Integrating People and Technology *By Design*

Design-First Instruction for Introductory Students in Information Technology

Mary Beth Rosson and John M. Carroll (IEEE Fellow)
Center for Human-Computer Interaction and College of Information Sciences and Technology
The Pennsylvania State University
University Park, Pennsylvania 16802 USA
mrosson@psu.edu

Abstract— **In the design and implementation of interactive systems, teams typically consider and debate multiple perspectives, for instance exploring objects comprising a problem domain, the user population, and current technologies that might be useful. In this paper we report a field trial of our approach to using analysis and design activities as an integrating framework for introducing introductory students to the dependencies among information, people, and technology in information systems development. In this course, students work individually and in teams to 1) analyze structured information; 2) understand relationships implicit in online information; and 3) design technology concepts. We describe the activities we have developed and a preliminary evaluation of student outcomes, including a discussion of the mediating influence of students' technology background.**

Keywords - design-based learning, interdisciplinary education, team projects

I. Introduction

In response to the information explosion in society – and the corresponding need for interactive systems to store, access, manipulate, and present information – the iSchool concept has surfaced as an interdisciplinary paradigm for university education in computer and information science [1]. An *iSchool* is a college, school or other university program concerned with the social, cultural, and technical issues surrounding the design and use of information systems. A defining feature is a focus on *information*: what information is; how it is gathered and used; how it is transformed and stored; and its risks, benefits, and other consequences for a multitude of stakeholders. iSchool researchers seek to understand information in a contextualized fashion, which leads to an interdisciplinary research community; for example our own program integrates computer science, psychology, cognitive science, sociology, business, education, law, geography, and medical informatics. Another focus point is *design*, by which we mean the materialization of information to support human activity, through a sociotechnical process that interleaves theory, sociocultural and psychological studies, and technology innovation and implementation [2].

Shared visions of iSchool education are still evolving. There is not yet a standard curriculum such as exists for computer science or engineering [3]; indeed many iSchools focus primarily on research and graduate studies. Our four-year baccalaureate program combines sociocultural and human-computer analysis with technology fundamentals like databases and networking. Although our undergraduate students are exposed to modern programming languages (e.g., Java), most do not develop strong software skills, limiting their capability for innovative systems design work. In this paper we describe steps we are taking to inject hands-on *design* experience into the program's introductory course, conveying basic analysis and design skills that would provide a solid foundation for more advanced system design courses and projects.

In brief, we enhanced our college's introductory course with design-oriented activities to reinforce the course's general learning objective to introduce an integrative view of information, people, and technology. The enhancements comprise several active learning modules that mix homework assignments with three phases of a semester-long team project. In the balance of the paper we present the motivation for and design of these activities, the results of our initial implementation in two large sections, and the broader implications concerning design as an integrative concept for technology education.

A. Design as an Authentic Integrating Activity

We propose that design can serve as a powerful integrating activity for students who are being introduced to the subtle and complex interacting influences of information, people, and technology in society. Through their design activities, students are led to articulate, confront and resolve tradeoffs, while at the same time experiencing the empowerment and reward that comes from creative work [4].

A particularly attractive aspect of design as an integrating concept is its *authenticity*. iSchools span the information disciplines to comprehensively address issues ranging from image processing to social policy. In this vast spectrum, design is a fulcrum. One cannot talk about information processing, storage and retrieval, information behavior, the use of information in groups, organizations, or in society, or information policy and regulation without making strong and substantive assumptions about the specific ways that information can be presented to and manipulated by people [2].

The information explosion on the web is at once a driving factor for the emergence and refinement of the iSchool vision and a resource for exploratory learning of design concepts and skills. A broad array of public information is available to any web-active user who seeks it, for example social networks, weather updates, stock information, news, sports, along with many others [5]. This web information and services can be used for authentic learning about information systems design

[6]. One defining feature of authentic learning is that students become immersed in real world problem settings, so that the understandings and connections they form are general and reusable in future settings [7] [8] - the web provides ready access to such settings.

Learning by design is authentic due to the open-ended yet goal-directed process that designers follow. Design is not puzzle solving; there is never a "right" answer [9]. But clearly design is motivated by goals; these goals are translated into more and more concrete specifications as they are better understood and mapped to possible solutions [4]. The authenticity of learning by design can be enhanced even more if it takes place in a team setting, with peers brainstorming and negotiating to construct shared design ideas. A shared process such as this allows students to experience the collaboration, tool manipulation, domain-specific goals and heuristics, problem solving, and reflection-in-action typical of professional work [10] [11].

B. *Leveraging the Web for Learning by Design*

The phrase "Web 2.0" has emerged as a label for web technologies that allow users to take an increasingly active role in their use of online information and services [12]. In other work, we have been investigating the opportunities and challenges in making these web technologies more useful and usable to end users [5,13]. For example, we are studying modern university students, young adults we call "web-active end users" – they engage in many ways and for may purposes with web information and services (e.g., media sharing, online news and discussions, social networking), but they have no programming background or skills to apply to these activities.

In addition to providing information in many forms, the internet hosts a rich selection of tools to visualize and make sense of information. Figure 1 shows a typical example from Digg Labs, the BigSpy visualization of , a visualization using timing, color, font size and numeric annotations to convey real-time newsreading patterns. Our studies of web-active end users indicate that they already understand and expect to work with dynamic web services like these. Thus we decided see if we can use web information systems of this sort to engage students' curiosity and motivate a deeper understanding of online information and its design implications.

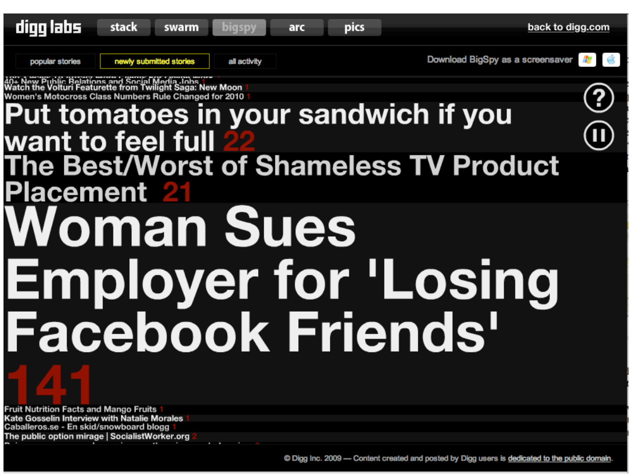

Figure 1. Screenshot from digglabs.com "BigSpy" visualization.

We organized students' exploration of web information system designs into three phases. First we emphasized the *structure* of the underlying information, so that students would begin to think of a stream of real-time web data as comprised of an organized sequence of information elements. Next we shifted attention to the *uses* of information – how to think about users' needs and preferences, with a focus on information analysis as a pervasive human activity. Third, we introduced simple technologies for *programming* with online information, leveraging emerging tools for web mashups [5]. We turn now to a more detailed presentation of the learning activities and student experiences.

II. COURSE ACTIVITIES

Historically, our introductory course introduces students to three facets of information-intensive systems: information, people, and technology. Table I summarizes the overall plan for the course, showing how the general concepts and concerns of information systems design recur across facets (e.g., layers, sociotechnical analysis, information organization); at the same time different elements within this pool of constructs come into focus within different facets (e.g., data concepts are primary in the first facet and usage concepts in the second). This general organization formed a background for the three activities focused on web information systems: we integrated the data analysis module into the first facet, information usage into the second, and web programming into the third.

TABLE I. OVERVIEW OF THREE-PHASE COURSE PLAN

1) INFORMATION: Understanding sources, types, roles, and management of information in digital society • Data basics: What is data, how do we store it? • Spreadsheets and databases: How do we create efficient and reusable information repositories? • Information sources: the Web, input and output, multimedia. • Information applications: What makes information relevant, how is it used to address problems, issues, or needs. • The future: Where are we headed?
2) PEOPLE AND ORGANIZATIONS: Understanding the mutual influences of people, organizations, society on information technologies • Human-computer interaction: Analyzing and designing information systems to respond to human needs and preferences. • Situated use: Representing and studying both explicit and tacit aspects of a usage context. • Groups and organizations: How the roles and relationships of groups and organizations affect information systems • Socio-technical analysis: interleaved evolution and adaptation of social systems and the technology in use. • The digital society: Use and design of IT in our world
3) TECHNOLOGY: Understanding the infrastructures, protocols, and tools for accessing and manipulating information • The Internet and Web: History, evolution, how it works. • Networks: Technology, protocols, media, methodologies for creating, maintaining, and debugging networks. • Layered systems development: Introducing the basic architecture of information-intensive systems analysis and design. • Quality attributes: Usability, reliability, maintainability, reusability • Emerging technologies: Artificial intelligence, multimedia, ubiquitous computing

Each module consists of an individual homework assignment and a phase of a semester-long team project. For example, the first module was focused on information, and students worked on a structured information analysis of a simple domain (an animal shelter) while their group brainstormed, identified, and analyzed the information domain that would be the focus for their semester project. We hoped that in their individual work students would gain basic concepts and skills, and through collaborations withteam members they would apply these skills to projects that are larger in scope. summarizes specific objectives for each module and the following sections describe each in more detail. A complete set of course materials can be obtained from the first author, but we provide a summary description here.

A. Module 1: Analyzing Structured Information

In the class sessions associated with first module, students were introduced to simple abstractions for thinking about the structure of online information. For instance, we visited the BigSpy website illustrated in Figure 1 and discussed the information attributes that might be used to create such a visualization. We talked about the use of tags for describing such structures, and visited RSS news feeds in browsers, using the "View Source" option to see the specialized tag set used to describe RSS data streams. We also talked about databases in general terms, using simple SQL expressions to show how logical expressions can be used to retrieve specific records or fields in a structured data set. In the individual homework, students analyzed a familiar object (the class itself) using a simple data tree that they then converted to a set of tags, illustrating the tags through some sample markup.

The Phase I project assignment was for each team brainstorm, identify and analyze an information domain that would form the basis of their semester project; they were encouraged to work with information domains for which members already were familiar with or had interest in researching. They produced a concept map (using the collaborative Mindmeister tool, mindmeister.com), investigated activities and information objects making up the domain, and defined and exemplified a set of XML tags for a central information object in the domain. Topics were diverse, for example: coaching college football, getting a record deal, using a university library, military communication, and online shopping. The major challenge during this phase was scoping the topic enough to guide their analysis of information used in the domain, and in particular to select an information object for detailed analysis. Examples of objects that teams analyzed and represented using XML tags included electronic patient records, schedules of varying sorts, a security audit, product inventory, and contracts of varying sorts.

B. Module 2: Visualizing Social and Organization Structures

In the second module, course content shifted to the human side of information technology in use. This included a basic introduction to human-computer interaction concerns and guidelines, as well as central concepts from collaborative work and socio-technical studies of organizations. A central issue was the many consequences that technology can have in different usage contexts, where context is defined and analyzed at multiple levels (individual, informal collaborations, project team, organization).

In the individual assignment, students were introduced to the Motion Chart tool that is part of Google Docs spreadsheets (this tool is a simple variant of the GapMinder tool introduced and popularized by Hans Rosling for analysis of world health data). Using Motion Chart, students can create simple time-based animations of data sets entered in a prescribed spreadsheet format. The spreadsheets must conform to an expected structure with respect to year information and other columns, but other than this the tool can visualize anything that includes numeric data as an "outcome variable" associated with a mix of either categorical or numeric "independent variables". In the tool the outcome variables are graphed and can be viewed as they change over time as a function of the other specified variables.

The data set provided to students was a randomized list of hypothetical company records. Each record had data about complaints to management for a given year, and the companies varied according to their adoption of computer-mediated communication tools (CMC), their size, and their industry orientation. Students were told to create a visualization that might explain the variation in complaints submitted. In this case there was an obvious correct answer, where companies that were smaller (thus benefiting more from the social distancing expected from CMC) and more competitive (thus provoking more complaints in general) were influenced to a greater extent by increases in CMC. Once they worked out how to use the tool, students had little trouble discovering and explaining this relationship based on our class discussions. Figure 2 contains a sample visualization shown at two different points in time.

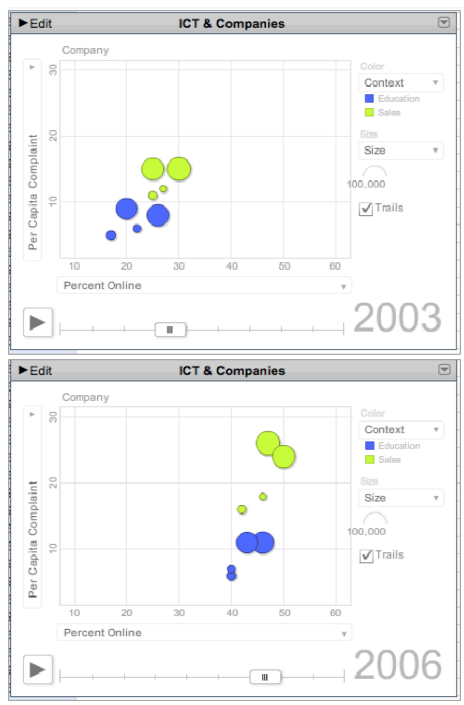

Figure 2. A sample Google Motion Chart at two points in time

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In this module, the teams were assigned to continue their work from Phase I, but shifting attention to the stakeholders and potential uses of the information they had analyzed earlier, with particular focus on the information object they had investigated and represented in more detail. The teams produced a table of usage situations with associated stakeholders, a stakeholder diagram that illustrated concerns associated with different levels of analysis, and persons (user descriptions) that conveyed typical characteristics of individuals drawn from across the proposed usage situations. For example, one team working in the problem domain of movie production considered use situations like researching actors and marketing movies; stakeholders that included cast members, director, production crew, unions, movie theaters; and person variables like personality, technology experience, and gender.

C. *Module 3: Designing Information Technology Solutions*

The final module was focused on the technology used in information systems. In class we discussed the technology from a systems perspective (e.g., network architectures with associated performance and security implications) as well as an end-user perspective (e.g., typical and more emerging input and output techniques, including multi-touch displays, augmented and virtual reality, and ubiquitous computing). We also discussed simple "programming" concepts, focusing on end-user techniques like faceted search, keyboard macros and web mashups.

The individual assignment was to experiment with an example mashup that had been created in advance. We used the Yahoo! Pipes tool (pipes.yahoo.com), as our ongoing research has indicated that its visual programming language is reasonably accessible to nonprogrammers [13] and it is robust enough for experimentation by unsophisticated users. The sample mashup was chosen as one that might be attractive to college undergraduates (college football enthusiasm was at its height then), and involved selection from and integration of two sports feeds. Students were required to explain how the mashup is working, and to carry out two different experiments to enrich its output – in one they simply changed the selection criteria, and in the other they integrated a third image feed. Figure 3 shows an example of the second experiment.

The team assignment in this module required production of both a written report and a final design deliverable in the form of a concept video. Because the students had not been taught programming skills, we instead taught them to use a range of techniques for mocking up design concepts (e.g., paper prototypes, animation of simulated workstation screens). They used these techniques to illustrate their design concepts that were then conveyed as part of a video. The video enacted one or more task situations associated with their information domain, with the appropriate mockups (e.g., a data visualization) inserted and "used" at relevant points. For instance, a team working on a library concept videotapes several cases where a student used a mobile phone mock-up (build with paper overlays) to access useful information that would help him locate and retrieve library resources while in the library. Sample videos can be obtained on request from the first author.

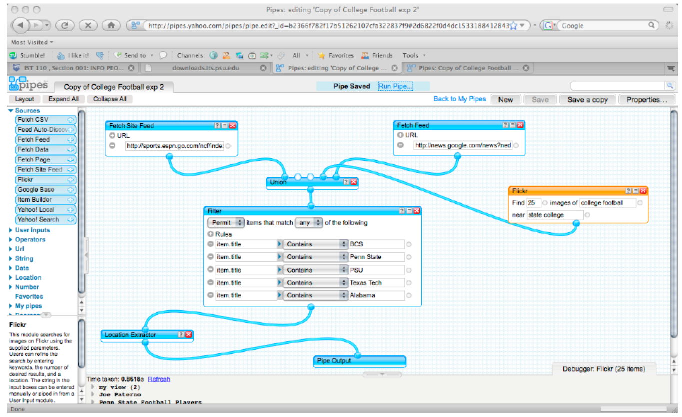

Figure 3. Sample output from Yahoo Pipes assignment.

TABLE II. SUMMARY RESULTS FOR HOMEWORKS AND TEAM PROJECTS

Individual Homework	Phases of Team Project
Information Structure Average score: 10.4 Max 12, range 3-12	*Information Domain Analysis* Average score: 23.8 Max 25, range 20-25
Visualizing Social Structures Average score: 14.2 Max 15, range 2-15	*Stakeholder and Usage Analysis* Average score: 33.0 Max 35, range 24-35
Web Information Mashup Average score: 17.4 Max 18, range 6-18	*Design Concepts Video* Average score: 33.0 Max 35, range 27-35

III. CLASSROOM EXPERIENCES AND OUTCOMES

The field trial of the three-phase curriculum took place in two large-enrollment sections of the course that was taught in Fall 2008 (one section had 137 students, the other had 126). Although the activities were assigned to all students, only data from students who gave informed consent to be research participants is summarized in this paper. Across the two sections, 158 students gave such consent, but because of missing data, some of the summary values reported here are based on a partial data set. Of the 143 students who indicated their major program of study, 91 (58%) were pursuing a major in this college; other students had not yet decided on major (13%) or were enrolled in some other program (e.g., Finance, Telecommunications, Psychology, Supply Chain). Because this introductory course can be used to meet a university-wide requirement for social science education, it tends to attract quite a diverse population of students. Among the 144 students who reported their gender, 22% were female and 78% male.

With respect to the design-focused learning activities, performance was generally high, as summarized in Table II. Although some students failed to submit one or more individual assignments, those who did tended to meet expectations; summing across all potential homework points (45), the average was 39.6 (88%). Performance on the team assignments was even stronger: out of 95 possible points, the average was 89.9 (95%). The high scores for team assignments are typical for classes of this sort, as evaluation of shared deliverables primarily focuses on whether the team followed the specification. Not surprisingly, both individual performance and team performance were related to students' final course grades (r=.79 and r=.49 respectively), with participation and quiz grades also playing important roles (r=.78 and r=.74 respectively. The overall class average was 87.8%, ranging 55.6% to 99.2%.

IV. PERCEIVED SELF-EFFICACY

In addition to the grade-related outcomes, we collected 33 self-efficacy ratings before the course began, with repeated assessment at the end of class. Self-efficacy refers to one's belief about specific capacities in a proscribed context or situation (e.g., a task; see Bandura [14]); items assessing self-efficacy are often used as surrogates for achievement as they tend to be highly correlated with other outcome measures. Our items were designed to assess capacities related to skills taught in this particular class; students responded on a scale from 1 to 7, where 1=Strongly Disagree and 7=Strongly Agree. The majority (24) of the items had been in use for several years by other instructors to assess learning objectives for this course. Nine items were developed for this project and focused on more specific capacities related to analyzing the structure of information and working with web information. A complete copy of the self-efficacy items can be obtained from the author.

TABLE III. SAMPLE SELF-EFFICACY ITEMS FROM FOUR SUBSCALES

Identification with the baccalaureate program (Program) • In the course of applying for an internship, I could describe at least three distinctive features of an IST education to the interviewer. • Despite my limited experience, I can make a convincing argument that problem-based learning is the best way to get a degree in IST.
Computer and Information Technology (Inf Tech) • If I were writing a show called "Computer World," I could create dialogue for characters such as data, memory, central processing unit, and motherboard. • In the checkout line at Wal-Mart a woman asks, "Why don't they just use a cash register? Why do they need bar codes?" I could explain barcodes to her and tell her how they reduce costs.
Web 2.0 Applications(Web 2.0) • If I were demonstrating the use of Flickr to my mother, I could describe several attributes of photos that it tracks to calculate social networks. • If my boss asked me to "mashup" the highlights from a presidential campaign, I could locate, combine, and visualize several online information feeds.
Structured Data Models (Data Model) • Although I am not a sales professional, I could predict 5-10 database fields that would be needed as part of an online grocery store. • Despite my limited experience with computer programming languages, I could use a mark-up language like XML to describe the people in my family tree

Rather than examine self-efficacy as a single construct, we used data reduction techniques to develop several subscales that assessed different aspects of students' beliefs about their capacities at the start and end of the course. Factor analysis of self-efficacy data from earlier instances of this course had revealed two stable factors, one interpretable as ability to appreciate and succeed at the baccalaureate *Program*, and another capturing general skills in *Information Technology*. Factor analysis of the new items developed suggested the presence of two additional factors that we identified as *Web 2.0* and skill in analyzing or building *Data Models*.

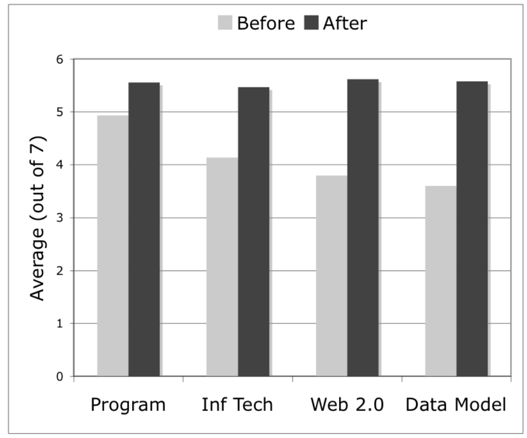

Figure 4. Self-efficacy scores at start and end of course.

To generate the indices we aggregated items loading most strongly on each of the four factors; the four constructs with examples of items loading strongly on each appear in Table III. Not surprisingly, average self-efficacy scores for these four capacities varied at the start of the semester, ranging from a mean of 4.94 for Program, 4.14 for Inf Tech, 3.80 for Web 2.0, and 3.60 for Data Models (F[1,142]=51.66, p<.0001). That is, these introductory students began their course with relatively more confidence about succeeding in the baccalaureate program, but relatively less confidence that they could design web systems or construct data models.

After creating the four indices and ensuring their reliability, we constructed isomorphic indices from the post-course survey. The resulting contrast of self-efficacy ratings before and after taking the course are graphed in Figure 4. As the graph suggests, students reported higher self-efficacy for all four indices after the class was over (t(106)=5.61 for Program; t(107)=9.73 for Inf Tech; t(106)=12.54 for Web 2.0; and t(106)=13.68 for Data Model; all significant at p<.0001).

We were particularly pleased to see the relatively greater self-efficacy increases for Web 2.0 and Data Model. At the start of the course, these ratings were lower than those for Program and Inf Tech (F(3,426)=58.72, p<.0001). At the end however, the ratings for all four subscales were about the same, suggesting that the perceived gains for specific capacities relating to Web 2.0 and Data Model were more substantial than the other two subscales. A one-way ANOVA that analyzed self-efficacy *gains* confirmed that this was true (F(3,318)=41.53, p<.0001). These survey results are promising, in that they suggest that students felt most impact in the specific capacities we had targeted with the new learning activities.

Because the student population in this class was quite diverse, and because a general goal for this course is to provide a broad introduction to information, people, and technology, we conducted an exploratory analysis of the possible relationship between students' starting background and their success in the class. We had included four expertise-related scales in the background survey: experience rated on 5-point scales for traditional programming languages, web authoring, working with digital media, and use of wiki/blogs. These four items were correlated, with an inter-item reliability of .71, so we created a single Tech Expert index by averaging the four items. The resulting index ranged from 1.0 to 5.0, with an average of 2.22.

Interestingly, students' technology background seemed to be unrelated to their overall performance in this introductory course: the correlation of Tech Expert with final course grade was -0.02, ns. It may be that the learning activities – including significant emphasis on team activities that might include peers with greater expertise – were enough to erase any advantage the more expert students had at the start. Not surprisingly, Tech Expert was closely related to all aspects of initial self-efficacy (r=.28 for Program; r=.49 for Inf Tech; r=.52 for Web 2.0; r=.60 for Data Model; all significant at p<.001). Informal comments from students after the syllabus was previewed on the first day reinforced this relationship, with many of the less sophisticated students voicing concerns about their chances of success in the course.

When we explored the relationship of students' technology background with *gains* in self-efficacy we found a striking pattern. For simplicity, we grouped students into low and Tech Expert groups using a median split. We found that although Low Tech Expert students reported lower self-efficacy for every subscale at the start of class, these differences were gone by the end of the semester. In other words, all students increased in self-efficacy, but those who began with the *least* technology background had the greatest gains. The differential gains for these less expert students were largest for the Web 2.0 and Data Model subscales (F(3,103)= 2.82, p<.05), again emphasizing their gains in knowledge and skills that are most "technical" and specific to this course. Figure 5 graphs these results emphasizing the relatively greater semester gains for Lo Tech Expert students in these two self-perception areas.

Although we hesitate to place too much emphasis on the results of these exploratory analyses, one interpretation of this pattern of results is that the three modules (and indeed the course in general) were of most use to students who had relatively little background with programming or online tools. This is a positive outcome for the more inexperienced students, but raises a question about the learning benefits of the new activities for students who arrive with a strong technical background. This issue of course is one that faces any educator who offers an introductory course to a diverse student population that includes many variations in prior knowledge and skills.

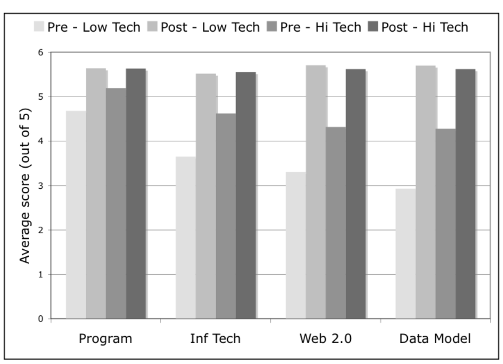

Figure 5. Self-efficacy scores at start and end of course.

At the end of the post-course survey, we asked students to reflect on whether the emphasis on design was useful to them. 95 students answered this question, and of these, most (83%) agreed that the emphasis on design was useful; the remaining students were either neutral (8.5%) or negative (8.5%). The rationale for these opinions was as one would expect – many of the positive responses cited the integrative effects of design thinking, or that it leads you to view problems from multiple perspectives. Of course these reflections were quite consistent with the rationale provided along the way as the project and homework activities were introduced, so to some extent the students are likely just "parroting back" what their instructor has told them. Some students (24%) made more specific comments, for example saying taking an information systems design perspective made them feel more connected to the real world, or that it made them feel better prepared them to work with real world problems. The neutral or negative comments tended to have less explanation, but seemed to come from students who felt they never "got it", or who complained that they already knew how to do everything presented in the class.

V. Discussion

We have described a design-based approach to promoting an interdisciplinary view of computer and information science, with an emphasis on introductory students who are first encountering and considering the challenges of the field. We experimented with several learning activities that focused first on data structure, second on discovery of implicit social and organizational relationships, and finally on innovative design concepts. We found that students were able to complete the activities, and that perceived self-efficacy for data modeling and web 2.0 application design increased. Finally, we found that these benefits were most apparent for the students with least technology background on entering the course.

While clearly still in its early stages, this educational development effort makes several contributions. At a practical level, we have developed and evaluated several specific learning activities suitable for an introductory class in the interdisciplinary information science programs that are emerging as part of the iSchool trend; these activities as well as our assessment instruments can be obtained by request to the first author. More generally, we have taken a step toward understanding whether and how design analysis and thinking can help novice information professionals learn to consider and integrate a range of different perspectives in solving information technology problems. Finally, we have documented the impacts of technology background, raising questions as to whether the activities should include more advanced learning options.

Taking a larger perspective, an introductory class such as we have described fits well within broader discussion of computer and information science curricula. For instance, there has been an ongoing discussion about whether and how to introduce more of a design (versus programming) emphasis early in an information technology curriculum. The materials and activities presented here offer one mechanism for introducing a more pronounced design emphasis prior to requiring a solid foundation in software development skills.

Although the activities prototyped in this class were successful, there is much to do. The individual and team assignments overlapped in broad terms, but our long-term pedagogical goal is to connect them more tightly. For example, we hope to decompose the work needed for the team project into individual components that each team member "practices" on the way to collaborating with his or her team. If we can do this, we may be able to reduce the tendency to distribute group work among people according to their starting levels of expertise – which of course counters much of the cooperative learning that we as educators hope to promote in group activities. We have found that the final team assignment – in which design concepts are mocked up in a video – is engaging, but we need more convenient and accessible tools for prototyping and video construction, so that the final design concepts can be expressed in a more realistic fashion. The more authentic the design outcomes can be, the better prepared the students will be for tackling interdisciplinary projects in the real world.

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