale 1 - 5	Once	Subjective
	Future Habits	Likert Scale 1 - 5	Once	Subjective
	Preference	Likert Scale 1 - 5	Once	Subjective
	Difficulty	Likert Scale 1 - 5	Once	Subjective
	Learning Effectiveness	Likert Scale 1 - 5	Once	Subjective
Perceived Practice Effect	Practice Perception	Likert Scale 1 - 5	Once	Subjective

Comprehension Level. This metric was measured objectively. It was measured by the seven-question quiz that was taken after each video. The questions asked participants to recall facts from the videos, which demonstrated how well they comprehended the content of the video. The comprehension score will be used to compare the practice speed groups in the Baseline Trial (T1), Practice Trials (T2-T5), and Test Trial (T6). An overview of the quizzes used to measure the comprehension level is below.

<u>Quizzes</u>

There are six seven-question quizzes (one quiz per video) to measure how well the participants comprehended the content of the video. Each question had one correct answer and five responses to select from. The questions and answers to the six quizzes can be seen in Appendix E. All the quiz questions are at the knowledge level, according to Bloom's Taxonomy (Anderson & Sosniak, 1994). The questions were created using multiple-choice question writing guidelines (Collins, 2006; Haladyna, Downing, & Rodriguez, 2002; Woodford & Bancroft, 2005).

The preliminary experiment with 18 students compared the difficulty and discriminability of each of the six quizzes to make them as isomorphic as possible. Difficulty for each question was determined by the item difficulty index (P), which is calculated from the formula P = R/T, where R is the number of correct responses for that question and T is number of total responses, including blank responses for that question. Discriminability for each question was determined through the item discrimination index (D), which is calculated by the formula $D = P_U – P_L$ where P_U is the percentage of students in the top 27% of scorers for the quiz who chose the correct response for that question. P_L is the percentage of students in the bottom 27% of scorers for the quiz who chose the correct response for that question (Sim & Rasiah, 2006). Due to the results of the preliminary experiment, some of the questions were changed to standardize the difficulty across the quizzes and to maximize the discriminability of the questions. An item analysis of the questions of the quizzes was performed at the end of the video-speed experiment. It demonstrated that almost all of the questions were at the "good" discrimination level, but that difficulty varied between the quizzes. Thus, the videos and quizzes will be counterbalanced in the experiment. The full item analysis is available in Appendix F.

Video-Speed Acceleration. This metric was measured objectively and used the comprehension level metric to calculate how the comprehension level per video changed when there was an increase in video-speed from one video to the next. The first change in video-speed occurred from Trial 1 to Trial 2 for the participants in both the 2X and 3X groups. The change in comprehension level will be compared between those two groups and benchmarked against the 1X group. The second change in video-speed occurred from Trial 5 to Trial 6 for both the 1X and 2X group. So again, the change in comprehension level will be compared between these two groups and benchmarked against the 3X group.

Practice Effect. This metric was measured objectively and used the comprehension level metric to compare the comprehension levels at the beginning (T2) and end (T5) of the Practice Trials.

Learning Efficiency. This metric was measured objectively and is determined by the amount of points earned on the comprehension quiz and the time taken to watch the video. For example, if fifty points were earned on the quiz and the video took five minutes to watch, then the learning efficiency score would be 10 points/minute (=50/5). Since the videos were different lengths of time and were counterbalanced across trials, the average time of nine minutes was used for the videos at the 1X video-speed. Thus, the comprehension score would be divided by 9 for the 1X video-speed, 4.5 for the 2X video-speed, and 3 for the 3X video-speed. This metric demonstrates how quickly and efficiently you can comprehend information with different video-speeds.

Cognitive Workload. This metric was measured subjectively three times during the experiment by using the NASA TLX survey. The NASA TLX survey is used to measure different aspects of workload, including mental demand (Hart & Staveland, 1988). The first survey (TLX #1) was completed after Trial 1, which was used as a baseline since all the participants watched the video in this first trial at the 1X video-speed. The second survey (TLX #2) was completed after Trial #5, which marked the end of the Practice Trials. Thus, TLX #2 measured how workload would be impacted by practice at the various video-speeds. The third and final survey (TLX #3) was completed after Trial #6, where each participant watched the video at the 3X video-speed. This measured how workload was impacted by an ultra-fast video-speed after practice at various speeds. The NASA TLX subscale of "Mental Demand" was also analyzed from the three NASA TLX surveys to determine how much mental demand each participant had throughout the experiment.

Video-Speed Preference. This metric was measured subjectively to determine students' video-speed preferences. It was measured at the end of the experiment through the post-experiment survey. There were six questions on the post-experiment survey and five of them pertain to video-speed preferences. Question #3: *I preferred watching the videos at the faster speed compared to the slower speed* is the only question that directly asked the participants about their preference, but the other four questions provided reasoning for their preference and for what their future habits will be.

Perceived Practice Effect. This metric subjectively measured whether the participant perceived getting better at comprehending videos at accelerated video-speeds after they had just practiced watching videos at that accelerated video-speed. The question was: *Videos were easier to comprehend after watching a few other videos at the same speed.* This metric, combined with the comprehension level changes over the Practice Trials, will help determine whether a practice effect occurred during the experiment. The NASA TLX and post-experiment survey, along with the pre-experiment survey, are explained more below:

<u>Surveys</u>

There were three surveys that were used in this experiment: the pre-experiment survey, the NASA TLX surveys, and the post-experiment survey. The pre-experiment survey consists of 13 questions and asked for the participants' demographic information and their video-watching habits. The pre-experiment survey can be seen in Appendix G. The NASA TLX survey consists of six questions that measure the amount of workload that the task demanded. The NASA TLX survey can be seen in Appendix H. The post-experiment survey consists of six questions about the participants' video-speed preferences and their perception of how practice affects their ability to watch faster video-speeds. The participants ranked their agreement with the six questions on a Likert Scale that went from 1: Strongly Disagree to 5: Strongly Agree. The post-experiment survey can be seen in Appendix I.

Experimental Design

This experiment was a six (T1-T6) by three (1X, 2X, 3X) mixed-subject design. In order to test the effects of different video-speeds, the participants were randomly split up into three different groups. The three groups are: 1X (179 wpm) practice speed, 2X (358 wpm) practice speed, and 3X[7] (573 wpm) practice speed. The 1X and 2X groups each had 16 participants and the 3X group had 15 participants. The three groups then completed six trials. Trial 1 and Trial 6 compared the three practice speed groups under the same video-speed. Trial 1 was the Baseline Trial, which ensured that all three groups could perform similarly at the 1X video-speed. Trial 6 was the Test Trial, which compared how the three groups handled the 3X video-speed after

[7] The 3X video-speed (573 wpm) is actually 3.2X normal speed. 3.2X normal speed was used due to limitations in the software used to accelerate the software, but "3X video-speed" will be used to standardize the name of the three groups.

practice at different video-speeds. Trials 2 through 5 were the Practice Trials, where the groups watched the videos at the video-speed they these were assigned to. These trials are known as the Practice Trials because they were used to test how practice at different video-speeds impacted the three groups in terms of comprehension score and engagement.

Table 12 demonstrates how the three video-speeds are spread throughout the experiment based on the two independent variables: the *Practice Speed Group* the participant is assigned and the *Trial Number*. Comprehension will be measured after each trial via a quiz about the video. Cognitive load will be measured after Trial 1, the last Practice Trial (Trial 5), and after Trial 6 via NASA TLX. Video-Speed Preference and Perceived Practice Effect will be measured at the end of the experiment with the post-experiment survey.

Table 12. Experimental Design

		Trial Number					
		T1	**Practice Trials (T2-T5)**				**T6**
Practice Speed Group	**1X Group**	1X	1X	1X	1X	1X	3X
	2X Group	1X	2X	2X	2X	2X	3X
	3X Group	1X	3X	3X	3X	3X	3X

The videos and quizzes were counterbalanced across all the trials by using a Latin Square, Order 6. The distribution of the videos and quizzes across the different trials and video-speeds can be seen in Table 13.

Table 13. Number of times each video is watched across each trial number and video-speed

	T1 (1x)	T2 (1x)	T2 (2x)	T2 (3x)	T3 (1x)	T3 (2x)	T3 (3x)	T4 (1x)	T4 (2x)	T4 (3x)	T5 (1x)	T5 (2x)	T5 (3x)	T6 (1x)	T6 (2x)	T6 (3x)
V1	7	3	3	3	3	3	3	3	2	2	2	3	3	2	3	2
V2	7	3	3	3	2	3	3	3	3	3	3	2	2	2	3	2
V3	8	3	2	2	3	3	2	3	3	2	3	3	2	3	3	2
V4	8	2	2	3	3	3	3	2	3	2	2	2	3	3	2	3
V5	8	3	3	2	2	2	2	2	2	2	3	3	3	3	2	3
V6	9	2	3	2	3	2	2	3	3	3	3	2	2	2	3	3

Procedure

The experiment had anywhere from one to nine participants at a session with each session lasting 1 to 2 hours. The experiment session began by having the participants read the informed consent and answering any questions about the experiment. A pre-experiment script was then followed to inform the students about the logistics of the experiment. These included instructions which standardized the experiment. Some examples include: the experiment must be done on Blackboard through the Google Chrome Browser, the videos should be watched in “full-screen mode”, and notes may **not** be taken during the experiment. The full pre-experiment script is in Appendix J.

The participants were then randomly assigned to one of the three practice speeds. The participants were handed unique task sheets, which contained the order in which to complete the tasks (since the tasks were counterbalanced across participants). An example task sheet can be seen in Appendix K. Next, each participant was given access to the Blackboard course, which contained all of the videos, quizzes, and surveys so that they could begin the experiment. The first task was to watch a warm-up video and to take a warm-up quiz. Each participant then filled out the Pre-Experiment Survey, which asked for their demographic information and their video-watching habits. Then each participant was instructed to complete the tasks in the order that appears in Table 14 below. The video and quiz numbers were specified on each participant’s unique task sheet.

Table 14. Tasks for experiment

Video-speed	Trial	Task
1X video-speed	Trial #1	Video
		Quiz
		NASA TLX Survey
assigned video-speed	Trial #2	Video
		Quiz
	Trial #3	Video
		Quiz
	Trial #4	Video
		Quiz
	Trial #5	Video
		Quiz
		NASA TLX Survey
3X video-speed	Trial #6	Video
		Quiz
		NASA TLX Survey

The video in the first trial was watched at the 1X video-speed (179 wpm) and the video in the sixth trial was watched at the 3X video-speed (573 wpm). The videos in the second through fifth trials (the Practice Trials) were watched at the video-speed that the participants were assigned to (1X, 2X, or 3X).

After both Trial #3 and Trial #5, the participants took a five-minute break to control for fatigue. The break consisted of leaving the room and walking in the hallway. After Trial #6, the student completed the post-experiment survey. The participant was then thanked and debriefed, which included explaining the goal of the experiment and answering any questions about the experiment.

Testing Environment

The experiment was done in a reserved university classroom. This classroom has 25 Dell Optiplex 980 desktop PCs with dual 24” widescreen monitors. All the videos, quizzes, and surveys were accessed using Blackboard through the Google Chrome Browser. The videos were stored in .mp4 files and were watched in full-screen mode. The participants provided their own headphones to listen to the videos, so as not to disturb other participants completing the experiment.

Data Analysis

For this experiment, an alpha level of .05 is considered significant and an alpha level of .10 is considered marginally significant.

Comprehension Score

A three by one ANOVA analysis was performed for the practice speed groups and a six by one ANOVA analysis was performed for the trial number. A six by three ANOVA analysis was also performed to understand the interaction between the practice speed groups and the trial number. To understand the impact of video-speed acceleration, a four by one ANOVA analysis was performed on the decrease in score that occurred in the four instances of video-speed acceleration. Finally, a three by four ANOVA was performed to analyze the interaction between the practice speed groups and the Practice Trials. Figures and tables were created to show the trends across the different practice speed groups and the trial numbers. Finally, paired Student's t tests were performed to understand whether there were significant differences in comprehension between the practice speed groups or trial numbers.

Cognitive Workload

A three by three ANOVA analysis was performed for the three practice speeds and the workload surveys of the three trials. Another three by three ANOVA analysis was performed for the three practice speeds and the mental demands of the three trials. Student's t tests were then performed to compare the individual workloads and mental demands of the practice speed groups and the three trials.

Video-Speed Preference and Perceived Practice Effect

The results to the six questions of the post-experiment survey were analyzed with six one by three ANOVA analyses. The three practice speeds and each question were the treatments for each ANOVA analysis. Student's t tests were then performed to compare the practice speed groups against each other for each of the individual questions.

Limitations and Assumptions

One limitation of this study was the standardization of the videos and associated quizzes. The videos and quizzes were not completely isomorphic because the difficulty indexes were not the same across the quizzes. Due to these limitations, the videos and quizzes were counterbalanced and the participants were randomly assigned to the three practice speeds. Thus, it is assumed that the variability in the videos, quizzes, and participants did not significantly impact the interaction between the practice speeds or the trial numbers.

Another limitation is that there was no extrinsic motivation for the participants to pay attention to the videos or do well on the quizzes. Controlling the environment to limit distractions and supervising the students to ensure they stayed on task helped mitigate this limitation, but these measures do not guarantee motivation.

The scope of the experiment is also limited. The experiment only tested comprehension for concept explanation videos at a high-school or introductory college level. The results should not be extrapolated to different video types, such as videos where the student has to do the example along with the speaker, or to different difficulty levels, such as concepts or examples at an elementary or professional/expert level.

Results

Comprehension

The independent variable *practice speed* was significant in terms of comprehension ($F(2,279)=11.73$, $p<.0001$). The other independent variable *trial number* was also significant in terms of comprehension ($F(5,276)=7.95$, $p<.0001$). However, their interaction was not significant. The effect of these two independent variables on the comprehension score can be seen in Figure 15.

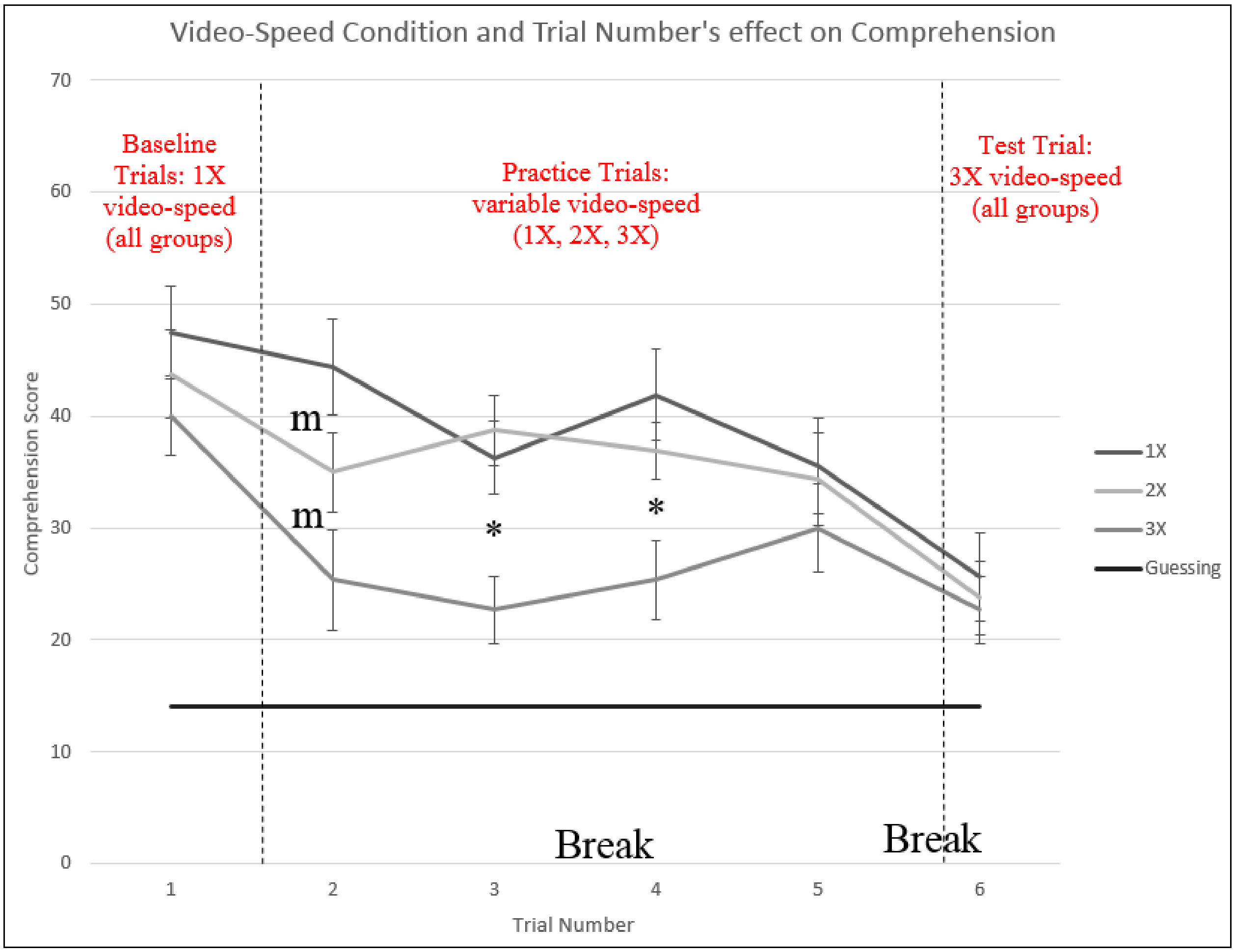

Figure 15. Comprehension Score across Trials and Conditions. *Break*: Five-minute break was given between trials 3 and 4 and trials 5 and 6; n=282 (47 students by six trials). Note:*=significant difference, m=marginal difference

In the Baseline Trial (Trial 1), there was no significant difference in comprehension between the three practice speed groups who all watched the videos at the 1X video-speed.

In the Practice Trials (Trials 2-5), the practice speed had a significant effect on the comprehension level ($F(2,185)=14.59$, $p<.0001$). Student's t tests were then done to compare the practice speeds against each other. It was found that the 3X practice speed group had significantly lower comprehension scores than both the 1X practice speed group ($F(1,185)=26.98$, $p<.0001$, $d=.90$) and the 2X practice speed group ($F(1,185)=15.60$, $p=.0001$, $d=.75$) during the Practice Trials. However, the comprehension scores for the 1X and 2X practice speed groups were not significantly different across the Practice Trials.

In Trial 2, the comprehension levels for all three practice speed groups were marginally or significantly different from each other, as shown in Table 15.

Table 15. Comprehension Score Comparison: Practice Speed Groups in Trial 2; n=47. Note:*=significant difference, m=marginal difference

Trial 2 - Comprehension Score			
Practice Speed Comparison	$F(1,264)$	p	d
1X vs. 2X	3.25	0.073^{m}	.22
2X vs. 3X	3.35	0.069^{m}	.23
1X vs. 3X	12.98	0.0004*	.44

For the rest of the Practice Trials (Trials 3 through 5), the 1X and 2X practice speeds had no significant difference in comprehension scores. The 2X and 3X practice speed groups' comprehension scores were significantly different in Trial 3 ($F(1,264)=9.26$, $p=.0026$, $d=1.33$). They were also significantly different in Trial 4 ($F(1,264)=4.77$, $p=.030$, $d=.96$), but were not in the last Practice Trial (Trial 5). In Trial 5, none of the comprehension scores for the three practice speed groups were significantly different from each other. The average percentage on the comprehension quiz for each practice speed group in the Practice Trials can be seen in Table 16.

Table 16. Average Quiz Grade across Practice Trials by Practice speed; n=188. Note:*=significant difference, m=marginal difference

Practice speed	% Correct on Comprehension Quiz
1X	56%
2X	52%
3X	37%*

In the Test Trial (Trial 6), there were no significant differences between the three practice speed groups who all watched the videos at the 3X video-speed.

Video-Speed Acceleration

From Trial 1 to Trial 2, two of the groups increased in speed. The 2X group increased from the 1X to the 2X video-speed. This led to a marginally significant decrease in score (F(1,264)=2.83, p=.094, d=.21). The 3X group increased from the 1X to the 3X video-speed, which led to a significant decrease in score (F(1,264)=7.46, p=.0067, d=.34). In comparison, the 1X group stayed at the 1X video-speed for these two trials and had no significant change. These changes in comprehension score from Trial 1 to Trial 2 can be seen in Figure 16.

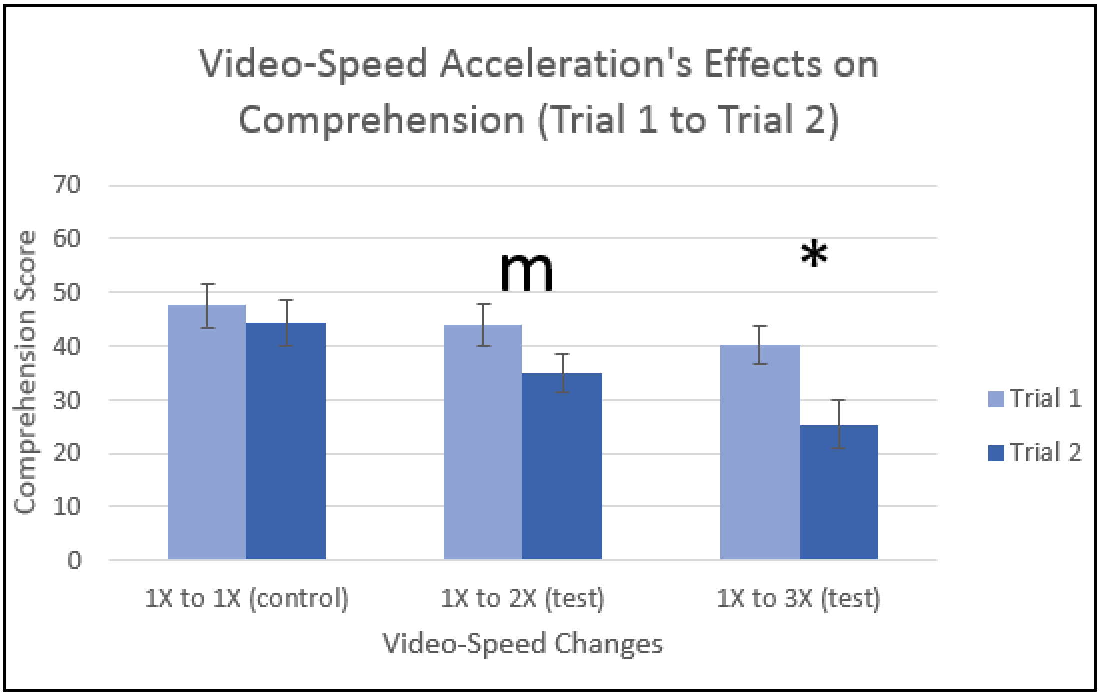

Figure 16. Change in Comprehension after Video-Speed Acceleration (Trial 1 to Trial 2); n=94. Note:*=significant difference, m=marginal difference

From Trial 5 to Trial 6, two of the conditions increased in speed. The 1X group increased from the 1X to the 3X video-speed, which led to a marginally significant decrease in score ($F(1,264)=3.70$, $p=.056$, $d=.24$). The 2X group increased again from the 2X to the 3X video-speed, which led to a significant decrease in score ($F(1,264)=4.18$, $p=.042$, $d=.25$). In comparison, the 3X group stayed the same at the 3X video-speed for these two trials and there was not a significant change in score. These changes in comprehension score from Trial 5 to Trial 6 can be seen in Figure 17.

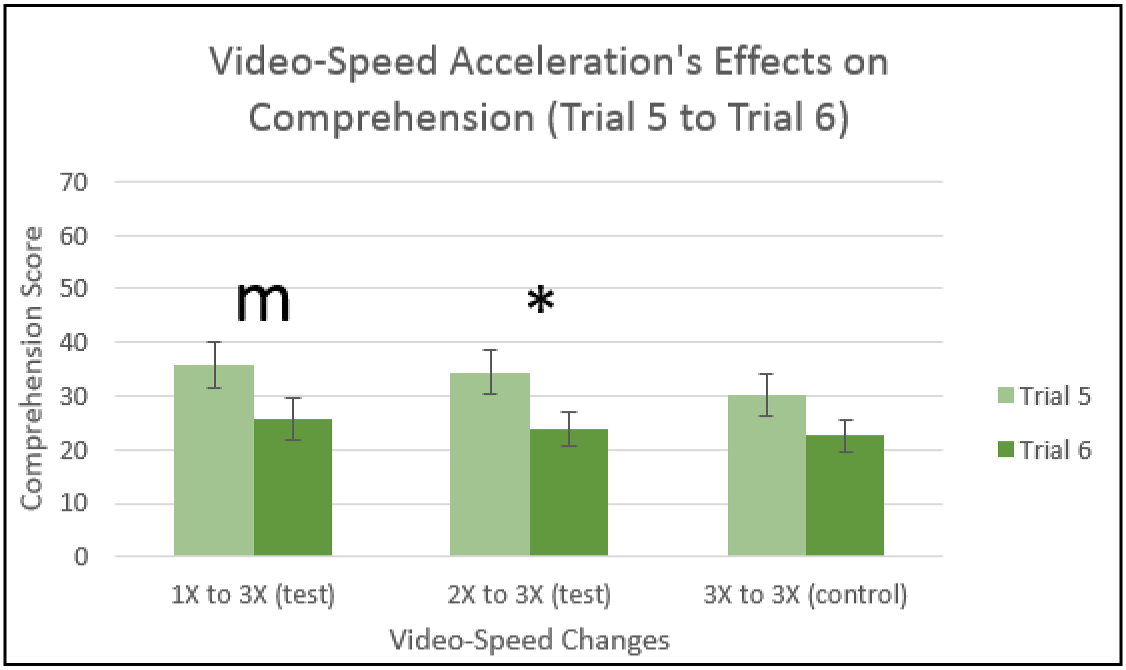

Figure 17. Change in Comprehension after Video-Speed Acceleration (Trial 1 to Trial 2); n=94. Note:*=significant difference, m=marginal difference

Overall, the increase in video-speed from 1X to 2X resulted in a 20% decrease in comprehension score, the increase from the 1X to 3X video-speed resulted in an average of a 32.5% decrease in comprehension score, and the increase from the 2X to 3X video-speed resulted in a 31% decrease in comprehension score. However, the results show there is no significant difference in the decrease in scores between these different instances of video-speed acceleration.

Practice Effect

For the 1X practice speed group, there was a marginally significant decrease in comprehension between Trial 2 and Trial 5 ($F(1,264)=2.83$, $p=.094$, $d=.21$). For the 2X and 3X practice speed groups, the change in comprehension between Trial 2 and Trial 5 was not significant. Figure 18 shows how the Practice Trials impacted the different practice speed groups' comprehension.

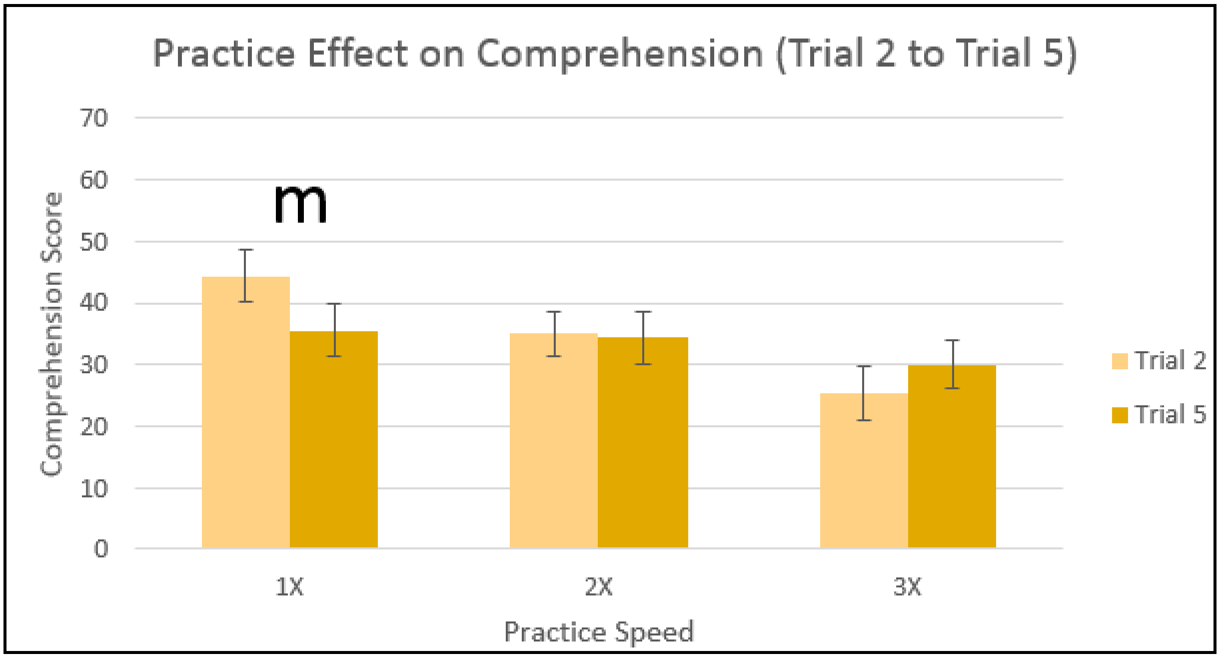

Figure 18. Change in Comprehension during Practice Trials; n=94. Note:*=significant difference, m=marginal difference

The changes in comprehension across the Practice Trials resulted in a convergence of comprehension scores across the three practice groups in Trial 5, which can be seen in Figure 19. In Trial 2, the practice speed is significant ($F(2, 44)=5.34$, $p= .0084$), but in Trial 5 the practice speed is not significant.

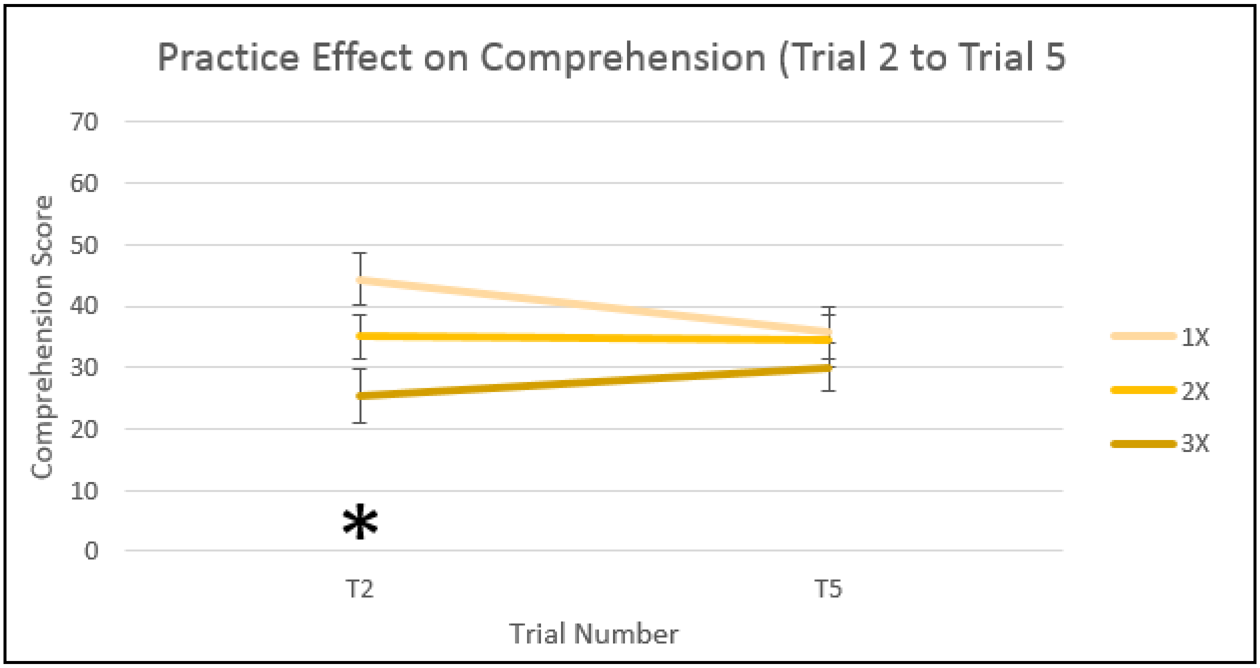

Figure 19. Convergence of Scores during Practice Trials; n=94. Note:*=significant difference, m=marginal difference

Learning Efficiency

The Learning Efficiency metric was measured over the Practice Trials to determine how the various video-speeds impacted the comprehension score gained per minute. The impact can be seen in Figure 20.

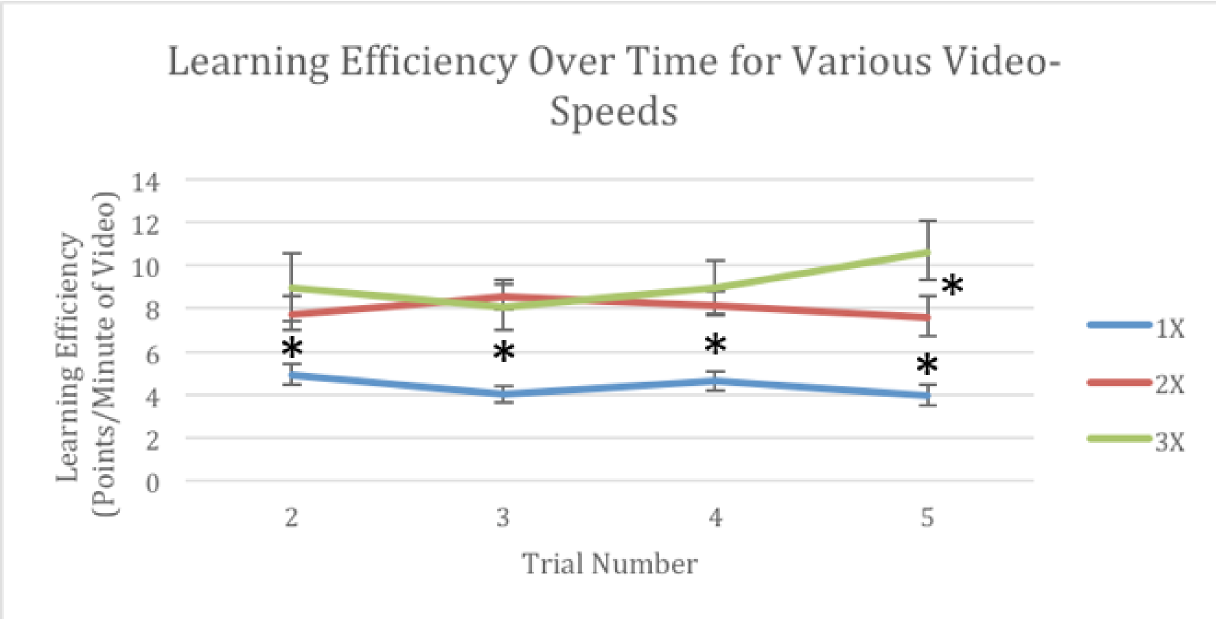

Figure 20. Learning Efficiency (Comprehension Points Earned per Minute of Video watched) across 1X, 2X, and 3X practice speeds during Practice Trials; n=188. Note:*=significant difference, m=marginal difference

The 2X practice speed group has significantly higher learning efficiencies than the 1X practice speed group across all four Practice Trials ($F(1,185)=34.41$, $p<.0001$, $d=.86$). The 3X group also has a significantly higher learning efficiency than the 1X group ($F(1,185)= 57.00$, $p<.0001$, $d=1.11$). The 2X and 3X practice speed groups are not significantly different in the first three Practice Trials, but the 3X practice speed does have a significantly higher learning efficiciency in the fourth Practice Trial ($F(1,176)=5.59$, $p=.019$, $d=.36$).

Cognitive Workload

Workload is the other main metric that was measured throughout the experiment. The results of the three different TLX surveys can be seen across the three different practice speeds in Figure 21.

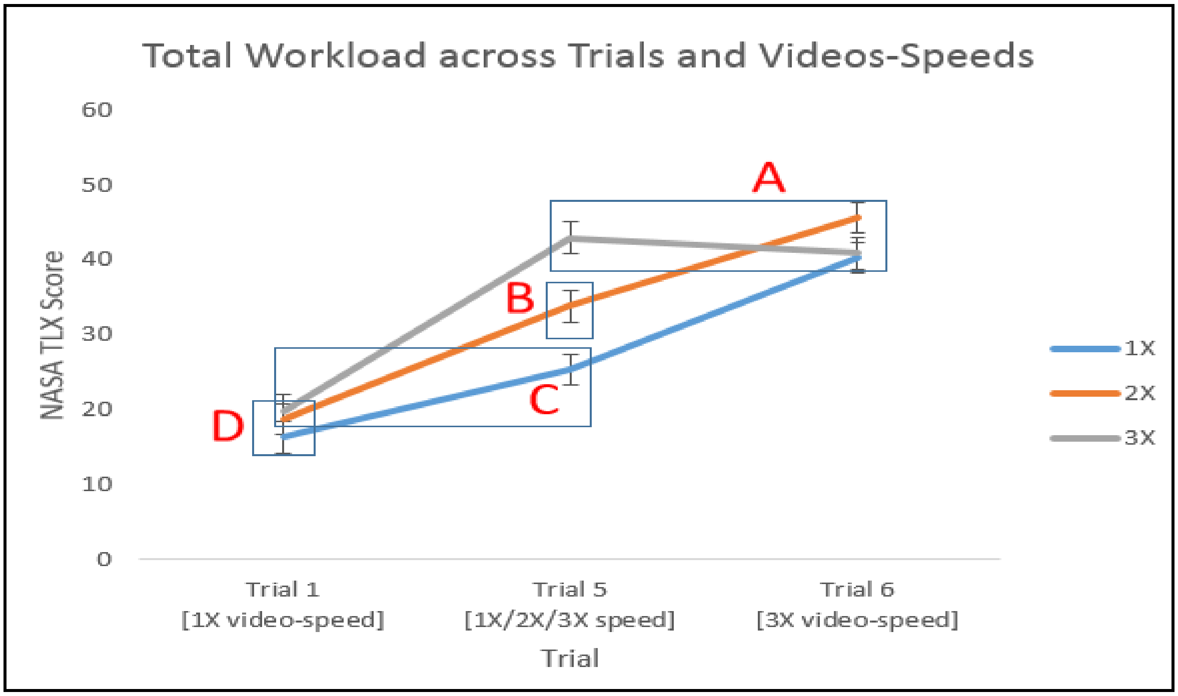

Figure 21. NASA TLX Score across Trials and Video-Speeds; n=141. Note: Boxes represent workloads that are not significantly different.

The boxes in Figure 21 group the values that are not significantly different. Thus, if two points are not in the same box then those points are significantly different. For workload the focus was on video-speed. Box A shows that the workloads of watching videos at the 3X video-speed were not significantly different. Box A groups all the points in the Test Trial (T6) and in the last Practice Trial (T5) for the 3X practice speed group. Box B surrounds the only point where the videos were watched at the 2X video-speed. The 1X video-speed was the only video-speed that had significantly different workloads in different trials. All of the videos that were watched in Trial 1 (1X video-speed) were not significantly different. However, the workload for the 1X practice speed group in the last Practice Trial (T5) had a significantly higher workload than the 1X practice speed group in the Baseline Trial (T1) ($F(1,132)=9.41$, $p=.0026$, $d=.53$).

The results for the Mental Demand Subscale of the NASA TLX are in Figure 22.

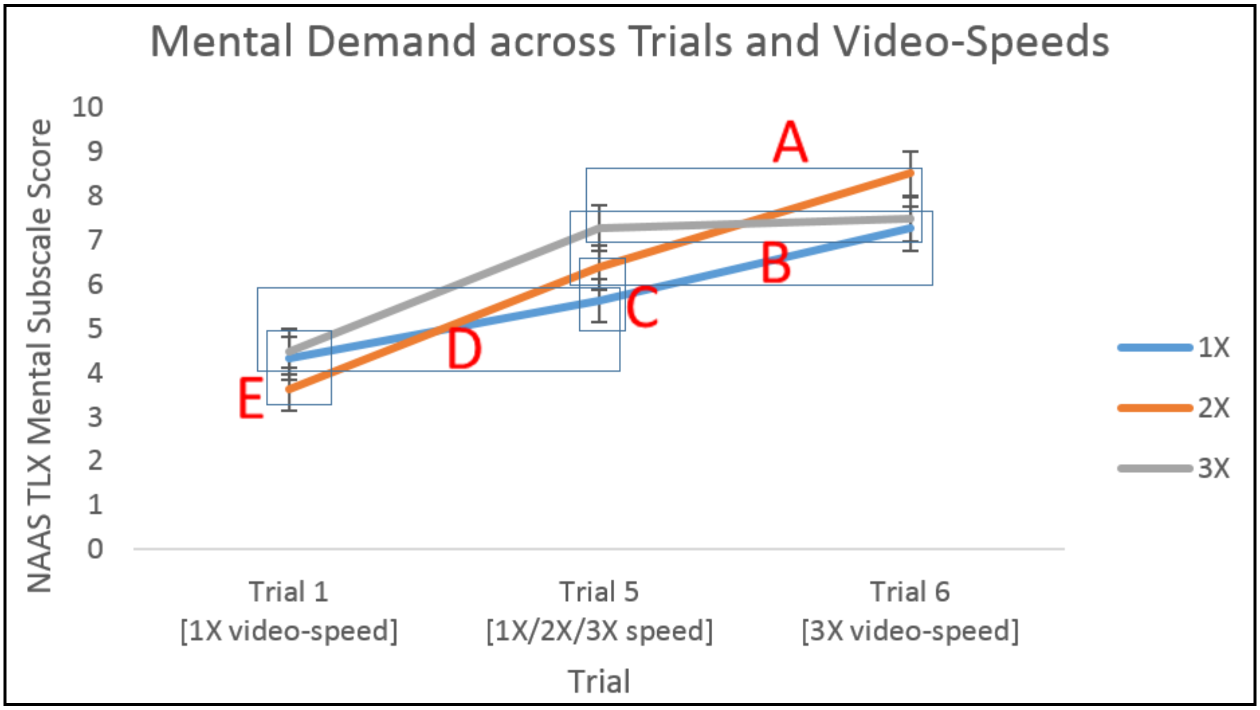

Figure 22. NASA TLX: Mental Demand Subscale score across Trials and Video-Speeds; n=141. Note: Boxes represent workloads that are not significantly different.

The mental demand subscale followed the same trend as the overall TLX results, except neither the 1X and 2X groups nor the 2X and 3X groups were significantly different in the Practice Trials.

Video-Speed Preference

Only three questions (Q2, Q4, and Q6) of the post-experiment survey had results that were marginally or significantly different between the practice speed groups. The results for these three questions can be seen below. The responses to Question #3 will also be discussed because of its direct relationship to Video-Speed Preference.

Question #2 is: *How likely is it that you will speed up educational/lecture videos in the future?* There was a marginally significant difference between the 2X and 3X practice speed groups' responses to this answer ($F(1, 44)=3.46$, $p=.069$, $d=.56$). There was no difference between the 1X or 3X practice speed groups' responses. The results to Question #2 are shown in Figure 23.

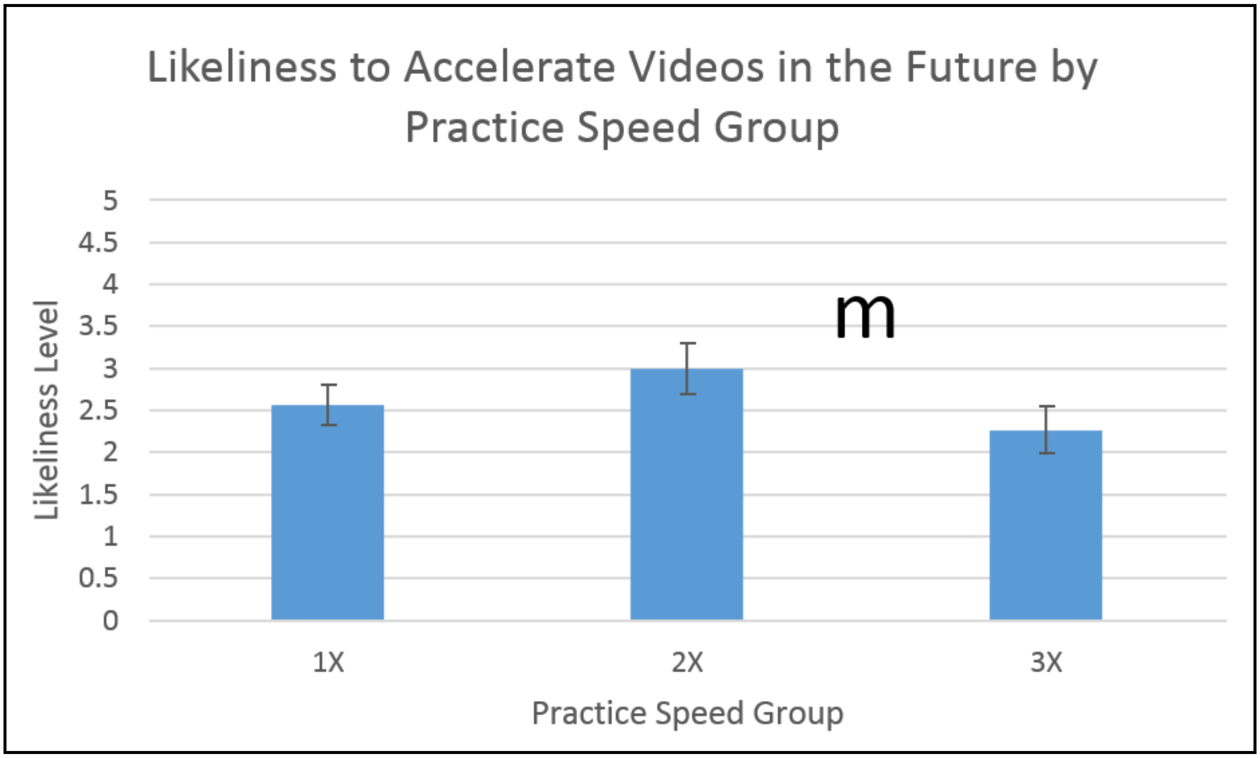

Figure 23. Video-Speed Future Habits by Practice Speed Group; n=47. Note:*=significant difference, m=marginal difference

The 2X group had the highest average response with this question, which was a 3 on the Likert Scale. That response corresponds to "Neither likely nor unlikely".

Question #4 is: *How much do you agree with the following: It was more difficult to comprehend the videos at the faster speed compared to the videos at the slower speed*. The response to this question from the 3X practice speed group was significantly different from the 1X practice speed group ($F(1, 44)=5.27$, $p=.027$, $d=.69$) and marginally different from the 2X practice speed group ($F(1, 44)=3.22$, $p=.080$, $d=.54$). The 1X and 2X practice speed groups were not significantly different. The agreement level for each practice speed group is shown in Figure 24.

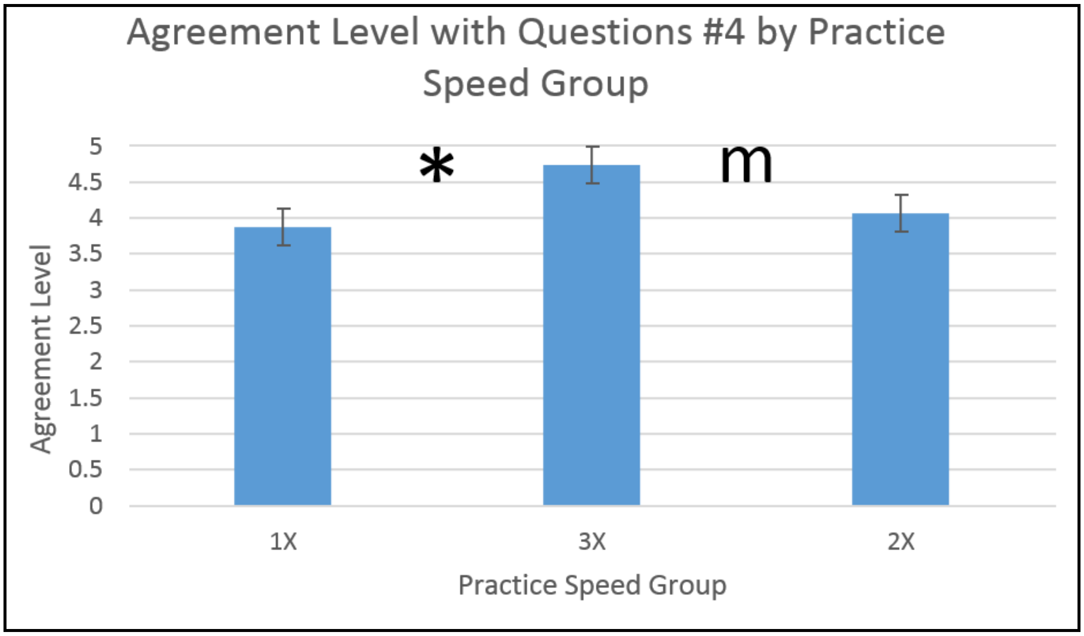

Figure 24. Perception of Difficulty of Comprehending Accelerated Videos by Practice Speed Group; n=47. Note:*=significant difference, m=marginal difference

This figure shows that the practice speed groups were around the 4 or 5 agreement level, which correlates to “Agree” or “Strongly Agree”.

Question #3 is: *How much do you agree with the following: I preferred watching the videos at the faster speed compared to the slower speed.* There were no significant differences between the three practice speed groups on this question. The responses demonstrate that the participants did not prefer the accelerated videos. The average response was 2.52 out of 5 with a standard deviation of 1.16, which means there was much variation in the responses. The average response of 2.52 is between “Disagree” and “Neither agree nor disagree”.

Perceived Practice Effect

Questions #6 pertains to the perception of a practice effect. It asks: *How much do you agree with the following: A video was easier to comprehend after watching a few other videos* ***at the same speed***. Figure 25 shows that the 1X practice speed group agreed the most and the 3X practice speed group agreed the least. The difference between the 1X and 3X practice speed groups’ responses is significant ($F(1, 44)=4.32$, $p=.043$, $d=.63$).

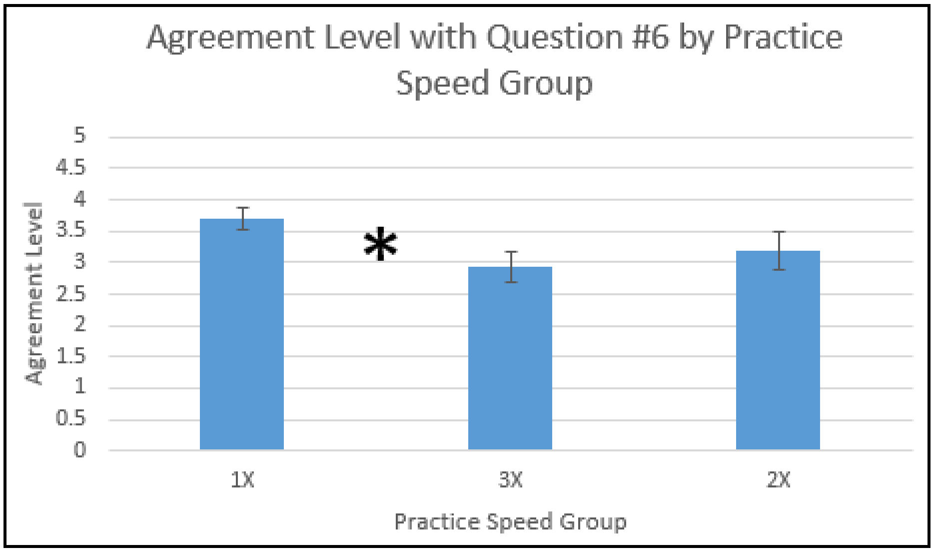

Figure 25. Perception of the Practice Effect by Practice Speed Group; n=47. Note:*=significant difference, m=marginal difference

The practice speed groups were around the 3 or 4 agreement level, which correlates to "Neither Agree nor Disagree" or "Agree".

Other Variables

Besides practice speed group and trial number, the only other variable that was significant in this experiment were the videos and the quizzes that tested comprehension of the videos ($F(5, 276)=12.8656$, $p<.0001$). The only videos that were not significantly different from each other were videos #1 and #5 and videos #2, #3, and #6. The video number was not included in the earlier analyses because the videos were counterbalanced across the trials and practice speed groups.

Other variables were analyzed for significance, but were found to not be significant. These include:

- Gender (male/female)
- Whether the participant was a native English speaker (yes/no)
- Class standing (freshman, sophomore, junior, senior)

- GPA
- Whether the student had prior experience watching videos at faster speeds (yes/no) Note: The students that had prior experience typically watched videos at a rate of 1.5X or less.
- The frequency at which individuals watch videos at faster speeds (more than a month, less than a month, less than a week, less than a day)

Discussion

Hypothesis #1

Hypothesis #1 states: *Initially, video acceleration will result in lower comprehension and higher cognitive workload. The changes in comprehension and workload will both increase in magnitude as the change in video-speed increases.* This hypothesis was almost completely supported by the results.

Without practice, comprehension decreased significantly or marginally significantly and cognitive workload increased significantly as videos were accelerated by a factor of the normal speed (1X to 2X, 2X to 3X, or 1X to 3X). However, the various decreases in comprehension that occurred from the different magnitudes of video-speed acceleration were not significantly different, even when the increase in video-speed was twice as great.

These results demonstrate that videos should not be accelerated to 2X normal speed or more if full comprehension is a top priority, especially if the important information is at the beginning of the video. However, full comprehension is not always the top priority, so the next subsection explains how practice comprehending accelerated videos could impact comprehension.

Hypothesis #2

Hypothesis #2 states: *After 18 minutes or less of practice watching accelerated videos, comprehension of accelerated videos will increase from its initial levels and preference for higher video-speeds will also increase.* There is not much evidence to support the hypothesis that 18 minutes of practice is sufficient to increase comprehension and preference at accelerated video-speeds.

The comprehension did not increase with practice. During the Practice Trials, there were no significant increases in comprehension among any of the practice speed groups. There was also limited participant perception of a practice effect for those in the accelerated practice speed groups (2X and 3X). Participants in the 1X practice speed group had the highest agreement with the fact that videos got easier to watch with practice while participants in the 3X practice speed group had the lowest agreement.

The preference for faster video-speeds also did not increase with increased video-acceleration; instead it decreased. The preference for the accelerated videos was highest for the 1X and 2X practice speed groups and lowest for the 3X practice speed group. Thus, compared to the control, preference actually decreased with exposure to the faster video-speeds.

Other Effects

Despite the lack of evidence for Hypothesis #2, there were other effects within the Practice Trials that were significant. In the first Practice Trial, the practice speed groups' comprehension levels were significantly different, but at the end of the Practice Trials, none of the groups' comprehension levels were significantly different. This convergence of the practice speed groups' comprehension levels over the Practice Trials occurred because the 1X practice speed group's comprehension level decreased, the 2X practice speed group's comprehension level remained the same, and the 3X practice speed group's comprehension increased. In fact, the 1X practice speed group's comprehension level decreased so rapidly that after the first Practice Trial, the 2X practice speed group's comprehension was not significantly different from the 1X practice speed group's comprehension.

This convergence could be from a variety of reasons: 1. The 1X group had to spend two or three times as long watching videos during the Practice Trials than the other two groups, leading to increased fatigue or boredom. 2. The accelerated videos caused the students to consistently focus throughout the Practice Trials because the increased speed used all of the students' cognitive capacity, which did not allow for distracting thoughts. 3. The novelty of the accelerated video engaged the 2X or 3X group participants throughout the Practice Trials. 4. Practice actually helped students comprehend the accelerated videos better, but the result was confounded by fatigue/boredom, so as not to be noticed in the experiment.

There are also many other plausible explanations. However, none of the above reasons were tested in the experiment; thus, more testing is needed to isolate the cause of the convergence. Regardless of the reason, the convergence of comprehension levels is a significant result. After one video, participants were able to comprehend consequent videos at the 2X video-speed as well as the participants at the 1X video-speed. After three videos, participants in the 3X group were able to comprehend the last Practice Trial video as well as the 1X and 2X groups.

In the Practice Trials, the learning efficiency was about twice as high for the 2X and 3X video-speeds compared to the 1X video-speed. This correlates to comprehending new facts from lecture twice as quickly. This time-savings is significant. If a student took 15 credits each semester, had all classes that used video lectures, and watched the videos at 2X normal speed, then the student would save 900 hours[8] of lecture over the course of a four-year degree.

The example above uses the 2X video-speed because the results show that acceleration at the 2X video-speed has a higher learning efficiency than the 1X video-speed and higher comprehension compared to the 3X video-speed. The 2X video-speed group was also able to maintain its comprehension level, despite the fatigue, boredom, or other effects that impacted the 1X video-speed group. Thus, 2X video-speed is useful if time is a priority and full comprehension is not. However, it’s important to note that 2X video-speed is not a universal recommendation for every situation. While learning efficiency is important, readers must also understand their priorities before deciding their preferred video-speed. Everyone in the experiment scored the highest on the first comprehension quiz after watching the video at the 1X video-speed. This demonstrates that if comprehension is the main goal, then it is important to watch videos at the 1X video-speed and take frequent breaks to reduce the effects of fatigue or boredom.

[8] Assuming 15-week semesters and lecture material is one hour per week per credit hour

CHAPTER VI: CONCLUSION

Summary of Findings

This research was broken down into three main studies. Study 1 strove to create an introductory engineering course that first-year engineering students performed well in and preferred by testing the effectiveness of TBL and video lectures. Study 1 found that there was a slight increase in performance with TBL and that students did prefer the TBL pedagogy and video lectures compared to a traditional lecture-based class.

Study 2 was derived from the desire to understand if lecture videos were a good investment and how students were using this investment. Study 2 discovered that three-quarters of the students did use the video lectures, but only half of the students watched at least two-thirds of the videos. It also found that about half the general student population accelerates lecture videos, but usually only to a maximum of 1.5X normal speed.

Study 3 originated because the surveys from Study 1 and Study 2 demonstrated that students liked the video lectures, but many were not getting through all the video content due to time constraints. Video acceleration appeared to be a natural fix for this. Thus, Study 3 tested how accelerated videos, with and without practice, impacted comprehension and preference. Study 3 demonstrated that video acceleration does significantly decrease comprehension. However, the 2X video-speed group's comprehension level did not decrease across the Practice Trials, unlike the participants at the 1X video-speed. Together, these studies provide a framework of implications for educators, especially those teaching introductory engineering courses.

Implications

The results of these three studies provide insights into creating effective and efficient classrooms. The majority of students preferred the TBL pedagogy with video lectures and the instructors noted that it was much easier to develop relationships with students in this model. The students also enjoyed the collaboration and interactivity that occurred in-class and the control over their learning outside of the classroom. The first-year students appeared to adapt well to the non-traditional pedagogy and there is some evidence that they performed better than previous students that completed the course using the traditional model. For these reasons, TBL with video lectures is recommended.

Students tend to watch videos in the 1-1.5X video-speed range, but under certain situations, educators may want to recommend that students accelerate videos beyond that range or even accelerate the videos themselves prior to distribution. Acceleration to the 2X video-speed may be useful when full comprehension of the video is not necessary, when time is constrained, and the amount of video to watch is of considerable length (>10 minutes) since fatigue or boredom is more likely to occur with longer videos. However, the complexity of the video, the motivation level of the students, and the video type will also impact whether accelerated video should be used.

Thus, more research is needed on video acceleration, but based on the results of these studies, video acceleration seems to be useful for TBL for several reasons. First, only 40-50% comprehension is expected prior to the RAP stage in TBL, which is when the videos are watched. Second, multiple students indicated they loved the ability to accelerate the videos and said that it even helps them focus more. Third and finally, accelerating videos has much higher learning efficiency, thus saving students' time.

The education and retention of first-year engineering students is very important to keep up with the global demand for engineers (Holdren & Lander, 2012; Marra et al., 2012). The TBL pedagogy provides a preferential environment where the student can engage with their peers and instructors. This preferential environment and increased engagement should decrease boredom and increase retention (Mann & Robinson, 2009). With the level of understanding needed in the preparation phase of TBL, video acceleration up to 2X normal speed could be used in TBL. With the increase in learning efficiency that video acceleration allows, students will save a great deal of time, allowing them to get through their coursework faster and thus, using their engineering knowledge sooner.

Future Work

These three studies demonstrate that team-based learning with video lectures provides several advantages for first-year engineering students, including the ability to accelerate the lecture videos outside of class. However, much more research is needed in the areas of TBL, video-speed preference, and video-speed's impact on student comprehension.

Team-Based Learning. More definitive results about TBL with video lectures could be obtained by focusing on the limitations of this study. A within-subjects test of TBL with video lectures would create an environment where the students' ability and experience level of the instructor would not change. This experimental design would entail having the instructor change pedagogy from TBL to traditional week-by-week, so the two pedagogies could be compared directly. The next semester or in another course section, the instructor could start with the opposite pedagogy to counterbalance the previous results.

Future work is also needed with virtual team-based learning. With the movement towards MOOCs and online learning that use lecture videos, more research needs to be performed about how team-based learning could be performed virtually and at a large scale. Since the general engineering curriculum (Chemistry, Calculus, Physics, etc.) at most four-year universities is the same, these courses would be a good place to start testing virtual team-based learning.

Video-Speed Preference. The video-speed preference surveys were done on a limited scale for this study. Research was done on whether Panopto or Echo360 currently record at which video-speeds students watch lecture videos. Unfortunately, these two software services do not. If video software could record the video-speeds at which segments of videos are watched, then a vast amount of information could be obtained about video-speed preferences. This information includes which course subjects and parts of videos are typically accelerated and how video-speed preferences change over type. If demographic information could also be obtained through the software, then a plethora of information could be obtained about how different subsets of the population use video acceleration.

Video-Speed Experiment. One main limitation about the accelerated video recommendation is that the participants were not motivated to score well on the quizzes or pay attention to the videos. Thus, a motivated individual may have maintained the maximum comprehension level that the participants scored in Trial 1. Thus, future work is needed to test video acceleration’s effect on a real class to understand its impact on motivated students.

Future work is also needed to understand why the three practice speed groups converged after the four Practice Trials. Understanding the effects that caused this convergence would help clarify video-speed recommendations. Boredom, fatigue, and engagement should all be measured in future experiments since they are the most likely reasons to have caused the convergence effect.

Along with these two recommendations, other facets of this experiment should be tested in future experiments. These facets include: the magnitude of the video-speeds tested, videos that are more or less complex, video types where the student has to do the example along with the video, video instructors that can be seen and that teach with PowerPoint or other typical lecture software, video instructors of different genders and ethnicities and with different accents and clarity of voice, the amount and length of breaks that are given during the experiment, daily practice for two years or more (similar to the practice blind adults incur), and the impact of practice sessions with day-long breaks between participants' trials.

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APPENDIX A: IE 148 FINAL SURVEY

Effects of Team-Based Learning and Video Speed on Learning Outcomes

Survey: Interacting with Video Lectures

This survey is voluntary and can be stopped at any time. Any questions in this survey may be skipped.

If you decide not to participate in this survey, that decision will not affect your grade in IE 148. If you decide to participate, then your answers to this survey will not affect your grade in IE 148.

1. At what rate do you normally listen to the lecture videos where Ben is the primary speaker:
    a. .5 x normal speed
    b. .75 x normal speed
    c. 1.0 x normal speed
    d. 1.25 x normal speed
    e. 1.50 x normal speed
    f. 1.75 x normal speed
    g. 2.0 x normal speed

2. At what rate do you normally listen to the lecture videos where Leslie is the primary speaker:
    a. .5 x normal speed
    b. .75 x normal speed
    c. 1.0 x normal speed
    d. 1.25 x normal speed
    e. 1.50 x normal speed
    f. 1.75 x normal speed
    g. 2.0 x normal speed

3. If you don't listen to the video lecture at "normal speed", which of the following are the main reasons that you listen to it at a different speed? (Circle all that apply)
    a. The concepts are new to you
    b. The concepts are complicated
    c. To be able to do the examples along with the speaker
    d. You've learned about the concepts before
    e. The concepts are simple
    f. To get through the videos as fast as possible
    g. Other:

4. In the last month have you changed the rate that you normally listen to the video lectures at?
    a. Yes
    b. No

5. If you answered, “Yes” to question 4, do you listen to the videos at a faster or slower rate than you used to?
    a. Faster
    b. Slower
    c. N/A
6. How many times during a 15-minute lecture video, on average, do you go back and re-watch something?
    a. 0
    b. 1-2
    c. 3-4
    d. 5-6
    e. 7+
7. How many times during a 15-minute lecture video, on average, do you pause the video to check to see that your example matches the example on the screen?
    a. 0
    b. 1-2
    c. 3-4
    d. 5-6
    e. 7+
8. How many times during a 15-minute lecture video, on average, do you change the rate of the video?
    a. 0
    b. 1-2
    c. 3-4
    d. 5-6
    e. 7+
9. How many times during a 15-minute lecture video, on average, do you enlarge the main screen (the screen that usually has Excel or the VB editor on it)?
    a. 0
    b. 1-2
    c. 3-4
    d. 5-6
    e. 7+
10. How many times during a 15-minute lecture video, on average, do you enlarge the speaker screen (the screen that shows Ben or Leslie)?
    a. 0
    b. 1-2
    c. 3-4
    d. 5-6
    e. 7+
11. How many times do you re-watch all or part of a video after watching the entire video?
    a. Never
    b. Almost never
    c. Half the time
    d. Almost always
    e. Always

12. What grade do you expect to get in IE 148?
    a. A- to A
    b. B to B+
    c. C+ to B-
    d. C- to C
    e. D to D+
    f. D- or lower
13. What is your current GPA at Iowa State University?
    a. 3.5-4.0
    b. 3.0-3.49
    c. 2.5-2.99
    d. 2.0-2.49
    e. 1.5-1.99
    f. N/A
14. What GPA do you expect to have at the end of the semester?
    a. 3.5-4.0
    b. 3.0-3.49
    c. 2.5-2.99
    d. 2.0-2.49
    e. 1.5-1.99
    f. N/A
15. How does the IE 148 team-based learning framework and video lectures compare to the other classes that you are taking that are more traditional lecture-style classes?
    a. Much better
    b. Somewhat better
    c. The same
    d. Somewhat worse
    e. Much worse
16. Why did you answer the way you did in Question 15?

17. What was your ACT and/or SAT score?

ACT: ____________

SAT: ____________

18. What comments do you have about the videos or their speed?

[TEXTBOX]

19. Would you be willing to be interviewed about your experiences with the videos?
[ ] Yes
[ ] No

APPENDIX B: RECOMMENDATIONS FOR TRANSFORMING TO TBL[9]

3.1 For instructors considering transforming to TBL: questions to be asked/answered

Deciding to flip part or all of a course requires important considerations before and during implementation:

- Will you use video? If so
  - What hardware and software meet both instructor and student needs in terms of accessibility, etc.
  - What purchases need to be made? Allow time to get things installed, understand your system, and test video creation and viewing prior to the course starting.
  - Have videos already been created that cover the subject area? Can they be used?
  - If not, who will do the video recording? If there is more than one instructor, dividing this responsibility makes it more manageable.
  - Do all of your students have access to the videos and sufficient bandwidth to watch them?
  - Can your videos be publically accessible? Are there copyright or university policies that address this?
  - What technical support do you have available to you?
- How will you motivate students to do the preparation? If it will include TBL, will you
  - Have RATs, and if so, will they be individual, team, or both?
  - Will you purchase IF-AT forms or make your own answer sheets?

3.2 For instructors considering transforming to TBL: lessons learned

- What works
  - 24/7 access but limited to enrolled students worked well for video accessibility.
  - Ask students for feedback on video and methods; they will buy into the concept better with input.
  - Recording and editing videos takes significantly longer than might be estimated. Depending on familiarity with and flexibility of software, plan for at least three times as long to record a video than to prepare for a traditional lecture, at least initially.
  - Having time to work with students 1-on-1 allows for more personalized and timelier instruction.
  - RATs must be formative; save summative assessments for exams and projects.
  - Video format best received (for this course) was presenter + PowerPoint + example software.
  - Take full examples out of teaching videos and make separate example videos.
  - Overview videos, which provide introductions to concepts, are well received by students.
- What doesn't work
  - Not all students will be motivated to prepare before class, and TBL will not necessarily provide enough incentive (i.e. social pressure) to do so. As students get farther behind, they get more frustrated, and either they do very poorly or they drop the class. This is no different from a traditional classroom, but the authors emphasize that a flipped format and TBL are not a panacea.
  - Flipping doesn't necessarily provide enough in-class time to complete the homework that was given in the traditional format classroom.
  - Using multiple versions of RATs each week reduces cheating (which is easier for students to do on multiple choice quizzes), but makes document creation and control harder to manage.
  - Trying to make quality (content, length) videos on tight time schedules is challenging.

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[9] The recommendations in Appendix B are adapted from: Potter, L., & Jacobson, B. (2015). Lessons Learned from Flipping a First-Year Industrial Engineering Course. In *ISERC*.

APPENDIX C: VIDEO-SPEED PREFERENCE SURVEY

Video-speed_Preference_A_General Survey

Note: This survey will be taken electronically. What follows is the list of questions to be used.

Video-Speed Preference Survey

1. What is your gender? [Male, Female option buttons]
2. What is your age? [Textbox]
3. Is English your native language? [Yes, no option buttons]
4. What is your Ethnicity? [Option buttons below]

[ ] AM – American Indian/Alaskan Native
[ ] AS – Asian Pacific Islander
[ ] HM – Hispanic, Mexican/Chicano
[ ] HP – Hispanic, Puerto-Rican Mainland
[ ] NR – Non-Resident Alien
[ ] WH – White, Non-Hispanic
[ ] AR – Arabic
[ ] BL – Black, Non-Hispanic
[ ] HO – Hispanic, Other
[ ] HR – Hispanic, P-R Commonwealth
[ ] UN – Unknown
[ ] MR – Multi-Racial

5. What is your year in school (by credit)? [Freshman, Sophomore, Junior, Senior, Graduate student option buttons]
6. What is your GPA? [Textbox]
7. What type of learner do you consider yourself to be? Check all that apply. ["Auditory", "Visual", "Kinesthetic", "Don't Know" check boxes]
8. Have you watched a video at a faster than normal rate before? (i.e. a video sped up by a certain rate, like 1.5x or 2x normal speed) [Yes, No option buttons]

   If you answered "no", please skip questions 9-12 and submit this survey.
9. At which rate do you normally speed up the videos you watch? [1.25x, 1.5x, 1.75x, 2.0x, Other:________ option buttons]
10. How recently have you watched a video at a faster than normal speed? [Less than a day,
11. When you watch a video that can be sped up, how frequently do you speed it up? [Never, Rarely, Sometimes, Most of the time, Always option buttons]
12. What types of videos do you normally speed up? Check all that apply. [Movies, Lecture Videos, YouTube videos, Other (can list more than one type, separated by commas, if applicable): __________________ checkboxes]

APPENDIX D: KHAN ACADEMY VIDEOS – VIDEO-SPEED EXPERIMENT

Warm-up video: **Flow through the heart**

URL: https://www.khanacademy.org/science/health-and-medicine/circulatory-system/fetal-circulation/v/flow-through-the-heart

Video #1: **Scale of earth and sun**

URL: https://www.khanacademy.org/science/cosmology-and-astronomy/universe-scale-topic/scale-earth-galaxy-tutorial/v/scale-of-earth-and-sun

Video #2: **Gibbs free energy example**

URL: https://www.khanacademy.org/science/chemistry/thermodynamics-chemistry/gibbs-free-energy/v/gibbs-free-energy-example

Video #3: **Types of immune responses: Innate and adaptive. Humoral vs. cell-mediated**

URL: https://www.khanacademy.org/science/health-and-medicine/human-anatomy-and-physiology/introduction-to-immunology/v/types-of-immune-responses-innate-and-adaptive-humoral-vs-cell-mediated

Video #4: **Pattern of US Cold War Intervention**

URL: https://www.khanacademy.org/humanities/history/euro-hist/cold-war/v/pattern-of-us-cold-war-interventions

Video #5: **Blood Sugar Levels**

URL: https://www.youtube.com/watch?v=JSFiOF7xGfE

Video #6: **Bonds vs. stocks**

URL: https://www.khanacademy.org/economics-finance-domain/core-finance/stock-and-bonds/stocks-intro-tutorial/v/bonds-vs-stocks

APPENDIX E: QUIZ QUESTIONS – VIDEO-SPEED EXPERIMENT

Quiz #1

1. How large is the earth's circumference?

   a) 25,000 km
   b) 30,000 km
   c) 35,000 km
   d) 40,000 km
   e) 45,000 km

2. How fast is a bullet or jetliner?

   a) 800 km/hr
   b) 1,000 km/hr
   c) 1,200 km/hr
   d) 1,400 km/hr
   e) 1,600 km/hr

3. How many days would it take you to travel around the circumference of the sun in a jetliner?

   a) ~150 days
   b) ~165 days
   c) ~180 days
   d) ~195 days
   e) ~210 days

4. How large is one astronomical unit (AU)?

   a) 150 km
   b) 150,000 km
   c) 15,000,000 km
   d) 150,000,000 km
   e) 1,500,000,000 km

5. How long would it take a bullet (assuming it never lost its initial velocity) to get to the sun?

   a) ~7 days
   b) ~7 months
   c) ~17 months
   d) ~7 years
   e) ~17 years

6. If the sun was scaled to have a five-inch diameter (the first sun that was shown in the video), how far away would the earth be (assuming the scale is kept)?

a) ~50 feet away
b) ~70 feet away
c) ~90 feet away
d) ~40 yards away
e) ~60 yards away

7. The partially shown sun (the second sun shown in the video) was how large in diameter, according to the speaker?

a) 15 inches
b) 20 inches
c) 25 inches
d) 30 inches
e) 35 inches

Quiz #2

1. What three things are needed to calculate the change in Gibbs Free Energy?

a) Hertz, Temperature, and Entropy
b) Heat Formations, Standard Molar Entropies, and Thermal Gradient
c) Gibbs coefficient, Energy coefficient, and Temperature
d) Enthalpy, Temperature, and Entropy
e) Heat, Thermal Gradient, and Sublimation

2. What type of reaction occurred in the video?

a) Endothermic
b) Sublimation
c) Isothermic
d) Synthesis
e) Exothermic

3. What were the units of measure for the final answer to this equation?

a) J/K*mol
b) No units
c) J
d) KJ
e) KJ/K

4. Why was the reaction spontaneous?

a) The change in Gibbs Free Energy equaled 0

b) The loss of energy was greater than the loss in entropy at standard temperature
c) The change in Gibbs Free Energy was greater than 0
d) There was a significant difference between the thermal gradients of the reactants and the products
e) There was a significant difference between the heat formations of the reactants and the products

5. Which of the following would cause the reaction to NOT be spontaneous?

a) If the reaction happened on the sun
b) If the reaction had a negative thermal gradient
c) If the reaction happened at absolute zero (0K)
d) If the change in H was -100 instead -890
e) If the molecules in this reaction had a higher Gibbs coefficient

6. The reaction combines which molecules?

a) 2 gas molecules
b) 2 liquid molecules
c) 3 gas molecules
d) 3 liquid molecules
e) 1 gas and 1 liquid molecules

7. After the reaction occurs, how many and what types of molecules are left?

a) 2 gas molecules
b) 2 liquid molecules
c) 1 gas and 1 liquid molecule
d) 1 gas and 2 liquid molecules
e) 2 gas and 1 liquid molecules

Quiz #3

1. What is a type of a non-specific barrier in your immune system that was mentioned in the video?

a) Hair
b) Stomach Acid
c) Liver enzymes
d) Red Blood Cells
e) White Blood Cells

2. What are non-specific phagocytes?

a) Hair
b) Stomach Acid
c) Liver Enzymes
d) Red Blood Cells
e) White Blood Cells

3. Which of the following is NOT TRUE about specific and non-specific immune systems?

a) Specific is adaptive and non-specific is not
b) Specific delivers a specific inflammatory response to certain viruses while non-specific does not
c) Specific requires exposure to bacteria and viruses while non-specific does not
d) Non-specific and specific can both incorporate white blood cells
e) Non-specific's only criteria is to 'eat up' things with double stranded DNA in order to protect the body

4. Where does the 'B' in B-lymphocytes come from?

a) Bacterium
b) Bilk
c) Blood
d) Boham
e) Bursa

5. What type of response does the B-lymphocyte participate in?

a) Thymus
b) Bacterial
c) Humoral
d) Bone Marrow
e) Red Blood Cell

6. What is the first line of defense for your immune system?

a) non-specific barriers
b) non-specific inflammatory response
c) non-specific response
d) specific/adaptive response
e) specific T-lymphocytes

7. What is the second line of defense in your immune system?

a) non-specific inflammatory response
b) specific/adaptive response
c) non-specific response
d) specific T-lymphocytes

e) specific B-lymphocytes

Quiz #4

1. Korea was under the colonial rule of which group?

a) China
b) Soviet Union
c) Japan
d) France
e) Western Europe

2. Cuba was under the colonial rule of which group?

a) Batista/Soviet Union
b) Castro/Soviet Union
c) Batista/United States
d) Castro/United States
e) Kennedy/United States

3. Vietnam was under the colonial rule of which group?

a) China
b) Soviet Union
c) Japan
d) France
e) United States

4. How did people become wealthy under colonial rule?

a) By doing questionable things for the controlling country
b) By doing entrepreneurial activities
c) By doing questionable things for the controlling country or by doing entrepreneurial activities
d) The majority did by doing questionable things for the controlling country with a few doing entrepreneurial activities
e) The majority did by do

5. What results did the three leaders that the U.S. tried to install in Korea, Vietnam, and Cuba achieve?

a) Wins only
b) Wins and stalemates
c) Wins, stalemates, and losses

d) Stalemates and losses
e) Losses only

6. What type of political ideology did Il-Sung, Castro, and Minh create in their respective societies in order to maintain continuous revolution?

a) Communist
b) Socialist
c) Marxist-Lenin
d) Capitalist
e) Colonial

7. Who did the United States support in Korea/Vietnam?

a) Rhee/Diem
b) Korean exiles/Vietnam exiles
c) Il-Sung/Minh
d) Batista/Castro
e) Capitalist rulers/socio-capitalist rulers

Quiz #5

1. What was the example the speaker gave for something that was NOT a normal meal?

a) A pint of honey
b) A quart of ice cream
c) A handful of desserts
d) A cup of sugar
e) A liter of soda

2. What ranges did the speaker draw for the x-axis and y-axis?

a) x-axis: 0 to 2 hours
y-axis: 0 to 200 mg/dL
b) x-axis: 0 to 8 hours
y-axis: 0 to 200 mg/dL
c) x-axis: 0 to 8 hours
y-axis: 0 to 250 mg/dL
d) x-axis: 0 to 24 hours
y-axis: 0 to 200 mg/dL
e) x-axis: 0 to 24 hours
y-axis: 0 to 250 mg/dL

3. For a normal person, what is the maximum level that your blood sugar concentration should be?

a) 30 mg/dL
b) 80 mg/dL
c) 120 mg/dL
d) 140 mg/dL
e) 180 mg/dL

4. For a normal person, what is a normal blood sugar level?

a) 30 mg/dL
b) 80 mg/dL
c) 120 mg/dL
d) 140 mg/dL
e) 180 mg/dL

5. You should consult a doctor if your blood sugar concentration is over what minimum range after fasting (not eating for a long time)?

a) High 100s to mid 110s
b) High-120s to mid 130s
c) High-140s to mid 150s
d) High-180s to mid-190s
e) High 200s to mid 210s

6. You should consult a doctor if your blood sugar concentration after a meal is over what minimal level?

a) 100 mg/dL
b) 140 mg/dL
c) 180 mg/dL
d) 200 mg/dL
e) 220 mg/dL

7. What were the three lines that were drawn on the chart?

a) Diabetic, Worried, Normal
b) Pre-prandial, Prandial, Post-Prandial
c) Diabetic, Possibly Diabetic, Not Diabetic
d) High Blood Sugar, Mid-High Blood Sugar, Normal Blood Sugar
e) Seek Medical Attention, Monitor Levels, Normal

Quiz #6

1. In this example, how does the company finance its debt?

   a) The company has plenty of money, so it doesn't need to finance its debt
   b) The company gets a 30-year, fixed rate bank loan for $6,000,000
   c) The company sells 6000 $1,000 bonds
   d) The company sells 10,000 $1,000 bonds
   e) The company gets a 30-year, fixed rate bank loan for $10,000,000

2. What did the speaker think was a great idea?

   a) Equity Financing
   b) Bond Financing
   c) The socks company
   d) Buying stocks over bonds
   e) Buying bonds over stocks

3. How much was each share worth in this example?

   a) $0.40
   b) $1.00
   c) $2.00
   d) $4.00
   e) $10 million

4. What is a security?

   a) The information on a company that a bank must see before the bank gives the company a loan
   b) The information on a company that stockholders want to see annually
   c) Something that can be bought or sold that has some sort of economic value
   d) The insurance that can cover a company's debt if it goes bankrupt
   e) Something that balances the difference between assets and equity in a company

5. Bonds are used to allow borrowing from which entity?

   a) The government
   b) Public markets
   c) Banks
   d) Municipalities
   e) Shareholders

6. What is a zero-coupon bond?

   a) A bond that only exists electronically, not physically

b) A bond that has no interest payments
c) A bond that doesn't give you stake in the company
d) A bond that doesn't give you discounts on the products/services of the company
e) A bond that has a higher interest rate than normal bonds

7. Why are quotes on bond prices not as easy to get as stock prices, according to the video?

a) The bond market isn't as big as the stock market
b) Bonds aren't as risky as stocks
c) There isn't as high of a demand for information about bonds as there is for stocks
d) Bond traders don't want bond prices to be transparent
e) Bond prices fluctuate a lot more than stock prices

APPENDIX F: ITEM ANALYSIS

Table 17 shows the results of the item analysis for the six quizzes. The results show that the discriminability of the quizzes is very high with only one question having a D value of 0.23, which is considered “Fair’ instead of “Good”. The difficulty of the questions was more variable. However, the majority of the questions are in the medium difficulty area, which has a standard deviation of 1.21.

Table 17. Item Analysis for the six quizzes

	Difficulty (P)				Discrimination (D)		
Quiz	Easy (>80%)	Medium (30 to 80%)	Hard (<30%)		Good (>.3)	Fair (.1 to .3)	Poor (<.1)
#1	1	5	1		7	0	0
#2	0	4	3		7	0	0
#3	0	4	3		7	0	0
#4	2	3	2		7	0	0
#5	1	6	0		6	1	0
#6	0	6	1		7	0	0
Standard Deviation	**0.82**	**1.21**	**1.21**		**0.41**	**0.41**	**0.00**

APPENDIX G: PRE-EXPERIMENT SURVEY

Note: This survey was taken electronically

1. What is your gender? [Male, Female option buttons]
2. What is your age? [Textbox]
3. Is English your native language? [Yes, no option buttons]
4. What is your Ethnicity? [Option buttons below]

[ ] AM – American Indian/Alaskan Native

[ ] AS – Asian Pacific Islander

[ ] HM – Hispanic, Mexican/Chicano

[ ] HP – Hispanic, Puerto-Rican Mainland

[ ] NR – Non-Resident Alien

[ ] WH – White, Non-Hispanic

[ ] AR – Arabic

[ ] BL – Black, Non-Hispanic

[ ] HO – Hispanic, Other

[ ] HR – Hispanic, P-R Commonwealth

[ ] UN – Unknown

[ ] MR – Multi-Racial

5. What is your year in school (by credit)? [Freshman, Sophomore, Junior, Senior, Graduate option buttons]
6. What is your GPA? [Textbox]
7. What type of learner do you consider yourself to be? Check all that apply. ["Auditory", "Visual", "Kinesthetic", "Don't Know" check boxes]
8. Have you watched a video at a faster than normal rate before? (i.e. a video sped up by a certain rate, like 1.5x or 2x normal speed) [Yes, No option buttons]

   If you answered "no", skip to question #13

9. At which rate do you normally speed up the videos you watch? [1.25x, 1.5x, 1.75x, 2.0x, Other:________ option buttons]
10. How recently have you watched a video at a faster than normal speed? [Less than a day, Less than a week, Less than a month, More than a month option buttons]
11. When you watch videos that can be sped up, how frequently do you speed them up? [Never, Rarely, Sometimes, Most of the time, Always option buttons]
12. What types of videos do you normally speed up? Check all that apply. [Movies, Lecture Videos, YouTube videos, Other (can list more than one type, separated by commas, if applicable): ___________________ checkboxes]
13. Do you have an above average amount of background knowledge in any of the following topics? [each answer will be a checkbox]
    a. Blood Sugar Levels as related to Diabetes
    b. The Immune System and types of Immune Responses
    c. U.S. involvement in the Cold War
    d. Astronomy, specifically about the Sun and the Earth
    e. Gibbs Free Energy (Chemistry principle) ☐
    f. How Blood flows through the Heart (Biology)
    g. Bonds and Stocks

APPENDIX H: NASA TLX Survey

NASA Task Load Index

Hart and Staveland's NASA Task Load Index (TLX) method assesses work load on five 7-point scales. Increments of high, medium and low estimates for each point result in 21 gradations on the scales.

Name	Task	Date

Mental Demand — How mentally demanding was the task?

Very Low — Very High

Physical Demand — How physically demanding was the task?

Very Low — Very High

Temporal Demand — How hurried or rushed was the pace of the task?

Very Low — Very High

Performance — How successful were you in accomplishing what you were asked to do?

Perfect — Failure

Effort — How hard did you have to work to accomplish your level of performance?

Very Low — Very High

Frustration — How insecure, discouraged, irritated, stressed, and annoyed wereyou?

Very Low — Very High

Note: Participants were told that the task was to understand the video that they had just watched. Thus, the participants were told the performance attribute should be ranked based on how well they understood the video.

APPENDIX I: POST-EXPERIMENT SURVEY

Note: This survey was taken electronically.

1. How comfortable were you with the speed of the last video? [“Very Uncomfortable”, “Somewhat Uncomfortable”, “Neither Comfortable nor Uncomfortable”, “Somewhat Comfortable”, “Very Comfortable” Likert scale option buttons]
2. How likely is it that you will speed up educational/lecture videos in the future? [“Very Unlikely”, “Somewhat Unlikely”, “Neither Likely nor Unlikely”, “Somewhat Likely”, “Very Likely” option buttons]

   How much do you agree with the following statements (question 3-6)?

3. I preferred watching the videos at the faster speed compared to the slower speed. [“Strongly agree”, “Agree”, “Neutral”, “Disagree”, “Strongly Disagree” Likert Scale option buttons]
4. It was more difficult to comprehend the videos at the faster speed compared to the videos at the slower speed.

   “Strongly agree”, “Agree”, “Neutral”, “Disagree”, “Strongly Disagree” Likert Scale option buttons]
5. I learned more (per video) from the videos at the faster speed compared to the videos at the slower speed. [“Strongly agree”, “Agree”, “Neutral”, “Disagree”, “Strongly Disagree” Likert Scale option buttons]
6. A video was easier to comprehend after watching a few other videos *at the same speed*. [“Strongly agree”, “Agree”, “Neutral”, “Disagree”, “Strongly Disagree” Likert Scale option buttons]

APPENDIX J: PRE AND POST EXPERIMENT SCRIPT

Pre – Experiment Script:

- Thank you for coming to complete the experiment today!
- Do you have headphones with you?
- Before we begin, I need you to read this informed consent and sign it if you agree to it.
    - Please note that you can leave the experiment or take a break for any reason at any time
    - Please note that there is an alternative extra credit option if you are doing this experiment for extra credit
- The experiment will be done on Blackboard, so all you need to do is to log into BB on a computer in this lab (I will specify the computer). The course is called "Extra Credit – Video-Speed Training" and you will select folder B.
- Please use Google Chrome to run Blackboard
- In the folder you will complete tasks according to the order they appear on a paper I give you.
- Click on the video link; don't click on the video player in Blackboard.
- For the raised hand part, please just come get me at that time
- Note: The videos are in order based on the last number; they are group together. Also, please notice that the workload surveys are not in order.
- Be sure to double check what you are clicking on to make sure that it matches what is next on your task sheet.
- Be sure to check off each task as you go through your task sheet.
- Make sure you are enlarging the size of the video to be the maximum size of the screen

- The first video is the warm-up video. Please use this video to figure out the volume settings and how the videos work.
- Please do not touch the controls for the video player (i.e. don't fast-forward or rewind any of the videos) – you can adjust the volume at any time, however.
- Please don't open the quiz until you have watching the entire video for that quiz. I know when you open the quiz and so you're data will be invalidated if you do that.
- Please raise your hand after taking each quiz. I will have you take breaks after two of the quizzes. You can get a drink/bathroom if you want, but you must walk around for at least 5 minutes.
- You may **not** take notes.
- Workload survey will ask questions about a task. The task is watching and learning from the video you just watched.
- If you have any problems or questions, please raise your hand and I will assist you.
- You may begin. Thanks again!

Post-Experiment Script

- Thank you for completing the experiment!
- The experiment is now over. You are free to leave. Thank you!

APPENDIX K: EXAMPLE TASK SHEET

- ☐ Warm-up Video
- ☐ Warm-up Quiz
- ☐ Pre-Survey
- ☐ Video #11
- ☐ Workload Survey #1
- ☐ V #1 Quiz
- ☐ Video #12
- ☐ V #2 Quiz
- ☐ Video #13
- ☐ V #3 Quiz
- ☐ Please raise your hand
- ☐ Video #15
- ☐ V #5 Quiz
- ☐ Video #16
- ☐ Workload Survey #2
- ☐ V #6 Quiz
- ☐ Please raise your hand
- ☐ Video #24
- ☐ Workload Survey #3
- ☐ V #4 Quiz
- ☐ Post-Survey
- ☐ Please raise your hand

Note: “Please raise your hand” indicates a time when the student had to take a five-minute break or when the student was done with the experiment.