AC 2011-1736: A STUDY OF ON-LINE TEXTBOOK USE ACROSS MULTIPLE ENGINEERING COURSES

John Chen, California Polytechnic State University

John Chen is an associate professor of mechanical engineering at Cal Poly. He joined the faculty there in 2008 after being on the faculty at Rowan University from 1998-2008. He is an active member of ASEE.

Christine A. Victorino, California Polytechnic State University, San Luis Obispo

Christine A. Victorino completed her B.Sc. at Queen's University, B.Ed. at the Ontario Institute for Studies in Education (OISE)/University of Toronto, and M.A. (Education) at California Polytechnic State University, San Luis Obispo. She is currently a Ph.D. student in Education at UC Santa Barbara.

Charles Birdsong, California Polytechnic State University

Charles Birdsong, Ph.D. Assistant Professor of Mechanical Engineering California Polytechnic State University at San Luis Obispo

Charles Birdsong has expertise in automotive safety, vibrations, controls, signal processing, instrumentation, real-time control, active noise control, and dynamic system modeling. He received his BSME at Cal Poly San Luis Obispo, MS and Ph.D. at Michigan State University where he worked on active noise control applications for the automotive industry. He has worked in the vibration test and measurement industry helping to drive new technologies to market and working with industry to meet their emerging needs. He is currently an Associate Professor at California Polytechnic State University at San Luis Obispo in the Department of Mechanical Engineering teaching dynamics, vibrations and controls and is involved in several undergraduate and master's level multidisciplinary projects.

Unny Menon, California Polytechnic State University

Unny Menon, Professor of Industrial and Manufacturing Engineering at Cal Poly San Luis Obispo from 1978 onwards. He also served as Dept.Chair, Senate Chair, Associate Dean and Assistant Provost at Cal Poly. His prior faculty positions were at Sheffield Polytechnic UK, University of Nottingham UK and at RT in Rochester NY. His industry appointments have included British Steel Corp., Bechtel, IBM, Northern Telecom, US Navy Research Station and NEC. His NSF and industry funded research has addressed Concurrent Engineering, Rapid Prototyping, Optimization of automated manufacturing systems and least cost blending models for steel making.

Marilyn Tseng, California Polytechnic State University, San Luis Obispo

Marilyn Tseng is an epidemiologist and Research Associate Professor and Lecturer in the Kinesiology Department at Cal Poly San Luis Obispo.

Tyler Scott Smith

"Tyler Smith is a Junior majoring in Biomedical Engineering at Cal Poly San Luis Obispo. He also works at Cal Poly's Center for Teaching and Learning, assisting faculty and staff with teaching resources. He is also member of Alpha Phi Omega, a coed national service fraternity and part of the Tissue and Microcirculation Repair Lab on campus. He expects to graduate in June 2012.

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A Study of Online Textbook Use across Multiple Engineering Courses

Abstract

In this study, our goals were to examine the implementation and effectiveness of online textbooks in three different undergraduate engineering courses. We compared students' attitudes and performance using surveys with Likert-type and open-ended questions conducted at three time points during the academic quarter, and pre- and post-course concept inventories. In one course, ME 422 (Mechanical Controls), we compared students' attitudes and performance with a control group that used only the printed textbook. Linear regression analyses for this course indicated significant differences between the online and printed textbook groups, with consistently more favorable scores in attitudes in the latter group. These differences were apparent from the first survey and became more pronounced over time. Significant differences were also found across the three online textbook courses on multiple survey items measuring students' usage and attitudes ($p < .001$). Preliminary findings suggest that student interaction with and attitude toward online textbooks differed based on the technical complexity of the course. The qualitative comments for the most technical course in the study (ME 422) indicated that the user interface and technical difficulties with entering symbolic solutions to the online environment were problematic. In contrast, students enrolled in IME 421 (Manufacturing Organizations), which covered general theory and used more case studies, had more favorable attitudes toward the online system. The remaining course, ME 302 (Introduction to Thermodynamics), while technical, did not typically require more than numerical solution input to the online environment, and showed responses that were generally intermediate between the other two courses.

Introduction

Despite the tremendous growth in the availability and implementation of online textbooks (also known as e-textbooks and digital textbooks), little is known about their impact with respect to student usage, attitudes, and learning outcomes. It should be noted that there is a distinction between e-books, which only include digital versions of paper books, and online textbooks, which typically include digital text as well as enhanced online course materials.

In undergraduate engineering courses, online textbooks have the potential to provide rich learning environments, which include traditional textbook content, online assessment tools (e.g., individualized homework questions, quizzes, automatic grading), enhanced multimedia content, and interactive simulations. Moreover, online textbooks are appealing to both students and instructors for their reduced cost, portability, and smaller environmental footprint. Despite the relative benefits of online textbooks, however, concerns about them include poor user interfaces, inconsistent or nonexistent standards among textbook publishers, restrictive licensing, limited range of available textbooks, and growing pains associated with learning new technologies.

In order to provide insight into students' attitudes and usage regarding online textbooks, we examined the following questions:

1. What is the extent to which students use online textbooks when assigned?
2. What are student attitudes regarding online textbooks?

3. How does the use of online textbooks affect student learning outcomes?

We examined these questions by implementing online textbooks in three undergraduate engineering courses: IME 421 Manufacturing Organizations, ME 302 Introduction to Thermodynamics, and ME 422 Mechanical Controls. The following are course descriptions from the university course catalog:

IME 421 Manufacturing Organizations (3 units)
Theory and principles for manufacturing organizations. Competitive advantage. Strategic planning and operations management for organizations and teams in a rapidly changing environment. Engineering management concepts and practices. Team-based projects and cases.

ME 302 Introduction to Thermodynamics (3 units)
Properties of working fluids and fundamental relations for processes involving the transfer of energy. First and second laws of thermodynamics, irreversibility and availability.

ME 422 Mechanical Controls (4 units)
Modeling and control of physical systems. Design of mechanical, hydraulic and electrical systems using time response, frequency response, state space, and computer simulation.

The three courses varied in their technical complexity, with IME 421 being the least technical and involving more conceptual knowledge, ME 302 being both technical and conceptual, and ME 422 being the most technical (for example, reliance on symbolic equations and use of advanced mathematics). In addition to our comparison of online textbooks in the three different courses, ME 422 conducted a comparison of students' attitudes and performance between a treatment group (online textbook) and a control group (printed textbook only).

Background and Literature Review

The implementation of online textbooks is an emerging area in both higher education and in the related scholarly research. The available research results should be viewed in light of the rapidly changing products being developed and offered by the various major publishers. That caveat notwithstanding, we review the available recent literature that studied digital or online textbooks.

In a recent review of the research on e-books (i.e., digital or PDF versions of traditional textbooks), researchers found that the greatest barrier to the e-book format was "cultural acceptance"[1]. That is, individuals who grew up with paper books found it difficult to transition to e-books. Even "digital natives" consistently exhibited discomfort with the digital format; however, the author noted that such cultural barriers will eventually dissipate as new groups of students enter college.

In terms of student attitudes and outcomes in the online learning environment, research conducted in a graduate macroeconomics class found that there were no statistical differences between "cyberlearners" (n1=32) and traditional learners (n2 = 31) on student outcomes, as measured by quizzes and tests.[2] Moreover, the authors found no statistical differences between the two groups regarding their attitudes toward the cyber vs. traditional learning environments. In general, the cyberlearners were very positive about their experience, and they cited the

following advantages to the cyber-learning environment: self-pacing, convenience, flexibility, and comprehensiveness of CD-ROM lectures. Accordingly, similar research found no significant differences between the online versus the traditional learning environments, that constructivist approaches worked well online, that faculty were satisfied with online education, and that students were typically pleased with their experiences.[3]

Among different subjects, digital textbooks were found to be most effective in language, sociology and science classes and less effective in English (as a second language) and mathematics classes.[4] The authors suggested that the digital textbook was not able to overcome the cognitive burdens for the English and math subjects.

Methods

I. Location and Participants

This study was implemented during the 2009-10 academic year at California Polytechnic State University (Cal Poly) in San Luis Obispo, CA. Cal Poly is a large, comprehensive university with approximately 16,000 students, and is part of the California State University system. The study was approved by the Institutional Review Board (IRB) and all participants consented to be involved in the study. Approximately 220 students participated in the study. Participation in the study was voluntary and uncompensated, and had no effect on the participants' grade. Table 1 includes descriptive statistics for all study participants.

Table 1: Description of the student participants.

			Race/ethnicity[a], %					Year in school[b]			
Course	**N**	**% female**	**White**	**Afric.-Amer.**	**Asian/ Pac.Isl.**	**Latino**	**Multi-racial**	**Soph.**	**Junior**	**Senior**	**Grad.**
IME 421	59	27	56	1.7	19	12	10	1.7	49	41	8.5
ME 302	33	33	82	3.0	6.1	9.1	0.0	3.0	42	49	6.1
ME 422 - Treatment	55	5.5	71	1.8	7.3	11	0.0	0.0	0.0	100	0.0
ME 422 - Control	65	14	75	0.0	11	7.7	4.6	0.0	0.0	97	3.0

[a] Remainder of participants either reported "other" or did not answer this question.

[b] For the data analyses, Sophomore and Junior students were grouped, and Senior and Graduate students were grouped.

II. Study Personnel

The research team consisted of three instructors (one each for IME 421, ME 302, and ME 422), one evaluator, one statistician, and one data specialist. Each of the three instructors was responsible for developing course-specific outcomes, teaching their individual courses, and assigning relevant homework and quizzes from the online textbook. The evaluator was responsible for obtaining student informed consent and conducting data collection (i.e., surveys and concept inventories). The statistician conducted analyses of all quantitative data collected,

and the data specialist was responsible for data entry and management. In addition, all study personnel were engaged in study design, coding of qualitative student comments, and interpretation of overall findings.

III. Textbook Usage

For the three comparison courses, online textbooks from the same publisher were required for all enrolled students. Each of the courses had a different instructor who had previously taught the course using the printed version of the textbook. The ME 422 and IME 421 instructors had also used the online textbook in at least one prior offering of their course. The ME 302 instructor had used an online textbook from the same publisher for an undergraduate engineering mechanics course. Thus, it can be said that all three instructors were familiar with the online textbook system and its use.

Following are descriptions of the online textbooks and how each of the instructors utilized the textbooks in their respective courses:

IME 421 Manufacturing Organizations
The online textbook provided a comprehensive suite of learning materials: entire textbook content, podcasts, case studies, contemporary video clips, online quizzes (with interactive review of correct answers that point to relevant portions of the textbook), a grade book, and simulation tools that illustrate concepts and challenges that arise in engineering management situations. The course content is largely qualitative with many organizational issues having broad scope for interpretation and ample opportunities for students to debate complex issues.

ME 302 Introduction to Thermodynamics I
The online textbook included printed textbook content, including all end-of-chapter problems, and additional sample problems with solutions. In addition, some sample problems were interactive in that variables may be altered by input and the resulting changes in the solution would be displayed either through text answers or by graphical solution. Select end-of-chapter problems were available to be solved by entering final text or numerical answers (without solution procedures) directly into the online textbook system, which then automatically graded the problem and provided immediate feedback to the student. The homeworks assigned in ME 302 typically included some brief reading, online problems and traditional paper-based problems which were submitted to the instructor for grading. Homeworks were assigned approximately on a weekly basis, each containing 4-8 problems, and approximately 30-60% of the problems were completed online. The online textbook was never used during class meetings or for quizzes or examinations.

ME 422 Mechanical Controls
The online textbook included printed textbook content (i.e., chapters), sample problems, and online homework. In addition, the online textbook included interactive media, such as animations which allow students to change parameters and view graphs or animations of how the system responds to parameter adjustments. During lecture, the online textbook was used to show parts of the book on a digital projector, and the animations

were used to illustrate new concepts. The online homework (with automatic grading) was used as the only form of homework assignments. Six to eight problems were assigned each week. Students were advised to print out the problem statements, solve them on paper, and then enter their answers into the website for instant feedback. The website showed the solutions after the assignments were due.

For ME 422, a control group (involving two class sections with a total of 65 students) used only a printed textbook, and the treatment group (also involving two class sections with a total of 47 students) used only the online textbook. The control and treatment groups were taught by the same instructor in consecutive academic quarters, using the same pedagogy and approach, and with similar lecture periods, assignments, and tests.

IV. Data Collection and Analyses

Surveys that measured textbook usage and attitudes using a Likert-type scale were administered at three times during the term (week two, midterm, and final (10^{th}) week). Additional data included pre- and post-course concept inventories that were developed or adopted for course-specific learning outcomes. For IME 421 and ME 422, the concept inventories were developed by the instructors prior to the start of the courses, but these did not undergo psychometric validation. For ME 302, an available thermodynamics concept inventory[5,6] that has been validated (Prince et al. 2010; Prince et al. 2009) was administered to this online-textbook section. An additional section of ME 302, taught contemporaneously by the same instructor and having the same assignments, quizzes and examinations, but using only the printed textbook, also took the concept inventory and acted as a comparison group for this specific learning outcome measure.

Survey responses were examined for differences between the control and treatment sections (ME 422 only), across the three online textbook courses, and over time in each course, using mixed linear regression models taking repeated measures into account. A comparison of means between the two ME 422 'control' sections and the two 'treatment' sections showed non-significant differences for most questions across all time points; thus, the two sections of each group (control and treatment) were combined in further analyses. Based on comparisons of model fit using Akaike's and Schwarz's Information Criteria,[7] a compound symmetry covariance matrix was selected for modeling. Main effects of treatment, time, and treatment-by-time interaction were tested before and after adjusting for sex, year in school, race/ethnicity, and grade point average (GPA). Results were not meaningfully different with or without adjustment for these covariates. Here we present the results based on the adjusted models. The same procedure was used to evaluate differences across courses. Statistical analyses were conducted using SAS software (version 9.1, SAS Institute, Cary, NC). Finally, qualitative student comments were collected through open-ended questions in the surveys, which were then coded for common themes and analyzed. The survey used in ME 422 is shown in Fig. 1. Surveys for the other two courses differed slightly from this, but only the common questions between the three surveys (#1 through #12) and the open-ended comments were analyzed and compared.

ME 422 Survey

For the purpose of this survey, [online textbook] materials include Assignments, Quizzes, Reading Content, Cases, Video Clips, Simulations, MP3 Files, Interactive Learning Resources, Flash Cards, and Crossword Puzzles.

1. I reviewed [online textbook] materials on a weekly basis, outside of the classroom.
    a. Strongly Disagree
    b. Disagree
    c. Neutral (neither agree nor disagree)
    d. Agree
    e. Strongly Agree
2. The [online textbook] materials are easy to navigate and use.
    a. Strongly Disagree
    b. Disagree
    c. Neutral (neither agree nor disagree)
    d. Agree
    e. Strongly Agree
3. The [online textbook] interface did not interfere significantly with the process of studying problems and answering questions.
    a. Strongly Disagree
    b. Disagree
    c. Neutral (neither agree nor disagree)
    d. Agree
    e. Strongly Agree
4. Reviewing [online textbook] materials has been an effective use of my time.
    a. Strongly Disagree
    b. Disagree
    c. Neutral (neither agree nor disagree)
    d. Agree
    e. Strongly Agree
5. In addition to course lectures and notes, [online textbook] materials have been necessary for my understanding of ME 422 course concepts.
    a. Strongly Disagree
    b. Disagree
    c. Neutral (neither agree nor disagree)
    d. Agree
    e. Strongly Agree
6. The [online textbook] assignments helped me learn the material as well as traditional homework assignments from a printed text.
    a. Strongly Disagree
    b. Disagree
    c. Neutral (neither agree nor disagree)
    d. Agree
    e. Strongly Agree
7. [Online textbook] materials increased my understanding of ME 422 course concepts.
    a. Strongly Disagree
    b. Disagree
    c. Neutral (neither agree nor disagree)
    d. Agree
    e. Strongly Agree
8. Use of [online textbook] materials has positively impacted my academic performance in ME 422.
    a. Strongly Disagree
    b. Disagree
    c. Neutral (neither agree nor disagree)

d. Agree
e. Strongly Agree

9. For future students of ME 422, I would recommend the use of [online textbook] materials.
    a. Strongly Disagree
    b. Disagree
    c. Neutral (neither agree nor disagree)
    d. Agree
    e. Strongly Agree

10. The [online textbook] materials have stimulated my interest in taking further courses in control systems.
    a. Strongly Disagree
    b. Disagree
    c. Neutral (neither agree nor disagree)
    d. Agree
    e. Strongly Agree

11. How much time did you spend reviewing [online textbook] materials for course-related assignments and quizzes? Please approximate number of hours per week.
    a. Not at all
    b. Less than 1 hour
    c. 1-2 hours
    d. 2-3 hours
    e. 3 or more hours per week

12. How much time did you spend reviewing [online textbook] materials for your own interest? Please approximate number of minutes or hours per week.
    a. Not at all
    b. Less than 1 hour
    c. 1-2 hours
    d. 2-3 hours
    e. 3 or more hours per week

13. Which version of the textbook and [online textbook] materials do you prefer? Please check one.
    a. E-textbook and [online textbook]
    b. Binder-ready textbook and [online textbook]
    c. Hardcover textbook and [online textbook]
    d. Binder-ready or hardcover textbook (with no [online textbook])
    e. None of the above

14. If applicable, what specific components of the [online textbook] materials increased your understanding of ME 422 course concepts? Please mark your response on the page (you may choose more than one).
    ☐ Assignments
    ☐ Quizzes
    ☐ Reading content
    ☐ Simulations
    ☐ Other _____
    ☐ Not applicable

15. How could the instructor have used [online textbook] better to improve your understanding of the course material?

16. Please provide any additional comments regarding the [online textbook] materials. Please write your response on the page.

Fig. 1: ME 422 survey. Note that the specific name of the online textbook system has been replaced in this figure with "[online textbook]". In the control group, this text would simply read "textbook."

Results

Among 109 students in ME 422 (only those students who took all three surveys were included in this analysis), linear regression analyses indicated significant differences between the online and printed textbook groups, with consistently more favorable scores in the latter group for questions 2-10 (Table 2). For questions 6-9, significant group-by-time interactions indicate that these differences became more pronounced over time, generally with scores increasing (more positive) in the control group and decreasing (more negative) in the treatment group. For question 11, a decrease in mean score for the control group and an increase in the treatment group was reflected in a significant group-by-time interaction, although mean scores overall were not significantly different. Finally, only question 6 showed a significant variation with time.

Among all 134 students using the online textbook (again, only students who completed all three surveys were included), significant differences were found across the three online textbook courses on all 12 survey items measuring students' usage and attitudes (Table 3). Scores were consistently highest for the IME 421 course and lowest for the ME 422 course except for question 11, which showed the reverse pattern. A significant effect of time was observed for questions 1, 2, 6, and 9. Mean scores decreased for all courses for these four questions, but a larger decrease in mean score for question 6 in ME 422 resulted in a significant group-by-time interaction. A significant group-by-time interaction was also evident for question 11; mean score among students in ME 422 in increased over time whereas they decreased in other courses.

Student learning outcomes were measured and compared between treatment and control groups in ME 302 and ME 422 using a concept inventory (IME 421 did not have a control group). In both courses, the "gains" in student performance on the inventories (defined as the difference between the post- and pre-course correct answers, divided by the number of incorrect pre-course answers) showed no significant difference between the treatment and control groups based on a two-tailed, unpaired t-test (ME 302: p=0.81; ME 422: p=0.25).

Table 2: ME 422 mean question scores by treatment group* and survey administration, and p-values for group, time, and group-by-time interaction from mixed linear regression models. Statistically significant results ($p<0.05$) are shown in bold type.

	Survey administration			p-values		
Question	1	2	3	Group	Time	Interaction
1				0.26	0.39	0.58
control	3.7	3.3	3.5			
treatment	3.4	3.4	3.2			
2				**0.001**	0.21	0.06
control	3.3	3.5	3.5			
treatment	3.1	3.1	2.6			
3				**<0.0001**	0.83	0.76
control	3.6	3.7	3.7			
treatment	2.3	2.3	2.1			
4				**<0.0001**	0.91	0.36
control	3.5	3.5	3.6			
treatment	2.6	2.6	2.4			
5				**<0.0001**	0.84	0.22
control	3.7	3.6	3.8			
treatment	2.6	2.5	2.4			
6				**<0.0001**	**0.02**	**0.0001**
control	4.0	4.0	4.2			
treatment	2.9	2.2	2.2			
7				**<0.0001**	0.49	**0.006**
control	3.6	3.9	3.9			
treatment	3.0	2.9	2.7			
8				**<0.0001**	0.88	**0.02**
control	3.6	3.7	3.8			
treatment	2.6	2.4	2.3			
9				**<0.0001**	0.78	**0.002**
control	3.8	3.8	4.0			
treatment	2.3	2.0	1.9			
10				**<0.0001**	0.88	0.11
control	2.7	2.6	2.8			
treatment	2.2	2.0	1.9			
11				0.67	0.58	**0.009**
control	3.6	3.5	3.4			
treatment	3.2	3.7	3.8			
12				0.38	0.22	0.13
control	1.6	1.4	1.5			
treatment	1.4	1.2	1.5			

* n=62 for control, n=47 for treatment.

Table 3: Mean question scores by course* and survey administration, and p-values for group, time, and group-by-time interaction from mixed linear regression models.

Question	1	2	3	Group	Time	Interaction
1				**0.02**	**0.008**	0.91
ME 422	3.4	3.4	3.2			
ME 302	3.4	3.3	3.0			
IME 421	4.0	3.7	3.6			
2				**<0.0001**	**0.03**	0.84
ME 422	3.1	3.1	2.7			
ME 302	3.7	3.8	3.5			
IME 421	4.2	4.2	4.0			
3				**<0.0001**	0.78	0.60
ME 422	2.3	2.3	2.1			
ME 302	3.2	3.4	3.0			
IME 421	3.8	3.7	3.8			
4				**<0.0001**	0.26	0.58
ME 422	2.6	2.6	2.4			
ME 302	3.1	3.4	3.0			
IME 421	3.8	3.7	3.7			
5				**<0.0001**	0.53	0.15
ME 422	2.6	2.5	2.4			
ME 302	2.5	2.7	2.3			
IME 421	3.4	3.5	3.6			
6				**<0.0001**	**0.002**	**0.01**
ME 422	2.9	2.2	2.2			
ME 302	3.5	3.5	3.1			
IME 421	3.8	3.9	3.7			
7				**<0.0001**	0.27	0.56
ME 422	3.0	2.9	2.7			
ME 302	3.1	3.2	3.1			
IME 421	4.0	3.9	3.9			
8				**<0.0001**	0.09	0.82
ME 422	2.6	2.4	2.3			
ME 302	3.1	3.0	3.0			
IME 421	3.9	3.7	3.8			
9				**<0.0001**	**0.006**	0.28
ME 422	2.3	2.0	1.9			
ME 302	3.2	3.3	2.9			
IME 421	4.0	3.7	3.8			
10				**<0.0001**	0.13	0.14
ME 422	2.2	2.0	1.9			
ME 302	2.2	2.5	2.1			
IME 421	3.2	3.2	3.3			
11				**0.03**	0.38	**0.0004**
ME 422	3.2	3.7	3.8			
ME 302	3.2	3.2	2.9			
IME 421	3.3	3.0	2.8			
12				**0.01**	0.56	0.06
ME 422	1.4	1.2	1.5			
ME 302	1.3	1.4	1.3			
IME 421	1.9	1.7	1.7			

* n=47 for ME 422, n=29 for ME 302, and n=58 for IME 421.

Surveys administered in all three courses included an open-ended question asking the students to comment on the online textbook. The majority of study participants did not respond, but a significant proportion did. The three instructors coded these comments for all three courses independently and compared the results. When there was a disagreement as to the proper code assignment, the instructors discussed the item until an agreement was reached. The codes used to categorize the comments are shown in Fig. 2. The codes were mostly developed by the three instructors before the study began based on guesses as to what students may comment on. Additional codes were added after the coding began to accommodate comments that were not anticipated.

Positive Comments:
P1 Well-organized
P2 Provides immediate feedback
P3 Convenience
P4 Lower Cost
P5 Helped learn subject matter
P6 Complemented my learning style

Negative Comments:
N1 Assign more problems
N2 Assign less problems
N3 Provide more guidance on how to use [online textbook]
N4 Provide more hints
N5 Provide more specific solutions to problems, not just final answer
N6 Limits instructor feedback
N7 Hard to read on computer
N8 Technical problems
N9 Cost savings not enough of a benefit
N10 Answer formatting problems
N11 Prefer paper homework
N12 Needs more hyperlinks, tables, charts, multimedia
N13 Not an effective learning tool
N14 Increased the amount of time to complete assignments

Fig. 2: Codes used to categorize student comments regarding the online textbook.

Table 4 lists the frequency and type of comments received in each course over time. In general, negative comments outnumbered positive ones, and both positive and negative comments decreased with time, with the negative comments falling to a somewhat constant level. It is clear that ME 422 students had the most negative experiences with the online textbook, even when the number of respondents in each course is taken into account. Conversely, even with the largest sample size, IME 421 students had relatively few complaints, though certainly there were concerns among them as well over the quarter. ME 302 students had approximately the same number of negative comments compared with IME 421, but had half the sample size. If the

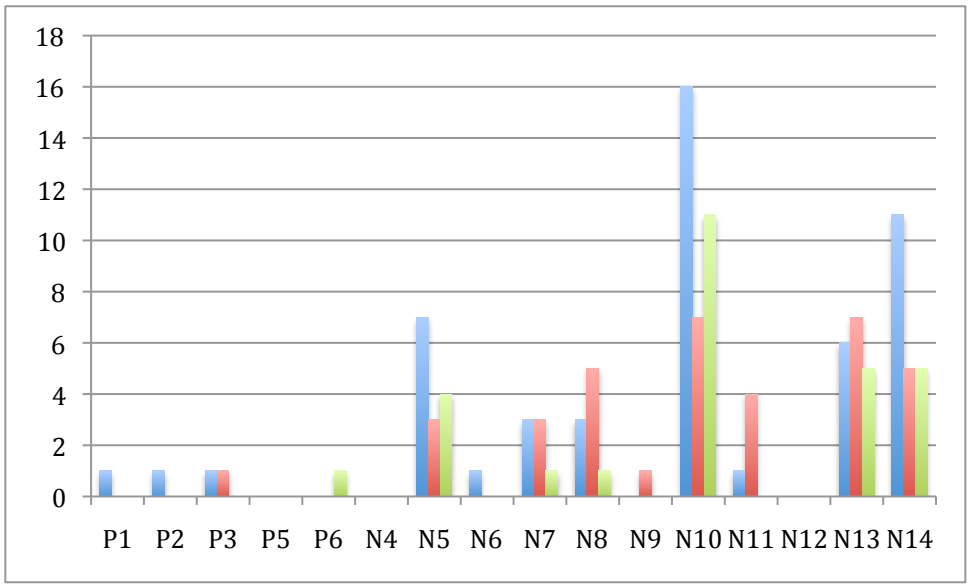
number of negative comments per student can be taken as a measure of the experience of the students in a course, the courses would clearly rank (from least to most negative) in the order of IME 421, ME 302, and ME 422.

Table 4 – Frequency and type of comments over time in each course.

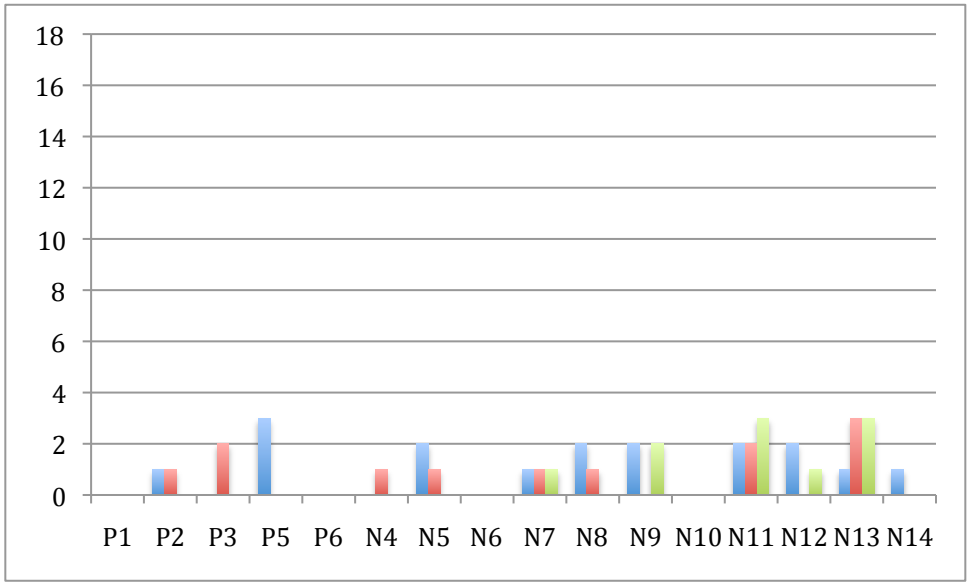
	ME422; n=47			ME302; n=29			IME421; n=58		
Survey #	1	2	3	1	2	3	1	2	3
# positive comments	3	1	1	4	3	0	1	0	2
# negative comments	48	35	27	13	9	10	15	8	8

Figure 3 shows histograms for each comment code, over time and in each course (note that some codes are left out since they were never cited). It is clear that in ME 422, the negative comments focused on several problems, and some were persistent through the quarter. The major problems included: N5, N7, N8, N10, N13, and N14. ME 302 has a broad distribution of negative comments, several of which persisted through the quarter, but none of which stood out among the others. Finally, in IME 421, it can be seen that the negative comments fell into three categories, N7, N8, and N13, with N7 and N8 less cited over time and N13 increasingly cited.

(a) ME 422



(b) ME 302



(c) IME 421

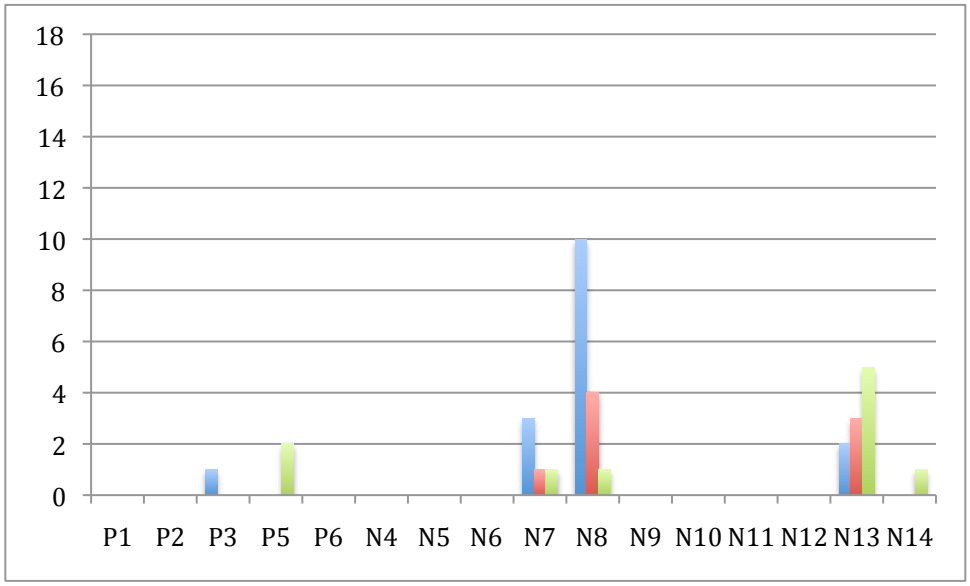


Fig. 3: Histograms showing occurrences of each comment code. For each code, the cluster of three data points represents surveys #1 (blue), #2 (red), and #3 (green), from left to right in each cluster.

Discussion

I. Interpretations of findings

The quantitative survey data was consistent with the coded qualitative comments, demonstrating better student attitudes toward the online textbook in IME 421, worsened student attitudes for ME 302, and lowest scores and more negative comments for ME 422. Thus, student interaction

with and attitude toward online textbooks differed significantly with each course. It is not clear whether these variations are due to the publisher's implementation of the online textbook for each course, or the instructor's use of the online textbook in each course. Our opinion is that the main cause is based on the technical complexity of the course and how the online textbook accommodated this. Students enrolled in IME 421 (Manufacturing Organizations), which covered general theory, used more case studies, and relied mainly on readings and multiple-choice assessments, had more favorable attitudes toward the online system, though certainly some complaints were consistently cited. ME 302 (Introductory Thermodynamics), while technical, did not typically require more than numerical solution input to the online environment, and showed opinions and attitudes that were intermediate between the other two courses. The survey and qualitative comments for the most technically complex course in the study (ME 422 Mechanical Controls) indicated that the user interface and technical difficulties with entering symbolic solutions to the online environment were problematic.

Learning outcomes, as measured by the pre- and post-course concept inventories in ME 422 and ME 302, were the same between the online and printed textbook cohorts. Clearly, using the online textbooks did not hinder the students' learning in these two courses, but the *quality* of their learning experience was negatively impacted by it. Several comments reflected the students' negative view of the extra time used to complete assignments in the online textbook, the frustrations with technical problems or answer formatting, and the lack of feedback on the solution procedure (rather than simply an answer) in solving problems.

In general, the qualitative comments indicate that students were consistently negative toward two problems: technical difficulties encountered with the online textbook (e.g., incorrectly graded problems, poor navigation in the web page, narrow tolerance in answers to numerical solutions), and the increase in time for completing assignments and frustration level as a result of using the online textbook. These findings may be a result of the students' conception of what an "online experience" should be – perhaps based on their common interactions with websites and applications – and the value they place on their time. Finally, it is interesting to note that for all three courses, even in IME 421, students felt that the online textbook was not an effective learning tool (comment N13), which again may reflect their expectations for an online textbook.

II. Limitations of study

This study has presented findings that are of interest and use to instructors and instructional designers interested in exploring online textbooks. We caution, however, that several limitations to the study should be considered when evaluating the results. First, our experience is specific to the publisher we chose (which was in turn based on the printed textbook we had originally chosen). Most major publishers have or are developing online textbooks, and other instructors' experience may very well be different from ours, depending on the publisher's implementation of the online textbook. Second, our study was a snapshot in time, and this time was early for our specific online textbooks. Indeed, even during the time of our study we saw improvements in the online textbooks implemented by the publisher, some of them based on the feedback we were providing, and there's no doubt that improvements will continue. Thus, future instructors may find significant improvements in some areas that we identified as particularly weak. Finally, we caution that our study did not rigorously control for how each instructor integrated the online textbook into his course, or even the extent to which each one used it. These and many other

issues are important in order to develop truly generalizable conclusions from any study, and future studies should be conducted with the goal of drawing such conclusions.

Conclusions

Online textbooks hold promise for improving student engagement and learning, increasing access, and decreasing cost. Our study has shown, however, that the publishers have much work to do. While access ("learning anytime, anywhere") and cost control has arguably been achieved, our students have repeatedly told us that these issues are secondary to their learning, the value of their time, and their understandable extreme aversion to frustration.

Among the pedagogical implications we draw are that:

- Online textbooks seem to be more suitable to courses that are less technically complicated, and have less reliance on symbolic solutions requiring specific formatting.

- Instructors adopting an online textbook should be careful in supporting the students in the learning environment by, for example, providing solution procedures in addition to the online feedback and extra time for technical difficulties (either at the student's end or because of the publisher's errors).

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