

DETC2007-35549

EVALUATING THE USE OF CYBERINFRASTRUCTURE IN THE CLASSROOM TO ENHANCE PRODUCT DISSECTION

Matt Devendorf and Kemper Lewis*
Mechanical & Aerospace Engineering
University at Buffalo, Buffalo, NY
{mdd7, kelewis}@eng.buffalo.edu

Robert B. Stone
Interdisciplinary Engineering
University of Missouri-Rolla, Rolla, MO
rstone@umr.edu

Timothy W. Simpson
Industrial & Manufacturing Engineering
Penn State University, University Park, PA
tws8@psu.edu

William C. Regli
Computer Science
Drexel University, Philadelphia, PA
regli@drexel.edu

ABSTRACT

Recent cyberinfrastructure initiatives seek to create ubiquitous, comprehensive, interactive, and functionally complete digital environments that consist of people, data, information, tools, and instruments for research communities. With product dissection as our unifying theme, we are forging a cyberinfrastructure to support undergraduate design engineering education through CIBER-U: Cyber-Infrastructure-Based Engineering Repositories for Undergraduates. CIBER-U pairs two of the nation's leading design repository developers with several active users and their students to realize a high-impact application of cyberinfrastructure in engineering undergraduate curricula involving freshmen through seniors. Specifically, CIBER-U combines product dissection activities at three universities with two digital design repositories, CAD modeling and animation, video, MediaWiki technology, multimedia, and undergraduate summer research experiences to enable cyberinfrastructure-based product dissection activities. Nearly 700 students have participated in the Phase I efforts of CIBER-U, which have focused primarily on generating, capturing, and storing data in two digital design repositories. Lessons learned from these efforts are presented from the students' perspectives as well as that of the faculty in both engineering and computer science. The implications for implementing CIBER-U on a national scale are discussed along with ongoing research.

Keywords: Product dissection, cyberinfrastructure, design repository, engineering design

1. INTRODUCTION

As we progress closer to a knowledge economy, the need for an infrastructure based upon distributed computing, information and communication technology (i.e., a cyberinfrastructure), becomes increasingly paramount. Before this cyberinfrastructure can become a reality, the base technologies underlying the cyberinfrastructure—the software programs, services, instruments, data, information, knowledge that reside above the cyberinfrastructure, and the enabling hardware, algorithms, software, communications, institutions, and personnel that make up the cyberinfrastructure—need to be identified, studied, and developed. The Advanced Cyberinfrastructure Program has proposed to “use cyberinfrastructure to build more ubiquitous, comprehensive digital environments that become interactive and functionally complete for research communities in terms of people, data, information, tools, and instruments” [1].

Central to such environments are digital libraries that enable the “collection, storage, organization, sharing, and synthesis of huge volumes of widely disparate information” [1]. The idea of cultivating digital libraries is not new, but actual research and deployment of wide-scale systems did not begin to appear until the mid- to late-1990s, mostly because of the establishment of the Internet [2]. Relevant engineering examples include the educational digital library hosted by the National Science Digital Library (<http://www.nsdlib.org>) and a digital library of learning resources for engineering education that is available through NEEDS – the National Engineering Education Delivery System (<http://www.needs.org/>). Such libraries provide access to resources and tools that support

* Please address all correspondences to this author.

innovations in teaching and learning; however, they provide limited support for engineering design, which presents unique and ongoing challenges in and of itself for storing, sharing, and retrieving large volumes of heterogeneous design-related data. In design practice, engineers perform a multitude of tasks using numerous tools and resources that generally do not exhibit a high degree of information integration due to differences and inconsistencies associated with how data is represented, stored, and referenced [3]. There is a clear need to integrate design information used in practice given that many engineering design tasks are driven by a need to find, manipulate, and communicate relevant design data in a timely and cost-effective manner.

Critical to developing and providing effective design data is being able to capture geometric and functional product information in digital formats. A prominent approach to capturing this information – and teaching engineering students about it – is through product dissection. Over the past fifteen years, there has been a resurgence of engineering dissection activities in U.S. universities to help teach engineering design practice. Many of these activities can be traced to Prof. Sherri Sheppard’s *ME 99 Mechanical Dissection* at Stanford, which started in 1991 [4,5]. Funded by the NSF-sponsored Synthesis Coalition, the course objective was to give mechanical engineering students an understanding of mechanical artifacts by answering the question, “How did others solve a particular problem?” Several courses followed, drawing heavily on the materials and activities in *ME 99* [6-14]. These course developments were in response to a general agreement by U.S. industry, engineering societies and the federal government that there had been a decline in the quality of undergraduate engineering education over the previous two decades [15,16]. As a result, there was a push towards providing both intellectual and physical activities (such as dissection) to anchor the knowledge and practice of engineering in the minds of students [7,17]. Product dissection enables “hands-on” activities to couple engineering principles with significant visual feedback [14]. Dissection can also be used to increase awareness of the design process [18], and such “learning by doing” activities encourage the development of curiosity, proficiency and manual dexterity, three desirable traits of an engineer [9]. Dissection also gives students early exposure to functional products and processes, and introducing such experiences early in the students’ academic careers has been shown to increase motivation and retention [12]. Finally, product dissection also provides opportunities to expose students to the wide array of product data related to (see TABLE 1).

Combining dissection activities with cyberinfrastructure has the potential to overcome many of the obstacles that product dissection faces: (1) start-up and maintenance costs, (2) space for disassembly and storage, (3) preparation of educational materials and activities, and (4) access to more complex products (e.g., copiers, refrigerators, automobiles) through virtual dissection. In engineering dissection, cost is a

major factor: maintenance costs alone average \$1000 per year at the University at Buffalo for 200 students to \$5000 per year at Virginia Tech for 1200 students. Cyberinfrastructure also has the potential to enable virtual engineering dissection, which parallels recent trends in biology [19]. Virtual dissection could broaden the use of engineering dissection for self-discovery and analysis of complex systems to enhance engineering intuition.

TABLE 1. DIFFERENT TYPES OF PRODUCT DATA [3]

Product data type	Traditional data format	Web-enabled data format
3D solid model	STEP	VRML
2D engineering drawings	DXF, DWG etc.	DWF
Images	TIFF, GIF, JPEG, etc.	GIF, JPEG
Unformatted documents	TXT	XML, HTML, TXT
Formatted documents	MS Word, Postscript	PDF, MS Word
Forms	Lotus 123, MS Excel	HTML
Sectors of database	Database	XML, HTML
Audio	WAV etc.	MP3
Video	MPEG etc.	MOV
Animations	-	VRML, Flash

With product dissection as our unifying theme, we are forging a cyberinfrastructure to support undergraduate engineering education through a two-year multi-university project that is entitled, CIBER-U: Cyber-Infrastructure-Based Engineering Repositories for Undergraduates. CIBER-U pairs two of the nation’s leading design repository developers with several active users and their students to realize a high-impact application of cyberinfrastructure in engineering undergraduate curricula involving freshmen through seniors. The next section outlines the first phase of implementation of CIBER-U. This occurred first at Penn State University and at the University of Missouri-Rolla in Spring 2006. Student feedback from these universities is also summarized. The follow-on implementation in Fall 2006 at the University at Buffalo (UB) is discussed next along with how the activities evolved from the initial offering. Feedback from UB students is also provided. Section 3 discusses lessons learned from our implementation of CIBER-U thus far. Closing remarks conclude the paper in Section 4 along with a discussion of future research.

2. PHASE I IMPLEMENTATION OF CIBER-U

The initial objective in the CIBER-U project was to study how common tools for information sharing and distributed, collaborative work can be used to support engineering education activities involving product dissection. Specifically, we examined the phenomenal success seen in the OpenSource software engineering community and identified several of the key cyber-infrastructure tools that have enabled this success. We chose to focus on three basic concepts that we felt were essential to sustaining effective collaborative and distributed work using cyberinfrastructure:

1. *Shared data repositories*: Rather than having students maintain their own private copies of working files, CIBER-U deployed a web-based repository in which all

project files were to be posted and shared. This required students to differentiate their local, working copies of project documents with those shared for use by their wider team and for review by graders and teachers.

2. *Version control:* For undergraduates, version control for documents and project files is typically done in an ad hoc manner. For example, one student “leads” the team and becomes the “referee” for project documents and synchronization. Such a hierarchy, however flat, creates project bottlenecks and introduces friction into the system. The ‘state’ of the project is somewhere among the team members, and there is no systematic method for ‘roll-back’ to earlier project states or to track project changes over time. CIBER-U required students to perform remedial version control for their project files, checking them into the project repository, and entering textual descriptions as project documents changed over time.
3. *Collaborative Editing:* The typical, serial method, for document authorship consists of students emailing around a MS Word file, each entering text in distinct sections in an asynchronous manner. The tempo of such activity is not suitable for projects that evolve rapidly or ones in which meta-information cannot be captured in the source document itself (e.g., scratchwork, background references, temporary data).

To study these three areas, the Phase I implementation of CIBER-U (Spring 2006 and Fall 2006) utilized three tools:

1. GForge (<http://gforge.org/>), an OpenSource version of SourceForge that provides project management and file sharing capabilities designed for software projects.
2. SubVersion (<http://subversion.tigris.org/>), a version control system for synchronization of revisions and file changes. SubVersion, and its predecessor application, Concurrent Versions System (CVS), were originally designed for configuration management of source code.
3. MediaWiki (<http://www.mediawiki.org/>), the OpenSource software behind the popular Wikipedia web portal.

During the Spring 2006 and Fall 2006 semesters, undergraduate engineering students made use of these tools to capture, share, and publish their course work (e.g., CAD files and project reports). At various points, the tools were customized and tailored to the specific needs of engineering education as described next.

2.1. CIBER-U Implementation in Spring 2006 (SP06)

In Spring 2006, CIBER-U was implemented in product dissection courses at Penn State (53 students) and University of Missouri-Rolla (UMR) (16 students) and an engineering design course at UMR taught to all engineering freshmen (about 450 students). The CAD repository was constructed using the GForge and SubVersion software packages. The emphasis in both implementations was on creation of new CAD models to populate the CAD repository. This implementation occurred through two trial runs in the product dissection courses at Penn State and UMR. The first involved 32 Penn State and 16 UMR

undergraduate engineering students dissecting a bicycle and creating CAD models for the following subsystems, which were grouped based on the number of parts to be modeled and estimated level of modeling complexity:

1. Frame, including handlebars, head set, and front fork
2. Shifters (front and rear) and front derailleur
3. Seat, including seat post and connection
4. Brakes (either center pull, side pull, or cantilever) and brake levers (on handlebars)
5. Bottom bracket assembly, including axle, bearings, cups
6. Front chain rings, crank arms, and pedals
7. Rear cassette and hub, including axle, bearings, and all nuts and washers
8. Front hub, spokes, rim, and tire
9. Chain and rear derailleur

The students worked in pairs for the dissection and in teams of four at Penn State (teams of two at UMR) for CAD modeling. The bicycle subsystems were randomly assigned to each team, and the teams were allowed to use any solid modeling software (e.g., Pro/Engineer, Catia, SolidWorks, Alibre Design, Unigraphics NX) to create their CAD models. Teams were instructed to model each part separately using the website and CAD repository to maintain their team’s models. The teams had about two weeks to complete their CAD models, which they were required to submit electronically via the website on the last day of the bicycle dissection activity in order for them to be graded. The second trial was identical to the first with two exceptions: (1) four-stroke, single cylinder internal combustion engines were used instead of bicycles and (2) the assignment was made two weeks earlier to give students nearly a month to work on their CAD models. The subsystems – grouped based on number of components and estimated modeling complexity – that were modeled for the engine were:

1. Piston, piston rings, wrist pin, connecting rod, and oil slinger
2. Crankshaft, camshaft, tappets, valve springs, and valves
3. Flywheel, key, magnetron, and air vane governor
4. Starter clutch, shroud, and pull cord
5. Crankcase and engine block, gasket, and main bearing
6. Cylinder head (including combustion chamber), gasket, spark plug
7. Fuel tank, muffler, and air filter
8. Carburetor (including Pulsa Jet fuel pump)

Students were again paired up for the dissection and randomly assigned to each subsystem in teams of two to four, and 43 Penn State and 16 UMR students participated in this dissection and CAD modeling activity.

The implementation in the freshman engineering design course at UMR also accompanied the CAD modeling module of the course as an extra credit exercise. Students were offered the opportunity to create solid models of product components over a one-week period of evening lab sessions. The students measured the physical components and created the CAD model in AutoCAD.

At the completion of each implementation of CIBER-U, students were asked to provide feedback on how frequently it was used, how easy it was to use, etc. The following details the feedback that we received from the implementations at Penn State, UMR, and UB this past year. Based on analysis of this feedback, lessons learned are then discussed in Section 4.

2.1.1. SP06 CIBER-U Feedback - Penn State

For the first trial at Penn State (bicycles), 17 of the 32 students responded to our request for feedback, a response rate of 53.13%. Table 2 summarizes the students' feedback on the frequency of using the website and CAD repository using a 5-point Likert-type scale that varied from 1 (Never) to 5 (A Lot) with 3 being Sometimes. Based on these ratings, the students rarely used the website and CAD repository to store/exchange files and interact with their teammates. The students also felt that they were not frequently encouraged to use these resources ($\mu = 2.18$) despite a reminder at the beginning of every subsequent class to work on the assignment and use the website.

Table 2. SP06 CIBER-U FEEDBACK, PENN STATE, TRIAL 1

Statement – Rate each on a scale of 1 (never) to 5 (a lot)	Std	
	Avg	dev
How frequently did you use the website and CAD repository?	1.59	1.00
How frequently were you encouraged to use the website and CAD repository?	2.18	1.07
How frequently did you exchange CAD models with your teammates?	1.88	1.17
Did the CAD repository facilitate interactions with your teammates?	1.88	1.27

Written feedback indicated that the website and CAD repository were used only to submit the *final* CAD models – as required – with 6 of the respondents (35.29%) stating that they did not use the website at all, leaving submission of the CAD files to one of their teammates. None of the 17 respondents reported creating a shared folder on the website for their team to use, as many indicated that they “worked on everything together until it was completed and then submitted the CAD models online”. When asked to provide feedback on the website and CAD repository, two responded that it was confusing to use and that better instructions were needed on how to use it. One person also suggested teaching CAD before assigning the material, although everyone in the class had used CAD at some point prior to taking the course.

The second trial (engines) did not fair much better. TABLE 3 summarizes the feedback from 21 of the 43 students (a response rate of 48.84%) on frequency of use, using the same 5-point scale. The results are essentially identical to those from the first trial despite having nearly twice as much time (4 weeks vs. 2 weeks) to work on the assignment. Three respondents (17.65%) reported that they could not figure out how to use the website, and as in the first trial, most respondents simply used the website and CAD repository to submit the *final* CAD models as required by the assignment.

When gathering feedback for this second trial, we also asked if students used any of the collaborative open-source development tools available on the website, and no one reported doing so with one person admitting, “[I] could not figure it out”. Likewise, none of the respondents reported using the website’s version control features for the CAD models. Teams simply divided up the work and shared CAD models via email and using flash drives, or they worked on it together until it was done and then uploaded it.

TABLE 3. SP06 CIBER-U FEEDBACK, PENN STATE, TRIAL 2

Statement – Rate each on a scale of 1 (never) to 5 (a lot)	Std	
	Avg	dev
How frequently did you use the website and CAD repository?	1.90	0.70
How frequently were you encouraged to use the website and CAD repository?	2.14	1.06
How frequently did you exchange CAD models with your teammates?	1.71	0.78
Did the CAD repository facilitate interactions with your teammates?	1.52	0.68

Several people (4 out of 17, 23.53%) reported not being able to figure out how to post data or that they had trouble doing so, citing “confusing”, “buggy”, and “took a long time to learn” as explanations for this. This frustrated several people, prompting one person to write that the website is “difficult in every way possible” and 5 people (29.41%) to suggest that we “get rid of the repository”. Students reported that it was much easier to communicate via email (9 out of 17, 52.94%) or just talk when in class (11 out of 17, 64.71%). One person used Penn State’s course management software (<http://cms.psu.edu>) to communicate with teammates and suggested that we use that in the future instead of the CAD repository. Other suggestions for improving the website and CAD repository included offering instant messaging (3 responses) and email (5), providing a better explanation of how the program works (2 responses), and making it simpler/easier to use (3 responses). Four people also wanted more help with CAD and/or online tutorials to help with the assignment, and one person suggested that we “make everyone use the same CAD software”.

2.1.2. SP06 CIBER-U Feedback - UMR

In the product dissection course at UMR, similar sentiment was recorded from the students as at Penn State. For the bicycle dissection trial, an hour-long tutorial session on using the SVN interface to upload and download CAD files was given to the students as part of the course. Of the eight teams, only six (75%) successfully uploaded their CAD files to the CIBER-U repository via the SVN interface. Common complaints indicated the “interface was too confusing,” “setting up the SVN client on individual computers took too long and was complicated,” and “it is easier just to e-mail the files...to other team members.” The two teams that failed to successfully upload their projects cited a connection problem.

Likewise, the second trial with the engine CAD models was not well received by the students. For the second trial, a

web-based upload site was available. Less than half of the teams bothered to commit their CAD models to the CIBER-U repository and chose to lose points on the project (note that this was the last project of the semester and many students had concluded that the lost points would not adversely affect their desired grade). Of the teams that did upload their models to the repository, none of them used the collaborative tools included in the initial CIBER-U website.

2.2. CIBER-U Implementation in Fall 2006 (FA06)

As a result of the feedback from the SP06 implementations at Penn State and UMR, we developed a new strategy for the Fall 2006 (FA06) implementation of CIBER-U, which was to be held at the University at Buffalo (UB) since dissection courses were not being offered at Penn State or UMR that semester. In particular, we shifted away from the version control and SVN-enabled approaches to a MediaWiki-based approach. We also allocated some student groups to be CIBER-U groups and others to be standard non-CIBER-U groups in order to assess the impact of the digital resources and technologies.

2.2.1. Details on FA06 CIBER-U Implementation at UB

In Fall 2006, the follow-on implementation of CIBER-U was deployed at the University at Buffalo in a sophomore-level design methodology course that involved 193 students. These students were organized into 39 groups, 9 of which were designated as CIBER-U groups that developed their project reports using MediaWiki and submitted them electronically. The other non-CIBER-U groups were designated as the “control group” and were to submit their project reports in a traditional hard copy format created using, for example, Microsoft Word.

The implementation at UB focused on dissection activities in a sophomore design course. The class was split into project groups, and each group was required to complete a comprehensive dissection project. For the course project, each group was given a product to disassemble, evaluate and reassemble. In the case of the CIBER-U groups, these products were cordless drills or disposable cameras. Other groups not participating in CIBER-U were given a range of consumer products to dissect (televisions, printers, small and large engines, etc.) The reason that the CIBER-U consumer products are different than the non CIBER-U products is to decrease costs associated with other universities using similar products in their implementations. For their project, the CIBER-U groups had access to information from similar products (the product was the same, but may have differed by brand) that had been previously generated and entered into the design repository. They were also required to develop their course projects in a WikiMedia format in the design repository.

The non-CIBER-U groups were allowed to use any digital resources that they could find to explore and determine information about their product; however, there was no direct access to digital reports or information about their specific

products given to these groups. This was a strategy chosen so that the effectiveness of using a design repository to gain information and insight could be compared against using common digital formats that are available to anyone. The CIBER-U and non-CIBER-U groups were each given a document listing the project report requirements (see sections from these documents in Figure 1a and Figure 1b, respectively) where the requirements for the project are identical, with the only difference being the introduction. The next section of the project report guidelines explains exactly what is expected in the submission (see Figure 1c and Figure 1d for excerpts from the CIBER-U and non-CIBER-U groups, respectively). This section was required to be different for the CIBER-U and non-CIBER-U groups due to the differences in their report formats.

As seen in Figure 1c and Figure 1d, there are stark differences for the CIBER-U group members. They are given access to some digital resources, namely, a template that contains hints and help for developing MediaWiki pages and the sections that are required in their final page. Even though the nature of the project report formats was different, the project requirements were kept very similar so the students would be working from the same starting point.

In addition to the project requirements, the CIBER-U groups were given access to a MediaWiki page that outlined their requirements in sections and explained the structure of MediaWiki so that the students would have some background to work from while generating their digital reports. As seen from the sample screen shot in Figure 2, the introduction section repeats the information that is presented in the Project Description, and subsequent sections outline techniques for coding MediaWiki pages. This page was made available to the students so that it would be easier for students to take initiative and learn the format themselves¹. Providing the template and user guide for the MediaWiki pages proved to be very effective, and there were no questions regarding the development of the pages. One advantage of the MediaWiki is the user interface and display. It has the ability to include many types of media, and display the information in a manner that is easy for others to read and evaluate.

2.2.2. FA07 CIBER-U Feedback - UB

At the end of the semester, all 193 of the students in the UB class (both CIBER-U and non CIBER-U groups) were asked to respond to a set of 10 statements (see Table 4) using a Likert-type scale ranging from 1-5, with 1 indicating complete disagreement, 2 indicating some disagreement, 3 indicating neutral, 4 indicating some agreement, and 5 indicating complete agreement. The statements were developed to measure the students’ exposure to, understanding of, and knowledge about the engineering-related digital technologies and tools at the focus of this project. The results are summarized in Table 4.

¹ The CIBER-U project report template for the UB students is available online at: http://gicl.cs.drexel.edu/wiki/Template_for_UB_MAE_277_Class.

Project Report Requirements

CIBER-U: Cyber-Infrastructure-Based Engineering Repositories for Undergraduates Projects

The final report will be electronically submitted in Wikimedia format (this is the same format that Wikipedia uses). A template will be provided to each group to help in the creation of this page. If there are problems using this format, additional help can be found at <http://meta.wikimedia.org/wiki/Help:Help>.

Before Disassembling the Product

- Describe the purpose of the product and how it works (your understanding at this point). What types of energy are used and how are they transformed?
- Operate the product, if possible. How does it run? If it doesn't why do you think it doesn't work? What type of motion or sounds does the machine make?
- How many components do you think the product is made of?
- How many different types of material are used in the product?

During Disassembling the Product

- Record each disassembly step, the tool used, the ease or difficulty involved.

After Disassembling the Product

- Record each component, material type, manufacturing process used for each component, model or part number, and any other description necessary (color, texture, etc.).
- Record the function of each component.
- Record the number of components and the types of components encountered (e.g., fasteners, support, housing, gearing, screws, etc.)
- Record why your group thinks each component was made out of its type of material.
- Record why your group thinks each component looks the way it does.

(a) CIBER-U Project Requirements

Digital Project Report

Final written reports in Wiki form are due *Friday, December 8, by 4:00PM (before class)*. On the GICL (Geometric and Intelligent Computing Laboratory) website, run by Drexel University, are example Wikimedia pages of products which are similar to the products which your group will be dissecting. For an idea of what is expected, the URL's to these pages are:

Drill: http://gicl.cs.drexel.edu/wiki/Dewalt_DW217_Drill
Camera: http://gicl.cs.drexel.edu/wiki/Kodak_Waterproof_Disposable_Camera

This page is not necessarily representative of the report format which your group will need to submit, these are simply examples so that your group may have an idea of what is expected. Here is a template of the Wikimedia page which is expected to be used by your group. *Do not edit this Wikimedia page, it is a reference.*

Template: http://gicl.cs.drexel.edu/wiki/Template_for_UB_MAE_277_Class

Each Wikimedia page should have the following sections:

- Executive Summary
 - This section is much like an abstract and summarizes the entire report
- Introduction
 - This section should include an introduction of the product and a brief description of group members (i.e. who was responsible for which sections or tasks)
- Before Disassembly Section
 - Requirements are listed above
- Disassembly Procedure
 - Document each step to disassemble the product
 - How difficult was each disassembly step?
 - What types of tools were required to perform this step?
 - Include a picture of each disassembly step
- After Disassembly
 - Requirements are listed above

(c) CIBER-U Digital Project Report

Project Report Requirements

The project report is meant to be part journal, part technical report. It should be a working document that team members are adding to throughout the semester. At a minimum, the report must include:

Before Disassembling the Product

- Describe the purpose of the product and how it works (your understanding at this point). What types of energy are used and how are they transformed?
- Operate the product, if possible. How does it run? If it doesn't why do you think it doesn't work? What type of motion or sounds does the machine make?
- How many components do you think the product is made of?
- How many different types of material are used in the product?

During Disassembling the Product

- Record each disassembly step, the tool used, the ease or difficulty involved.

After Disassembling the Product

- Record each component, material type, manufacturing process used for each component, model or part number, and any other description necessary (color, texture, etc.).
- Record the function of each component.
- Record the number of components and the types of components encountered (e.g., fasteners, support, housing, gearing, screws, etc.)
- Record why your group thinks each component was made out of its type of material.
- Record why your group thinks each component looks the way it does.
- Record a list of design changes/improvements your group thinks could be incorporated into the

(b) Non CIBER-U Project Requirements

Project Report

Final written reports are due *Friday, December 8, by 4:00PM in 104 Knox Hall (before class)*. The following format should be used:

- Times New Roman, 12 font, 1 ½ space, 1 inch margins.
- Have a cover page with group number, group member names and signatures, date, and product used.
- Use references, if you have used outside sources of information (use APA referencing style www.apastyle.org).
- Use figures, tables, and pictures to aid in effective communication.
- You must include an executive summary, examples of which are on the class website. This is like an abstract and summarizes the entire report.
- Your report should not read like a book report or essay – it is a technical report and therefore needs sections and subsections. The sections should answer the questions posed regarding the product disassembly, design, manufacturing, and assembly in a coherent, effective manner. It should look like one person wrote it, even though everyone in the group contributed to it.
- Include snapshots of the CAD drawings in the report. Full dimensions are not necessary on the figures, but include a scale or a reference dimension on the figure. Electronic versions of the CAD drawings can be turned in on a disk or CD with the report.

Oral Project Report

Your group will prepare a *6 minute* presentation on your product and its design. Include only the highlights of your report and the insights you found to be most interesting. Be sure to include discussion on the design changes your group would recommend. Presentations will occur during the last 2 weeks of class.

(d) Non-CIBER-U Project Report (Hard Copy)

FIGURE 1. CIBER-U AND NON CIBER-U PROJECT REQUIREMENTS

[article](#) [discussion](#) [view source](#) [history](#) [watch](#)

Template for UB MAE 277 Class

Contents [hide]

- 1 Executive Summary
- 2 Introduction
- 3 Before Disassembly Section
- 4 Disassembly Procedure
- 5 After Disassembly
 - 5.1 Part Table, including:
- 6 Assembly
- 7 After Assembly
- 8 References
 - 8.1 Guide to Writing Wiki Code
 - 8.2 This is an example table

Executive Summary

This section is much like an abstract and summarizes the entire report.

Introduction

This section should include an introduction of the product and a brief description of group members (i.e. who was responsible for which sections or tasks)

Before Disassembly Section

General notes about the product (it's condition, how it works, how many parts, types of materials, etc)

Disassembly Procedure

- Document each step to disassemble the product
- How difficult was each disassembly step?
- What types of tools were required to perform this step?
- Include a picture of each disassembly step

After Disassembly

Part Table, including:

- Part number
- Part name
- Number of parts of this type
- Part material
- Part manufacturing process
- Image of the part
- CAD file for selected parts

Assembly

- Document each step to reassemble the product
- How difficult was each assembly step?
- What types of tools were required to perform this step?

FIGURE 2. SAMPLE OF CIBER-U PROJECT REPORT TEMPLATE

TABLE 4. FA06 CIBER-U FEEDBACK, UB

Statement	CIBER-U (Avg.) ²	Non-CIBER-U (Avg.) ³	t-statistic ⁴
1. This class has exposed me to relevant and leading digital design tools.	4.02	3.64	t = 2.38 ^a
2. I have a better understanding of the role of digital formats and tools in engineering design from this class.	3.98	3.58	t = 2.65 ^a
3. I believe that digital reports and associated tools (repositories, assembly animations, etc.) can be useful in engineering design.	4.62	4.30	t = 3.31 ^a
4. The availability of digital resources helped further my understanding of the product my group had.	4.11	3.66	t = 3.02 ^a
5. The digital resources that I used (CIBER-U, Internet) communicated information in an efficient and user-friendly way.	4.33	3.58	t = 6.02 ^a
6. The project guidelines allowed me to be creative in my project report.	3.98	3.77	t = 1.35
7. Viewing past projects or templates strongly influenced the information I conveyed in my project.	4.09	3.52	t = 3.52 ^a
8. The digital resources restricted, or limited, the information that I could put in my final report.	2.44	2.50	t = 0.39
9. I have learned how to use digital formats to record and convey information.	4.02	3.42	t = 4.41 ^a
10. I was able to use digital formats (MediaWiki, CAD files, pictures, etc.) to learn about my project.	4.20	3.87	t = 2.69 ^a

^a Result was statistically significant ($p < 0.01$) when comparing CIBER-U groups to non CIBER-U groups.

Statements 1-3 dealt with general exposure to the digital design technologies. As is evident from the t-statistics, the CIBER-U groups felt like they were better exposed to these technologies as a result of interacting with them through the course of the course project.

Statements 4 and 5 are quite telling as well. The CIBER-U students felt strongly that the digital resources strengthened their understanding of their product and allowed them to communicate project information in an effective way. Most importantly, the CIBER-U students were significantly stronger in their response to Statements 4 and 5 compared to the non-CIBER-U students.

Statements 6 and 8 both dealt with how the project guidelines (e.g., digital vs. non-digital requirements) either restricted or enhanced people’s ability to be creative and to effectively communication the project information. While both the CIBER-U and non-CIBER-U groups felt like the project guidelines allowed them to be creative and did not restrict their communication, there was not a significant difference between the groups. One of the initial concerns of using a design repository was that exposing students to previously generated projects and introducing a framework would stifle creativity and would guide thinking in a certain

² Population size: 45

³ Population size: 145

⁴ Using unequal variances, for two-tail, t-critical = 1.98

direction. It is very promising that there were no statistically significant differences between the two populations. This suggests that the students were no less creative or directed by previous reports than students who did not have access to this information.

One of the potential significant benefits of on-line repositories and associated tools is the availability of past information, including projects from the other universities. In Statement 7, it is clear that the CIBER-U students did feel as if they were influenced by the existence of past reports and templates. Since the groups were given a guideline to follow, it is unclear whether or not the guideline or the past projects had more influence. More evaluation is necessary to determine which had a greater effect. This may have both advantageous and disadvantageous outcomes, depending upon the value of the existing information. More insight will be gained into this issue when studying the project reports.

Statements 9 and 10 evaluate the students’ learning and knowledge. While both sets of groups agreed with the statements, the CIBER-U groups were significantly higher in their agreement with these statements. This supports one of our initial project objectives to not only expose students to on-line cyberinfrastructure tools and technologies, but also to teach them these technologies. Because the non-CIBER-U students also agreed with these statements, it is clear that by having these technologies as an integral part of the course and the group presentations, even the students not in a CIBER-U group are being exposed and learning the technologies.

Over the coming semester (Spring 2007), we will be studying the differences, similarities and resulting impact of the digital and hard copy versions of the project reports. This will include an assessment of the impact of technology exposure and use, the common project report elements, and the non-common report elements that may be attributed to the level of technology used (or lack thereof).

3. LESSONS LEARNED FROM CIBER-U

We discovered that undergraduate engineering students required considerably more education and training – as well as “buy in” – to use these cyberinfrastructure tools than we expected. Unlike common tools such as file sharing of MP3s and videos, these tools met with some degree of resistance. Possible reasons for this include (a) the tools were designed for Computer Science and software problems, not general engineering design problems; hence, there are user interface and workflow issues that do not exactly match the needs of the students in an engineering education context, and (b) students lacked the training materials and the incentives for using them.

The difficulties that were encountered in the Spring 2006 implementation were noted, and a new approach was developed in the summer. In Fall 2006, the use of MediaWiki transpired with much greater success. Earlier problems, specifically (b), were addressed by improving the student requirements and the reference materials that were provided to

the students. The problems that were initially faced were broken down into four categories that were determined to be the root cause.

3.1. User Interface

The MediaWiki user interface is quite simple and the way which the GICL website (the space that hosted the project reports) was organized also facilitated a user-friendly interface. Each initial page was pre-created for every CIBER-U group. It was thought that the easier it was made for the students to access and edit the pages, the more likely they would be to take initiative and get working on them. This was proven to be true because there were not any questions or complaints regarding the digital reports. The survey results also show that the students believed that the format was user friendly and communicative.

3.2. User “Buy In”

One of the difficulties of getting students to try new technologies is to get the students to believe that the work they are doing is worthwhile and beneficial to their education. The benefit of using a MediaWiki format for developing design repositories is that many students have seen and used Wikipedia. So, this format was not completely foreign to them. Since MediaWiki format is rather simple and easy to use, the students had few difficulties learning how to develop the pages for their reports. Moreover, the availability of the pre-existing MediaWiki pages allowed the students to see first-hand the benefits of viewing their project in a digital environment. The answers to Statements 1-3 from the UB survey show that the students bought in to the concept of using digital formats in engineering design and agreed that they were useful and effective in communicating information.

3.3. User Workflow

User workflow was easily manageable with the MediaWiki software. All changes to the MediaWiki pages are updated instantly, and a digital signature is left by the user who made the changes. This is important because, at any time, a group member can view the MediaWiki page and see what changes have been made, what work has been done and how the project is progressing. This makes it much easier for group members to hold each other accountable for work because all progress and contributions can be easily accessed. Another benefit of using MediaWiki is that the data presented on the page is viewable to anyone in the world with an Internet connection. This makes teamwork much more efficient and eliminates having to wait for updated information from other group or team members sent via email, for instance. All information regarding the project is available immediately and in one central location that any team member can access.

3.4. User Training

Since MediaWiki is a very simple, straightforward format, the learning curve is very gentle. Editing the text

within the pages is not much different than editing a document in Microsoft Word once the page format has been created. It is believed that the template, or user guide, which was provided to the students in the CIBER-U groups, was also responsible for the success of the MediaWiki approach. The template empowered the students to learn the format themselves yet allowed for creativity within their own pages. It made the information needed to complete the project available in one convenient location. Also, the students could manipulate the formatting because all work done is instantly updated. We learned that students responded well to the approach used to create the pages, that they did not face any large obstacles, and that there was no help required from the course instructor.

One benefit of the CIBER-U approach was, in spite of some of the issues presented by the students, all of the information generated by the student teams has been captured for use in later classes. While many students noted that they used email and pen drives, etc. to share data—finding this easier than the CI tools—without the CI tools, none of this information or exchange would have been formally captured. If the course were taught in a traditional manner, little of the student output would be captured, preserved, and most importantly, be reusable. With the CI approach, the information is captured and preserved as part of the process, requiring no additional work on the part of instructors (but requiring adaptations in the behavior of the students). Hence, primary beneficiaries of the approach will be future students and instructors who can make use of the captured data in follow-on classes and in subsequent class years. While this is something that it is not possible to measure the impact of at the current time, it is clear that this repository of experience and projects is a valuable outcome, and an emerging objective is to make the process of capture and preservation as transparent and easy as possible for the students who are the content creators.

4. CLOSING REMARKS AND FUTURE WORK

The results from each implementation looks promising and significant steps in evolving the CIBER-U approach have been made. For the remaining year of the CIBER-U project, we intend to expand on the use of MediaWiki and improve upon the first implementation to make the interface more uniform and user friendly. In addition to this, we plan to develop and deploy more customized tools for engineering design education based upon our findings from Phase I implementation. If a repository is to be a resource for many different types of product information, it is important that the manner in which that information is displayed and organized in the digital format be taken into consideration. Since much of this is new in engineering, especially within an educational setting such as this, a research challenge is to determine the optimal method, or structure, for capturing and displaying information. This is necessary so that users can intuitively

locate the information that they seek, which might be contained on different pages for different products.

We have also identified several new interdisciplinary, research challenges in computer science based on this work. First, the need for easy-to-use tools to represent, capture and organize engineering information within (and for) an engineering educational context has become readily apparent. Second, existing tools suitable in one domain (i.e., versioning tools for software design) need to be adapted to the workflow of other domains (e.g., engineering design and design education). Lastly, archival and long-term storage of complex engineering data remains an open and challenging problem that will be addressed in the coming year.

The next phase of CIBER-U will build upon the lessons learned in this work. There is also a need and plan for broader and more detailed assessment procedures. This will include control groups at each university, similar to the UB implementation, and focus groups of students to better evaluate their experiences and opinions. Finally, we are also examining the scalability of CIBER-U through a follow-on project that includes five additional universities and engages over 10,000 students in engineering and computer science.

ACKNOWLEDGMENTS

We gratefully acknowledge support from the National Science Foundation through NSF Grant No. OCI-0537220; a collaborative research grant involving Penn State University, University at Buffalo, University of Missouri-Rolla, and Drexel University. Any opinions, findings, and conclusions or recommendations presented in this paper are those of the authors and do not necessarily reflect the views of the National Science Foundation.

REFERENCES

- [1] Atkins, D. E., Droegemeier, K. K., Feldman, S. I., Garcia-Molina, H., Klein, M. L., Messerschmitt, D. G., Messina, P., Ostriker, J. P. and Wright, M. H., 2003, "Revolutionizing Science and Engineering Through Cyberinfrastructure," *Report of the National Science Foundation Blue-Ribbon Advisory Panel on Cyberinfrastructure*, National Science Foundation, Arlington, VA.
- [2] Fox, E., Akscyn, R., Furuta, R. and Leggett, J., 1995, "Digital Libraries," *Communication of the ACM*, 38(4), pp. 23-28.
- [3] Zhang, S., Shen, W. and Ghenniwa, H., 2004, "A Review of Internet-based Product Information Sharing and Visualization," *Computers in Industry*, 54(1), pp. 1-15.
- [4] Sheppard, S. D., 1992, "Mechanical Dissection: An Experience in How Things Work," *Proceedings of the Engineering Education: Curriculum Innovation & Integration*, Santa Barbara, CA.
- [5] Sheppard, S., 1992, "Dissection as a Learning Tool," *Proceedings of the IEEE Frontiers in Education Conference*, Nashville, TN, IEEE.
- [6] Agogino, A. M., Sheppard, S. and Oladipupo, A., 1992, "Making Connections to Engineering During the First Two Years," *22nd Annual Frontiers in Education Conference*, Nashville, TN, IEEE, pp. 563-569.
- [7] Lamancusa, J., Torres, M., Kumar, V. and Jorgensen, J., 1996, "Learning Engineering by Product Dissection," *ASEE Conference*, Washington D.C., ASEE.
- [8] Lamancusa, J. S., Jorgensen, J. E. and Zayas-Castro, J. L., 1997, "The Learning Factory-A New Approach to Integrating Design and Manufacturing into the Engineering Curriculum," *Journal of Engineering Education*, 86(2), pp. 103-112.
- [9] Beaudoin, D. L. and Ollis, D. F., 1995, "A Product and Process Engineering Laboratory for Freshmen," *ASEE Journal of Engineering Education*, 84(3), pp. 279-284.
- [10] Felder, R., Beichner, R., Bernold, L., Burniston, E., Dail, P. and Fuller, H., 1997, "Update on IMPEC, An Integrated First-Year Engineering Curriculum at North Carolina State University," *Proceedings of ASEE Annual Conference and Exhibition*, Milwaukee, WI, ASEE.
- [11] Mickelson, S. K., Jenison, R. and Swanson, N., 1995, "Teaching Engineering Design through Product Dissection," *Proceedings of the ASEE Annual Conference and Exhibition*, Anaheim, CA, ASEE.
- [12] Carlson, B., Schoch, P., Kalsher, M. and Racicot, B., 1997, "A Motivational First-Year Electronics Lab Course," *ASEE Journal of Engineering Education*, 86(4), pp. 357-362.
- [13] Demetry, C. and Groccia, J., 1997, "A Comparative Assessment of Students' Experiences in Two Instructional Formats of an Introductory Materials Science Course," *ASEE Journal of Engineering Education*, 86(3), pp. 203-210.
- [14] Barr, R., Schmidt, P., Krueger, T. and Twu, C.-Y., 2000, "An Introduction to Engineering Through and Integrated Reverse Engineering and Design Graphics Project," *ASEE Journal of Engineering Education*, 89(4), pp. 413-418.
- [15] Fincher, C., 1986, "Trends and Issues in Curricular Development in Higher Education," *Handbook of Theory and Research*, J. Smart, ed., Agathon, New York, pp. 275-308.
- [16] Nicolai, L. M., 1995, "Designing a Better Engineer," *Aerospace America*, 30(4), pp. 30-33.
- [17] Brereton, M. F., 1998, "The Role of Hardware in Learning Engineering Fundamentals: An Empirical Study of Engineering Design and Dissection Activity," *Ph.D. Dissertation*, Mechanical Engineering, Stanford University, Palo Alto, CA.
- [18] Otto, K. N. and Wood, K. L., 2001, *Product Design: Techniques in Reverse Engineering and New Product Development*, Prentice Hall, Upper Saddle River, NJ.
- [19] Guerard, E. B., 2000, "'Digital Dissection' Draws Debate in Schools," *eSchool News Online*, <http://www.eschoolnews.com/news/showStory.cfm?ArticleID=256>.