

**AC 2009-518: DEVELOPING UNDERGRADUATE STUDENTS' DESIGN SKILLS  
USING ON-LINE VIDEO MODULES AND ACTIVE-LEARNING EXERCISES**

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# Teaching Undergraduate Engineering Students Auxiliary Design Skills via Online Video Modules and Active Learning Exercises

## Abstract

Biomedical Engineering undergraduates at the University of Wisconsin-Madison participate in six semesters of engineering design. In addition to engineering design aptitude, successful designers require proficiency in an auxiliary set of skills related to the design process. We have created professional development training materials on topics associated with auxiliary design skills for students within this design course series. Topics include working in teams, interacting with clients, presentation skills, design ethics and regulations, and global design. The training materials consist of an online video archive of experts speaking on such topics and associated active learning exercises. Using online, pre-recorded expert lectures makes class time available for conducting the active learning exercises, including working on design projects. The training content is modular, allowing small or large portions to be incorporated in a range of design courses. The impact on student learning related to these topics was evaluated during the 2008-2009 academic year through a combination of qualitative and quantitative methods.

## Introduction and Background

In 2005, a new course for undergraduates, “Introduction to Engineering Research,” was created as the first one-credit course in a research sequence at the University of Wisconsin – Madison (UW). Subsequently, supplemental materials were created to enhance this course and make these resources widely available to other faculty and programs with similar goals for undergraduate students. These supplemental materials were then refined into a collection of learning objects, taking the form of short presentations by experts (videos/audio/slides), readings, and in-class active learning activities. Currently, the collection consists of twenty-five video presentations with an average video/audio length of 14 minutes, twenty-four associated readings, and fourteen lesson plans that have been incorporated into the “Introduction to Engineering Research” course and an optional evening seminar series.<sup>1</sup> Evaluation of these offerings suggested that undergraduate students found them to be interesting, informative, and useful towards their development as researchers.<sup>2</sup> One of the key objectives in the initial effort was to provide opportunities for active learning with the use of the learning objects that enhance student engagement in a classroom or seminar environment which might otherwise rely upon lecture alone.<sup>3-4</sup>

Given that there are a number of additional topics that are critical for the practice of engineering design we embarked on a collaboration to develop a similar set of modular, on-demand learning objects focused on auxiliary skills needed in engineering design in general and biomedical engineering design in particular. We selected the UW Biomedical Engineering (BME) Department as a test case for our approach because of the rich design “backbone” that is at the center of its curriculum. Students in the UW BME program are required to complete a six-semester design course series, such that they take a design course every semester they are in the program (sophomore through senior years).<sup>5,6</sup> Students work in 4-person teams and each team works on a different project. All the projects are client-based, real-world design problems,

solicited from the medical and life sciences faculty around the university and from biomedical engineering companies. Each design team meets weekly with each other and their advisor in class; teams also meet frequently with their client outside of class. Despite the heavy time and workload demands of these design courses, all but one are 1-credit only. Thus, time is at a premium for design students and in-class time when team members can meet face-to-face and engage in active learning is especially valuable.

Balancing the need to instruct new design students and provide in-class time for teamwork is a significant challenge for UW BME design faculty. Typically, up to 20 minutes of in-class time every other week is spent educating first semester students about the basics of design: the design process, keeping a design notebook, writing a progress report, teamwork and leadership, fundamentals of oral and poster presentations, etc. In addition, outside experts are frequently brought in to discuss auxiliary topics that may be relevant to the students' design projects, such as designing human and animal experiments, protection of intellectual property, engineering ethics, or global engineering design. However, students' enthusiasm for and interest in lecture topics that are not of immediate importance is low. Additionally, there is resistance from both students and faculty to substantially increase the assignments, or "deliverables", due each semester that do not directly pertain to their design.

Therefore, the principal goal of this current work was to deliver information pertinent to auxiliary design skills online, outside of class, thus making additional class time available for student teams to engage in active learning and work together on their specific design project. Building on the research-oriented collection of learning objects, the primary learning objects developed here are a collection of videos and short in-class activities focused on design-related topics. Students were encouraged to view the videos on their own time; only one new deliverable was introduced as an out-of-class activity. Table 1 lists the topics that were developed, which are available online at [www.mrsec.wisc.edu/Edetc/research/](http://www.mrsec.wisc.edu/Edetc/research/).

Since UW BME design students take six semesters of design, not all topics are presented each semester. Furthermore, not all of the topics in Table 1 are pertinent to all BME design students in any given semester. For example, a team may work on a project that deals with animal experiments in one semester (see topic: Animal Welfare) but human subjects (see topics: Institutional Review Boards and Human Factors and Ergonomics) another semester. Topics for which new learning objects were introduced in the Fall 2008 semester were Working With Clients, Progress Reports, Oral Presentations, Poster Presentations, and Global Engineering. The first four topics consisted of online video lectures with accompanying slide presentations. Each of these topics addressed activities and deliverables already incorporated into the ongoing course; thus additional activities were not developed. For instance, the videos and slides for Oral Presentations and Poster Presentations were assigned to students before their own poster and slide presentations were due. Additionally, the videos on Working with Clients and Progress Reports were provided to students as a resource to improve upon their regular interactions with clients and advisors. Global Engineering is one of those topics which are not presented every semester. Because most students did not specifically address issues related to Global Engineering within their current design project, a reflective essay based on the video content was added as a required assignment for all students. This assignment was designed to further encourage viewing

of the video and assess understanding of the concepts it presented. The assignment is provided in Appendix I.

New topics for which learning objects were introduced in Spring 2009 included Human Factors and Ergonomics and Design Ethics. For the topic of Human Factors and Ergonomics, students were encouraged to watch a video on the topic and/or view narrated slides produced by a BME faculty member. An optional evening workshop was later offered for students whose current design project required the topic. For the topic of Design Ethics, students were assigned to watch a video to prepare for a short, in-class ethics case study activity. This activity was designed to introduce a systematic method for considering ethical dilemmas prior to completing an essay assignment based upon a BME design-specific ethics case study.<sup>7</sup>

**Table 1: Topics in the Context of (Biomedical) Engineering Design**

- Professional Communication
- Working With Clients
- Leadership and Teams
- Progress Reports
- Oral presentations
- Poster presentations
- Design Ethics
- Institutional Review Boards
- Animal Welfare
- FDA Approval
- Human Factors and Ergonomics
- Global Engineering Design
- The Design Process
- Design Laboratory Notebooks
- Codes and Standards
- Product Design Specifications
- Intellectual Property in Design
- Intellectual Property Agreements
- Patent Applications
- Career Paths in Biomedical Engineering

## **Results**

During Fall 2008, students were asked to complete two short, anonymous electronic surveys: the first midway through, after assignment of the first three topics (Working With Clients, Progress Reports, Oral Presentations), and the second at the end of the semester. There were 88 survey respondents for each survey of a possible 122 students (as the surveys were anonymous, it should not be assumed the same 88 students responded to the two surveys). These surveys were designed to determine which resources students used and how helpful they found the format and the content to be toward their own learning (refer to Appendix II for the full survey content). In the mid-semester survey, 61% of students indicated a preference for video format of the

presentations over live in-class lectures, whereas 15% preferred live speakers and 24% indicated no preference for video versus live. Overall, students found the online materials simple to use, demonstrating that the format itself did not prohibit utilization of these learning objects. Open-ended comments suggested several reasons for preferring online video presentations to live lectures in class. First, students appreciated the flexibility of the video presentations – they could watch on their own schedule and at their own pace. Second, students also liked the ability to go back and review the videos and accompanying slides as necessary. And, third, senior students in particular were glad that class time was freed up for more teamwork on their projects, as they had already been exposed to the particular content numerous times. As one senior student noted:

“I thought it was WAY better to have these videos available because you can listen to them on your own time and there are no distractions so you can get more information out of them rather than listening to a lecture in class. Especially since these presentations get repetitive each year.”

[Note, in the fall semester, mixed sophomore/junior teams are created for peer mentoring purposes. As a consequence, in order to provide introductory material to sophomores, it is presented to juniors as well, which is redundant.]

This survey also indicated that students were relatively selective in which material they accessed. Of the first three video topics offered (Working with Clients, Progress Reports, and Oral Presentations), 33% of students watched all three videos, 26% watched none (although some accessed the accompanying slides), and the balance watched only one or two of the videos. Many students commented that they did not watch the Progress Reports video in particular because they were not responsible for writing progress reports in the current semester (a task performed by the team leader). Table 2 shows how the videos and slides were accessed during the first half of the Fall 2008 semester, broken down by class and video topic. It is interesting to note that for each topic, fewer senior students accessed the materials, as might be suggested by their previous exposure to the topics and their perspective that the material was more a resource for review than a requirement to view:

“Being in our 5th semester doing a BME design project, we have already heard, read, or seen most of this information previously, so I really appreciate not having to spend valuable working time to get a repeat of the similar information in class each semester. Yet, if we feel we would like a refresher or update, that option is available by watching the videos and slides online, which is a nice resource to have.”

**Table 2. Percentage of BME Design Students Viewing Videos and/or Slides, First Survey**

Class	Working With Clients	Progress Reports	Oral Presentations
Sophomores (N=21)	81	62	90
Juniors (N=25)	72	52	68
Seniors (N=42)	57	48	48

In the second survey, students were asked to rate the helpfulness of the videos and slides for the final two topics, Global Engineering and Poster Presentations. On a scale of one (no help) to five (great help) students rated the usefulness of the video presentation on Global Engineering in

“understanding issues of global design” ( $3.5 \pm 1.0$ ) and “considering how their design could be altered for use in a developing nation” ( $2.8 \pm 1.3$ ), which was the topic of the reflective essay assignment (Appendix I). Although many students commented that they found the video interesting and it helped them to understand the issues behind global design overall, many felt that their current design projects, many of which were related to advanced research and medical techniques, would simply be of little use in a developing nation:

“My project this semester was a computer algorithm, so I was unable to modify it for use in most developing nations. The video was very useful in helping me understand some of the issues surrounding global design, especially that the best solutions are often the least technical.”

These comments indicated to the authors that the Global Engineering activity had not been optimally designed, as it did not pertain equally to all students, and that future assignments could be developed using more generic cases rather than students’ own projects as a basis.

A much higher overall percentage of the students viewed the Global Engineering video than other videos (Table 3). Not only was a new assignment based upon this topic, but the topic itself is only addressed in class perhaps once or twice during the six semesters of design, as compared to other topics which are presented more frequently. It is postulated that, as hoped, these factors promoted use of the video on a topic that may not have immediate interest to students because the information was not required for their current design project.

**Table 3. Percentage of BME Design Students Viewing Videos and/or Slides, Second Survey**

Class	Global Engineering	Poster Presentations
Sophomores (N=22)	86	71
Juniors (N=26)	85	65
Seniors (N=40)	98	25

Students also rated the helpfulness of the Poster Presentation video and slides in “understanding the elements of an effective poster” ( $3.0 \pm 1.0$ ), “designing their own poster” ( $2.8 \pm 1.1$ ), and “preparing to present their poster” ( $2.8 \pm 1.1$ ). Of the students who rated the Poster Presentation materials as less helpful, the following response was typical:

“I’ve already made several posters and done many presentations, as I assume many [junior] students have by now.”

Implementation of the new topics on Human Factors and Ergonomics and Design Ethics are currently underway.

## Discussion

Prior experience with curricular redesign of the course “Introduction to Engineering Research” has shown that access to online learning objects allows students more flexibility in their use of course content and allows instructors more flexibility in their use of class time. This finding was supported by the results shown here in which we implemented online learning objects in

engineering design courses. Particularly when guest lecturers are relied upon for content on a particular topic, the instructor often gives up more class time and sacrifices opportunities for active learning activities such as team-based design work. These same experts can often deliver the main messages relevant to their topic in a shorter time frame when asked to do so in front of a video camera. Also, with these online learning objects, students can access the material when convenient and at their own pace (repeating and rewinding the video as necessary). Finally, these resources are available online to other faculty members who teach engineering design and may not have easy access to experts on particular subjects.

In engineering design courses, most learning is hands-on, self-directed, and otherwise “active.” Of the online learning objects implemented in BME design courses in the Fall 2008 semester, four out of five had pre-existing active learning exercises associated with the content (Working with Clients, Progress Reports, Oral Presentations and Poster Presentations) and for one a new deliverable was designed and used (Global Engineering). Our ability to evaluate the efficacy of the learning objects which had pre-existing active learning exercises was hampered by student familiarity with the topics. That is, several students commented that the content presented in these videos was repetitive from previous semesters. These same students had been exposed to the active learning exercises previously as well (i.e., they had worked with clients, written progress reports, and given oral and poster presentations before). It is not surprising, then, that these four online learning objects were less useful and less appreciated by more senior students. To better serve these students, it might be helpful to create a set of “advanced” videos, particularly for topics that are presented and used every semester, that go more in depth. In this way senior students can continue to develop their skills while preserving their access to more basic material if they need to review.

For the Global Engineering learning object, a new deliverable was designed and implemented. This module was the most highly viewed of all videos. This finding supports the idea that accountability for student use of the online learning objects can be enhanced by tying the content to in-class activities or required assignments.

A few potential limitations of this study are worth noting. First, because this transition in teaching format occurred with a large cohort of students and multiple faculty already comfortable with the prior organization of the design sequence, the authors faced some challenges from both the instructors and students in modifying how content was delivered, how class time was used, and what assignments were added to the deliverables. These obstacles would not be faced by instructors creating courses with online video modules and active learning exercises de novo. Also, the surveys with which we assessed the utility of the learning modules do not capture improvements in student skills. A more thorough assessment would require assessment of student work relevant to the learning objects implement. We did conduct student focus groups to gain more insight into the value of the learning objects. We also have ongoing efforts to evaluate the impact on student learning through in-depth analysis of the discussions with the student focus groups and also subject coding of assignments such as the Global Engineering essay.

A long-term goal of this project is to introduce the engineering design learning objects collection to UW design faculty in disciplines other than BME within the College of Engineering in order

to broaden the impact of these materials. Already the website hosting the “Topics in the Context of Research” and “Topics in Engineering Design” videos ([www.mrsec.wisc.edu/Edetc/research](http://www.mrsec.wisc.edu/Edetc/research)) was accessed by 2,231 unique visitors between August 29, 2008 and March 16, 2009, with 59% of these individuals residing in Wisconsin. To further broaden the collection’s applicability and usage will likely require more discipline-specific content development, but will also promote some reflection on the similarities and differences in approaches to design in the different engineering disciplines. For the learning objects that currently have only video-based content, the authors plan to develop further active-learning activities, such as workshops on applying for approval to perform human or animal experiments or case study discussions on intellectual property protection. Finally, as noted above, more thorough qualitative and quantitative data analysis techniques are being used to evaluate the impact of these online video modules and active learning exercises on educational outcomes.

## **Conclusion**

In summary, we have developed and assessed the use of online professional development training materials and associated active learning exercises on topics associated with auxiliary design skills for students within a biomedical engineering design course series. Our results indicate that online training materials were easily accessed and useful to students, helped reduce redundancy in fundamental topic presentation to more advanced students, and were considered a potentially valuable future resource by the students. In general, the least experienced students took most advantage of the training materials, which allowed students to learn or reinforce the content based on their own self-determined need for additional learning.

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## Appendix I: Reflective essay assignment on global engineering

The following essay prompt was given to all BME design students toward the end of the Fall 2008 semester:

Describe how your device (or a device that *you* have previously designed) would be altered for use in a developing, non-industrialized country. In addition to technology and infrastructure considerations, how might cultural differences come into play? (350-450 words)

## Appendix II: Surveys

### First survey, mid-semester Fall 2008:

The first survey was administered as an email survey, with surveys sent to and compiled by Dr. Katie Cadwell. Identifying artifacts (such as name or email address) were deleted after downloading all of the surveys.

BME \_\_200, \_\_300, \_\_400 (Please mark with an “X”)

1. For each video/slide presentation, please mark with an “X” the box that corresponds to the presentation materials that you have viewed.

	Watched video and viewed slides	Watched video but did not view slides	Viewed slides but did not watch video	Neither watched video nor viewed slides
“Working with clients” by Prof. Murphy				
“Progress reports” by Prof. Block				
“Oral presentations” by Prof. Ogle				

2. Which advice from Prof. Murphy’s presentation did you find most useful in interacting with your client?
3. How did you prepare your progress reports differently after viewing Prof. Block’s video and/or slides?
4. How did you edit your oral presentation per Prof. Ogle’s advice?
5. Please rate your agreement with the following statement: The online videos were easy to use.

(Disagree strongly) 0 ----- 1 ----- 2 ----- 3 ----- 4 ----- 5 (Agree strongly)

Comments:

6. Mark with an "X" your preferred format for presentation of the information provided in the videos:

Live speaker during class       View video outside of class       No preference

Other (please specify) \_\_\_\_\_

Additional comments on video lectures:

Second survey, semester-end Fall 2008:

The second survey was administered online using radio buttons and open comment boxes. The following is an outline of the questions posed to BME design students.

1. In which BME design course were you enrolled for Fall 2008?
2. Indicate if you watched the video lecture by Prof. David Beebe on global engineering.
3. How much did viewing Prof. Beebe's lecture help you to learn about global design? Each sub-question was rated on the scale:  
no help (1)...a little help (2)...moderate help (3)...much help (4)...great help (5)...n/a
  - a. Understanding issues involved in global design.
  - b. Considering how your design could be altered for use in a developing nation.
4. Please comment on your ratings above (optional).
5. Indicate if you watched the video and/or viewed the accompanying slides on preparing and giving poster presentations by Prof. Susan Hagness.
6. How did Prof. Hagness's video and/or slides help with your own poster? Each sub-question was rated on the scale:  
no help (1)...a little help (2)...moderate help (3)...much help (4)...great help (5)...n/a
  - a. Understanding the elements of an effective poster.
  - b. Designing your poster.
  - c. Preparing to present your poster.
7. What advice from Prof. Hagness did you find most useful in preparing and presenting your own poster? (optional)

## References

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- <sup>1</sup> The compilation of these learning objects is available online at [www.mrsec.wisc.edu/Edetc/research/](http://www.mrsec.wisc.edu/Edetc/research/).
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- <sup>6</sup> Tompkins, W.J. "Implementing design throughout the curriculum," *Proc. Annual Conference of the Biomedical Engineering Society*, Chicago, 2006: 35.
- <sup>7</sup> As of this publication, the assessment results of Spring 2009 implementation were not yet available. Details of these activities, assignments, and subsequent evaluation will be presented at the meeting.