

# Assessing One Aspect of Design Learning: Qualitative Analysis of Students' Design Rationales\*

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*This paper explores the ability of undergraduate engineering students to write effective design rationales that describe the reasoning driving their decisions as they create solutions for open-ended design problems. This study sought to uncover the ability that students have to write design rationales that effectively capture their justifications for key design decisions, identify the strengths and weaknesses found in the design rationales prepared by the students, and determine if the quality of the students' design rationales improved with practice over the course of a 10-week academic quarter. While the students' attitudes toward activities associated with design rationale were generally more negative than their attitudes toward the rest of the class activities, their written design rationales indicated improvement over the quarter in their ability to provide concise, discipline-specific justification for their design decisions. This paper presents findings that include students' initial perceptions of their ability to justify design, their attitudes toward design rationale, the strategies that students used to justify key design decisions, and students' ability to write design rationales based on principles from their academic discipline.*

**Keywords:** design decisions; design rationales; student's design concept.

## INTRODUCTION

ONCE STUDENTS from engineering and design disciplines enter the workforce they are required to justify their design decisions to team members and to stakeholders, and they can be held responsible for the implications of their decisions on the products they design. As educators, it is important for us to help students perceive their own design processes by encouraging them to become aware of the choices they have made, the reasoning driving their choices, and the alternate decisions not chosen. It is difficult to teach undergraduate students how to become not just competent designers but also reflective and sensitive designers. Typically, undergraduate students in engineering and design disciplines spend much of their effort grappling with the fundamental concepts, tools, and techniques used within their field. Their mental efforts are often focused on satisfactory completion of class projects rather than reflecting upon the implications of their design choices or understanding how their solutions are situated within a larger solution space.

Design rationales—a logical justification for a design—provide a means for designers to document their thinking during or immediately after they design an artifact. Methods for capturing design rationales vary from recording fine-grain to course-grain decisions and from using formal

notations to normal prose [1–8]. Irrespective of the method used, the purpose of design rationales is to capture and record the designer's reasoning such that it can be revisited and examined at a later date. The act of recording design rationale also provides designers with a chance to reflect upon decisions and consider the soundness of their reasoning and thus the soundness of their design.

This paper explores the ability of undergraduate engineering students to prepare effective design rationales for three Web design problems. After presenting an overview of design rationale research, this paper will present a qualitative study performed on a junior-level engineering class that is required for newly admitted Technical Communication majors at the University of Washington. This study sought to:

1. Uncover the ability students have to write design rationales that effectively capture their justifications for key design decisions;
2. Identify the strengths and weaknesses found in the design rationales prepared by the students; and
3. Determine if the quality of the students' design rationales improved with practice over the course of a 10-week academic quarter.

After discussing the results of the study, this paper will conclude with ideas about how educators can improve the visibility of students' design thinking through the inclusion of reflective design rationale assignments.

\* Accepted 17 December 2005.

## DESIGN RATIONALES

Multiple decades of work exist on design rationale techniques, notations, and capture systems. Moran and Carroll's 1996 edited collection on the topic, *Design Rationale: Concepts, Techniques, and Use*, provides a broad view of the area [1], as do the review papers by Hu *et al.* [2] and Regli *et al.* [3]. Carroll and Moran [4] broadly define design rationales as 'an expression of the relationships between a designed artifact, its purpose, the designer's conceptualization, and the contextual constraints on realizing the purpose,' and as 'the logical reasons given to justify a designed artifact' (p. 8). Regarding what is included within design rationales, Regli *et al.* [3] describe them as containing 'all the background knowledge such as deliberating, reasoning, trade-off and decision-making in the design process of an artifact' (p. 209). These definitions address a core competency that professional designers need within their workplace: the ability to communicate successfully details of design decisions and their implications to team mates and to stakeholders such that the group, as a whole, has the knowledge needed to move forward collectively in an oftentimes complex design process.

Research on design rationales often involves the use of formal rationale notations such as IBIS [5], the QOC (Questions, Options, Criteria) notation [6], or DRL (Decision Representation Language) [7], and management systems (some with computer-supported collaborative work features) that maintain rationale elements, many of which are described in [2, 3]. When attempting to identify an effective method for capturing design rationale and recording design decisions, it must be kept in mind that the activity of design itself is still a subject of study and how design rationale can be incorporated into industry practice is an open question. Some issues that need to be addressed include:

- The different levels at which design decisions are made, ranging from a lower level reflective process where individual design moves are tested and evaluated [8] to a higher level social activity where multiple designers communicate and negotiate their decisions.
- The fluid and dynamic nature of design processes makes it difficult to record the 'why' of the design, yet this is vitally important in production settings where a single design decision may have long-lasting effects and where employees leave before necessary historical knowledge can be recorded.
- A better understanding of industry needs for recording design rationale, given that many design rationale software systems have been prototyped for a variety of design and planning disciplines, yet these systems have not been widely adopted [2, 3, 5].

It is clearly a difficult problem to institute a formal

method for capturing design rationale within a corporate setting, and even more so to select or devise a way for undergraduate students to capture design rationale formally. Students face additional challenges: they are still learning how to use the design tools that are common in their field, and they are still grappling with their field's principles and design techniques. Adding a complex design rationale capture method is likely to inflict an unwelcomed intellectual burden on undergraduates. Merely emphasizing that students write well-reasoned essays that describe their design rationale should serve the purpose of teaching students how to justify design decisions.

Thus, as educators we feel that it is important to step back from design rationale systems research and instead look at how students justify their design decisions such that we can identify strategies for improving students' ability to communicate design decisions and increase their awareness of the need to communicate design decisions effectively in a corporate culture. By understanding the kinds of assumptions students make when justifying design and the kinds of problems they have during the act of communicating design rationale, we can improve our ability to help students gain awareness of how their decisions are situated in a larger context. This allows us to help them improve their ability to communicate decision reasoning and justification both across their team and to a broader audience of stakeholders. By exposing students to the act of creating design rationales as a normal and expected part of design, we expect to help students learn how to become more reflective designers and learn how to begin situating their design activities within a larger context, in addition to learning how to communicate their design reasoning confidently. Furthermore, the communication of design rationale within the classroom provides more opportunities for student-to-student dialog *about* design decisions.

## STUDY DESCRIPTION AND METHODS

A study was performed during the Autumn of 2004 with 12 students enrolled in TC 310, a required 10-week course for newly-admitted Technical Communication (TC) majors at the University of Washington. The purpose of this course is to help students learn how to design effective solutions to common information and interaction design challenges, and to introduce students to a variety of software packages that they will need to use in other TC courses and in their future careers. As part of the primary purpose—learning how to design effective solutions—the students must learn how to:

1. Analyze the needs of the users who would use the information artifacts that they will design, plus analyze the users' context of use, and the purpose of the information artifact;

2. Make informed design decisions by leveraging knowledge from multiple disciplines (graphic design, information design, interaction design, and usability);
3. Critically evaluate the effectiveness of their design decisions and select the most promising solution.

The course was organized around a series of eight weekly design assignments. Each week students create a new information solution while simultaneously learning a new software tool. The course used a studio-style of instruction in which students attended a weekly hands-on tutorial, and a weekly presentation and critique session. The class also included a weekly discussion and brainstorming session in which students were introduced to their next assignment and actively engaged in an analysis of the assignment led by the instructor. In addition to creating solutions for each weekly design assignment, students were required to write design rationale essays that explained and justified key design decisions.

Of the eight weekly assignments, the second, fifth, and eighth assignments (mockups for Web pages, a set of Web pages, and a sitemap for a large Website) were chosen for analysis to compare how their design rationales evolved over the academic quarter. These design rationales were analyzed for the students' ability to capture justification for individual design decisions effectively. The rationales were first examined for the students' ability to identify the intended primary users of their solution, to identify the users' information needs and goals, and to describe the context in which their solution would be used by the users. Next, the rationales were examined for the kinds of justification that the students used, including a specific examination of their ability to justify design decisions using their evaluative judgment regarding the usability of their solution. Analysis of the rationales was compared with the instructor's field notes and the anonymous responses given by students during a first-day survey and a mid-quarter course evaluation survey. Twelve students were enrolled in this course and five gave permission to have quotes from their work included in this paper.

It is important to note that the students in this class were mostly novice designers and for most this was their first quarter in the Technical Communication department. Some of the students expressed concerns about being able to learn all of the software packages and a few referred to themselves as computer novices. At the same time, a few students were already adept with the software packages and worked on their own during the tutorials. Many of the students came in with the expectation that the class was only a software tools class and were surprised to find out that design was a central component. This is illustrated by a student who remarked, after handing in the second assignment, that the course wasn't what

he originally thought it would be about (e.g., learning how to 'use tools and stuff'), but instead that it was more about 'how to design and justifying your design.'

The research results are presented in following three sections. The section 'Students' Attitudes Toward Rationales' begins by looking at students' perceptions of their ability to justify designs upon entering the class and their mid-quarter attitudes toward design rationales. The following section, 'Students' Ability to Justify Design Decisions', discusses the strategies that the students used to justify key design decisions and how these strategies evolved over the quarter. Next, the section 'How User Analysis Motivated Design Justification', discusses the students' ability to include user analysis within their design rationales and use user analysis to motivate their design. This section is followed by further discussion about the study and the study results, and conclusions.

### STUDENTS' ATTITUDES TOWARD RATIONALES

Students entered the class with a belief that they were already able to justify their design decisions. On the first-day survey, 73% of the students either agreed or strongly agreed that they were able to justify their design solutions using information from their academic major (see Table 1). Yet, and perhaps more telling, students were less sure of their abilities to ask questions while designing (Table 2) or identify criteria for judging the effectiveness of solutions (Table 3).

From the student's perspective, the design rationales proved to be one of the least enjoyable aspects of the class, being the only aspect to receive an average score below the midpoint (2.5) of the rating scale for the mid-quarter course evaluation (see Table 4). Yet, the students realized the value in the design rationales as something that made them think and prepared them for work (3.5 and 3.5, respectively, on a scale of 0 to 5). It is interesting to note that students placed low value (2.6 for *Made you think?* and 2.0 for *Prepared you for work?* on a scale of 0 to 5) on in-class analysis of upcoming assignments (see Table 4). This in-class analysis, performed immediately after the next assignment was handed out, involved an analysis of the weekly design problem such that students could begin making informed design decisions—design decisions that they might later record in their design rationales. Clearly, the students reported that doing the design assignments made them think (4.3 on a scale of 0 to 5, see Table 4). Given that most of the design assignments required the students to design kinds of information artifacts that they have never been asked to design before, perhaps the analysis of the design problem and its potential user scenarios was too abstract an exercise without the students first engaging in some hands-on design for the problem.

Table 1. Students' self-perceptions of their ability to design solutions using information from their discipline, taken from the first-day survey

I can justify my design solutions using information I have learned in TC (and related) courses.		
Answer	Responses	Percentage
Strongly disagree	0	0%
Disagree	0	0%
Slightly disagree	0	0%
Neutral	2	18.18%
Slightly agree	1	9.09%
Agree	6	54.55%
Strongly agree	2	18.18%

Table 2. Students' self-perceptions of their ability to ask questions that lead them to effective solutions, taken from the first-day survey

When presented with problems requiring TC knowledge, I can ask questions that lead me to effective solutions.		
Answer	Responses	Percentage
Strongly disagree	0	0%
Disagree	1	9.09%
Slightly disagree	1	9.09%
Neutral	0	0%
Slightly agree	4	36.36%
Agree	3	27.27%
Strongly agree	2	18.18%

Table 3. Students' self-perceptions of their ability to judge the effectiveness of solutions, taken from the first-day survey

I can identify criteria for judging the effectiveness of TC solutions.		
Answer	Responses	Percentage
Strongly disagree	0	0%
Disagree	1	9.09%
Slightly disagree	0	0%
Neutral	3	27.27%
Slightly agree	2	18.18%
Agree	4	36.36%
Strongly agree	1	9.09%

Table 4. Average student ratings of class aspects taken during from the mid-quarter survey. Rating scale ranged from 0 to 5, with 0 being low and 5 high

Aspect of class	Enjoyed?	Made you think?	Prepared you for work?
Open-ended design assignments	4.2	4.3	3.7
Writing design rationales	2.3	3.5	3.5
Learning selection of software tools	4.4	3.5	3.8
Presenting solution to the class	3.0	3.4	3.5
Identifying and asking questions to presenters	2.7	3.1	2.8
In-class analysis of upcoming assignments	3.2	2.6	2.0
Software tutorials	3.5	3.5	3.3
Grading of assignments	3.6	3.2	2.9
Feedback on the assignments	4.3	3.7	3.3
The course overall	4.0	3.8	3.7

When asked in class for additional feedback about the design rationale component of the class, one student volunteered that the exercise of writing design rationales felt as if he was 'B.S.ing' the instructor and teaching assistant because he was 'making things up after the fact' to justify his design decisions. Some of the students agreed. When asked for further more details, students volunteered that the design rationales seemed like something they 'had to do' that took 'a good deal of time' after already spending a lot of time designing (and learning a new software tool).

Given that many of the students entered with the perception that they were already able to justify their design and given that fast-paced nature of the course's assignments, it is likely that the many students rushed through their rationales and didn't see the value of them. Furthermore, the students made it clear to the instructor that during the mid-quarter review that they were writing their rationales after they had completed their design; they may have felt a disconnect between the act of designing and the act of recording and justifying their key design decisions. To quote Carroll and Moran [4], 'even modest approaches to capturing rationale are now very labor-intensive. Members of a design team may not be inclined to pause and reflect when they might otherwise be sketching and prototyping; management may balk at staffing a designated 'rationale analyst' (p. 17). Even in the more exploratory and open-ended structure of a undergraduate university classroom, the same pressures against capturing rationale are found: students feel pressured to complete the important part of the assignment—the solution they are designing—and some seemed to look at the rationale as extra work. Yet, the design rationale required for each exercise was given enough weight in the grading scheme (40% of each design exercise) to signal to the students that it was indeed an important component.

Another factor that may have contributed to the students feeling as if they were 'making things up' when explaining their design decisions was the fact that they were doing user-centered design in a fictional setting as mock-interns for a company of their choosing. Thus, part of this feeling of

'making things up' may have stemmed from the assignments themselves requiring the students to imagine the eventual end-users. Even when the instructor provided more concrete end-user information in the form of personas and scenarios, nearly half of the students still indicated that the design rationale component felt as if they were 'making things up to rationalize why they made their decisions.' This information, coupled with the fact that students placed low value on the importance of in-class analysis of the design problems at the very beginning of each design cycle hint at a missed opportunity for linking design activity with design rationale. If the class schedule was restructured to include analysis of the design problem once the students had already begun their own designs (but with enough time left for them to revise their designs), they may be better primed to recognize the connection between their design reasoning and their design activities.

### STUDENTS' ABILITY TO JUSTIFY DESIGN DECISIONS

While there are many kinds of reasoning one can employ while justifying Website design decisions, Technical Communication places strong emphasis the importance of designing usable solutions. The students were required to make sure that there were no obvious usability problems in their solutions and they were required to write design rationales that used user-centered reasoning. It was not required that the students write rationales that justified design decisions using usability arguments. Nonetheless, a number of students did.

Usability is a new topic for most of the students who take TC310. It is introduced at the beginning of the quarter and made a part of the weekly presentations and discussions. Making usability-based design decisions can be challenging for the students: the students need to have knowledge of how people perceive, learn and remember information, and it is helpful if the students have already learned at least some guidelines for good information/interaction design. Because much of this information is introduced during senior-level courses (TC310 is typically taken during a Technical Communication major's junior year), TC310 placed emphasis on applying basic principles of usability to simple information and interaction design problems, adding this to an already packed 10-week syllabus. In this sense, the students derived guidelines for usable Websites (and other information artifacts) from first principles during instructor-led class discussions.

Early in the quarter (second assignment), the students used a variety of ways to justify their design decisions. Some made business cases and justified their design decisions based on a kind of user experience that they were trying to create. Others justified their design by stating how their design included information that the users need to

complete other tasks at work. Some included arguments based on their assumptions of how usable their solution would be for the intended users. Nonetheless, a few students wrote early rationales that read as high-level descriptive narratives of their design steps without providing reflective analysis or justification for their decisions (e.g., first I added an *employee profiles* menu option under the *about us* link to the main page; next I created the *employee profiles* pages to have the same look and feel as the Acme Corp main page . . .). Many students combined this style of descriptive narrative with additional statements that justified some (but not all) of their design decisions.

By the middle of the quarter (fifth assignment), most of the students were justifying their design decisions by employing some user-centered reasoning, which is emphasized in their academic discipline. Overall, five were using usability-based justifications that directly referred to usability principles; many of the remaining students alluded to aspects of usability as a means to justify some of their design decisions. Still, two students continued to provide design rationales that were mostly a narrative description of their final design and that almost entirely lacked user-centered justification (or any justification) for their design decisions. Were these descriptive 'rationales' indicative of some students not having anything else to provide as justification for their design? If so, was it because they were novices at information design and interaction design or was another factor the cause? All students received written feedback on their design rationales, typically with corrective suggestions, and class discussion emphasized the importance of using user-centered justification for design decisions. Other factors (e.g., student motivation) may have contributed to the lack of user-centered justification in these two cases.

While we cannot decisively state that the students' lack of repertoire of information/interaction design techniques and usability knowledge was a major contributing cause of the descriptive 'rationales' that lacked justification of design decisions, as the quarter progressed, the rationales became more focused and concise, made less use of text that purely described their final solutions, and made more use of text devoted to justifying design based on usability principles and what they had determined about the intended users and their information needs and goals. The following example illustrates this progression in one student's work.

For the second assignment, the student motivated the incorporation of employee profile Web pages (requiring both navigation design and page design) by creating a business-centered scenario that had a marketing focus—a focus toward creating an initiative that would create greater customer loyalty toward a brand. The scenario did not mention or address any needs that the real users might actually have but instead couched the users'

needs from a marketing point of view. The rest of her rationale described each major design decision and justified them largely through a logic that focused on creating a specific kind of user experience that would engender brand loyalty (see below). (The names of the companies for which students created solutions have been replaced with generic names in order to mask the identity of the students. Otherwise, the quotes from the design rationales have only been edited for spelling errors. Emphasis in all student excerpts has been added by authors to highlight aspects of students' rationale discussed in this paper.)

Supplying the option of learning about the CoffeeHouse associates (employees) provides the consumer with a personal touch. Most consumers will go into a CoffeeHouse location and purchase a beverage or snack twice a day. When consumers make CoffeeHouse part of their daily routine, they may become attached to it and want to learn more about the people behind their cup of coffee. The information given in the profile includes why they joined the company, as well as what their favorite CoffeeHouse beverage is. This information is important to share because *by hearing about a CoffeeHouse associates positive experiences with the company, loyalty from the consumer is reestablished.*

In the fifth assignment, this student instead motivated her design for a set of corporate Intranet pages by enumerating a series of information that certain employees would need while performing their job. These included ' . . . contact information of fellow associates in the department, access to past projects so that they can learn about what the company has worked on, and other resources, including writing references and educational programs in technical communication.' She then justified her design decisions by describing why the information she included on each Webpage is useful to these employees as they performed their jobs (see below).

I also feature past projects on the website. This is *so that associates can look and see what marketing tactics have been used and learn how they did or did not benefit the company.* For example, if people really responded to the fact sheet that displayed information about the holiday beverages, and sales that year went up, they can reference to that sheet to make a new one for the next year. Also, *seeing past projects gives the associate the opportunity to see what others in the department have been working on.*

Additionally, she attempted to justify design decisions based on the creation of a certain kind of user experience (see below).

. . . it is important to have a blurb on the main communication page about what people in the department do because *it tells the associates that they are valued assets to the company* and that, without them, CoffeeHouse would not be able to function, or be as successful as it is today. When the associates know that they are valued and needed, they are motivated to work harder. Another feature is on the contact information page. In addition to the email address

and position of the associate, I also have their photograph posted. *This puts a face to the name around the office so that other associates who may not have the chance to meet with people in corporate will know who is who.*

The design rationale for her eighth assignment takes a different approach. The student begins the rationale by motivating her design with a usability-based challenge: representing a complex Website's structure through a sitemap that a user could understand after quickly glancing at it:

The CoffeeHouse Webpage is very large and complicated; there are so many pages that are linked to one another. . . . Even in the first three levels, there are many pages in the CoffeeHouse website. The greatest challenge of this assignment was to create a site map that neatly displayed these three levels in a manner in which *one could quickly glance at it and understand the hierarchy of the website.*

She then justified most of her design decisions by thinking about how the user would understand the sitemap that she had created. For example, she justified her use of a color-coding scheme as follows:

I decided to color-code the levels *to increase the clarity of the website map . . .* by adding colors it is now easy to determine what the levels are by glancing at the map. Another feature that I added was the key at the bottom left to explain what the colors meant. This is so that *the user understands which colors represent what level.*

While this particular student was a newly admitted major who had not yet completed other upper-level TC courses, and a novice to usability and Website information/interaction design, she exhibited the ability to progress toward the kind of design reasoning (user and usability-focused) that would be expected of her after graduation, if employed within her discipline.

Some students, particularly in the fifth and eighth assignments, attempted more sophisticated justifications based on usability principles. The following excerpts from their design rationales illustrate this:

*To make the text easy to read,* I used a sans serif font sized 14 points and left ample white space. *To make navigation easy,* I added in-text links to the homepage so that users could have two ways to link to the second level pages (I figured the homepage would be the main link listed under the 'for site owners' section, and that users would get to the other pages from there).

The contacts page includes email links to the Communication Department staff along with their job titles *so that users can decide* which person would best address their needs. The email links are in a different color than the page links *so that users do not confuse them.*

When the user is on a second-level page, the link for that page (in the navigation column) is not hot, but it is highlighted *to help cue the user* as to where he/she is. The highlighting is accomplished by using a lighter

background for that link box and having the text in bold.

Because the pages each serve a function very different from each other, and the layout for the content varies, *the user should not make mistakes remembering where they found the information.*

I chose to include only the narrowed list of links from Acme Corp's site map to keep it to manageable size. . . . This design summarizes the long list into more noticeable categories, which are *easier for users to scan*. Some categories have been renamed; for example, 'Wear Us' has been changed to 'Acme Store' and 'Talk to Us' has been changed to 'Contact Us' to better reflect the information these categories contain. *These revisions prevent users from choosing the wrong category.* To clue users into the navigation structure, I used standard icons *to signal the pull out and drop down lists.*

As illustrated in these excerpts, some of the students were able to provide examples of usability-based justification. In fact, a few students wrote design rationales that consistently grounded most of their design decisions in usability-based arguments and prior precedent.

#### HOW USER ANALYSIS MOTIVATED DESIGN JUSTIFICATION

Defining the primary users, identifying their goals and information needs, and understanding the context in which the users would use the Websites was an important aspect of each weekly assignment. This kind of user analysis is central to the field of Technical Communication and during the mid-quarter survey, 11 out of 11 students indicated in a short-answer essay question that 'analysis of users or audience' is what differentiates Technical Communication from other design-related disciplines. Many of the students also felt that the importance of designing for specific users adds difficulty to the process of justifying design decisions. Seven out of 11 students stated that the most difficult aspect of justifying their design decisions was determining if their 'decisions fit [their] users,' being able to 'see from the point of view of the users, even when it contradicts your own [point of view],' and learning how to 'step into the users' shoes' or 'put oneself in the users' place.' One student wrote: 'I find it difficult to trust my assumptions. How do I know how someone I've never met will be using [my solution]?'

While Technical Communication stresses the importance of involving actual users in the design process and testing the design on target users (and these results, in turn, strongly influencing the final design of solutions), it is not uncommon for professional Technical Communicators with Bachelor's degrees to rely on information about their users that they have not directly gathered. Thus, although the students' were placed in an artificial situation in which analysis of their users needed to be based on guesses and common sense,

and on student-generated scenarios, the amount of high-quality data about their users and first-hand experience with actual users may be limited even when they take their first job.

Within the second assignment, students tended to talk about the users by focusing on business-centric arguments that defined the users in the terms of 'consumers' or 'customers.' The needs of the users were then defined in terms of business problems rather than needs or goals from the actually user's point of view. Here is one typical example:

Because so many consumers interact with Coffee-House associates everyday and consume the products, it is important that the consumer gets the opportunity to learn more about the people who are helping to serve them their daily cup of coffee, as well as learn more about the corporation with whom they interact daily.

Here, the student defines the users of the Website as the consumers who frequent a chain coffee shop but the needs attributed to these users—having the opportunity to learn more about the coffee shop employees—are not motivated by stated needs of these consumers (after all, how would merely learning more about the employees address their goals and needs regarding their experience with the coffee shop?) and instead hint at a kind of business-oriented or marketing-orienting rationale for reaching out to these customers by creating the appeal of a more personal, perhaps even small-business, environment.

A minority of students combined business-oriented rationale with some user analysis. Below is an example in which the student's design is motivated by a business goal: to provide information that would 'attract potential investors.' This, in turn, motivates analysis of information needs those potential investors might have.

I chose the user context where the most opportunity for profit exists. Management profiles, from my perspective, fulfill this possibility. Management profiles attract *potential investors* who make their decisions based on what they see from the 'top-down.' The investor who would most likely look at Acme Corp's website rather than consult with their broker to study management profiles would be an investor familiar with the format of corporate profiles. The *potential investor's expectations vary* but include the desire to *retrieve* relevant information about management's credentials, ability to *provide* leadership and/or the manager's interests.

By the fifth assignment, students progressed toward identifying the primary users (and sometimes secondary users) and identifying goals and information needs held by those users. No evidence of a purely business-centered approach to defining the users' needs was found in the fifth or eighth assignments. In these later assignments, many students were trying to imagine the needs and goals of actual users. Furthermore, they attempted to problematize these needs and goals in order to illuminate areas for design improvement, thus

motivating the design solution for their assignment. For example, one student interpreted the fifth assignment as an opportunity to create a new section of a corporate Intranet that would aid employees during a recent corporate growth spurt:

Many folks were promoted to middle management to mentor these new recruits and these folks were not familiar with established protocols and terminology used between departments. As a result, it was inevitable that communication problems would arise within interdepartmental correspondence. These problems were compounded by the lack of a training program that versed the new managers and recruits in company philosophy and branding, a program that would have given them the terminology and tools they would have needed to communicate with each other regardless of their position within the company. *The primary user of any solution then, will be the recently promoted middle manager and all new recruits.*

The following two examples show how students identified specific needs or problems that users would encounter with the structure of two corporate Websites and they tied these problems to goals that the users have, such that they could motivate later design decisions.

The users of this site map could be: people who are visiting the site and are *using the site map to try to find something*, people who *want an overview of the whole structure of the site* (whether they are site visitors or company employees), or people who are *working on the site*—updating, adding a page, re-designing. For these potential users a site map can be: a navigational tool, an overview, or a design tool. For both users who want to see an overview of the whole site and for designers who are figuring out how to update or add to the site, *the map needs to show the site's overall structure*—what the 'big categories' are, what pages are within each of those big categories, and how some pages are connected across categories. For users who want a navigational tool, *the site map needs to enable people to 'spot' the particular content they are looking for*. Ideally, clicking that item on the site map would take the user to that page.

The actual structure of Acme Corp's site is *not easy for users to access*. It is laid out almost entirely in just two levels, with over 800 second-level pages (I ran the Visio automatic generator to get a feel for the structure). Because of the size of the site, the flatness of its design is *not useful for users* other than to impress them with its magnitude; *they cannot get a grasp of the types of information available* and it would take them an enormous amount of time to find a specific topic they were looking for.

In the first example, the student identifies three different kinds of users with separate yet related goals. She then relates these goals back to her design task: creating a sitemap. In the second example, the student identifies an overall problem with the Website's size and structure from the perspective of potential users. This realization of a problem becomes the motivating force for his design.

While there is evidence of the students becoming increasingly more sensitive to the needs and goals

of their primary users and developing an awareness of how such needs and goals could motivate their design, most of the design rationales lacked the level of sophistication in defining the users that was collectively elicited during class discussion—the in-class analysis of upcoming assignments that students ranked less favorably (Table 4), as described earlier in this paper. The discussion period occurred each week when new assignments were introduced to the class. During this discussion the primary and secondary users were identified, their goals and information needs were enumerated, and specific aspects of their context were identified. Class discussion then turned toward linking this information about the users to specific design implications. Each week, the class discussion resulted in a large table (written on the classroom white-board) that highlighting this analysis.

When doing their design and writing their rationales, student needed to apply the results of the more generalized class discussion to their specific design problem for a specific company of their choosing. (Students worked in teams of three in which each team selected a company or organization for which they would pretend to be interns and design solutions for use within that company.)

Within the student's rationales, the resultant analyses across a single assignment (the fifth assignment) ranged from more detailed descriptions of the user's needs (see first example, below) to less detailed (see second example, below).

Employees at the Acme Corp need an intranet that they can use as a useful resource for different aspects of their work. These include contact information of fellow associates in the department, access to past projects so that they can learn about what the company has worked on, and other resources including writing references and educational programs in technical communication. A website such as this would be used daily by Acme Corp employees to finish tasks and learn more about opportunities to grow in the company.

I imagine the users of this intranet site to be the members of the company's Communication Department, as well as other members of the staff who may need to contact us or see more about what we do.

Two of the twelve students did not explicitly describe the users and their needs for the fifth assignment. Instead, they only referred to aspects of this information in an indirect manner while describing their solution.

## DISCUSSION

The data collected do not permit us to analyze why the students began the quarter with business-centered analysis. Are they culturally biased toward placing business needs in front of end-user needs? Nonetheless, the weekly in-class discussion plus the TA's and instructor's feedback on their assignments encouraged them to focus



their attention on the needs of the primary (and secondary) users. Yet, it is interesting to ask how we can leverage the observed students' tendency toward business-centered analysis. Perhaps class discussion could more actively contrast business-centered versus user-centered design rationale, thus making the students more aware of the potential complexities, conflicts of interest, and richness of the design challenges they will face after graduation.

Throughout the quarter, the students improved their overall ability to ground their design decisions in user needs that they identified. By the middle of the quarter, many students exhibited the ability to identify problems that users might have and use those problems as a motivating factor for their design. Some rationales would begin by situating their assigned design problem within the context of a problem faced by the primary user, in which the user's problem was either a usability problem or an information-need problem that the student had identified or created through a scenario. Their rationale would continue by describing their solution as a solution to this more constrained and defined problem. It is curious to note that the student who was most vocal at expressing discontent about writing weekly design rationales was the student who was most effective at constraining the weekly design problems by inventing detailed scenarios that described very specific needs and goals of primary and secondary users. One might guess that this student's discomfort stemmed from feeling as if he was pushing the boundary when redefining the weekly design assignment—an act that, perhaps, he didn't feel he had authority to do as an undergraduate student.

Given the students' inexperience with the difficult design problems found outside of their education and given the open-ended nature of the weekly assignments, it is likely that at least some students felt some discomfort with the lack of strict problem definition when they needed to justify their design. Rather than merely justifying their design for a problem that was strongly defined within the assignment, they needed to justify their design for a problem that was partially defined by the assignment and partially by each student. That said, eliminating the open-ended nature of the problems might lessen the course's appeal to the students: during the mid-quarter review, the students gave very positive ratings to the open-ended nature of the assignments (see Table 4). Perhaps a compromise can be struck by requiring the students to rigorously identify (i.e., write down and include at the beginning of their rationales) their primary users, possible secondary users, a short list of specific needs and goals, and a short description of the users' context of use.

Yet, for this more rigorous analysis to occur, the students need to make a leap from the general discussion of the weekly design problem (with its generalized discussion of users, user goals and

needs, and context) to the specific application of the design problem to their chosen company/organization. Rather than having the instructor constrain this aspect of the design problem from the start, one alternative is to have the students perform an in-class exercise where they perform this more specific user analysis and then discuss it with fellow classmates (supervised by the instructor). This would help them constrain their design problem *before* they begin their design, alleviating the feeling that they were 'making things up after designing.' Another alternative is to allow students to first begin to design a solution and then use a class activity, such as a discussion, that allows them to analyze their design with respect to users' needs, goals, and the solution's level of usability. Through this analysis, the students constrain the design problem and then they can revise their solution accordingly. Either alternative would help them further define the problem in the presence of fellow classmates and the instructor (and TA), alleviating any possible feelings that they are going out on a limb when later doing this on their own. Finally, it would allow the students to get immediate corrective feedback from the instructor and TA plus suggestions on what they might want to keep in mind while seeking a solution to their newly constrained problem.

### LOOKING FORWARD . . .

This study asked how well students are able to justify their design decisions. While this paper presented evidence collected during the three-month academic quarter in which this study was conducted, some additional anecdotal evidence sheds, perhaps, a little more light on student learning. For the final assignment in the class, the students needed to select work from their eight weekly assignments and build an annotated professional portfolio showcasing their work. The portfolio annotations for each assignment needed to include a description of the design problem and their (potentially edited and revised) design rationale. After the quarter ended, I encountered some of my Autumn 2004 students in our computer lab. Some have mentioned to me that the process of building a portfolio was a great experience and that they were using their portfolios for upcoming internship applications. One student excitedly told me about an upcoming interview with a major software company and how the interview will require her to give a 50-minute presentation of her portfolio to a room full of people. I asked her how she felt about that and she replied that she prefers this style of interview much more than going to round after round of one-on-one technical interviews because she will 'have greater control over the direction of the interview because [she] knows how to talk about her design.' It could be interesting to perform

follow-up interviews or surveys on students to see if, overall, they had become more confident of their ability to describe their design reasoning.

Based on the results from this study, the following changes were made for the Spring 2005 Quarter class, which only recently began. A short 20-minute lecture with discussion was added in which a set of design guidelines are presented and discussed, and weekly readings that cover those design guidelines were added. Both of these additions were made in order to provide the novice information/interaction design students with building blocks for good design solutions. While no formal analysis has been done, it is the author's impression that the design rationales from the first and second assignment in the Spring 2005 class seem comparable to the rationales produced only by mid-quarter within the Autumn 2004 class. If this assessment holds up under more rigorous analysis, it lends support to the argument that students' lack of repertoire and novice-status in information/interaction design may have inhibited their ability to justify their design decisions.

## CONCLUSIONS

This study sought to characterize the students' ability to write design rationales that effectively capture their justifications for key design decisions; identify the strengths and weaknesses found in the design rationales prepared by the students; and determine if the quality of the student's design rationales improved with practice over the course of a 10-week academic quarter. Overall, the students showed improvement throughout the quarter. Their ability to capture user-centered justification for design decisions became more apparent as the quarter progressed. Nonetheless, students were critical of the design rationale component of the class and it is likely that some of their negative feelings stemmed from the open-ended nature of the assignments and their novice-level knowledge of information/interaction design.

Although this study looked at a small, specific instance of design rationale in education, one could apply these findings to similar classroom situations—assignments in students need to design unique solutions to open-ended problems. Given that design itself is a difficult process, novice design students may feel more comfortable writing design rationales when the overall challenge presented in the design problem is more constrained. For each design problem at this level of education, students must struggle with learning new tools and new design techniques while also trying to understand new problems for which they must design a solution. They accomplish this each week with a Spartan design repertoire. While we must accept that these novice designers will struggle with their tools, we can help allay their newness to each problem by providing greater context for the design problem—

while the design problem may still be a weekly class exercise, the complexity of the problem can be made more visible to the students and the written rationale serves as a place for the students to reflect upon their design justification and their vision for evolving the design if it had been a real-world exercise.

In this case, for example, greater context for design problems could be provided through more detailed scenarios that motivate the problem and through user data and usage cases. Students could then utilize this extra information, alleviating their concerns that they are 'making it all up' when they must later write design rationales or orally present their solution for class critique. Furthermore, briefly introducing them to design guidelines and principles that they will learn in later classes will provide a bootstrapping mechanism to help them build up their otherwise Spartan design repertoire. Here, the goal would not be to have them master this advanced information, but instead to let them explore it and use it to the best of their ability such that they have a set of guidelines (used as rules of thumb) that allow them to produce better quality design more rapidly and *understand why* it is better quality design. This information, especially when reinforced through the in-class tutorials and their own design efforts, primes them for senior-level classes.

This study represents only a small step toward achieving the goal of educating reflective engineers who are not only trained in producing good designs but are also highly capable of critiquing and soundly justifying design decisions. As companies hold greater amounts of intellectual property and as product engineering becomes more geographically fluid, there will be an increasing need to have a workforce that is well-able to articulate, critically justify, and record design rationale. Despite the wealth of research in design rationale formalisms and systems, companies have been slow to adopt these approaches. While some may find these notation and systems cumbersome to use, perhaps another aspect of the problem is that engineers are not practiced at writing design rationale.

This research steps back from design rationale formalisms to explore how engineering students communicated design rationale in a junior-level course. Moving beyond the limited nature of this study and the implications it has for designing courses similar to this one, this study also raises questions about the design rationale itself. How well would junior engineers at a corporation perform? How would experts perform? Would they be able to capture and communicate key design decisions that accurately communicate their assumptions and intent? What kind of knowledge is specifically implicated in the ability to justify not just the interesting or focal design decisions, but also the seemingly (to the designer) mundane and routine decisions? Performing other naturalistic research such as this study may bring

us closer to understanding how we could devise more successful systems for capturing design rationale in the workplace and how we could best teach engineers to communicate it effectively.

*Acknowledgements*—This work was supported by National Science Foundation grant REC-0238392 awarded to the second author. In addition, we would like to thank those individuals whose feedback helped us make the paper stronger.

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