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The efficacy of screencasts to address the diverse academic needs of students in a large lecture course

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ABSTRACT

In large lecture courses, it can be challenging for instructors to address student misconceptions, supplement background knowledge, and identify ways to motivate the various interests of all students during the allotted class time. Instructors can harness instructional technology such as screencasts, recordings that capture audio narration along with computer screen images, to supplement the lecture with content that addresses the diversity in student academic backgrounds, motivations, and interests, to extend the classroom experience, and reach the individualized needs of students. This study documents the strategic use of screencasts in a large introductory Materials Science and Engineering (MSE) course, and examines their impact on student usage and course performance. To assess the efficacy of screencasts, students were surveyed to determine how they used screencasts and whether they perceived these resources to be helpful. In addition, we correlated student usage based on website hits with student performance (e.g. final grade) to determine statistical significance. Since the course is comprised of students from different academic and social backgrounds, we also analyzed usage and performance patterns for particular student subgroups. The results indicate that students perceive the screencasts to be helpful and tend to use the resources as a study supplement. Overall, usage of screencasting in its various forms is positively and significantly correlated with course performance as indicated by the final grade. The most substantial gains were found for students with the least amount of prior exposure to concepts in the course material. These

results indicate a potential for screencasts to address the various academic needs of students in a large lecture environment.

Keywords: Instructional technology, screencasts, conceptual understanding, materials science

BACKGROUND

A screencast is a movie that captures the activity on a computer screen with real time audio commentary. Screencasting has been successfully implemented as a training tool for task-centered activities in a variety of contexts [1–3]. Screencasts have been used to record and replay PowerPoint lectures and other training materials, but any application—including animations or drawing programs—may be captured along with audio commentary, then posted on a course management website and replayed at students' leisure. Used properly, this approach can be a rich supplementary resource. It includes written, audio, and video elements, thus reaching students with many different learning preferences. Screencasts may be fast-forwarded, rewound and paused as necessary, and are available "on demand" and accessible to students at any time of day (in contrast to office hours, live chats, etc.). Our implementation of the screencast creates a flash movie that can be accessed through the course management website, but students may also elect to subscribe to the screencast via iTunes, allowing students to watch them on any mp3 player. The production of screencasts is extremely simple thanks to powerful software packages now available that range in both price and capability [4].

LITERATURE REVIEW

Instructors are using audio and visual podcasts or screencasts to replace lecture, to supplement lecture material, or to assign projects for which students create video podcasts [5]. Perhaps the most straightforward and widely adopted use of screencasting is in recording lectures as they are delivered in the classroom, and posting the lectures online through a course management website. Figure 1a shows a screenshot of a lecture screencast from a course at the University of Michigan. In this case, it includes video of the instructor and of the presentation slides. The use of screencasts as a replacement of live lectures has been proposed as a strategy to shift class time towards more interactive activities [6], or mitigate the high likelihood of problems during live in-class demonstrations [7]. However, adoption of these technologies has been hampered by the perception that providing these resources will result in a drop in student attendance [8], despite early analyses

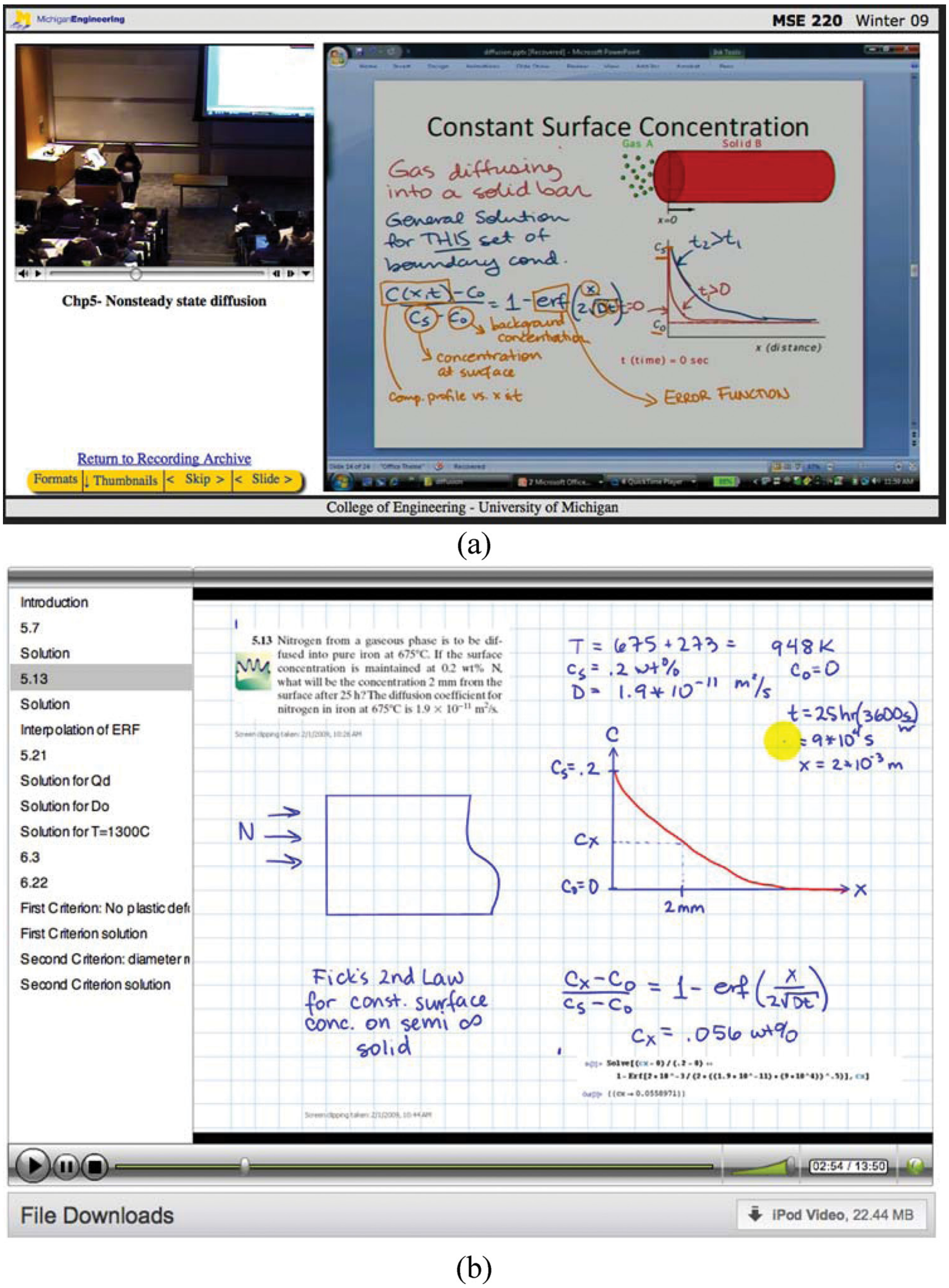

Figure 1: (a) Lecture recording and (b) Homework solution screencast.

showing little impact in this regard [9]–[12]. Typically students self-report using the posted lecture material for review, or to make up absences [13]–[16].

Initial data suggests that screencasting can be a tremendously useful resource for students. Several studies show that screencasting is perceived by students as beneficial, [16]-[20] though not a substitute for instructor-student interactions [20]. One study analyzed course performance by comparing students who used screencasts to students who attended live lectures, and determined that students benefited from screencasts especially if they had lower class attendance [21]. Grabe and Christopherson have done valuable studies looking at screencasting as a resource for note-taking, and they have found positive correlations of screencast usage with exam performance [15].

The use of screencasts that supplement regular lectures, however, is still an active area of research. Lee, Pradhan, and Dalgarno developed screencasts to scaffold learning of object oriented programming in an introductory computer science class [22]. In that study they found no statistical significance for the effect of screencasts on learning, perhaps because actual usage of the screencasts was not monitored. Other studies show evidence of higher retention of material when presented in screencast form rather than as live lectures. Dey and coworkers developed 20-minute presentations that emphasize a concept in physics in three formats: a live lecture, a screencast with voice narration, a screencast with narration and a video of the speaker [23]. They found that students viewing the screencasts remembered key concepts better than those who attended the live presentation. Students reported a preference for having the image of the speaker in the screencast, but its absence had no impact on the retention of material.

These results are promising; however, more data are needed to explore the impact of screencast use on student performance, and to examine the impact of these resources on individual student learning. With increasing attention to issues of social equity, it is also important to determine if gender, race, native language, or socio-economic status are factors in students' success in utilizing new technologies. With these issues in mind, our study takes a form that builds on and extends other analyses of web-based lecture resources.

SCREENCAST DEVELOPMENT AND BEST PRACTICES

In this course, screencasts were used in different ways: to capture lectures as they occurred, to disseminate solutions to assignments (e.g., homework, quizzes and exams), and to clarify topics that the students themselves identified as unclear. While each type of screencast served a somewhat different purpose, they are all similar in terms of development and production.

The College of Engineering at the University of Michigan has specially equipped lecture halls that record and publish lectures automatically. All images projected onto the screen are captured, and a camera mounted at the back of the room documents the action at the lectern. Audio is recorded via a lapel microphone worn by the instructor, and microphones in the classroom capture the comments of the class. These elements are automatically produced into a stream file that may be accessed by a course management website, an example of which is shown in Figure 1a. Such a sophisticated in-class infrastructure is not strictly necessary for capturing and posting lectures online. Similar results may be achieved by using any number of commercial screen capturing software [4], [7].

Recent advances in personal computing hardware and software have made the production of screencasting easier than ever. All that is necessary is a personal computer capable of running any of the currently available screencasting software packages. There are several options that range in price and capability, and learning to use them is akin to using basic modern movie editing software. In some cases, an external microphone may be advisable if the internal microphone results in unacceptable audio quality.

There are four aspects of developing screencasts: content preparation, recording, editing and production, and publishing. As in any good teaching practice, the success of the resource is based on identifying the learning goals for students and preparing content based on these ideals. The purpose of the screencast will strongly determine its tone, structure, and content. For example, questions that come up in class may be best answered with a quick and casual video, whereas an extremely detailed and polished video is more appropriate for homework solutions. In either case, it is generally better to keep screencasts short (with the exception of capturing regular lectures), on the order of 15 minutes or less. Various elements may be incorporated into the screencast to better support its purpose, such as written text and pictures, movies and animations, or applications. Once the materials for the screencast are ready, the screencast may be recorded, edited, and produced using screencasting software. Another factor that must be considered is how the finished product will be disseminated. Options include a closed access course management website, a course blog, or a more public video viewing site. In each of these cases, there are slightly different issues pertaining to the production quality and copyright issues. For instance, a screencast that will be published on a public site should be accurate, high quality, and free from any copyrighted material. Screencasts on access-controlled sites, on the other hand, do not necessarily have to hew to such high standards and make it easier to protect intellectual property. Zhu and Bergom provide additional recommendations for screencasting, especially lecture capturing [24].

The majority of this study was focused on the efficacy of supplemental screencasts as student learning tools. Figure 1b shows an example of a homework solution screencast, and a full example may be viewed at jmmg5.engin.umich.edu/hw04/hw04.html. This approach is more detailed than annotated written solutions, because it is possible to show the student where in the text or lecture notes the concept is described, talk through setting up the problem, and demonstrate how to use computational tools, such as Mathematica or Excel, to find the solution. The most novel application of this approach, however, is in the creation of supplemental screencasts that clarify topics that the students themselves identify as unclear. This approach is adapted from the "muddiest point" classroom assessment technique [25], where students are directed to an online survey throughout the term to self-assess their confidence on a variety of learning objectives for each unit. The instructor created the "muddiest point" screencasts when at least 30% of students indicated their need. The benefit of these "muddiest point" screencasts is that only the students who need or want the supplemental material access it. An example of this type of screencast may be viewed at jmmg5.engin.umich.edu/dislocation/dislocations.html.

ANALYSIS OF SCREENCAST USAGE DATA

Over the course of four semesters, the authors conducted a study to investigate whether screencasts are an effective tool for student learning in a large introductory lecture course. The study was performed in MSE 220, Introduction to Materials and Manufacturing, which averages nearly 200 students with different backgrounds and motivation. The goal of this research is to determine the efficacy of screencasts in MSE 220 by determining how students use different kinds of screencasts, which students use them, and whether and for whom screencasts affect learning. We examined the efficacy of screencasting in detail for two terms (e.g., Fall 2008 and Winter 2009), although data collected in Fall 2006, Fall 2007, and Winter 2010 inform some of the analysis. Every effort was made to keep the course the same between the various semesters. The same instructor taught the course for all terms using the same syllabus, text book, lecture notes, and homework assignments. One difference between the semesters is that previous screencasts were made available immediately in the later semester, with additional screencasts added in response to student demand. While midterm student feedback and end-of-term course evaluations were used to assess the overall course, an end-of-term online survey was also conducted to evaluate students' perceptions of screencasts in particular. With the approval of our Institutional Review Board, the survey asked students about how they used the screencasts, and whether these resources were helpful in providing a deeper understanding of the course concepts. For Fall 2008 and Winter 2009, the response rate for the online survey was greater than 65% (e.g., 68% for Fall 2008 and 66% for Winter 2009).

For statistical analysis, additional student information was collected (e.g., demographic and usage data) for each term in order to correlate these factors with course performance. The office of the registrar provided information on race/ethnicity, gender, citizenship, academic level, major, GPA, and SAT/ACT scores for each student. The office administering course management servers provided usage data for each student enrolled in the class, including information on which screencasts were viewed and when they were accessed; however, no information was available for the duration of use for each resource. PASW Statistics 18 software (www.spss.com) was used for all quantitative analyses. Correlations were run to explore the relationship between usage and performance for all students. Basic descriptive analyses were conducted for usage and performance measures, both overall and according to the dimensions of gender, race/ethnicity, major, etc. Additionally, correlations, one-way analysis of variance (ANOVA) and post-hoc analyses were used to test for significance in usage and performance means across these various dimensions. In the particular case of student academic background, one-way analysis of variance, and post-hoc analyses were used to test for significance in the relationship *between* usage and performance for each of the possible majors. Where theoretically appropriate, smaller subgroups were combined to increase sample size for these means comparisons. For all ANOVA tests, Levene statistics were examined for violation of the assumption of equality of variance. For tests that revealed significance, unless otherwise noted, no violation of this assumption was found. When violation of the equal variance assumption was found, Welch and/or Brown-Forsythe robust F tests are included in footnotes.

COURSE BACKGROUND AND STUDENT DEMOGRAPHICS

Materials Science and Engineering (MSE) is concerned with the study and development of materials used in virtually every physical process and engineering discipline. Due to its interdisciplinary nature, MSE 220 is taken as a technical elective by many students in the College of Engineering at the University of Michigan. Student academic backgrounds and class levels in MSE 220 are summarized in Table 1. In general, the populations of students in the two terms examined in this study look very similar with regard to the distribution of gender, race and ethnicity, and academic performance. The majority of students (.70%) during each term were from three departments: Aerospace Engineering (AERO), Chemical Engineering (ChE), and Industrial and Operations Engineering (IOE). Students majoring in Nuclear Engineering and Radiological Sciences (NERS) and MSE comprise of a small fraction of the student population for both terms (less than 9% and 5% respectively). The category for “Other Engineers” includes small numbers of undeclared engineering majors, engineering physics, Electrical Engineering, Mechanical Engineering, and Civil Engineering students. In both terms at least 40% of the students were juniors. In particular, AERO students were most likely to be juniors. ChE students were split between junior and senior level students. IOE students were

	Fall 2008		Winter 2009	
	Number	Percentage	Number	Percentage
Sex				
Males	165	75.3	130	73.0
Females	54	24.7	48	27.0
Total	219	100.0	178	100.0
Race/Ethnicity*				
Caucasian	141	64.4	96	53.9
African American	6	2.7	14	7.9
Asian	39	17.8	28	15.7
Hispanic	2	0.9	14	7.9
Native American	1	0.5	2	1.1
None*	30	13.7	–	–
Not Indicated	–	–	24	13.5
Total	219	100.0	178	100.0
Academic Level				
Senior	59	26.9	76	42.7
Junior	101	46.1	75	42.1
Sophomore	59	26.9	26	14.6
Freshmen	–	–	1	0.6
Total	219	100.0	178	100.0
Major				
Aerospace (AERO)	60	27.4	36	20.2
Chemical (ChE)	49	22.4	45	25.3
Nuclear Eng. & Radiological Sciences (NERS)	19	8.7	9	5.1
Industrial and Operations (IOE)	53	24.2	60	33.7
Material Science (MSE)	9	4.1	5	2.8
Other Engineering (Mechanical, Civil, etc)	26	11.9	22	12.4
Other (Non-Engineering)	3	1.4	1	0.6
Total	219	100.0	178	100.0
Cumulative GPA				
Average Cumulative GPA	3.18	–	3.09	–
4.0-3.6	48	21.9	31	17.4
3.5-3.0	93	42.5	73	41.0
2.9-2.6	48	21.9	40	22.5
2.5-2.0	24	11.0	29	16.3
1.9 and below	6	2.7	5	2.8
Total	219	100.0	178	100.0
Citizenship Status				
U.S. Citizen	184	84.0	156	87.6
Perm. Resident	13	5.9	9	5.1
Non-Resident	22	10.0	13	7.3
Total	219	100.0	178	100.0

* Students who identify themselves as "none of the above"

Table 1: Student background characteristics for Fall 2008 and Winter 2009.

most likely to be seniors in Winter 2009, but had approximately equal proportions of juniors and seniors in Fall 2008. AERO, ChE, and IOE students typically had similar mean GPAs, ranging from 3.1 to 3.3 for both terms.

A consequence of this wide range of majors enrolled in the course is diversity in disciplinary background and motivation of the students. Figure 2 lists the core courses required by MSE and the three departments with the largest number of students participating in the course. The bolded course names are those that contain topics that are similar to those covered in MSE. ChE, which is based on chemical and life sciences, has five directly similar courses, with topics such as thermodynamics, kinetics, and mass transfer. AERO, which concerns itself with the design and fabrication of air and space vehicles, has four courses that cover topics related to mechanical behavior and thermodynamics, although these courses are very specifically targeted at issues in aerospace and less so on material properties. IOE pertains primarily to integrated systems and draws expertise from

Materials Science & Eng.	Chemical Engineering	Aerospace Engineering	Industrial & Operations Eng.
• **Principles of Engineering Materials** • **Physics of Materials** • **Thermodynamics of Materials** • **Kinetics & Transport** • **Structure of Materials** • **Mechanical Behavior**	• **Materials and Energy Balances** • **Chemical Thermodynamics** • **Fluid Dynamics** • **Heat and Mass Transfer** • **Separation Processes** • Reaction Engineering and Design	• **Intro to Aerospace Engineering** • **Intro to Solid Mechanics and Aerospace Structures** • **Intro to Gas Dynamics** • **Aircraft and Spacecraft Structures** • Aerodynamics • Aircraft and spacecraft Propulsion • Space Flight Mechanics • Aircraft Dynamics	• Economic Decision Making • Operations Modeling • Probability and Statistics • Intro to Optimization • Intro to Markov Processes • Ergonomics • Linear Statistical Models • Data Processing

Figure 2: Comparison of the core courses required by the largest constituents taking MSE 220 to the Materials Science core. Courses listed in bold are those with content relevant to Materials Science.

mathematics and social sciences. As such, there are no courses in the IOE curriculum that pertain directly, or even indirectly, to topics in MSE. Therefore, despite the fact that on average IOEs have comparable academic indicators (e.g., GPA, SAT, ACT) as the rest of the class, they start MSE 220 at a disadvantage for having less experience with the class material in prior coursework.

RESULTS AND DISCUSSION

This work focuses on determining which groups of students use screencasts and whether their use improves performance in the course. We focus on screencasts based on solutions to assignments (e.g. homework, quizzes, and exams) and "muddiest point" topics in MSE 220 during Fall 2008 and Winter 2009 semesters. Previous work on these types of screencasts and lecture recordings suggests that students typically used these resources as a study supplement and found them to be helpful [17]–[19]. Other studies support this finding [21]. For instance, 89% of students from Fall 2008 and Winter 2009 who responded to the survey and viewed the homework solution screencasts (N=126/141) or viewed the quiz solution screencasts (N=96/108) felt that the explanations for each topic were helpful. One student from the Winter 2009 class explained,

> *Screencasts both showed solutions and problem strategies. The verbal explanation makes it more understandable than a simple [homework] solution handout.*

In Fall 2008, one student said, "Quiz solution screencasts allowed me to quickly see any errors I made." While another student mentioned that "the quiz solution screencasts allowed me to clarify concepts I didn't fully understand before the quiz, and helped me master them before the exam."

Unlike the homework or quiz solution screencasts that were created for every assignment, the "muddiest point" screencasts were developed when at least 30% of students indicated that they wanted additional information to clarify their understanding of course concepts. Eighty-six percent of the students (on average) who responded to the survey and viewed the muddiest point screencasts felt that the explanations given in the muddiest point screencasts were "somewhat helpful," "very helpful," or "extremely helpful" during these terms. In Winter 2009, one student explained,

> *[The "muddiest point" screencasts] were very clear and the step-by-step explanations cleared up any confusion I had. For example, on the phase diagram examples it was really helpful to see [the instructor] actually trace the path in question and reference the problem to help me to be able to use the text to help solve the problems.*

Furthermore, students (N=216) rated their level of agreement with the statement, “I have a deeper understanding [of course concepts] due to [these resources]” at a 3.3/4.0 or higher for both terms (1=Strongly disagree, 2=Disagree somewhat, 3=Agree somewhat, 4=Strongly agree). One Winter 2009 student explained,

> *I really liked listening to the solution explanation to the homeworks even if I got the problem right. Just listening to the way the problem was reasoned out in words helped me to remember processes and procedures better.*

These positive perceptions highlight the value of the screencasts from the student point of view; however, they also illustrate the need to discover more specifically which students use screencasts and how often they use them, as well as, whether screencasts improve their learning (i.e., final course grade).

Overall Usage and Performance

Although the overall usage of screencasts was somewhat higher in Winter 2009 than Fall 2008, both terms show a positive significant correlation between usage and performance. For the purpose of this study, usage data was examined in terms of the *number of website hits* per student, which estimates how often students accessed various screencasts. In Fall 2008, 25 screencasts were developed and made available in Winter 2009. Eight more screencasts were developed in Winter 2009 in response to student queries for a total of 33 screencasts in that semester (Table 2). Students were most likely to view the homework solutions and the muddiest point screencasts, and were least likely to view the quiz and exam solution screencasts (Table 2).

	Fall 2008		Winter 2009	
	Number of Screencasts	Number of Hits	Number of Screencasts	Number of Hits
Homework solution	12	2604	13	2220
Muddiest Point	9	1405	15	2280
Quiz and Exam solution	4	355	5	430
Total Screencasts	25	4364	33	4930

Table 2: Number of screencasts and website hits for all types of screencasts in Fall 2008 and Winter 2009.

The screencast usage patterns vary between the two terms and are characterized in Figure 3 by the *level of screencast use* which includes six usage groups ranging from non-users (with 0 website hits) to very high users (with over 41 website hits). Less than 8% of students did not access any of the screencasts for both terms (Fall 2008: 16 non-users out of 219 students; Winter 2009: 14 non-users out of 178 students). The usage levels depicted in Figure 3 show a large difference in the number of very low and very high users between the two terms. Fall 2008 is characterized by having 49% of students who are low and very low users (N=107). Winter 2009, on the other hand, has 38% of its students as high and very high users (N=67).

It is not entirely clear as to why the usage pattern varies between these terms. It is possible that the variation is due to how screencasts were advertised differently to students and whether students were aware of the preliminary research that indicated the helpfulness of screencasts [19]. In Fall 2008, students were not informed about the preliminary research because the data was still being tabulated; however students from Winter 2009 had the advantage of knowing the performance benefits of screencasts. Furthermore, at the beginning of each semester the previously developed muddiest point screencasts were immediately available for students to view. In Winter 2009, students had access to nine muddiest point screencasts from the beginning of the term, compared to only

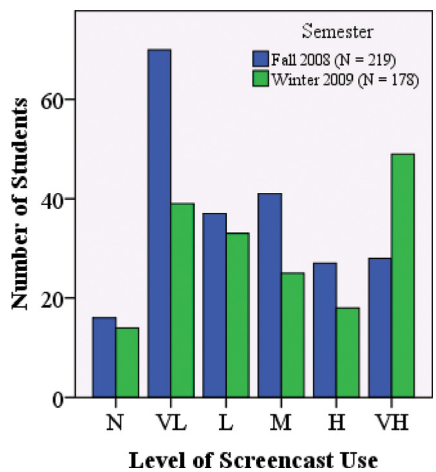

Figure 3: Level of screencast use based on the number of website hits for Fall 2008 and Winter 2009. Level of screencast use are defined as follows: non-users (N) with 0 website hits, very low users (VL) with 1–10 website hits, low users (L) with 11–20 website hits, mid-level users (M) with 21–30 website hits, high users (H) with 31-40 website hits, and very high users (VH) with more than 41 website hits per term.

three in Fall 2008. This provides additional opportunity for students to increase their usage of the screencasts. For the purpose of this study, we attempted to reduce other inconsistencies between the two terms by designing the classes to have the same instructor who presented lecture material relatively consistently; comparable homework, quiz, and exam questions; and similar methods for identifying "muddiest point" topics. Although the usage patterns vary between the semesters, the student populations are demographically similar (see Table 1), so we have chosen to combine the two semesters for statistical analysis.

The analysis above shows how often students used screencasting in its various forms, however it is essential to know whether screencast usage actually improved student performance as indicated by their final grades in the course. Indeed, we find that students benefited from using screencasts in both Fall 2008 and Winter 2009. A positive significant correlation is found between the number of website hits and final course grade: $r = .245$, $p = .000$. This modest yet statistically significant correlation shows that students who use screencasts more tend to receive higher grades in the course. This result is comparable to other researchers' findings [21]. When we control for GPA, the magnitude of this correlation is somewhat reduced but the statistical significance is retained: $r = .178$, $p = .000$. In other words, assuming that GPA is an indicator for expected performance in this course, higher screencast usage still produces a higher final course grade when comparing students of similar past academic accomplishment.

With these general relationships in mind, we look at usage and performance for particular groups within the larger student population of MSE 220. Specifically, the dimensions of gender, citizenship, race/ethnicity, academic level, and academic major are investigated, but only academic major is found to be a significant indicator for usage and performance benefits.[1]

Usage and Performance by Gender, Citizenship, Race & Ethnicity, and Academic Level

In all, when we examine differences in means for screencast usage (i.e. website hits) and course performance (i.e. final course grade) across the dimensions of gender, citizenship, race/ethnicity, and academic level, the results are mixed, stimulating interesting pedagogical questions. For each dimension, we explore whether certain subgroups benefit more or less from screencast use. As well, we explore whether usage is in fact mediating the observed relationships between being in particular subgroups and course performance. Table 3 depicts the mean number of website hits, mean final course grade, and number of students for each of these student populations, and Figure 4 shows the distribution of usage.

When analyzing gender, there is no significant difference between the usage patterns or performance between males and females (Figure 4a). Essentially both groups are performing at comparable levels and are positively impacted by their use of screencasts.

[1]. Tables highlighting the details of the statistical analysis are included for academic background (major) only.

	Fall 2008 and Winter 2009		
	Mean No. of Website Hits	Mean Final Course Grade (%)	Number of Students
Sex			
Males	23.13	82.81	295
Females	23.37	83.50	102
Total	23.19	82.98	397
Citizenship Status			
U.S. Citizen (U.S.)	22.33	82.84	340
Non-U.S. Citizen (Non)	28.33	83.84	57
Total	23.19	82.98	397
Race/Ethnicity			
Caucasian (Cauc.)	21.80	83.13	237
Asian	24.63	83.31	67
Historically Underrepresented Minorities (URM) +	20.64	78.76	39
Total	22.22	82.66	343
Academic Level			
Sophomore (Soph)	18.04	79.52	85
Junior (Jr.)	24.87	84.71	176
Senior (Sr.)	24.33	83.01	135
Total	23.22	83.02	396
Major			
Aerospace (AERO)	20.49	83.38	96
Chemical (ChE)	19.03	85.94	94
Nuclear Eng. & Radiological Sciences (NERS)	16.00	84.64	28
Industrial and Operations (IOE)	32.14	82.24	113
Material Science (MSE)	28.36	80.15	14
Other Engineering (Mechanical, Civil, etc)	19.29	78.47	48
Other (Non-Engineering)	12.25	77.38	4
Total	23.19	82.98	397

Table 3: Means for screencast usage (number of website Hits) and course performance (final course grade) across background characteristics in Fall 2008 and Winter 2009.

Examining citizenship using one-way analysis of variance shows that Non-U.S. Citizens (permanent residents and non-residents) used screencasts at significantly higher rates than U.S. Citizens [$F(1, 395) = 3.96$, $p = .047$], with an average of 28.33 website hits per student compared to 22.33

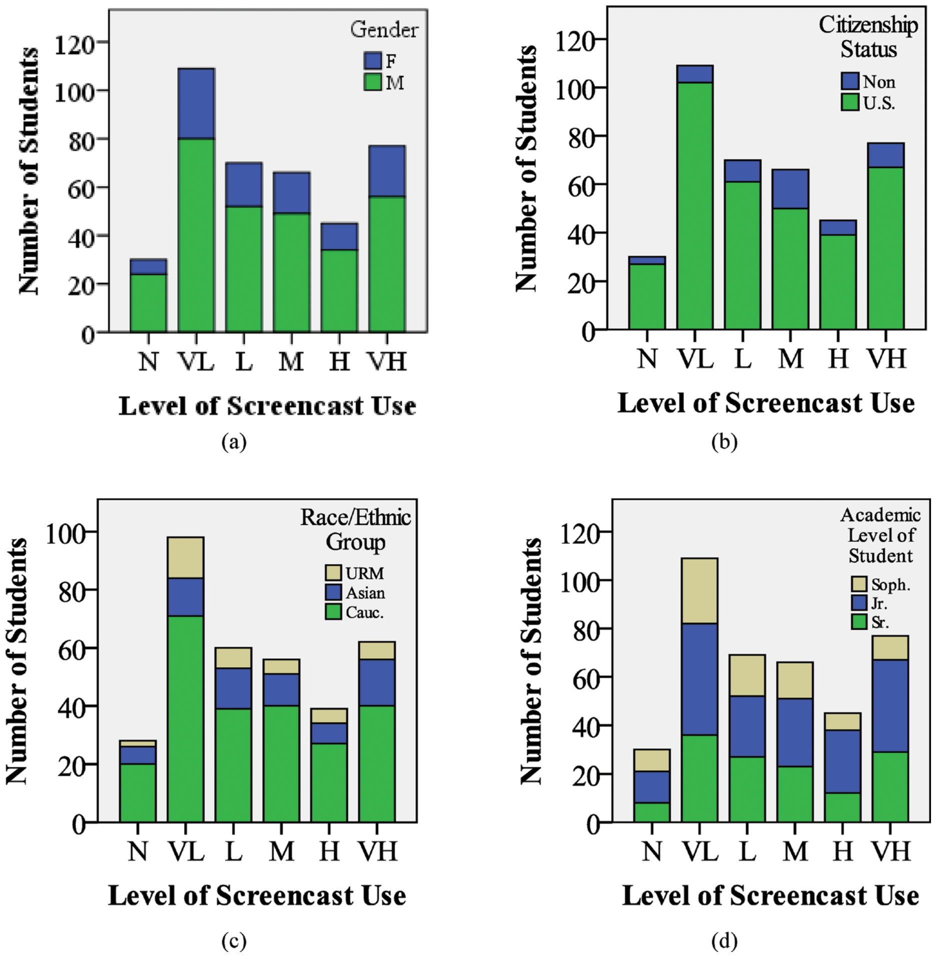

Figure 4: Level of screencast use by (a) Gender, (b) Citizenship, (c) Race/Ethnicity and (d) Academic level for both terms. Level of screencast use are defined as follows: non-users (N) with 0 website hits, very low users (VL) with 1–10 website hits, low users (L) with 11–20 website hits, mid-level users (M) with 21–30 website hits, high users (H) with 31–40 website hits, and very high users (VH) with more than 41 website hits per term. Gender is defined as follows: females (F) and males (M). Citizenship status is defined as follows: Non-U.S. citizens comprising of permanent residents and non-residents (Non), and U.S. Citizens (U.S.). Race/ethnicity are defined as follows: historically under-represented students in engineering comprising of African Americans, Hispanics, and Native Americans (URM); Asians (Asian); and Caucasians (Cauc.). Academic levels are defined as follows: sophomores (Soph.), juniors (Jr.), and seniors (Sr.).

website hits per student respectively. (See Table 3). Despite this significant difference in mean screencast use, similar analysis revealed no significant difference for mean academic performance when comparing U.S. Citizens and non-citizens [$F(1, 395) = .52$, $p = .471$]. While both groups are performing on par with one another, the higher screencast use by Non-U.S. Citizens suggests that, for this group, screencast use may be the vehicle by which performance is raised to a level comparable to their U.S. Citizen counterparts. Certainly, both groups are benefitting from screencast use as each maintains a significant positive correlation between number of website hits and performance ($r = .228$, $p = .000$ and $r = .342$, $p = .009$ for U.S. Citizens and Non-U.S. Citizens respectively). While the slightly higher magnitude of the correlation for non-citizens implies that perhaps this group may be benefitting from screencast use a bit more than U.S. Citizens and thus should be encouraged to continue to use at higher rates, this difference is only slight and therefore should be interpreted with caution.

We examined differences in mean screencast usage and mean course performance across three racial/ethnic categories—Caucasian, Asian, and those racial/ethnic groups that have been historically under-represented (URM) in the College of Engineering. These include African American, Hispanic, and Native American students. Those students who marked "None" or did not indicate a racial/ethnic identity are excluded from these analyses and comprise 13% of the student population. While it appears that Asians use screencasts at slightly higher levels than Caucasians and URMs (see Table 3), one-way analysis of variance finds no significant difference in mean usage between these groups [$F(2, 340) = .64$, $p = .526$]. In contrast, similar analysis reveals significantly different means for performance [$F(2, 340) = 3.52$, $p = .031$], due primarily to the difference between the higher average performance of Caucasians (83.13) compared with that of URMs (78.76) ($p = .027$). Essentially, comparable usage of screencasts is paired with lower course performance for URMs in relation to both Asians and Caucasians, begging the question of whether performance *might* be similar between the groups if URMs were to increase their screencast usage and presumably raise their performance. We find however, that Caucasians are the only group to retain significance for the positive correlation between screencast use and course performance ($r = .251$, $p = .000$). The lower course performance of URMs appears to be unrelated to screencast use—the significant relationship between being a URM and lower course performance is retained even after controlling for number of website hits ($r = -.139$, $p = .006$). Rather, the lower course performance of URMs is mediated by GPA—when this measure is controlled for, the significance of the relationship between being a URM and receiving a lower final course grade disappears completely ($r = -.004$, $p = .929$).

We also tested means for usage and performance across academic level (sophomore, junior, and senior) using one-way analysis of variance and found significant differences in both website hits

$[F(2, 393) = 3.31, p = .038]$ [2] and final course grade $[F(2, 393) = 8.60, p = .000]$.[3] Sophomores used screencasts at significantly lower levels than juniors ($p = .015$) and seniors ($p = .044$)—means of 18.04, 24.87, and 24.33 respectively. As well, sophomores performed at significantly lower levels than both juniors ($p = .000$) and seniors ($p = .022$)—means of 79.51, 84.71, and 83.01 respectively. Essentially, being a sophomore has a negative effect on both usage and performance, suggesting the potential for increased usage to result in higher performance. However, when the overall positive, significant correlation between usage and performance is broken down by academic level, significance is retained by juniors ($r = .194, p = .010$) and seniors ($r = .309, p = .000$), but not sophomores ($r = .184, p = .091$). Thus, it appears that even sophomores who are using screencasts at higher levels are not experiencing the same performance benefits as are their junior and senior counterparts. Indeed, the negative relationship between sophomore status and performance retains its significance even after controlling for number of website hits ($r = -.162, p = .001$). In contrast, the significance of this relationship disappears when GPA is controlled for ($r = -.055, p = .273$), meaning that the relationship between being a sophomore and receiving a lower final course grade seems to be mediated by GPA and not screencast use.

Usage and Performance by Academic Major

Analyses of screencast use and performance according to student major illustrate differential use of screencasts by particular students. We focus our analysis on the three majors that comprise the largest portion of the student population; namely, Aerospace Engineers (AERO), Chemical Engineers (ChE), and Industrial and Operations Engineers (IOE).[4] Our results show the potential for screencasts to impact course performance differently depending on students' academic preparation/backgrounds. This finding suggests that students who enter the course with academic backgrounds (majors) that have provided them with experiences and knowledge of the concepts to be covered in MSE 220 may perform comparatively better in the course, since they are already quite familiar with course material (Recall Figure 2). Thus, these students may be predisposed to use the screencasts

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[2]Significance was also found using robust tests of equality of means. Welch robust F test: $F(2, 236.405) = 4.598, p = .011$ and Brown-Forsythe robust F test: $F(2, 375.439) = 3.630, p = .027$. These tests were run to determine significance given violation of the assumption of equality of variance at the $p < .05$ level: a Levene statistic of (2, 393) 3.64, $p = .027$.

[3]One freshmen was excluded from the analyses in Winter 2009 due to insufficient sample size.

[4]In order to insure adequate sample size for comparative purposes and to satisfy normality and equality of variance assumptions, the major groups with sample sizes below twenty were excluded from statistical analyses. Additionally, MSE students were not included due to the fact that the University of Michigan College of Engineering offers/recommends an alternate course specifically for MSE students that fulfills the introduction to MSE requirement. As such, the small number of MSE students who opt to take MSE 220 are unlikely to be representative of MSE majors in general (most of whom are enrolled in MSE 250). Finally, Other Engineers were excluded for theoretical reasons. Meaningful interpretation of results is hindered by variability in academic background among constituent majors (Mechanical Engineers, Electrical Engineers, etc.).

less frequently. In turn, students whose academic backgrounds have prepared them the least for the course content may use screencasts the most, perhaps due to their lack of familiarity and confidence related to the concepts, and that screencast usage results in better performance overall.

This finding needs to be placed in context of student performance by academic major *prior to* the introduction of screencasting. Analysis of student performance in Fall 2006 shows that students across academic majors performed differently, with IOEs performing least favorably among all the major groups. One-way analysis of variance indicates significant differences in means for final course grade across each of the three largest major groups [$F\ (2, 113) = 4.04$, $p = .020$]. (See Table 4 & 5 in Appendix). In this case, post-hoc tests show that this significance is attributable to the differences between IOEs and ChEs ($p = .015$), while no significance is found for AERO students in relation to the other major groups at the $p < .05$ level. (See Table 6 in Appendix).

In terms of course performance for Fall 2008 and Winter 2009, Figure 5a illustrates the number of students in each major who fall into each of five grade categories (ranging from F through A). ChE students tend to concentrate at the high end of the spectrum receiving a mean grade of 86% (Table 3). In fact, ChE students perform the best of all three major groups (see Table 4 in Appendix), but this mean course grade is only statistically significant ($p=.005$) in relation to IOE students (82%) based on the Tukey post hoc test. Comparisons between IOE and AERO and between AERO and ChE were not significant at the .05 level. (See Tables 5 & 6 in Appendix for full ANOVA results.) It is important to note that AERO, ChE, and IOE students have comparable mean GPAs when they enter MSE 220, despite this difference in course performance.

Screencast use is distributed variably, yet certain patterns emerge when focusing on the three largest major groups. IOEs comprise the bulk of very high users (Figure 5b) and are using screencasts at significantly higher rates than ChE or AERO students with mean number of website hits of 32.14, 19.03, and 20.49 respectively (Table 3). In contrast, ChE and AERO students are more likely to be very low and low users (Figure 5b). One-way analysis of variance shows a significant difference in the means for the number of website hits between the three largest majors [$F\ (2, 300) = 12.35$, $p = .000$][5] — attributable to the difference in usage between IOE and AERO students ($p = .001$) and IOE and ChE students ($p =.000$) based on the Games-Howell test. (See Tables 7 & 8 in Appendix.) Comparisons between ChE and AERO students were not significant at the .05 level. Essentially, IOE students were significantly more likely to have higher screencast use compared to students in other majors.

Interestingly, IOE students who are most likely to use screencasts at high levels, tend to receive grades in the middle range when all majors are compared (Table 3). This is particularly noteworthy

[5]Significance was also found using robust tests of equality of means. Welch robust F test: $F\ (2, 198.480) = 10.529$, $p = .000$ and Brown-Forsythe robust F test: $F\ (2, 277.955) = 13.006$, $p = .000$. These tests were run to determine significance given violation of the assumption of equality of variance at the $p < .05$ level: a Levene statistic of $(2, 300) = 11.219$, $p = .000$.

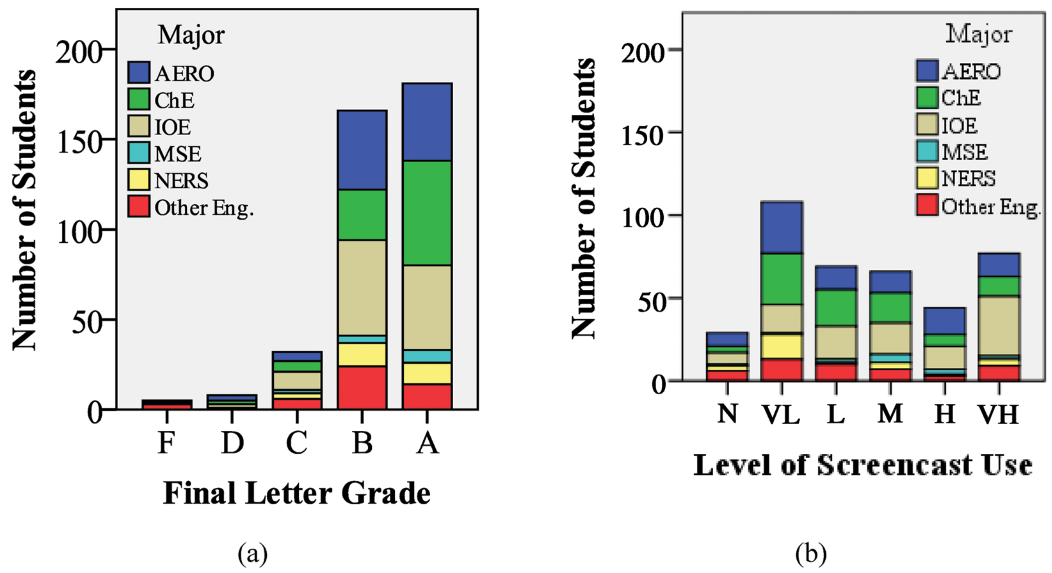

Figure 5: (a) Final letter grade and (b) level of screencast use by Academic Major. Screencast usage levels are defined as follows: non-users (N) with 0 website hits, very low users (VL) with 1-10 website hits, low users (L) with 11–20 website hits, mid-level users (M) with 21–30 website hits, high users (H) with 31-40 website hits, and very high users (VH) with more than 41 website hits per term. Majors are defined as follows: Aerospace Engineering (AERO), Chemical Engineering (ChE), Industrial and Operations Engineering (IOE), Materials Science Engineering (MSE), Nuclear Engineering and Radiological Sciences (NERS).

given their low academic performance prior to the introduction of screencasts in Fall 2006 and the relative dissimilarity in course requirements for IOE students in comparison to other majors (Figure 2). On the other hand, ChE students performed the best of all three majors regardless of the availability of screencasts. Therefore, the supplementary screencasts are most helpful to students whose academic background is dissimilar to Materials Science.

These results show that IOEs perform on par with fellow AERO and ChE students (despite their lack of prior exposure to course material) at least in part because of their higher screencast use. In examining the impact of the level of screencast use (ranging from very low to very high) on final course grade, we find that IOEs are the *only* major group for which course performance differs significantly between different usage levels, meaning that for these students high usage is significantly related to high course performance. A one-way analysis of variance for each of the three largest major groups shows significance for IOE students [$F(4, 101) = 6.619$, $p = .000$][6] (see Table 9 in Appendix), while Games-Howell post-hoc results attribute this to the difference in course performance means between the very low usage group and the very high usage group ($p = .035$). The means for all other usage groups were not significant at the .05 level. (See Table 10 in Appendix). This indicates that IOEs who are using screencasts the least are significantly more likely to receive lower grades, while those using screencasts the most are significantly more likely to receive higher grades. In a similar test for AEROs, despite the initial significance of the course performance means across the various screencast usage levels [$F(4, 83) = 2.680$, $p = .037$], Tukey post-hoc tests indicate no significance for any of the usage levels in relation to each other. As well, Games-Howell comparisons show only *slight* significance between the means for very low users and very high users ($p = .52$), with no significant differences in means for any of the other levels of usage at the $p < .05$ level. (See Table 11 in Appendix). This suggests that AEROs who use screencasts at very low levels are *somewhat* more likely to receive lower grades and vice versa, however this significance was only slight and should therefore be interpreted with considerable caution. Finally, no significance was found between performance means across levels of screencast use for ChE students. For these students, screencast use appears to be unrelated to course performance. Indeed, the positive relationship between ChE status and performance retains its significance even after controlling for both the number of website hits and cumulative GPA ($r = .215$, $p = .000$).

Summary

In this work, various types of screencasts were developed to address student needs in an introductory lecture course in Materials Science. Homework solution screencasts and "muddiest point" screencasts were used the most by students, and screencast usage was positively and significantly correlated to overall performance in the course. In other words, those students who used screencasts more earned a higher grade in the course. When we examine differences in means for screencast usage and course performance across the dimensions of gender, citizenship, race/ethnicity, academic level, and major; the results are mixed. For both gender and citizenship, students appear to benefit from screencast use more or less equally, regardless of whether they are male or female, U.S. Citizens or not. In terms of race/ethnicity and academic level, certain groups do demonstrate different relationships between screencast use and performance. However, for the two groups who stand to gain the most in terms of final course grade (sophomores and URMs), we find that GPA, rather than screencast use, provides the best explanation for course performance.

[6] Significance was also found using robust tests of equality of means. Welch robust F test: $F(4, 39.720) = 3.632$, $p = .013$ and Brown-Forsythe robust F test: $F(4, 41.433) = 5.465$, $p = .001$. These tests were run to determine significance given violation of the assumption of equality of variance at the $p < .05$ level: a Levene statistic of $(4, 101) = 5.606$, $p = .000$.

In contrast, there was a significant difference in screencast usage and performance across academic major, with ChE students and IOE students standing out among the major groups. Those students most prepared to encounter and subsequently master MSE 220 course content (the Chemical Engineers) use screencasts at low levels, while receiving the highest grades in the course. Indeed, for ChE students, no significant differences in means for final course grade are found across levels of screencast use and the positive relationship between being a ChE and receiving higher final course grades is not mediated by either usage or GPA. It appears that these students stand to benefit the least from screencast use. Quite the opposite of ChE students, IOE students begin the semester with the least familiarity with course content, use the screencasts the most, and receive average grades in the course. It is remarkable that the students who enter with the least preparation in Material Science are not receiving the lowest grades in the course, which was the case prior to the introduction of screencasts. Looking across the various semesters, it appears that IOE students have the *most* to gain by using the screencasts, since they start out at a disadvantage in terms of academic preparation for the course. Indeed, once screencasts became available and IOEs began to use them at high rates, this group improved their collective performance remarkably.

IMPLICATIONS AND FUTURE WORK

Our research shows the positive impact of screencasts as a supplementary resource to aid student learning, especially for those whose academic background may have provided them with less familiarity with course content than other students despite having similar overall grade point averages. We also find that other demographic dimensions, such as gender, citizenship, ethnicity, and academic level, are not significant indicators for the relationship between use and performance. However, interesting trends emerge that bear further study. For instance, while we find that Non-U.S. Citizen use screencasts at high rates and sophomores use at low rates, the reasons remain unclear.

Some researchers have noted the impact of academic preparation on student performance [26]-[30]. In particular, Zhanf and RiCharde showed that academic preparation, study skills, and the college environment are correlated with academic achievement in freshman; however, academic motivation and self efficacy were not [30]. Our research extends this finding by demonstrating that students who enter a course with comparable academic ability, but whose academic backgrounds prepared them less for the course content, showed gains in performance based on their use of screencasts. Seifert et al. [27] found that students who have the lowest academic preparation, parental education, involvement in high school prior to college, and academic motivation experienced the highest benefits as a result of good practices in undergraduate education as described by Chickering and

Gamson [31]. Using screencasts as supplementary resources is an example of one of Chickering and Gamson's principles in that these resources respects diverse talents and ways of learning by allowing students the flexibility to study concepts at their own pace and in more detail.

In all, the development of screencasts for a large lecture survey course has the potential to "level the playing field," and may be applied to courses where there is a wide range in student academic background knowledge such as introductory computer science courses, design courses, and even laboratory courses where students may enter with varying levels of familiarity with experimentation and writing lab reports. Further, this research used a variety of screencasts to aid student learning. Faculty who want to strategically develop their supplementary resources should consider creating "muddiest point" screencasts in courses comprised of students from a variety of academic backgrounds; while homework solution screencasts are applicable to any course where step by step explanations of procedures are necessary. Since students perceive *all* screencasts to be helpful, their development offers benefits above and beyond traditional text-based resources, as they can synthesize many resources, and provide a multimedia presentation of concepts that can reach a wider range of learners.

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APPENDIX

						95% Confidence Interval for Mean	
	Major	N	Mean	SD	SE	Lower	Upper
Fall 2006	AERO	41	81.41	5.88	.92	79.56	83.27
	ChE	21	85.27[d]	6.48	1.41	82.32	88.22
	NERS	11	83.22	5.81	1.75	79.32	87.12
	IOE	54	80.17	7.88	1.07	78.02	82.32
	MSE	16	81.69	6.09	1.52	78.44	84.93
	Other Eng. (Mech., Civil, etc.)	23	83.38	7.06	1.47	80.33	86.44
	Other (Non-Eng.)	1	–	–	–	–	–
	Total	167	81.91	6.94	.54	.80.85	82.97
Fall 2008 & Winter 2009	AERO	96	83.38	8.98	.92	81.56	85.20
	ChE	94	85.94	7.30	.75	84.44	87.44
	NERS	28	84.64	6.90	1.30	81.98	87.31
	IOE	113	82.24	9.51	.89	80.47	84.01
	MSE	14	80.15	18.57	4.96	69.43	90.87
	Other Eng. (Mech., Civil, etc.)	48	78.47	11.36	1.64	75.17	81.77
	Other (Non-Eng.)	4	77.38	11.11	5.55	59.70	95.05
	Total	397	82.98	9.69	.49	82.03	83.94

Table 4: Mean Performance (Final Course Grade) by Student Academic Background (Major).

ANOVA	Between Groups df	Within Groups df	F	sig
Fall 2006	2	113	4.04	$p = .020$
Fall 2008 & Winter 2009	2	300	4.76	$p = .009$

Table 5: Summary of ANOVA of Means for Course Performance (Final Course Grade) by Student Academic Background (Major).

	Comparisons	Mean Weight Difference (kg)	Std. Error	95% CI Lower Bound	95% CI Upper Bound
Fall 2006	AERO vs. ChE	−3.85	1.87	−8.31	.60
	IOE vs. AERO	−1.24	1.45	−4.68	2.19
	IOE vs. ChE	−5.10*	1.80	−9.36	−.83
Fall 2008 & Winter 2009	AERO vs. ChE	−2.56	1.26	−5.54	.42
	IOE vs. AERO	−1.14	1.21	−3.99	1.71
	IOE vs. ChE	−3.70**	1.22	−6.57	−.84

* $p < .05$, ** $p < .01$

Table 6: Tukey Post-hoc Comparison of Mean Course Performance (Final Course Grade) by Student Academic Background (Major).

ANOVA	Between Groups df	Within Groups df	F	sig
Fall 2008 & Winter 2009	2	300	12.35	p = .000

Table 7: Summary of ANOVA of Means for Screencast Usage (Number of Website Hits) by Student Academic Background (Major).

Comparisons	Mean Weight Difference (kg)	Std. Error	95% CI Lower Bound	95% CI Upper Bound
AERO vs. ChE	1.46	2.54	−4.54	7.45
IOE vs. AERO	11.65**	3.11	4.30	19.00
IOE vs. ChE	13.11**	2.94	6.17	20.05

** $p < .01$

Table 8: Games-Howell Post-hoc Comparison of Mean Screencast Usage (Number of Website Hits) by Student Academic Background (Major) in Fall 2008 and Winter 2009.

ANOVA		Between Groups df	Within Groups df	F	sig
Fall 2008 & Winter 2009	IOE	4	101	6.62	$p = .000$
	AERO	4	83	2.68	$p = .038$
	CHE	4	85	0.44	NS

Table 9: Summary of ANOVA of Means for Course Performance (Final Course Grade) by Screencast Usage (Level of Screencast Use) for Aerospace , Chemical and Industrial and Operations Engineers in Fall 2008 and Winter 2009.

Comparisons	Mean Weight Difference (kg)	Std. Error	95% CI Lower Bound	95% CI Upper Bound
Very Low (1–10) vs. Low (11–20)	−10.50	4.18	−22.95	1.95
Very Low (1–10) vs. Mid (21–30)	−10.39	4.12	−22.68	1.90
Very Low (1–10) vs. High (31–40)	−6.72	4.55	−20.05	6.62
Very Low (1–10) vs. Very High (41+)	−12.78*	3.98	−24.83	−.734
Low (11–20) vs. Mid (21–30)	.11	2.10	−5.91	6.13
Low (11–20) vs. High (31–40)	3.78	2.88	−4.69	12.26
Low (11–20) vs. Very High (41+)	−2.28	1.84	−7.60	3.03
Mid (21–30) vs. High (31–40)	3.68	2.76	−4.54	11.89
Mid (21–30) vs. Very High (41+)	−2.39	1.65	−7.15	2.37
High (31–40) vs. Very High (41+)	−6.07	2.57	−13.88	1.75

*$p < .05$

Table 10: Games-Howell Post-hoc Comparison of Mean Performance (Final Course Grade) by Level of Screencast Use for Industrial and Operations Engineers in Fall 2008 and Winter 2009.

Comparisons	Mean Weight Difference (kg)	Std. Error	95% CI Lower Bound	95% CI Upper Bound
Very Low (1–10) vs. Low (11–20)	−1.48	2.31	−8.07	5.11
Very Low (1–10) vs. Mid (21–30)	−.17	2.53	−7.42	7.08
Very Low (1–10) vs. High (31–40)	−5.91	2.60	−13.35	1.53
Very Low (1–10) vs. Very High (41+)	−6.16†	2.18	−12.36	.03
Low (11–20) vs. Mid (21–30)	1.31	2.23	−5.28	7.90
Low (11–20) vs. High (31–40)	−4.43	2.32	−11.21	2.35
Low (11–20) vs. Very High (41+)	−4.69	1.83	−10.05	.68
Mid (21–30) vs. High (31–40)	−5.74	2.53	−13.14	1.66
Mid (21–30) vs. Very High (41+)	−5.99	2.09	−12.21	.22
High (31–40) vs. Very High (41+)	−.25	2.18	−6.67	6.16

† $p < .10$

Table 11: Games-Howell Post-hoc Comparison of Mean Performance (Final Course Grade) by Level of Screencast Use for Aerospace Engineers in Fall 2008 and Winter 2009.