Creating an Interactive Learning Environment with Reusable HCI Knowledge

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Abstract: We propose an interactive learning environment for Human-Computer-Interaction design based on a new form of reusable design components organized in a knowledge repository. Our repository focuses on reusability and accessibility to share design knowledge among students. We evaluate how these reusable components impact student knowledge of the design domain and their reuse of HCI knowledge. Results show that by exposing students to valuable concerns and alternatives for the design of interactive systems, these reusable components can improve students' understanding of the design scope and lead to an increased use of existing HCI knowledge in their designs.

Introduction

The field of Human-Computer Interaction (HCI) has conducted much research over the years that benefits how designs are created. Much of this research exists in many forms such as theories, guidelines, or observational studies that are taught to students learning interface design. However, our experience in teaching introductory undergraduate HCI classes forces us to recognize that students are often lost in this collection of design research and cannot easily apply it to their own designs. As a result, many students rely on intuition to mold their interfaces and start developing them without addressing proper design concerns and evaluating alternatives.

Most design concerns for interactive systems have numerous design solutions, each having advantages and disadvantages to their use. Success can often be measured by how well students apply solutions to each important development concern to create a coherent overall design that solves an existing problem. However, understanding the domain is essential to understanding the range of solutions. The reuse of existing HCI knowledge is also vital in creating adequate design solutions. But the question remains as to how to expose students to previous efforts so they can understand the scope of design concerns and alternatives.

We introduce an interactive learning environment for HCI based on a new form of reusable design knowledge components organized in a repository focusing on reusability and accessibility to share among students. By exposing students to valuable concerns and alternatives for the design of interactive systems, these reusable components could improve students' understanding of the design scope and lead to an increased use of existing HCI knowledge in their designs.

Background and Motivation

Knowledge Reuse

Whittaker, Terveen, and Nardi (2000) addressed a problem of radical invention in HCI and proposed making incremental improvements based on prior designs. They believe designers should consult radical invention only when they have previously referred to prior work and cannot improve upon it. They propose designing around reference tasks, outlining common problems and metrics required for evaluation. Reference tasks can therefore focus designers' efforts on designing around important design concerns. This lack of focus is a recurrent problem for students, who often consult radical invention for their own development. A rigorous analysis of a design problem may outline some important design concerns for the intended system. However, due to their lack of experience in

interface design, students can leave out important concerns which negatively impact their design. We believe students should focus on important design concerns and understand what their design alternatives and tradeoffs are.

Reuse entails the notion that design processes incorporate previously created artifacts to aid in the creation of new designs. The artifacts can appear in many different forms. The benefits of reusing design patterns in HCI (Borchers, 2000) as well as other forms of design knowledge (Sutcliffe and Carroll, 1999) have been explored. It can often be harder to create new design knowledge than to reuse and adapt existing knowledge for new designs. The encapsulation of features, observations, and theories in the form of design knowledge can serve as a delivery method for design alternatives. Their use during the design process can certainly prove beneficial to students aiding their decisions by weighing possible design choices and consequences. How the transfer of design knowledge can progress and how it can help advance HCI education is a definite research interest.

Notification Systems Design

To build and evaluate reusable design components, the design domain for this work was constrained to notification systems. Notification systems are systems used in dual task situations. While performing a primary task, such as writing a word document on a computer desktop, notification systems interrupt users to provide monitored information for a secondary task. Examples include car navigational systems, stock tickers and instant messengers. Because of the variety of domains in which notification systems are needed, it is important to understand the goals of the systems we design in terms of conveying the information in an appropriate manner. The notification systems domain was chosen because it has a well defined framework describing system and user goals (McCrickard et al., 2003). The framework can be used as a method to evaluate student designs in terms of the effectiveness of a system's information design options and user goals.

Designing interactive systems using claims

Claims describe the upsides and downsides of design decisions and record reusable HCI knowledge. To improve student designs and HCI skills, we developed a claims library for the development of notification systems (Payne et al., 2003). The library contains claims about notification system design aspects and aims to make it easier and quicker for students to build their designs by exposing them to previous design solutions and the tradeoffs associated with their use. A claim within the library is represented as a set of attributes—title, design features, upsides, downsides to capture the effect a feature will have on a user within a usage scenario. Figure 1 is an example claim created by a student and stored in the claims library.

Using MSN style popups to alert
A clickable window about 1/24th the screen size appears in the bottom right hand of the users work area for a limited number of seconds, briefly alerting the user of a certain event, then disappearing. If the user clicks on it, it will give more details about the alert and possible actions to take.
+ User gains a quick overview of information which could be important to him or her.
+ User can access more information by clicking on the popup.
- Could appear on top critical information in the primary task application.
- May provide too much interruption from the users primary task

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Figure 1: A claim created by a student in the claims library

Students are able to search for claims using multiple criteria and receive matching claims as a result. When needed, students can create new claims and add them to the library. This cycle previously proved to be useful in guiding students through their design process by exposing them to a range of design solutions and tradeoffs for their interactive system designs (Fabian et al., 2004). Previous research has demonstrated how an integrated development environment for interface design can guide to the selection of a set of claims that successfully acts as a design prototype (Lee et al., 2004). However, problems inherent to the characteristics of reuse still exist. The lack of organizational structure leads to problems in understanding the notification systems domain (Wahid et al., 2004) and

selecting claims that adequately cover important design concerns. Understanding the characteristics of the domain is essential to successful reusing. The quality and writing of claims also reduced their reusability in other systems.

Using a Domain Taxonomy to Outline Design Concerns

We have seen the students' relative inexperience may cause them to ignore important design concerns fundamental to the domains the applications belong to. We consequently created a notification systems taxonomy to guide them into addressing the proper concerns when they design their solutions through a decomposition of the design domain. Our goal is to position the taxonomy as a tool to further the utility of our system, giving students an opportunity to gain further design skills. The taxonomy is described in Figure 2.

For the notification systems domain, we focus on three important aspects: critical parameters, notification system types, and notification systems methods. We adopted the three critical parameters of interruption, reaction, and comprehension and the 8 different notification system types defined by the IRC framework (McCrickard et al. 2003). Much of the notification methods were derived from previous literature and our own expertise. The taxonomy was built to provide student designers with a set of important design concerns that define the domain as well as an effective categorization for our reusable design components. These components are classified under each element of the taxonomy and represent a set of design alternatives for each design concern.

Notification Systems
- **Critical Parameters** (Interruption, Reaction, Comprehension)
- **Notification Methods** (Voice, Visual, Haptic/Tactile, Audio)
- **Notification Systems Types** (Secondary Display, Information Exhibit, Critical Activity Monitor, Noise, Alarms, Diversion, Indicator, Ambient)

Figure 2: The notification systems taxonomy outlines key design concerns for students

Reference Claims as Reusable Design Components

We believe students can benefit from the reuse of claims. In our previous claims library effort, claims were mostly created by students as they were designing new systems. However, the quality and lack of organization of the claims in the library limited their potential reuse by other students. Inspired by reference tasks, we propose *reference claims* as an improvement over regular claims, to acquire design knowledge and focus student designers' attention. A collection of reference claims portraying relevant design knowledge allows students to describe needed design features. We propose four main characteristics of reference claims to improve their knowledge sharing capabilities.

- *Applicable***:** Reference claims, like reference tasks, encapsulate knowledge central to a domain. Reference claims are created by educators who have expertise in a domain giving them the ability to associate potential reference claims with their places in the domain taxonomy. Educators can maintain quality and coordinate the testing and validation of reference claims, contributing to a growing body of domain knowledge.

- *Parent:* Reference claims can act as parent claims from which traditional claims can be instantiated through specification. The knowledge encapsulated in reference claims allows students to use them by tailoring the knowledge, leading to new instantiations of design features. Each new feature can be a marked proposition for how core domain knowledge can be reused by students for their designs.

- *Abstract:* Because the sharing of fundamental knowledge is imperative, reference claims need to be reused. It is often hard to reuse a claim if the language and scope is too specific, making it more difficult to apply to a different situation. The nomenclature can no longer be informal like the traditional claims. They must achieve a level of language abstraction that will allow students to reuse the reference claim in a different context, but within the same domain.

- *Artifact Independent***:** The claim's depicted knowledge does not depend on the use of a specific artifact such as a widget or application. Claims should not specifically describe a design solution as an existing application but rather as a possible design alternative for many possible applications.

Figure 3 presents an example reference claim. First, the claim depicts knowledge pertinent to the notification systems domain—a method for notifying users of some form of monitored information. Connecting reference claims to a specific domain increases their applicability and accessibility within the domain by placing them in the taxonomy. Second, when linked to specific claims the claim can be used as overarching knowledge for more specific claims that are based on the same concept. By instantiating new variations of design features based on this knowledge, student designers can propose new ways of building a system based on previous research. For instance, taking the example reference claim and applying it to the problem of auction bids allows students to explore how the knowledge can be used to solve a problem within the domain. Third, the language does not restrict the use of the claim to specific sub-domains of notification systems such as online auction systems for example. It is not over specified in any way. Fourth, the knowledge is not explicitly tied to any artifact and therefore, can be used to design any notification system. For example, a claim about the use of visual encodings in an icon constricts the use of the claim to icons. The color changing behavior should be independent of the icon itself, allowing the same behavior to be applied to different artifacts.

Use of Visual Encodings for Notifications
Using visual encodings to represent information in a notification delivery event
+ Decreases interruptions because users are not forced to read textual information
+ Allows for quick recognition and interpretation of visual encodings
- Requires that the user be familiar with the encoding use for the piece of information
- Requires that there be enough distinction between different types of encodings to avoid confusion

Figure 3: A reference claim example. It follows the four characteristics that differentiates it from traditional claims

We believe that the characteristics of reference claims make them an improvement over regular claims for sharing important HCI knowledge among students and benefit their designs. By using reference claims as reusable components organized in a taxonomy, students learning interface design are exposed to important design concerns and design alternatives. One of our goals in this paper is to evaluate the reusability and accessibility of reference claims and try to gauge the impact of their use during the design process.

Evaluating the Reference Claims Library as an Interactive Learning Environment

Reference Claims in the Claims Library

We decided to modify our claims library to include reference claims organized in a taxonomy. Using the four characteristics of reference claims, we created 50 new reference claims that covered the span of the taxonomy. Students were able to browse the library by navigating within the taxonomy and viewing claims associated with each category. Figure 4 and 5 illustrate our reference claims library.
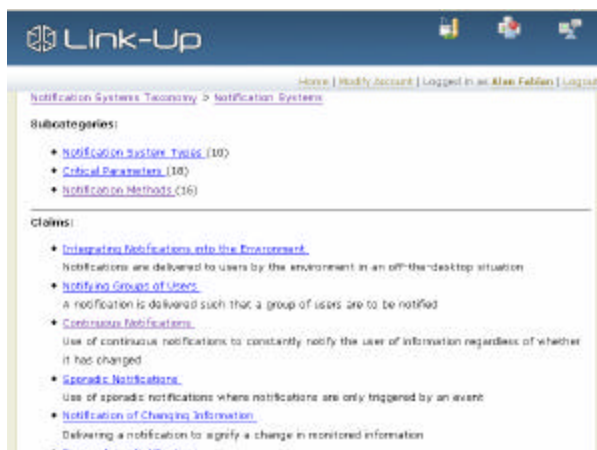
Figure 4: Notification system taxonomy in the library. Claims are available under each design concern.
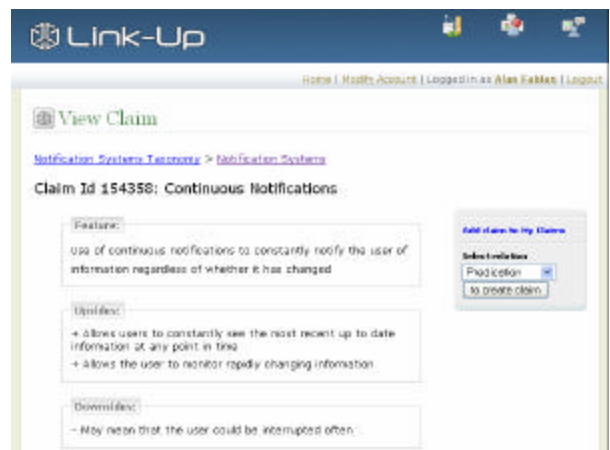
Figure 5: Reference claim in the library. Students can see its feature and the tradeoffs associated with its use.

Experimental Design

Our experimental design revolved around the investigation of two main points of interest. First, we wanted to know how well the claims organization in a taxonomy could lead to a more complete design that covered important design concerns. Second, we wanted to gauge the ability of reference claims to increase the amount of reuse and therefore the amount of HCI knowledge transferred to students. The claims library was prepared for a study that would allow students to collect claims and create a conceptual design for a notification system.

Twenty-four HCI students participated in our study. All the students were familiar with the use of claims and the domain of notification systems. Each student was paired to create a total of 12 groups for the study. Our instructions presented each group with a scenario depicting the need for a notification system in a train station and asked them to work together to design a notification system to solve the problem.

To create the system, they were instructed to access the claims library and search for claims they believed would apply to their design. For every claim they wished to reuse, they were told to write down the unique ID number of the claim on a list we provided. If they could not find a claim they needed, the option to create claims was given. We did not place a time limit and asked the students to end their design process when they felt their system was sufficiently described by their claims.

We altered two different variables in two different ways to create four conditions for our study. The first variable was the type of claim designers would be given access to. In the Search and Browse (SB) condition groups could view traditional claims by using a search engine or browse through the library linearly to view all the claims. In the Reference Claims and Taxonomy (RT) condition, reference claims could be found by browsing through the taxonomy and viewing the claims associated with each category. At no point were users able to view both types of claims. The second variable changed the instructions that were given to the students regarding the design of the notification system. The Guided (G) condition provided half the groups with extra guiding instructions pointing out design aspects to consider while designing notification systems. The Unguided (UG) condition did not received these instructions in any way. All the groups were placed in one of the conditions with a total of 3 in each condition. At the end of the experiments all students were asked to individually fill out a post-questionnaire. The questionnaire consisted of open ended questions asking to describe their design and questions based on a seven-point Likert scale.

Results and Discussion

Design Impact of the Reference Claims library

Our first point of interest was to gauge our tool's ability to lead to "better" designs. Our assumption is that for a design to achieve a greater degree of success, it should incorporate the concerns addressed by the three design guidelines we identified: critical parameters, notification types and methods. We decided to assign design scores to each group based on how well they accounted for the three guidelines: critical parameters, notification system types and notification methods (see Table 2). The list of claims was analyzed and decisions were made based on whether the claims specifically addressed any of the design concerns. One point was given for each design concern successfully addressed by the set of claims. The maximum score possible was 5, with 3 points for critical parameters and one point each for notification system type and notification method. Three experienced notification systems researchers worked independently to rate the designs from each group and the scores were then averaged and used in our analysis (see Table 3).

The analysis of the design scores proved to be very encouraging. We found a significant difference in design scores between the SB and RT conditions (t(10)=-4.48, p=0.001). This overall result was bolstered by differences between the individual conditions (see Table 3). The UG SB and the UG RT conditions had a significant difference (t(4)=-3.96, p=0.016) and the G SB and G RT condition was close to having a significant different (t(4)=-2.29, p= 0.08). The unguided RT groups actually performed better than the guided RT groups hindering the need for guidelines in the RT condition.

We attribute these results to the structure of the taxonomy. The top-level structure of the taxonomy defined the overall domain in terms of the three design aspects we expected everyone to consider. If students wanted to consider a critical parameter such as interruption, they could easily do so by entering that part of the taxonomy. This process was not possible in the SB condition. This inherent inhibiting factor is further exemplified when we consider all four experimental conditions. In the G condition, we see a considerable difference, although not

statistically significant, between the SB and RT conditions (see Table 3). In the UG condition, we see a solid significant difference. This leads us to conclude that even when the students were told what to consider, they were not able to do so. The lack of organization and poor writing of the traditional claims, which were larger in number and covering all design concerns, contributed to this factor. When students in the RT condition were told what characteristics to incorporate in their design, they were able to do so relatively successfully. When they were not told what to consider, they still implicitly considered many of these aspects. These results demonstrate organizing claims in a taxonomy can lead students to create more complete designs. By using this taxonomy as a reference for what to consider, students can therefore quickly understand and define they important design concerns they need to address for their systems.

Certainly the current state of the taxonomy also proved to be beneficial to designers in another way. Students were asked to rate their familiarity with the notification systems domain before and after the experiment. A seven-point Likert scale was used for this question. The students subjected to the RT condition were found to show a significant improvement in their perceived familiarity with the domain (t(22)=-2.56, p=0.017). We could not find any significant improvement in the SB condition students (t(22)=-1.32, p=0.2). This is another factor contributing to the increase in consideration of the design aspects—a potentially helpful tool for student designers. The results demonstrate the taxonomy's ability to focus students' design efforts around key design concerns.

Reusability of Reference Claims

Our second point of interest was that using reference claims and a notification system taxonomy would increase students' reuse of HCI knowledge. Comparing all the groups in the SB and RT conditions yielded appealing results (see Table 4). A T-test suggests the number of claims reused in the RT condition was significantly greater than in the SB condition (t (10) =-2.53, p=0.029). The significant difference in the amount of reuse between all the groups in the SB and RT conditions demonstrates that the exposing students to reference claims can increase the use of HCI knowledge compared to regular claims.

	SB	RT	SB & RT
UG	**Mean = 1.77** **SD = 0.50**	**Mean = 3.88** **SD = 0.76**	Mean=2.83 SD=1.29
G	**Mean = 2.33** **SD = 0.66**	**Mean = 3.44** **SD = 0.50**	Mean=2.88 SD=0.80
G & UG	**Mean = 2.05** **SD = 0.61**	**Mean = 3.66** **SD = 0.63**	

Table 3: Mean and standard deviations for the design scores. Significant differences are color coded.

	SB	RT	SB & RT
UG	Mean=9 SD=4.5	Mean=13 SD=3	Mean=11 SD=4.09
G	Mean = 7.66 SD=4.16	Mean=14.33 SD=4.04	Mean=11 SD=5.17
G & UG	**Mean = 13.66** **SD = 3.26**	**Mean = 8.33** **SD = 3.98**	

Table 4: Mean and standard deviation for the number of reused claims. Significant differences are in red.

The most important reason for the increase in reuse is the way the claims are written. Students found most of the reference claims could be used in a different context. We observed that the same claims were applied to completely different systems. This is an indication of them being able to easily apply the high-level concepts to their designs. The claims were not tied to any artifacts, making them easier to reuse. Most traditional claims were very specific in many cases. Students found traditional claims that only partly defined the description of the design feature they wanted to implement. This was evident when we compared their claims to the textual description of their system. Some groups decided to create more general claims because they could not find any appropriate claims.

The classification of claims by categories in the RT condition may have improved browsing capabilities by allowing them to discover claims rather than requiring them to formulate queries. The query formulation process usually requires the user to anticipate the contents of the library and to know the important design concerns that need to be covered. Reuse may have been inhibited by the lack of familiarity with the library in the SB condition. By grouping claims into clusters in the RT condition, reference claims were made more accessible, increasing the probability of being found and reused. In some cases the RT condition allowed students to realize they needed more claims. The

taxonomy made them notice there were aspects of the notification systems domain that they may not have been considering. Therefore, they were more prone to look for more claims covering specific aspects of a design, subsequently increasing the number of reused claims. Without a taxonomy students only looked for claims if they had a predetermined design aspect they wanted to consider. The results demonstrate the ability of reference claims to increase the amount of reuse and therefore the amount of HCI knowledge transferred to students. Reference claims therefore position themselves as an effective means to teach students design alternatives for their systems and to limit the amount of time they spend trying to recreate design features that already exist, and have identified tradeoffs associated with them.

However, there are problems associated with the reusability of reference claims. We asked users to rate how well they believe their claims represent their design using a seven-point Likert scale. Our analysis suggested the reference claims were less representative with a mean of 4.16. The traditional claims had a mean rating of 5.13. The difference, however, was not found to be significant (p=0.093). As a follow up to the above question users were also asked to answer in an open ended manner as to why they created the claims they did. Of all groups that used the reference claims, one group specifically said that the claims were too general to apply to their system. Two other groups said that they wanted to add more features to their system that the reference claims did not cover. These observations lead us to believe that reference claims are not necessarily better at describing the intended designs. Reference claims seemed too abstract to capture the design accurately. The opposite was said about the traditional claims—students found them to be too narrow in scope, capturing additional undesired characteristics.

The combination of reference claims and traditional claims can be a perfect solution to addressing this problem. A collection of claims created to specify a system should account for gradually changing levels of scope. This motivates the use of both reference claims and traditional claims during the design process. Reference claims can describe high-level goals of a system, but without traditional claims the designers cannot narrow down how to implement a system. One student did mention that there was a need to add more specific features not mentioned by reference claims, supporting our assessment. This vision is consistent with our suggestion that the knowledge contained within reference claims should cause the creation of new design features in the form of traditional claims, leading to incremental improvements in the overall design.

Conclusion and Future work

We proposed an interactive learning environment for Human-Computer-Interaction design based on reusable design components organized in a knowledge repository. We introduced a domain taxonomy as a means to expose students to important design concerns as well as a categorization method for the reusable design components. Inspired by reference tasks, we introduced an improved form of claims, reference claims, as an effective reusable design component to share design alternatives with students. We then proceeded to investigate the use of reference claims in a taxonomy during the design processes, and found the following significant results:

- Reference claims organized in a taxonomy improve student designs by exposing novice designers to important design concerns and the corresponding design alternatives.

- They also lead to a significant increase in reuse of HCI knowledge during design, exemplifying their knowledge sharing capabilities.

- However, although they can determine high-level goals of a system, they may also need to be tied to more specific claims to accurately describe system features.

These conclusions confirm our belief that our leaning environment based on reference claims can benefit students learning HCI. The taxonomy exposes students to important design concerns and improves their understanding of the design domain. Reference claims convey students the knowledge gathered from previous designs and their organization in the taxonomy teaches them a range of design solutions along with the tradeoffs associated with their use. However we discovered that although reference claims do provide the advantage of being more reusable than traditional claims, they also lack the specificity that would enable them to more accurately define the intended systems. This is why traditional claims are still important to students designing interactive systems. We intend to improve our tool by giving students the ability to access both reference claims in a taxonomy and traditional claims. In order not to hinder the benefits of the taxonomy and reference claims, we believe that traditional claims should be linked to reference claims through the use of claim relationships, allowing designers to navigate from reference

claims to traditional claims using claim relationships (Wahid et al., 2004). Students will be able to more accurately define their designs using linked traditional claims without hindering the positive aspects of reference claims.

Instructors could use this interactive learning environment in introductory HCI classes to complement traditional HCI guidelines and theories. Its interactivity and organization can improve over traditional HCI material used in class by making it easier for students to access a wide range of HCI knowledge and to understand its impact by applying it to a concrete design. Instructors could use this environment to teach students how to use important HCI knowledge by presenting it as a design feature addressing a design concern. Additionally, new claims can be added to the library as novel knowledge is identified to instantiate new design alternatives. We believe this tool has the potential to enable students to better understand how to use core HCI knowledge to address important design concerns when they design interactive systems.

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