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Instructional Technology Software Reuse: A Case Study

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ABSTRACT
Software reuse is a major issue in information systems research; it has become a particularly important area of focus recently with regard to instructional software. We report here on an experiment in which a set of three Web-based interactive labs developed by researchers at one university for a course at that university, were modified and reused in a similar course at another university. The paper focuses on implementation details of the project, assessment results, and observations regarding guidelines for successful reuse of non-commercial instructional technology.

Keywords
instructional technology, reuse, case study

INTRODUCTION
Software reuse has been defined as “the use of existing software artifacts or knowledge to create new software” (Frakes and Terry, 1996). Generally speaking, the idea of reuse is to improve software development productivity and software quality. While examples of successful reuse have been documented, the myriad significant challenges to implementing a software reuse policy in corporate settings have been noted (Kim and Stohr, 1998).

More recently, as instructional technology has become more widespread, reuse has become a particularly important area in the arenas of education and training (Littlejohn, 2003; Wiley, 2000a). Duncan (2003) notes that reuse in the instructional technology context typically refers to the reuse of “learning objects”. Definitions of the term learning object include “any entity, digital or nondigital, that may be used for learning education or training” (IEEE, 2002) and “any digital resource that can be reused to support learning” (Wiley, 2000b). As in the business world, a focus here is on software productivity and quality though, naturally enough, in the academic world the effort is more directed towards collaboratively sharing efforts across (as opposed to within) organizations.

Some examples of instructional software reuse include:

- The MIT Open Courseware Initiative (Long, 2002; Margulies, 2003).
- The European Union’s Ariadne Foundation (http://www.ariadne-eu.org/), whose mission “is to enable better quality learning through the development of learning objects, tools and methodologies that enable a ‘share and reuse’ approach for education and training.”
- Various online teaching resources (e.g., syllabi and Web pages) available from MERLOT, the Multimedia Online Resource for Learning and Online Teaching (www.merlot.org).
- Established “coursepacks” that is, collections of course materials, available from academic publishers or distributors (for example, www.xanedu.com and http://academickeys.com/all/course.php).
- Assorted java applets, typically useful for visually illustrated mathematical concepts, and physical, biological and chemical principles. (As a case in point, a Google search on the terms “central limit theorem” and “applet” will, as of this writing, yield dozens of hits.)
- Course management systems (such as BlackBoard and WebCT).
We report here on an experiment in which a set of three Web-based interactive labs developed by researchers at one university (Carnegie Mellon) for a course at that university, were modified and reused in a similar course at another university (Seton Hall). This paper focuses on the management issues of the project; details of the implementation of the project, assessment results, and observations regarding guidelines for successful reuse of non-commercial instructional technology are discussed.

THE EXPERIMENT

Researchers at Carnegie Mellon University (CMU) designed some dozen interactive labs for use in an introductory, undergraduate course in statistics in the social sciences (Meyer and Lovett, 2002). Each lab is structured around one or more motivational questions that the student must answer by analyzing, in a systematic way, the data provided. (An example of this type of question is, “Is there a drinking problem among students at this university?”) The labs were designed based on an intelligent tutoring system (ITS) framework (Anderson et al. 1995) and initially creating using ITS modeling software. With the aim of making the labs accessible over the Web, they were rebuilt using standard Web technologies: html and javascript.

In terms of learning objectives, the focus of the labs is to “facilitate student learning of problem-solving skills that had previously appeared to be most difficult, namely, (1) planning and selecting appropriate statistical analyses, (2) evaluating the validity of statistical inferences, and (3) transferring these and other skills to new contexts (e.g., from homework to exam, from current class to downstream courses)” (Pew Grant Program in Course Redesign, 2002a).

The following outlines the benefits of the project (Pew Grant Program in Course Redesign, 2000).

- “Use an intelligent tutoring system … to introduce, supervise, and provide individualized feedback on student lab and homework exercises;
- Rely on [the system] to provide immediate feedback to students as they progress;
- Use of [the system] to provide a consistency and abundance of feedback;
- Eliminate five to six TAs; and
- Reduce the labor-intensive nature of the remaining TA support.”

Evaluation (Pew Grant Program in Course Redesign, 2002b) indicates both increased student learning and reduced costs (due to the elimination of half the required TAs).

A basic statistics course is commonly required at all universities and is typically offered within the various disciplines (e.g., business, psychology, economics, etc.) Virtually all such courses share a common core set of topics, for example, descriptive statistics, probability basics, sampling, and hypothesis testing. Course coverage within topics vary (for example one course might include hypothesis testing for both one and two sample cases, while another might cover only the one sample case). Further, additional topics may be covered in some courses and not in others – for example, ANOVA may or may not be included. Given the numerous students taking these courses and the common core of subject matter, undergraduate statistics seems a good choice of focus for reusability.

Table 1 outlines some of the course details at the two institutions.

<table>
<thead>
<tr>
<th>Institution Characteristics</th>
<th>Carnegie Mellon University</th>
<th>Seton Hall University</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. Statistics Students</td>
<td>~200/semester</td>
<td>~140/semester</td>
</tr>
<tr>
<td>Course Structure</td>
<td>One lecture section, meets twice per week (all students) plus five lab sections, each meets once per week, ~40 students per lab.</td>
<td>Four-six sections per semester, each meets twice per week (lectures), ~30 students in each section, no lab.</td>
</tr>
<tr>
<td>Course Personnel</td>
<td>One professor/instructor (lecture section), five graduate TAs (one per lab section), five undergraduate assistants (one per lab section).</td>
<td>One professor/section.</td>
</tr>
<tr>
<td>How the Software is Used in the Course</td>
<td>Students do the labs in lab periods, with guidance and assistance from TAs and</td>
<td>For labs one and two, students started labs in class, with guidance and assistance from professors, and completed them at home.</td>
</tr>
</tbody>
</table>
Of particular note is the reduced contact time for the course at Seton Hall University (SHU). One incentive for the using the software at SHU is the opportunity to provide a laboratory experience without the additional laboratory time. One disadvantage of adapting the labs for use at SHU is the additional burden it puts on already precious class time.

PROCEDURE

Initial

Our group at SHU has been active in the area of instructional technology; this work led us to contact the principal investigator of the project at CMU. Initial discussions were held during the late spring – early summer of 2003.

1. After some discussion between the two research groups, and the opportunity to explore the labs, it was agreed upon that we would try to implement a subset of the labs locally, shooting for a start date of the fall of 2004. It should be made clear that there was no obligation, contractual or otherwise between the two groups. The group at CMU indicated they were happy to help, though they made it clear that they were in no position to provide support (in the sense of commercial software support).
2. From the outset it was realized that at least some modifications of the labs would be required due to the fact that students in the course at CMU utilize the Minitab statistical package while the course at SHU utilizes Excel. At the point in the lab where the student determines the correct statistical technique to apply, the lab provides appropriate instructions for doing so. At minimum, these instructions would have to be updated. (Surprisingly, this turned out to be a complicated issue; more below.) Beyond this, it was expected that the opportunity to create new labs would be presented.

Organizational

1. Initial discussions were held with the faculty slated to teach the course at SHU in order to determine who would participate in the pilot. The following issues were pertinent.
   a. Only full-time faculty were considered. We felt that the potential risk of this pilot project should not be borne by the one part-time faculty member teaching the course.
   b. Those faculty members with significant experience teaching the course were preferred. Put another way, a general “comfort level” was desirable. The one new faculty member teaching the course was not considered.
   c. Faculty had to be comfortable with the additional class time required to introduce and run the labs. Discussion with the faculty indicated that three labs seemed about right in terms of balancing the value of the software and the limitations imposed by class time.
   d. Ongoing meetings would be required to monitor progress/problems during the semester. Faculty would have to be willing to participate.
2. Ultimately two instructors teaching a total of three sections were brought on board. One of these instructors was slated to teach one section, the other two sections. It was decided that the instructor teaching two sections would use the labs in only one of his sections so that we could use his other section as a control group.
3. Preferred topics for the three labs were discussed with the course faculty at SHU. Ultimately the following lab topics were decided upon for the three labs: descriptive statistics, hypothesis testing and simple linear regression.

Technical Issues

Examination in detail of the existing labs was undertaken to see which could be used, in whole or in part. The issue here was to see which of the existing labs focused on statistical topics and techniques that were covered in the course at SHU. CMU’s course has more contact hours and covers more material, so clearly not all labs, or all questions (parts) of all labs would be appropriate for SHU. At the same time, it was entirely possible (and turned out to be the case) that the existing labs would not suffice for the desired topic coverage at SHU.

As stated previously, the labs were built using standard Web technologies. Each lab is comprised of the following: 3 javascript files, 16 html files, and 44 jpg files. (An additional Minitab file is used for holding the associated dataset and is
ultimately downloaded by the student for data analysis.) Modifying an existing lab or creating a new one means editing and/or creating content in two of the javascript files. For some perspective, in the first lab there are 7632 total lines of executable (that is, non-comment) code. The two javascript files that define an individual lab contain 625 lines of executable code. (The bulk of the code is in the other javascript file.) These measures are comparable in the other labs.

To be clear, modifying an existing lab to create a new lab means editing these two javascript files; this in turn requires at least a rough knowledge of javascript, a solid grounding in statistics, and a thorough understanding of how the labs work and why. In our project, these requisites skill were fulfilled by one individual on the project team.

Lab Development

Lab 1 – Descriptive Statistics

Building the first lab began in earnest at the start of the semester. For this lab we were able to use an existing lab exactly as it was, aside from removing the Minitab instructions and replacing them with the equivalent instructions for Excel (and recreating the Minitab data file in Excel). We created the Excel instructions (in MS Word) and the Excel spreadsheet and simply forwarded them to CMU where a graduate student working on the project was generous enough to make the required changes.

Lab 2 – Hypothesis Testing

In this case we modified an existing lab by eliminating one question, rearranging the order of the remaining questions and updating the analysis instructions and data from Minitab to Excel. The files were emailed to us; editing and testing were done by us locally.

Lab 3 – Correlation and Simple Linear Regression

There wasn’t a single existing lab at CMU that matched the way this material was taught in the course at SHU. This presented us with two options: cobble together a new lab from the material in several existing labs or create a “truly” new lab – one with new motivational questions, a new data set and new analysis strategy. As we were interested in exploring the effort required in creating a new lab in this sense, we chose the latter option. Our experience was that most of the additional work in this approach was due to the effort required to come up with an interesting, real world problem and data set and was not due to the effort required to actually edit the javascript files.

Building and testing the labs was done by one of us, a faculty member on the project team at SHU. Each lab took on the order of ten hours to build and debug. Additionally, though objectively the task of building successive labs became more difficult, the mechanics of doing so became easier as the developer gained experience.

ASSESSMENT

There are three components to assessment here: 1) determining the effectiveness of the labs in terms of teaching and learning, 2) measuring student satisfaction with the labs and 3) gauging benefits of reusing the software, as opposed to developing it from scratch.

Effectiveness

To determine the effectiveness of the labs we compared final exams scores of the section that used the lab and the one that didn’t, both taught by the same instructor.

We offered six sections of the course in the fall of 2003 and used the lab in two of them. Two sections were taught by one instructor; we used the labs in one of these sections and not in the other so that we could compare outcomes between a section that did use the lab and one that didn’t use the lab, controlling for instructor. The procedure for assessment between these two sections follows.

We first determined which of the two sections taught by the same instructor should use the labs. As we did not have the option of assigning students to sections, our goal here was to assure ourselves that the two sections were comparable. We collected Math SAT scores for the students in both sections and performed a two sample t-test test for equality of these scores. There was no significant difference between the mean scores (n₁=30, n₂=30, t=-.09, p-value=0.93), nor of the standard deviation of the scores (F=1.259, p-value=0.540), so the sections seemed to be equivalent with respect to math skills. As we had to choose, we decided to provide the labs to the section that had the slightly lower mean score and the slightly larger standard deviation.
In the section that did not use the labs, students were given problems from the labs and/or similar problems in a traditional, paper-based (non-interactive, no immediate feedback) format.

As a measure of the efficacy of the labs in terms of student learning of the course material, we compared final exam scores of the two sections. We performed a two sample t-test for equality of these scores. There was no significant difference between the mean scores ($n_1=28$, $n_2=29$, $t=0.97$, p-value=0.33), nor of the standard deviation of the scores ($F=1.156$, p-value=0.708), so there does not seem to be a significant difference in the performance of the two sections as measured by the final exams.

It should be noted that CMU, in their assessment studies, developed measures beyond the existing exam questions to gauge the effectiveness of the tutor with respect to the specific learning goals of the project. (These goals are specified here in the second paragraph of “The Experiment” section.) These assessments indicated positive learning outcomes (Pew Grant Program in Course Redesign, 2002b).

### Student Satisfaction

To measure student satisfaction with the labs we administered a simple survey after each lab was turned in to students in both sections that used the labs. The survey was comprised of three questions and a space for making comments. The survey document is reproduced in Figure 1 and summary results are provided in Figure 2.

<table>
<thead>
<tr>
<th>Statistics Lab Survey</th>
</tr>
</thead>
<tbody>
<tr>
<td>The following questions refer to the lab you just completed. Please answer each of the survey questions below using the 1 to 5 scale.</td>
</tr>
<tr>
<td>Note that your survey answers are anonymous.</td>
</tr>
</tbody>
</table>

1) Did you find the tutor easy to use?  
   - Difficult  
   - Easy  
   1 2 3 4 5

2) Did you find the tutor to be an interesting way to learn?  
   - Uninteresting  
   - Interesting  
   1 2 3 4 5

3) As a result of using the tutor, do you think you understand the material better?  
   - No Change  
   - Understand Better  
   1 2 3 4 5

Please write down any other comments you had relating to your experience with the tutor:

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Generally these results and the open-ended comments indicate that the students found the labs relatively easy to use, interesting and worthwhile. The bulk of the comments were very positive, extolling the merits of working independently on interesting problems, having a structure that supported the process of statistical analysis and getting immediate feedback. There were two areas of generally negative comments:

The labs could not be saved; in other words, a student could not return to a partially completed lab and resume where s/he left off. As the labs take on the order of an hour or more to complete, if the student had not completely finished the lab s/he would have to start from the beginning upon resuming. This weakness was offset by the fact that it was possible to save a text transcript of a lab session, therefore (in addition to generally having a record of one’s work) by working off this record.
Weitz et al.

Instructional Technology Software Reuse

one could quickly reconstruct a lab session. Nonetheless, students regularly cited this as a problem. The current version of the lab allows for saving.

![Figure 2: Student Survey Results](image)

The second area was more problematic: in the first two labs, students found the Excel instructions to be too general. As it turns out, writing instructions for students to do data analysis in Minitab is quite straightforward, while the equivalent in Excel is more challenging. An example will highlight the difficulties. The instructions for creating a histogram in Minitab are as follows:

- From the Graph menu, choose Histogram.
- Under "Graph Variables", in the first row type the variable name you selected (or just double click on it in the variables list on the left).
- Click "OK".

These three simple, general (in the sense that they can be used for any lab, no matter which column of data are under analysis) steps produce a good looking histogram. For Excel, doing the same requires telling the student a) that to get to the Histogram Options window requires clicking on the Tools menu and then Data Analysis, b) what is meant by a “bin width” and how to specify it in Excel (you need to create another column), c) that if the first row of the data under consideration includes a label, the appropriate box should be checked in the histogram options window, d) that the chart options box should be checked as well, e) that the Pareto and Cumulative Percentage boxes should not be checked, and f) what the difference is between the output options of Output Range, New Worksheet Ply and New Workbook.

To be clear, we are generally agnostic with respect to the relative merits of Minitab and Excel as tools in this course. However one observation that naturally results from this work is that when using Excel as opposed to Minitab, the level of detail in the instructions to the students for conducting their statistical analysis becomes a pedagogical issue. (And the problem becomes more acute when doing analyses that Excel does not do at all, like box plots.)

**Productivity**

Traditionally, the productivity and quality benefits of reuse are estimated via formal metrics (Kim and Stohr 1998, Poulin and Carlson 2004, Frakes and Terry 1996). Here we gauge the benefits of reuse by comparing the actual effort required to build and debug the original labs and the actual effort required to modify and implement the lab for reuse.

**Original Effort – CMU (M. Lovett, personal communication, February 19, 2004)**

- Original design: 1/4 time faculty member + one instructor summer
- Implementation utilizing ITS software: one programmer 1/2 of a year
- Re-implementation in html/javascript: one programmer 1/3 of year (plus small amount of faculty and instructor time principally to refine design)
Ongoing small faculty time, instructor time and programmer time to do refinements and to realize some original goals of the project that were not included in original design.

In summary, the original development required approximately one year of programmer time and the equivalent of half a year of faculty member/instructor time.

Effort to Modify – SHU

- Software modification, project coordination: 1/4 faculty time
- Coordination at CMU: small amount of graduate assistant time.

Net Savings:

- One year of programmer time
- 1/4 faculty member/instructor

OBSERVATIONS AND FUTURE RESEARCH

In this research we have described a case study of learning object reuse. We have detailed the successful reuse of a set of three interactive laboratories designed for use in an undergraduate statistics lab. Assessment was performed on three measures: learning outcomes, student satisfaction and cost (time) savings. The students seemed pleased with the labs, found them interesting and easy to use, and felt like they learned something by using them. Our independent measure of learning outcomes – comparing final exam results for one section using the labs and another control section – did not yield any significant difference. One direction of future work will concentrate on following the lead of the researchers at CMU in exploring learning effects we may not have uncovered using this approach. Our own judgment, and that of the course instructors involved, is that the labs were a worthwhile endeavor with respect to teaching and learning.

Finally, we have documented significant savings of approximately one year of programmer time and the equivalent of 1/4 of faculty time as a result of reusing existing software as opposed to creating it from scratch. These results are for a non-commercial product, built initially without any thought to reuse outside the original development environment. Perhaps more importantly it’s not clear that building these labs (or other sophisticated instructional technology) from scratch is in fact an option for institutions like SHU that don’t have access to research resources like graduate students and programmers (or budgets for them). It appears that what is required for projects such as this one are some technical and subject area knowledge on the part of the reuse team, cooperative faculty teaching the course(s) in question, and some level of cooperation from the originating institution.

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REFERENCES