International Journal of Engineering Education Vol. 30, No. 3, pp. 566–575, 2014
Printed in Great Britain
0949-149X/91 $3.00+0.00

Effect of Supplemental Instructional Videos on Student Performance in Engineering Mechanics Class*

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Short, instructor-created videos were introduced to a junior-level engineering mechanics class for use as a supplementary resource. The videos focus on a single course concept and demonstrate appropriate problem-solving technique. This technique was found to appeal to students across a variety of majors and learning style preferences and was shown to be effective regardless of a student's past academic history. Many students realized modest to moderate improvement in performance on homework assignments and exams by using the videos as a review. Based on student feedback and access patterns, the videos are shown to serve as a valuable supplement (but not a replacement) for traditional in-classroom instruction. The future of digital content libraries and virtual environments for learning is also discussed.

Keywords: video learning; asynchronous learning; online learning

1. Background and introduction

The effect of supplemental instructional videos on students' mastery of key concepts and problem-solving techniques was studied by introducing a suite of short instructor-developed videos into an introductory engineering course. This course's main focus was introducing the engineering problem-solving method in the context of engineering mechanics concepts. The videos demonstrated the procedure for solving representative problems through the understanding and application of key course concepts. By design, most videos were between five and ten minutes in length. Videos were created to demonstrate the application of most major topics in the course.

In order to assess the impact of these on-demand tutorials, we collected demographic and academic performance statistics were gathered for each student enrolled in a sophomore-level mechanics course during the fall and spring semesters: gender, cumulative GPA prior to the start of the course, grades on mid-term and final exams, final grade in the course, learning style preferences (using Felder's Learning Style Inventory, [1]), and video usage trends. Video usage was tracked using Blackboard's statistics tracking feature, showing when each student accessed each video.

Using these data, we evaluated the impact of the videos on learning and the effects of academic history, gender, and learning style preference on the likelihood that the student would use and benefit from the videos. Additionally, we gathered data through anonymous course-end-feedback surveys seeking specific opinions about the video resource.

The sample population consisted of a total of 349 students from two semesters (182 from the fall semester and 167 from the spring semester). Students taking the course in the fall were non-engineering majors from a variety of mathematics, science, social sciences, and humanities backgrounds. Enrollees in the spring semester were generally engineering majors. Course content and organization did not change between semesters. The combined student population included 325 men and 24 women (see Fig. 1).

The students' majors represented a diverse selection of the fields of study offered at our institution. The distribution of academic majors is shown in Fig. 2.

A course-wide administration of Felder's Learning Styles Inventory showed that the students preferred a variety of learning styles (see Fig. 3). This student population consisted primarily of Sensing, Visual, Active, and Sequential learners, which Felder and Silverman [2] found was the most common learning style preferences among engineering students, a significant subset of our student population.

2. Rationale and need for the study

The past decade's revolution in remote connectivity is changing the face of education. Education, at its root, is the communication of ideas between people. Before this revolution, this communication most usually took place in formal classrooms and during informal in-person meetings and distance education consisted of a student completing course requirements with a textbook, course notes, and perhaps some live or taped video viewing of lectures at a location somewhere other than the classroom.

Distance education students completed assignments and mailed them to the professor. With the

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* Accepted 20 October 2013.

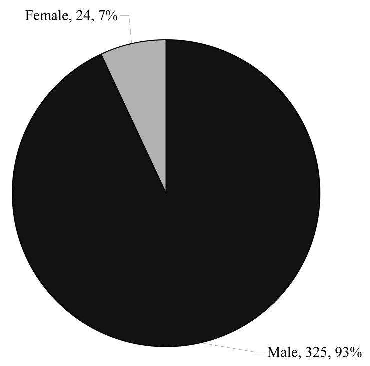

Fig. 1. Student population gender distribution.

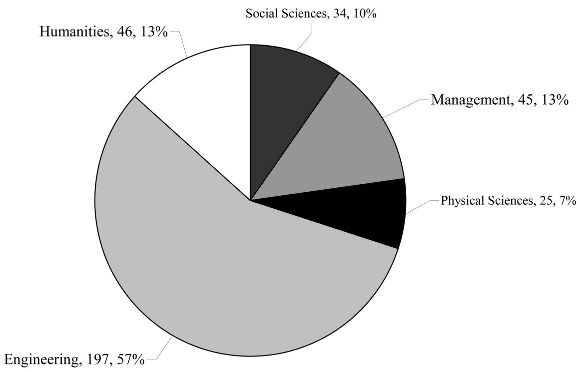

Fig. 2. Course Enrollment by Category of Major.

advent of the internet, these distant students' access to instructors, fellow students, and course material improved; materials are now accessed through internet portals, and conversations can take place via e-mail and/or chat rooms. Video-teleconferencing technology further improved capabilities by enabling real-time interaction between student and teacher.

Outside of the classroom, the same technologies that improved distance education have caused a significant shift in the way we access information. We can now get news, watch television shows, and access almost all our entertainment content remotely. Individuals have the freedom to get the information and entertainment they want at the moment they want it, with near-total control over the timing and venue of the presentation [3].

The expectation and reality of control over information flow outside the classroom translates to new challenges and new possibilities for education. These changes have developed more slowly in the education arena than in others, but it is reasonable to believe that the current generation of college students desire more control over their education, much as they do over information in other aspects of their lives. Prensky [4] refers to students today as "digital natives"—they have grown up with ubiquitous technological devices and internet access, which they use regularly to maintain social contact, obtain news, and for entertainment. They have, in the process, become used to pulling information to themselves on an as-needed and near-instant basis, and are less content with simply allowing information to be pushed to them according to educational or other needs that have been selected for them by others.

This has presented a significant quandary for the entertainment industry and for education, and innovative solutions will be needed. In the entertainment industry, the effects of changes in content can be readily measured; the number of hits on a

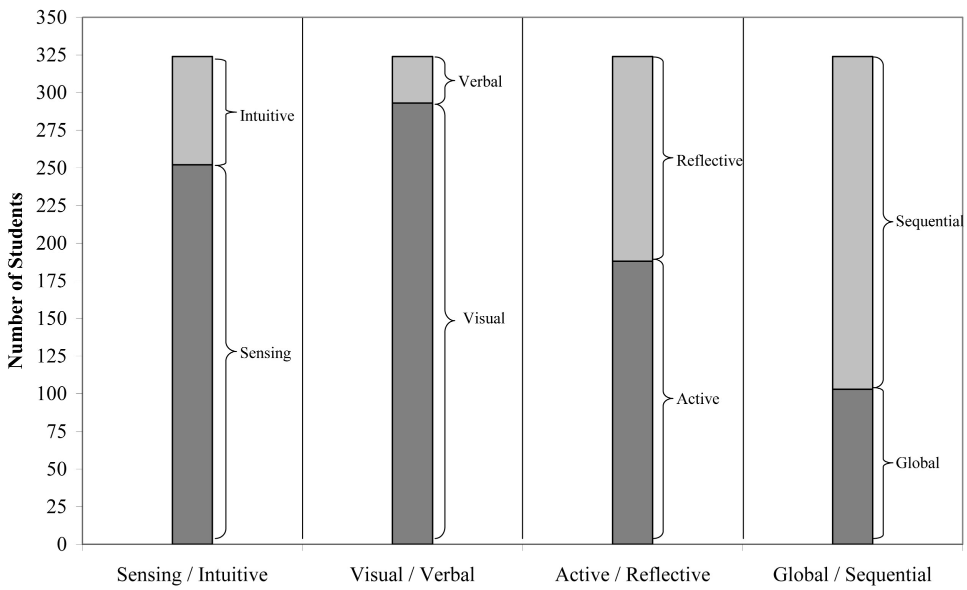

Fig. 3. Learning Style Preferences for Students Enrolled in CE300.

website, the number of views on YouTube, the number of downloads of a song or movie from iTunes or Netflix.

Competing with modern students' drive towards pull content is Prensky's assertion that most teachers are "digital immigrants" who must gradually adapt to the technology that their students take for granted. Students today are increasingly "bewildered", "disappointed", and even "disillusioned and dispirited" in the way that these digital immigrant teachers attempt (or, in many cases, do not attempt) to integrate technology into coursework [5]. This finding is strongly corroborated by recent research by the Pew Internet and American Life Project ([6]. In the authors' experience, the slow response of Universities and their faculty to the emergence of social networks also speaks to the gap between student expectations (nearly every student visits Facebook daily, for instance) and their "non-Native" professors. Thus, the question all teachers should be asking is: How can we harness technological advances to improve our courses? A second question is: How can we ensure that the technological advances appeal to our students and improve their learning?

This paper describes the introduction of a pull information resource into a junior-level Statics and Mechanics of Materials course: a suite of short instructional videos developed by course instructors and posted on a course website. The effect of the videos on student performance in the course is analyzed, and the role of the videos in students' learning is discussed.

3. Description of instructional videos

The instructional videos created for this study were between five and ten minutes long and focused on discussion of isolated concepts or demonstrations of specific problem-solving technique.

They were not videographic records of an instructor's presentation in class or lecture-length discussions; based on informal conversations with students, we believed that short videos would allow students to focus on problem areas and were more likely to be used than longer-format videos. In addition, class attendance is required and rigorously enforced at our institution, so a lecture-length record of in-class activities would have been redundant for our students. In institutions where class attendance is left to the student's discretion, a video record of instruction may prove to be a valuable benefit to students who are not able to attend class or who are part of the institution's distance learning program. Instructors must weigh this benefit against the possibility that making videos of their lessons available to students may disincentivize classroom attendance by in-residence students and prevent them from contributing to the lesson by answering questions and participating in classroom discussion.

Many software packages may be used to create the instructional videos, and the hardware requirements are minimal. We used Camtasia screencasting software to capture the videos, and a tablet computer with stylus input to capture handwritten notes in digital ink. A wide variety of screencasting and digital whiteboard software programs are available both for traditional computers and for tablets and smartphones. Many are free to download. In addition, an instructor may find it convenient to use a video camera to record himself/herself working a problem or explaining a concept on paper, whiteboard, or chalkboard.

The videos were generally simple in nature and were designed to replicate the student's experience solving problems for the class. The instructor worked problems in his or her own handwriting over a PowerPoint slide set up to resemble problem worksheets commonly used in class. The instructor narrated the process as the problem solution progressed. A standard microphone headset was used to improve audio quality. Editing was minimal; occasionally, the videos were re-recorded to eliminate an accidental error in the problem-solving process or misspoken explanation, but we did not conduct detailed sound editing to refine vocal presentation or remove background noises, nor did we edit together multiple "takes" of a problem to optimize the presentation. We created the recordings in our offices or classrooms, not in a recording studio. The instructors who created the videos had minimal prior experience in creating, editing, or producing videos and required little training to operate the software. The process was specifically designed to make recording easy on faculty, in order to encourage production of as many videos as possible and minimize reliance on outside technical support. We distributed the videos on the course's Blackboard site.

4. Analysis of the practice: student use and outcomes

4.1 Usage patterns for instructional videos

In order to maximize the educational benefits to the course, the videos were made available to all enrolled students. While this made it impossible to compare students using the videos to a traditional control group, it did permit observation of the rate at which students chose to use the resource. Students chose to make use of the videos to varying degrees; 257 (73.6%) students watched at least one video and 92

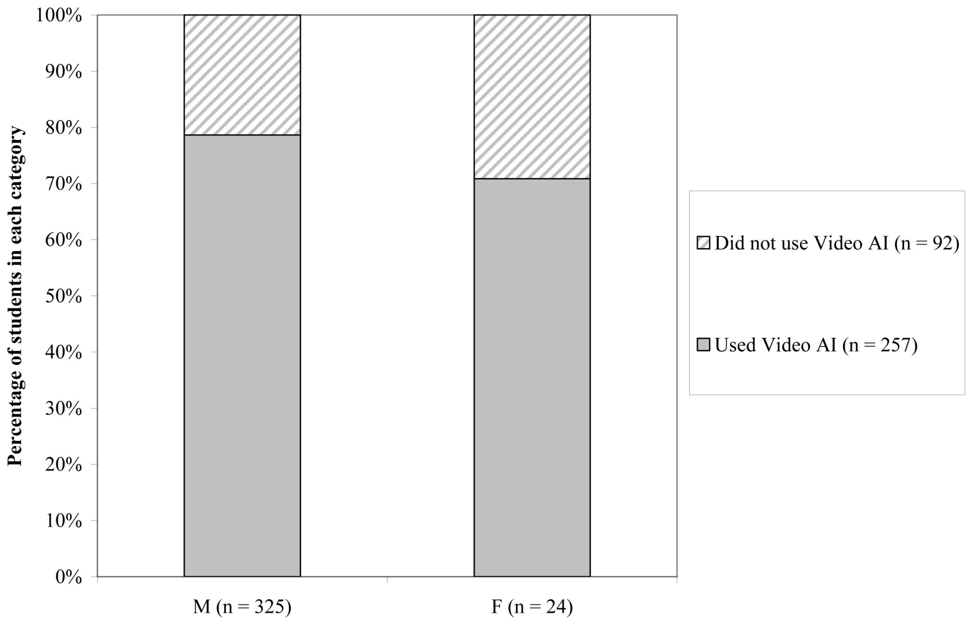

Fig. 4. Video Usage by Gender.

(26.4%) students watched none. Although the videos were used throughout the semester, usage peaked immediately prior to graded assignment due dates and mid-term exams. The highest usage occurred on the day prior to the final exam.

The user vs. non-user groups showed somewhat similar demographics with respect to gender, major course of study, learning style preference, and academic history. Figures 4–7 illustrate the demographic characteristics of students who chose to use or not use the instructional videos. These figures show that men were about 10% more likely to use the resource than women; engineering students were about 15% more likely than those in other disciplines; and students with low to average past academic performance were significantly more likely to use the videos than the students with the highest grade point averages.

4.2 Academic benefit

During the initial offering of the instructional videos, when videos were developed and released mid-semester, students who used the resource while studying for a midterm exam experienced a measur-

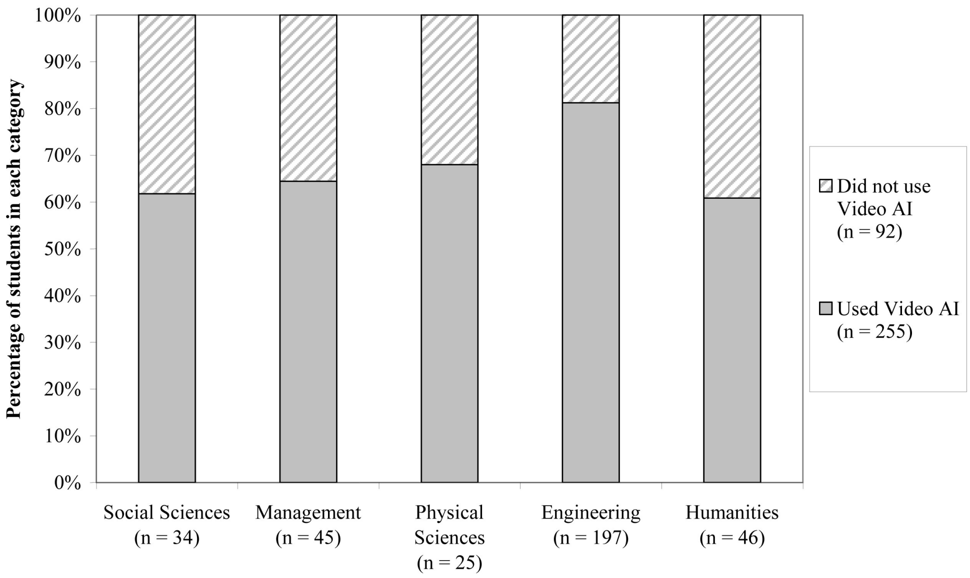

Fig. 5. Video Usage by Category of Major.

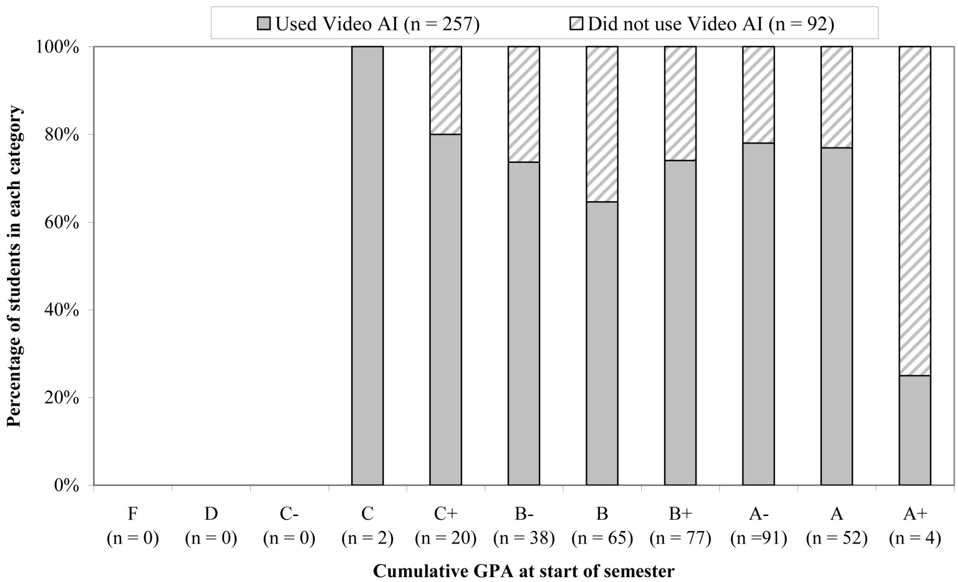

Fig. 6. Video Usage by Cumulative GPA at Start of Semester.

able academic benefit: they scored much better than they had scored on an earlier midterm exam, before the instructional videos were available [7]. To more rigorously investigate the hypothesis that using the videos improved the students' academic performance, the range of topics covered in the instructional video library was expanded and the videos were made available to students in the next academic year. Ideally, each student using the videos during the study period would have a "control" counterpart: a student of similar major, gender, academic ability, and learning preferences who did not choose to use the videos, allowing reliable isolation of the academic benefit the student derived from using the videos during the semester. Such close matching of students who did and did not choose to use the videos was not feasible given the actual student population in the course. To isolate the effect of using the videos, the student's course-end grade was predicted based on his or her grade-point average prior to starting the course. The predicted grade was then used as the student's virtual control: his or her actual performance in the course was compared to predicted performance, and the difference was assumed to derive from use of instructional videos.

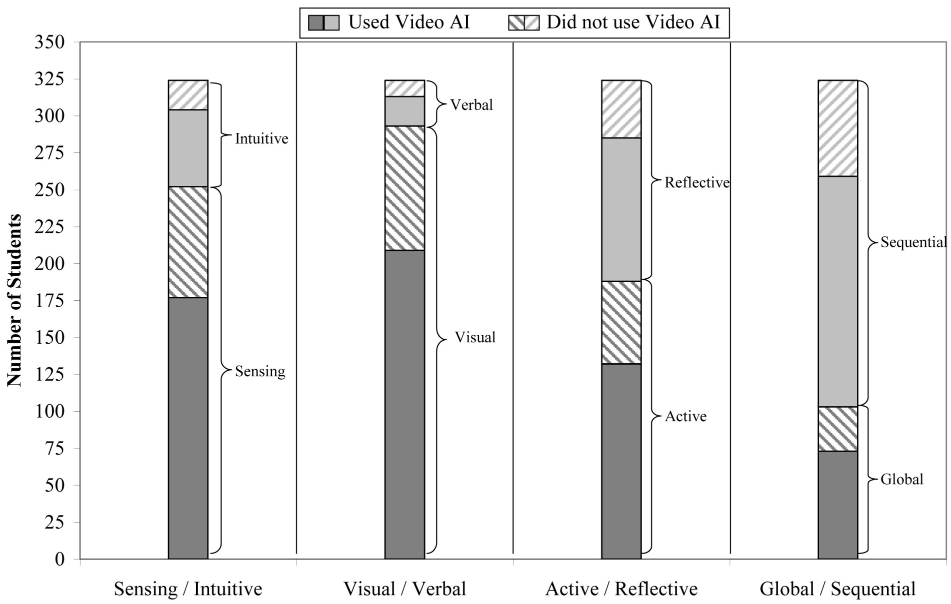

Fig. 7. Video Usage by Learning Style Preference.

4.3 Predicting course-end grades

Because the distribution of student grades in the course was generally skewed positively, with a few outliers of exceptionally high or low performers, we fit a Pearson Type III distribution to the logarithm of the students' entering GPA values and used this distribution to predict their final course grades. Further discussion of the reason for the selection of this probability distribution is included in [3].

This approach minimized the distortion caused by the skewed distribution and presence of outliers.

Figure 8 show that students who made use of the videos during the semester saw better-than-predicted grades at the end of the course at a higher rate than students who did not use the videos. The lines in Fig. 8 are linear best-fit lines for the actual and predicted grades for each group of students.

4.4 Normalized gain: correcting for differences in academic ability

Any voluntary educational resource offers more potential benefit to weaker students than stronger students, simply because students with lower grades have more room to improve. A student predicted to score 95% in our course can only improve his or her performance by the remaining 5%, while a student predicted to score 70% can increase by 30%. This situation gives the illusion of more significant improvement in the case of the weaker student if, for example, the "A" student improves his or her final course grade by 1 point and the "C" student improves his or her course grade by 6 points. (In each case, the students have incrementally improved their performance by 20%; that is, they have earned 20% of the remaining points separating their predicted grade from a perfect score.) Thus, analyzing each student's response to the videos based solely on the raise in course grades over their expected grade may under-represent the benefit of the supplementary resource to students who are already strong.

To eliminate this bias, we use a normalized gain to compare student performance. Normalized gain is the ratio of the actual gain to the potential gain (based on the student's predicted course grade). Figure 9 shows that students who chose to use the videos to supplement their studying saw larger average normalized gains than those who did not use them. This approach assumes a maximum course grade of 100%; in the actual application, a very few students earned course grades higher than 100%.

This conclusion is also supported by examining results statistics for each of the two groups. While both groups were predicted to perform nearly identically (87.2% vs. 87.1%) we see that those who chose not to watch any videos performed very close to the prediction (87.3%) while those who used the videos had an average grade of 88.4%.

Figure 10 shows the distribution of normalized gains experienced by male and female students who used at least one video tutorial. Most students experienced a slight positive benefit from video use.

Men who used videos and those who did not were predicted to perform nearly identically, but those who chose to watch videos saw a more significant

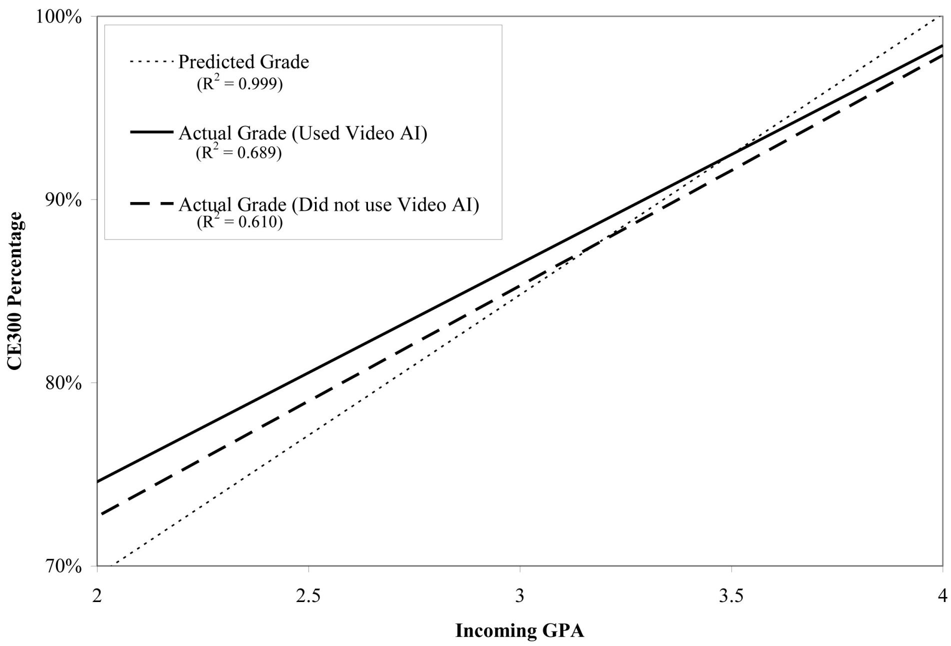

Fig. 8. Predicted vs. actual performance in course-end grade for students with and without instructional videos.

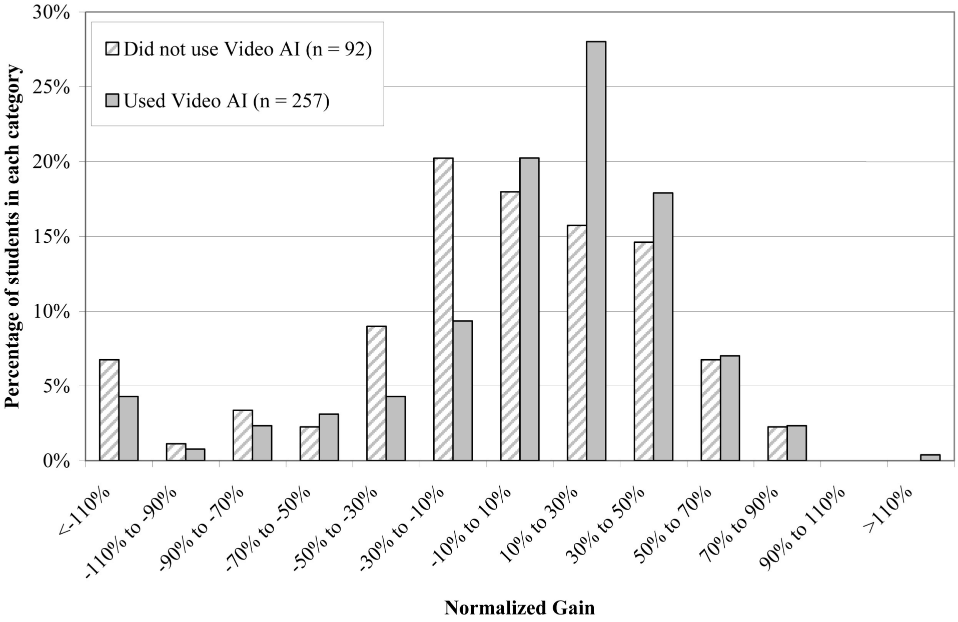

Fig. 9. Normalized Gain (comparing those who used instructional videos with those who did not).

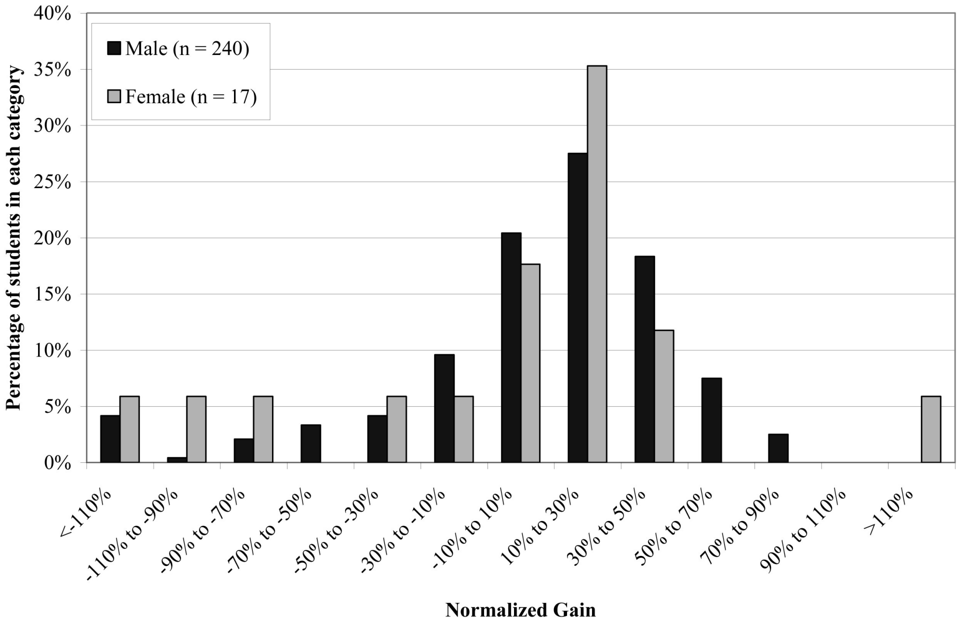

Fig. 10. Normalized Gain (comparing male and female students who used instructional videos).

increase in grade (+1.2%). It is notable that this is not the case for the female population. Although students who used the videos were predicted to perform slightly better than those who did not, the opposite proved true: they performed slightly worse. Female students who used the videos experienced a statistically insignificant negative normalized gain; female students who did not use them experienced a slight positive normalized gain. This may be an artifact of the relatively small number of female students in the course or may indicate that the videos are more helpful to male students than to female students. The difference may also be related to other factors not investigated in this study. Further study is needed to determine the specific benefit of instructional videos to female students in engineering courses.

The academic benefit of tutorial videos appears to be independent of the major course of study chosen by students. As shown in Table 1, the modest improvement for those who watched videos is present across the spectrum of academic disciplines. Students studying engineering or physical sciences responded slightly better to the videos, as measured by two separate metrics: likelihood of use as described earlier and greater-than-average improvement of course grade.

The increase in academic performance across academic disciplines is also seen through the descriptive statistics in Table 1. The benefit seen in aggregate appears to be independent of chosen course of study. The only academic discipline for which this does not appear to be the case is the humanities.

This may be indicative of student preference for this engineering course—those choosing to focus on a humanities discipline tend to perform worse in math and science courses and they most likely have less desire for such a course than a student who has chosen to study engineering.

5. Discussion and future work

This analysis clearly demonstrates the appeal and benefit of video-based on-demand tutoring to students; this benefit was not strongly influenced by learning style preferences, academic majors, and academic performance histories. Additional research may provide useful insights into the degree of universal appeal these video tutorials have for students who are diverse with respect to other characteristics. Although further analysis is needed, the user demographics for YouTube support this study's preliminary conclusion that short, on-demand videos are appealing both to male and female students; in July 2013, 52% of YouTube's users were female [8]. YouTube's user demographics may also help to predict the usefulness of these videos to students outside the traditional college age range; 57% of YouTube users are age 35 or older.

On-demand video-based learning is clearly effective at relaxing time-of-day constraints for learning within traditional college courses in which students have access to classroom lectures and have contact with professors during out-of-class office hours. Online content also has the potential to relax location constraints: to allow learning to take place at any location that is convenient for the student, even across the globe from the professor. Additional research is needed to predict the attractiveness and utility of the type of videos described here if they were implemented as part of an online distance-education course, though the possibility is certainly worth exploring and has doubtless been used somewhere in the educational enterprise, though perhaps not assessed thoroughly in terms of effectiveness.

More broadly, the educational enterprise as a whole has a strong and continuing need to meet students on their own ground; it works, and the

Table 1. Descriptive statistics comparing academic disciplines

		Engineering		**Humanities**	
		Used videos	**Did not use videos**	**Used videos**	**Did not use videos**
	Sample Size (n)	160	37	28	18
Predicted Grade	*Average*	88.3%	88.5%	87.1%	83.6%
	Median	89.6%	88.4%	89.5%	82.4%
	Standard Deviation	6.7%	7.1%	9.0%	8.7%
Actual Course Grade	*Average*	90.2%	89.9%	85.7%	82.4%
	Median	91.7%	91.2%	87.3%	84.0%
	Standard Deviation	5.7%	6.4%	7.8%	9.0%
		Management		**Social Science**	
	Sample Size (n)	29	16	21	13
Predicted Grade	*Average*	84.1%	86.4%	84.1%	87.3%
	Median	82.9%	86.8%	85.4%	89.7%
	Standard Deviation	8.4%	6.4%	9.3%	6.6%
Actual Course Grade	*Average*	85.4%	85.6%	84.6%	85.8%
	Median	88.4%	88.7%	84.8%	85.6%
	Standard Deviation	8.0%	8.0%	8.3%	5.1%
		Physical Science			
	Sample Size (n)	17	8		
Predicted Grade	*Average*	86.3%	91.8%		
	Median	88.7%	90.4%		
	Standard Deviation	9.4%	5.7%		
Actual Course Grade	*Average*	87.4%	92.9%		
	Median	88.9%	93.9%		
	Standard Deviation	7.0%	5.6%		

authors predict that on-demand learning of the type described here is still in its infancy. Ubiquitous bandwidth is enabling a shift in not only the availability of information, something that has become a fundamental part of how we gather information to us, but also is expanding to allow true virtual environments which are beginning to capture the interactions and reactions of real people in real time. It is this, the presence of people, which makes things compelling.

People are unpredictable, challenging, fun, annoying and without doubt, the most interesting thing there is. World of Warcraft, Second Life and other massive, multiplayer online games (MMOGs), where the principal things the actor encounters are representations of other users, are highly appealing, especially to those under 30, and presage a growth in such environments for more serious uses. Students in recent informal pollings in the classroom said that they no longer desire recreational use of the computer, gaming in particular, unless it includes other people as live players. It is thus easy to predict a virtual learning environment which is actually richer, more open and far less expensive than our current university model. Experiments like the one described here will certainly persist, but the likely big future winner will be an immersive learning environment where ready interaction with professors, fellow students, virtual objects and other embedded media (like the short videos described here) will be rich, immediate and natural to the user.

Some educators may be concerned that multiplication of on-demand digital environments will dehumanize learning and remove creativity, spontaneity and other intangibles from the intellectual growth of their students. Only time will tell, but the success of the MMOGs points to something quite different; people prefer to interact with real, live people, not simulated devices or laboratories, not stored images of people, but multi-capable, unconstrained and active persons who share the actor's goals. All of this implies a demand for increasingly varied virtual classrooms populated with knowledge, objects and a staggering array of simultaneous communication paths and social networks. These requirements in turn indicate a growth rather than diminishment of Lowman's [9] necessary components for great teaching; interpersonal rapport and intellectual excitement. For teachers, this means creating content and environments that the students want rather than need for survival, thus converting that offering from ''push'' to ''pull'' content. This revolutionary conversion represents an extraordinary challenge, but it is a challenge that must be overcome if we are to meet the students on their own ground.

6. Conclusions

The results of this study support the use of on-demand video-based instruction, particularly for addressing student questions about the processes associated with solving engineering problems. Further, those students most challenged by the material appear to benefit most, with a strong minority of students preferring to learn using this instructional mode. Additional research is needed to develop techniques for improving the videos' effectiveness among specific populations; in general, however, the gains in student learning enabled by the videos well repaid the minimal instructor time needed to create them.

References

1. B. Solomon and R. Felder, Index of Learning Styles Questionnaire. www.engr.ncsu.edu/learningstyles/ilsweb.html. Accessed 14 January 14 2008.
2. R. Felder and L. Silverman, Learning and Teaching Styles in Engineering Education, *Engineering Education*, **78**(7), 1988, pp. 674–681.
3. J. Bruhl, J. Klosky and E. Bristow, Assessing the Impact of New Teaching Methods by Predicting Student Performance, *American Society of Engineering Education, Zone I Conference*, West Point, NY, 2008.
4. M. Prensky, Digital Natives, Digital Immigrants, *On the Horizon*, **9**(5), 2001. http://www.marcprensky.com/writing/default.asp, Accessed 16 October 2008.
5. C. Barone, Technology and the Changing Teaching and Learning Landscape: Meeting the Needs of Today's Internet-Defined Students, AAHE *Bulletin*, May 2003 issue.
6. D. Levin and S. Arafeh, The Digital Disconnect: The Widening Gap between Internet-Savvy Students and their Schools, in *Pew Internet and American Life Project,* Washington, DC, 2007.
7. J. Bruhl, J. Klosky and E. Bristow, On Demand Learning—Augmenting the Traditional Classroom, *Proceedings of the 2008 American Society of Engineering Education Annual Conference*, Pittsburgh, PA, 2008.
8. YouTube Demographics, http://www.youtube.com/yt/advertise/demographics.html, Accessed 9 July 2013.
9. J. Lowman, *Mastering the Techniques of Teaching* (2nd Ed.). Jossey Bass, San Francisco, CA, 1995.

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