2006-1497: LIBRARY OF STUDENT-AUTHORED INTERNET VIDEOS FOR JUST-IN-TIME LEARNING IN SUPPORT OF THE CAPSTONE DESIGN EXPERIENCE

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Internet Library of Student-Authored Videos for Just-in-Time Learning in Support of the Capstone Design Experience

Abstract

Over the last decade, capstone design courses have progressively required more sophisticated design and manufacturing processes as the entire product realization process has been incorporated into these courses. At the same time, the general population of engineering students has less hands-on shop experience than their predecessors, the number of required manufacturing-oriented courses has decreased, and the complexity of tools used for detailing designs and handling materials have become more specialized. To remedy this situation, the authors have implemented a learner-centered approach for creating and maintaining an internet archive of just-in-time videos that support the capstone design experience. The approach we have developed is responsive to competency gaps identified by the Society of Manufacturing Engineers and is aligned with five pillars of on-line learning advocated by the Sloan Foundation (learning effectiveness, accessibility, student satisfaction, faculty satisfaction, and cost effectiveness). The paper includes a methodology for video development that elevates skills of three distinct audiences within the capstone design program (undergraduate student users, undergraduate student authors, and graduate student mentors/faculty/professional staff).

Introduction

In today's rapidly changing world, state-of-the-art approaches to design and just-in-time methods for learning relevant tools, techniques, and technologies are in great demand[1,2]. For many organizations, especially Universities, this problem is accentuated by a large annual turnover of those who participate in research and development. An approach to knowledge transfer that integrates physical, virtual, and human elements is likely to be most effective with a broad spectrum of learner/practitioners[3]. This begins with programs for training mentors and technical advisors in new technology areas. It can be enriched through special environments where knowledge resides in an easily accessible format that is regularly updated and expanded through efforts of a broad community[4,5].

A new type of design laboratory, known as Mindworks, has been created to support just-in-time learning about machine design and local manufacturing capabilities that are frequently used in capstone design projects. This laboratory contains design artifacts, quick references, manufacturing videos, and mathematical models for solving common machine design problems. This unique space for learning and practicing design is documented extensively on the web at www.webs1.uidaho.edu/ele/mindworks. Mindworks resources have evolved through project work in a required Machine Design class as well as elective classes in Lean Manufacturing and Advanced Machine Design. The mission of these courses is to support better decision-making and higher levels of technical excellence in the capstone design course. The archive of student-authored internet videos described in this paper is just one dimension of the Mindworks laboratory.

With inexpensive video and home editing equipment, students with an engineering background can efficiently and effectively integrate technical principles with practical demonstrations of skills in 2-3 minute video clips. Our experience is that engaging topics can be analytical, graphical, hands-on, or philosophical in nature. Because of their brevity, student teams can rapidly develop a story line, illustrate their concept in a story board, and receive feedback from peers/instructors that allows them to collect and edit relevant footage in an afternoon. Results from different engineering cinematography teams are organized thematically and posted on the Mindworks website.

Students are introduced to individual videos in the Mindworks library through a 10-15 minute cycle of classroom viewing and critiquing. Considerable flexibility exists in classroom use of these videos such as introducing new topics, reviewing old topics, energizing students about a design challenge, or connecting different topics. Later on in the capstone design course, students can access the videos in a just-in-time fashion to address a specific design or manufacturing challenge. For those students interested in mentoring others on manufacturing practices, they can use the videos to develop mindshare about best practices and to standardize safety, equipment usage, and maintenance procedures. Since the initiation of the Mindworks laboratory project two years ago, capstone design products have continued to evolve in complexity and the average level of industry funding has steadily increased.

Capstone Design Course Context

The capstone design experience at the University of Idaho is a two-semester sequence that involves a variety of projects sponsored by regional industry. This culminates in the largest academic design show in the Pacific Northwest where design teams from departments of Mechanical Engineering, Electrical Engineering, Civil Engineering, Chemical Engineering, Biological Systems Engineering, Metallurgical Engineering, and Computer Science display their work to the public. Information about this annual event can be found at www.uidaho.edu/expo.

The Mechanical and Electrical Engineering Departments have joined forces in an interdisciplinary class that meets concurrently and has uniform project expectations. More than 80 seniors and a half-dozen graduate student mentors are part of this combined enterprise. Roughly 1/3 of the design teams have both ME and EE members, 1/3 have only ME members, and 1/3 have only EE members. All teams are required to respond to the needs of an external customer, maintain personal logbooks, prepare a problem statement with specifications, present their solution in various design reviews, fabricate a working prototype, write a design report, and document their design process on a course web page (http://seniordesign.engr.uidaho.edu).

Our capstone course design parallels many other capstone programs across the country[6,7] and follows the methodology advocated by standard design textbooks[8,9,10,11]. Our local implementation has evolved over the last ten years to align better with our design infrastructure and ABET learning outcomes[12]. A unique feature of our program is the team of graduate student mentors known as the Idaho Engineering Works (IEW) that fosters professional and technical excellence by mentoring undergraduate design teams[13]. This is facilitated by the layout of a 5000 ft^2 design suite that includes a CNC equipped machine shop, project assembly area, CAD laboratory, conference/study area, and graduate student offices. As shown in Figure 1, we take pride in our shop and strive to maintain high levels of organization and cleanliness. The shop is on display for all to see through windows at the end of the building entryway.

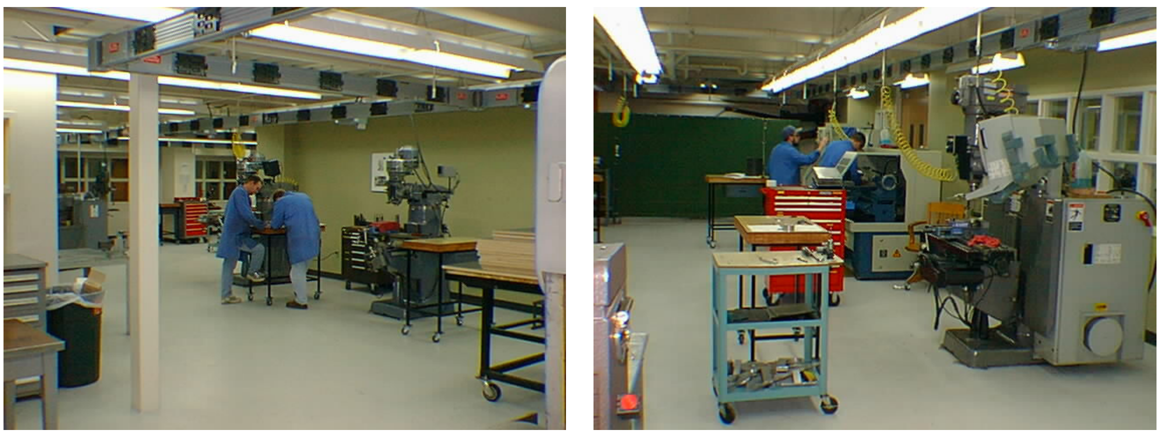

Figure 1. Engineering Shop: Manual Mills (left), 2-axis CNC mill and CNC lathe (right)

We use our professional staff to train our graduate student mentors that in turn teach our seniors and other students the manufacturing skills they need to fabricate components. While a mill or lathe is setup or a cutting process is ongoing, a rich conversation between mentors and seniors often ensues about how a mill or lathe works and what are the special features and limits of this equipment. It is this tacit information exchange that leads to better understanding of manufacturing processes and a “feel” for what is possible in the shop. Many of these students will never operate this type of equipment in their professional lives, but we receive continuous feedback from alumni as well as employers about ‘special understanding’ gained through capstone design prototyping.

We recognize that the demanding task of mentoring senior design teams takes leadership, management, and proficiency with state-of-the-art tools. In order to better cultivate these skills in design team mentors, a semester long graduate seminar has been created. This seminar allows IEW members to share and reflect on actions taken with individual teams to find collective solutions for common problems.

Despite extensive mentor development, experience has shown that seniors often need substantial shop training in order to complete their projects. This often leads to extended fabrication time, reducing the availability of shop facilities for other design teams. In 1999, we implemented a three week mini-project at the front end of the capstone design course as a means of expanding manufacturing skills required during detail design and prototype fabrication[14]. While the mini-project was highly motivational for capstone design students and was highly effective in growing mentoring skills among graduate students, lessons learned by design teams were widely separated from when these skills needed to be applied in their projects, only a subset of manufacturing processes could be explored in depth, and considerable graduate student effort was required to set up and run this mini-project.

In 2002, a three-week summer short course in lean manufacturing was initiated to replace the mini-project, providing advance preparation for a subset of the seniors entering capstone design as well as the IEW mentors. This course introduces manufacturing skills (design for manufacturability, shop safety, efficient use of resources, cleanliness, location of tools, drawing package formulation, proper tolerancing, lathe operation, milling machine operation, and welding) along with lean thinking concepts (value stream mapping, visual workplace design, 5S, batch size reduction, standardized work, quality at the source, celluar flow, pull/kanban, design failure mode effects analysis, and continuous quality improvement). As part of this course, we have developed an annual kaizen event where teams of two students identify a need for specific design/fabrication practices in capstone project work, create a resource to advance this practice, and receive peer review prior to its finalization. Since the initiation of the Mindworks laboratory two years ago, a significant number of these have resulted in the just-in-time videos that are the subject of this paper. Additional videos have been created by students in the required machine design course and in several technical electives associated with advanced machine design.

Requirements for Local Internet Videos

Research on asynchronous learning underscores the benefits of hybrid course design that combines preparatory activities, constructivist approaches, and face to face interaction[4,5]. Quality, scale, and breadth are three critical issues that should be considered in creating e-learning resources. Quality includes learning effectiveness, accessibility, student satisfaction, faculty satisfaction, and cost effectiveness. Learning effectiveness results from use of accurate cognitive models, engagement of multiple learning styles, alignment of assessment methods, and connection with a motivating learning environment. Accessibility requires prompts for timely use, instant availability, and indexing for easy retrieval. Student satisfaction is likely to be greatest if e-learning resources are organized around concrete situations that are locally relevant. Faculty satisfaction is likely to be greatest if the content is rigorous and if student performance perceptibly improves as a result of the learning experience. Cost effectiveness can be assured by creating many learning objects that are small in scope and easily upgradeable. Scalability refers to multiple contexts which a particular resource can be used. Breadth refers to completeness and diversity in the set of topics.

Beliefs about adult learning put forward by the Greenfield Coalition for shareable learning activities also informed our work[15]. These beliefs include:

- Learning is a shared responsibility between learner and teacher.
- Faculty should play a key role in guiding the learning process.
- Whenever possible, real-world linkages should be used to enhance learning.
- Learners must take time to prepare for learning activities.
- Learning is social, requiring group processing of new ideas.

In order to realize these beliefs, three different audiences are engaged in video creation—undergraduate design students, undergraduate design authors, and graduate student/faculty/staff consultants. The value of the resource is enhanced by having a community of users and developers rather than a single audience. Wisdom of experienced staff is queried by learner authors, framed around actual hardware created with local shop equipment, encapsulated in video materials that do not require extensive course design or professional cinematographers, and validated by the next generation of students. Intentionally, the audience is local, rather than national, keeping the cost of production low and the opportunity open to make revisions at almost any time.

Video Production Process

We have used the process shown in Figure 2 to create and maintain our library of internet videos. This follows a standard instructional design process including needs analysis, negotiating design specifications, developing skills and scripts, filming with a video camera, and just-in-time use as well as continuous improvement[16]. The primary party responsible for each step is shown in italics. An example storyboard for MIG welding training as well as a quick reference created for our MIG welder is shown in the Appendix. The video created from this storyboard can be viewed on the Mindworks web site: www.webs1.uidaho.edu/ele/mindworks.

The entire process took about one week as an extra-curricular homework assignment. Students worked in teams of two, spending 1½ - 2 hours per day on video design and development activities. This involved extensive interaction with graduate student mentors and professional staff members. Needs analysis and topic selection was conducted by graduate student mentors, faculty, and professional staff in planning the course. Student teams selected topics of personal interest. Design specifications were approved 1-2 days after author teams received their assignments. Background research, skill development, creation of quick references, and script generation was completed in another 2-3 days. Filming generally took less than two hours and editing took no more than three hours. The total time invested in each video project was typically 10-15 hours.

1. **Needs Analysis**

- Identify behavioral goals (knowledge, skills, and attitudes) => *mentors, faculty, and staff*
- Identify relevant concepts => *mentors/faculty/staff*
- Analyze audience background => *student authors*
- Establish local context (hardware examples & equipment) => *student authors*

2. **Design Specifications**

- Research relevant design and manufacturing techniques => *student authors*
- Observe relevant design and manufacturing techniques => *student authors*
- Propose objectives for video => *student authors*
- Approve objectives for video => *mentors, faculty, and staff*

3. **Developing Skills and Scripts**

- Obtain training on tools/equipment => *mentors, faculty, and staff*
- Assemble resources => *student authors*
- Create storyboard and quick references => *student authors*
- Approve storyboard and quick references => *student peers and mentors/faculty/staff*

4. **Filming and Implementation Planning**

- Film video => *student authors*
- Edit video => *student authors*
- Identify situations/prompts for video use => *mentors/faculty/staff*
- Maintain video in library => *mentors/faculty/staff*

5. **Just-in-Time Use and Continuous Improvement**

- Answer questions about video => *student users*
- Debrief students after video => *mentors/faculty/staff*
- Identify strengths and areas for improvement => *mentors/faculty/staff*
- Prioritize video topics for next round of development => *mentors/faculty/staff*

Figure 2. Methodology for Video Production

Educational Impact

With less than fifteen hours of effort, our students have succeeded in generating video resources and quick references that improve their own skills for the capstone design experience and leave a legacy for future students about to engage in detail design or fabrication activities. These resources include:

- Shop Safety
- Feeds and Speeds
- CNC Lathe
- Shop Tool Inventory
- MIG Welding
- Rapid Prototype Machine
- Finishing a Part
- Drilling and Tapping
- Tramming a Mill
- HAAS Mill
- Measurement Devices
- TIG Welding
- Heat Treatment
- Anodizing

As part of a lean manufacturing technical elective, twenty-six students and six graduate student mentors responded to a questionnaire about skill development associated with course work that included the student-authored video projects. Both groups rated their professional development using the following scale:

1 = able to explain importance of skill to others
2 = able to perform in skill with coaching
3 = able to independently perform skill, learning more as needed
4 = able to teach skill to others

Averaged responses are shown in Table 1. Not surprisingly, graduate mentors were more confident in all areas than the undergraduates that they mentored. In many areas, undergraduates felt that project work enabled them to independently elevate their skills. Surveys that study educational impact of videos on undergraduate users are still under development.

Table 1. Impact on Manufacturing Competencies

Competency Area	Undergraduate Authors	Graduate Mentors
Shop Safety	3.5	3.9
Shop Cleanliness	3.5	3.9
Tool Storage & Use	3.4	3.8
Milling Operations	3.2	3.7
Lathe Operations	2.7	3.4
Welding Operations	3.1	3.4
CNC Mill Coding/Usage	2.4	3.3
CNC Lathe Coding/Usage	2.1	3.2
Tolerancing Part Drawings	2.7	3.7
Design for Manufacturing	3.1	3.7

In addition to specific manufacturing competencies, students had an opportunity to apply many transferable skills in the cognitive, social, and affective domains that underlie competency gaps recognized by the Society of Manufacturing Engineers[17,18]. Tables 2-4 identify these team-based design skills and map these skills for the three audiences associated with the video project (undergraduate users, undergraduate authors, and graduate mentors). Based on experience of the authors, many of these skills limit performance in the capstone design class and are likely to do so in professional practice. More detailed surveys are planned for future courses where students undertake video projects to further probe cognitive, social, and affective skill development.

Table 2. Cognitive Skill Development Associated with Video Production

	Undergraduate Users	Undergraduate Authors	Graduate Mentors
Exploring Context	X	X	
Outlining	X	X	
Clarifying Expectations	X	X	X
Identifying Issues	X	X	X
Identifying Constraints		X	X
Choosing Alternatives		X	X

Table 3. Social Skill Development Associated with Video Production

	Undergraduate Users	Undergraduate Authors	Graduate Mentors
Checking Perceptions	X	X	X
Defining Purpose	X	X	X
Being a Good Citizen	X	X	X
Organizing a Message		X	X
Sharing Traditions			X
Assisting Others			X

Table 4. Affective Skill Development Associated with Video Production

	Undergraduate Users	Undergraduate Authors	Graduate Mentors
Being Curious	X	X	X
Being Open-Minded	X	X	X
Respecting Safety	X	X	X
Accepting Help		X	X
Acknowledging Others		X	X
Seeking Assessment		X	X

Conclusions

Short, student-authored videos can serve as an effective tool for participant-centered learning surrounding site-specific design and manufacturing resources that are critical for successful design prototypes. Many of these are often not explored in required coursework or formal training sessions. Close collaboration between undergraduate student authors and experienced consultants (graduate student mentors, faculty, and professional staff) assures that all five dimensions of electronic resource quality identified by the Sloan Foundation (learning effectiveness, student satisfaction, faculty satisfaction, accessibility, and cost-effectiveness) can be assured. Availability of inexpensive video equipment, participant-centered production methods, and regular updating makes this video production method attractive for professional engineering organizations that want to capture organizational learning in a manner that actively involves and engages current and future employees.

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Appendix – Video Story Board

Title:

MIG Welding Training

Purpose:

"This video provides students with an easy-to-follow set of instructions on how to properly prepare and set up a MIG welder as well as the proper technique to use when welding. We will start by discussing safety precautions."

Safety:

1) Wear a helmet
   "This will protect your eyes from the brightness of the welding process."
2) Wear gloves
   "This will protect your hands from being burned."
3) Cover skin
   "This protects your skin from being sunburned."
4) Wear a shop coat
   "This is protection for your clothes."
5) Ensure are is well-ventilated
   "This protects you from breathing in a lot of smoke."
6) Scratch off galvanized surfaces
   "If necessary, get rid of as much galvanized surface as possible. It is toxic. Position ventilation next to weld area to remove gases."

(Show video of student observing each safety precaution.)

Welder Set-up:

"Now that we have taken the proper safety precautions, let's set up the MIG welder…"

1) "Ensure fan is on for ventilation."
2) "Ground welder to table or part being welded."
3) "Plug in welder."
4) "Turn on the welder."
5) "You can determine the wire gauge using books, or calling Oxarc. New materials are always coming onto the market and data in welding books may be obsolete."
6) "Refer to chart under welder hood to determine wire speed and thickness."
7) "Set wire speed and thickness dials."
8) "Ensure that the CO_2 tank pressure is around 28 psi.
9) "Start welding, using nozzle dip as necessary, to prevent splattering."

(Each of the steps will be spoken as the video clip shows someone going through each of these steps at the welding station.)

Welding Technique:

(Show clip of someone welding at different speeds to demonstrate good technique, fast technique, and slow technique. Show what different beads look like. Describe what the welder is doing and explain what is right or wrong.)

Types of Welds:

(Show clip of someone using a butt weld, fillet weld, and lap weld. Describe what the welder is doing and explain what is right or wrong.)

Closing:

"Ensure that the area is cleaned up and everything is put back the way it was before you arrived. If you have questions, ask the shop supervisor. Review the MIG quick reference posted in the welding area before you begin each welding session."

MIG Quick Reference:

1. Make sure that ventilation fan is on at all times.
2. Plug the welder into the 220 overhead outlet.
3. Open main valve on CO_2 tank and adjust line pressure to 22-28 psi.
4. Turn welder on.
5. Refer to chart on inside cover of welder for wire speed and voltage settings.
6. Ground welder to table or part.
7. Wear gloves, shop coat, and welding helmet. <u>Cover all skin to prevent burns</u>.
8. Warn others that you are beginning to weld by saying "COVER".
9. Coil ground cable and torch, return welder to condition below.