Image is Everything: Advancing HCI Knowledge and Interface Design Using the System Image

Jason Chong Lee, C. M. Chewar, and D. Scott McCrickard
Center for Human-Computer Interaction and Department of Computer Science
Virginia Polytechnic Institute and State University
Blacksburg, VA 24061-0106 USA
1-540-231-7409
{chonglee, cchewar, mccricks}@cs.vt.edu

ABSTRACT

As the field of human-computer interaction matures, the need for proven, dependable engineering processes for interface development becomes apparent. Our continuing work in developing LINK-UP, an integrated design and reuse environment, suggests that a better understanding of the system image is key to the successful evaluation of design prototypes, and an aide in applying knowledge from the repository. This paper describes our ongoing work to enhance LINK-UP by developing and augmenting the system image to make it the central communication point between different stages of design and between different stakeholders. We report on a study of the new task flow that demonstrated the value of the system image within a broader design context. Overall, our findings indicate that the effective creation and use of knowledge repositories by novice HCI designers hinges on successful application of existing HCI design concepts within a practical integrated design environment.

Categories and Subject Descriptors

H.1.2 [**Models and Principles**]: User/Machine Systems – *Human Factors*; H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *Evaluation/Methodology*

General Terms

Design, Human Factors.

Keywords

Analytic evaluation, scenario-based design, claims, usability engineering, system image, stages of action, critical parameters, science of design, notification systems.

1. INTRODUCTION

The field of human-computer interaction (HCI) is concerned with the development of interfaces that allow people to effectively use computers to meet their goals. As this field continues to mature, there is an increasing need for a structured, methodical way to both apply and further develop HCI knowledge. This "science of design" will bring proven, dependable engineering processes to interface development, providing a framework from which researchers can advance HCI knowledge. One approach to creating a science of design infrastructure is the development of reusable knowledge repositories. The accumulation and reuse of design knowledge will allow both researchers and practitioners to build on established HCI knowledge and will also support the dissemination of knowledge across domains. Design environments that are integrated with these repositories will facilitate the production of reusable knowledge and provide the context in which knowledge can be reused [4].

This motivated our work on LINK-UP, an integrated design environment that supports a scenario-based usability engineering process centered around the use and development of a knowledge repository [13]. The overall goal of LINK-UP is to validate the use of a reusable knowledge repository as a basis for developing a science of design. Key in creating this is adequately capturing the vision of the designer and relating it to the experience of the user to enable reflection and iteration on the design. This will in turn support the use and creation of reusable knowledge.

To this end, we build on the work of Don Norman, an ACM SIGCHI Lifetime Achievement Award Winner and author of the seminal HCI book *The Design of Everyday Things*. We revisit his concept of a *system image*, a representation of a design that acts as a bridge between the designer's conception of a system and the user's conception of a system [12], and applied it to our design environment (see figure 1). In our initial work, we integrated Norman's ideas into the analytic module to allow HCI experts to evaluate nonfunctional prototypes using a digital representation of a system image. An initial study confirmed that the system image supported effective analytic evaluation of initial design prototypes, but also suggested that it was instrumental in the application of information from the knowledge repository [7].

We worked to redesign the initial architecture to further develop our own interpretation of Norman's system image, as well as to apply other concepts derived from HCI so that LINK-UP better supports interface design and the generation of reusable design knowledge. We conducted a study of the new task flow with a group of novice HCI designers that demonstrated the value of the system image as a central part of the LINK-UP system and its effectiveness at supporting interactive system design. However, participants encountered problems during the design process caused by differing understandings of key HCI concepts that were integrated in LINK-UP. Overall, our findings indicate that the effective creation and use of knowledge repositories by novice HCI designers hinges on the successful application of existing HCI design concepts within a practical integrated design environment.

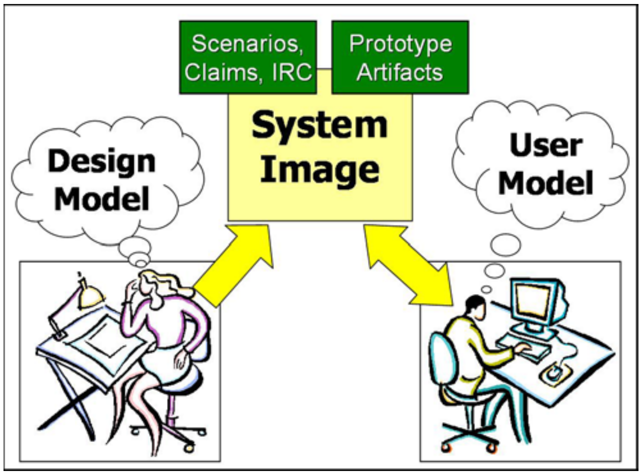

Figure 1. Norman's conceptualization of the system image. The designer captures the system intentions in a prototype or working system, along with supporting documentation and help, enabling the study of user interaction with the system.

2. BACKGROUND

To situate our approach among other HCI research, we review the foundational concepts of LINK-UP. We directly extend the work of Carroll et al., perhaps best known for *scenario-based design*. The theoretical underpinnings of this design process—that of Norman's theory of action—are of most interest to us, so we discuss both. A final concept reviewed in this section is that of critical parameters, central to our quantitative approach for assessing interface usability.

One classic theory in interface design literature is Norman's theory of action [12]. Since user tasks are composed of psychological goals and intentions, and are accomplished with control mechanisms to physically manipulate system states, he recognizes two different expressions of a task (physical and psychological) that must be resolved within a human-computer interaction system. Norman established the idea that governing the usage experience is the consistency of two conceptual models—the *design model* held by the designer and the *user's model* based on the user's understanding of the system. Each model can be analyzed as stages of action, which describe the cyclical evaluation and execution of tasks across the *Gulf of Execution* and the *Gulf of Evaluation*. To facilitate a user's evaluation and execution of tasks, designers must develop conceptual models as they would develop the scaffolding of a bridge. Several factors contribute to each of these conceptual models. The design model should be inspired by a requirements analysis, including consideration of a user's background, situational context, and task-oriented goals. This model expresses the designer's understanding of user needs and is a representation of the intended functionality for the system. The user's model is formed by the user's understanding of the *system image*, the physical system and its documentation (see figure 1).

The key idea we continue with is that Norman's view of the role of an interface designer is to develop the system image so that the user's model and design model are compatible.

Carroll's work endeavors to build a scientific approach to research and interface development, which he argues can be achieved by making explicit the underlying design rationale of interface artifacts [1][14]. He asserts that theory-grounded HCI research can drive innovation by expressing, testing, and reusing "falsifiable" hypotheses (or *claims*) about the psychological effects an artifact has on a user. Scenario-based design (SBD) is an approach to interface development, providing an inquiry method to help designers reason about elements of a usage situation and receive participatory feedback from stakeholders [14]. Through the development and sharing of narrative descriptions of users solving problems with designed systems, designers are able to create the scaffolding across Norman's Gulfs—and develop systems with design-user's model compatibility. Using Carroll's approach, HCI professionals and software developers conduct an explicit *claims analysis* in formative and summative usability engineering efforts, continuously striving to balance and validate tradeoffs of use. A claims analysis record for a single system, and the accumulation of records from multiple systems, holds valuable design-related knowledge that, as Carroll has argued, should facilitate component reuse, motivate further empirical research, and inspire high-impact innovative development.

Enabling comparison of these conceptual models, as well as reusing suitable design artifacts, is a central goal to our research. We draw upon the notion of critical parameters to facilitate the design model and user's model comparison. Newman has argued that, in order to conduct meaningful modeling and usability evaluations to allow systems to become progressively better, we first must define or adopt critical parameters. *Critical parameters* are figures of merit that transcend specific applications and focus on the broader purpose of the technology [11]. He implies that well-selected critical parameters can function as benchmarks– "providing a direct and manageable measure of the design's ability to serve its purpose"—and indicate the units of measure for analytic methods that predict the success of an early design. The convergence of Newman's ideas with Carroll's provides the theoretical basis for our project: The iterative process of gauging critical parameters, embodied in design artifacts and expressed with claims, should guide an evaluation of the system image and provide indices for reusable design knowledge.

3. INITIAL LINK-UP DEVELOPMENT

This section introduces the LINK-UP system, a suite of web-accessible database services that our research group is developing and testing to support HCI education.

3.1 Introduction to LINK-UP

LINK-UP is an integrated design environment, providing designers (particularly novices) with structured process support and access to reusable interface design artifacts. Designers use LINK-UP in all stages of their interface design effort—from requirements analysis to usability testing. LINK-UP allows the designer to draw from other archived design efforts, providing general inspiration, offering alternatives for presentation and interaction choices, and cataloging artifacts according to known or anticipated psychological effects [3][6][13].

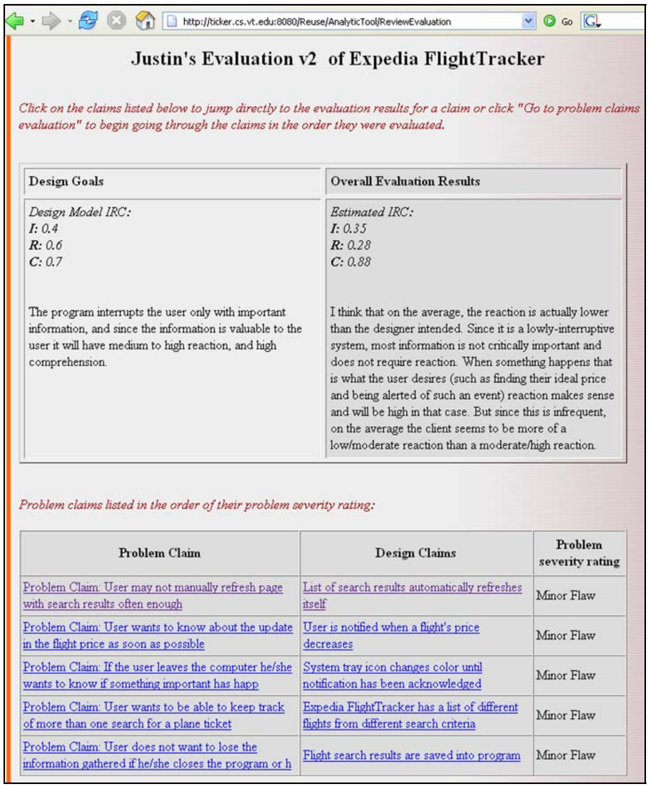

Figure 2. Screen showing an evaluated system image. The designer can view identified mismatches between the design and user models by selecting the claims at the bottom.

While it might seem compelling to record a wide variety of psychological effects, we constrain our attention to only those that are most essential to the success of a design—the critical parameters. Since critical parameters are unique to a class of systems, we also constrain our study to a single type of interface—notification systems. These systems are typically used in divided-attention situations, delivering users information of interest while they are engaged in other tasks [9]. To identify potential critical parameters for the notification systems design area, McCrickard's background work has probed the commonalities within this family of systems in order to provide a general guiding comparison framework, referred to as the *IRC*. The IRC is a quantitative assessment of the levels of interruption (I), reaction (R), and comprehension (C) that a user will achieve through the use of a notification system. Different situational and usage requirements demand different IRC levels, just as the actual IRC levels will vary based on notification artifacts and user characteristics [9]. IRC levels (or other critical parameters) provide catalogue values for claims, lending natural organization for design knowledge reuse.

LINK-UP guides a developer through an interface development process, helping them assess the targeted (design model) IRC values, find appropriate design ideas/artifacts/claims, and determine the actual IRC levels (user's model) that are achieved by the interface prototype. The LINK-UP system is composed of several modules (supporting multiple phases of project work), to include a Requirements Analysis module [4], a module for Participatory Design [10], an Analytical Evaluation module [8], and an Empirical Evaluation module [7]. All modules access the Design Knowledge Repository (detailed in [13]).

3.2 Analytic Evaluation using System Images

The Analytic Evaluation module of the initial version of LINK-UP incorporated Norman's concept of a system image and supported the analytic evaluation of design prototypes. An *analytic evaluation* is the process by which expert evaluators identify usability problems in a prototype interface by 'simulating' the way users will perform certain tasks. The evaluations can detect design flaws earlier, resulting in overall project cost savings from costly empirical user evaluations or major redesigns later on in the development process.

Generally, the designer will first use the module to create a system image by linking design artifacts (scenarios, claims and prototype screenshots) to corresponding problem artifacts. Next, an evaluator will study the design artifacts, which conveys a structured representation of the prototype that they then use to estimate the user's model. Finally, the designer goes back and iterates on his design based on the feedback. The strength of this approach is that the system image explicitly links the design and user models, allowing designers to pinpoint problems in the prototype design and in the system requirements (see figure 2).

As a pilot study, we ran a test in which HCI students used the Analytic Evaluation module to create a system image and evaluate each others' designs. The system image aided evaluators in the efficient evaluation of prototype designs. However, the participants failed to leverage the critical parameters in the evaluation process and in the later redesign of their systems. This was caused by a disconnect between the system IRC values, and how they could be applied to specific design decisions. Nevertheless, results suggested the process of using the module helped to reinforce the student understandings of the other critical HCI concepts of scenario-based design and claims [8].

4. ENHANCING LINK-UP

We began redesigning LINK-UP to further investigate the incorporation of existing HCI concepts so that it better supports design processes and the creation of reusable design knowledge.

To this end, we incorporated Carroll's interpretation of the stages of action [14] within the LINK-UP development process. As a result, designers would express requirements for each stage in terms of the IRC critical parameters. This was done to provide additional guidance to designers in developing and applying claims and to better support the use of critical parameters within the design process.

In addition, the task-flow was modified such that the system image would act as the central component of the LINK-UP architecture through which the different modules would interact. For example, the result of an evaluation from the empirical evaluation module might suggest some required design change. The designer can then run a participatory negotiation session with end users using the system image as the communication point between them. Changes that are made to the prototype design can be reflected in the system image, which can then be used by any of the other modules in the next design iteration. LINK-UP therefore better supports the rapid, iterative development cycles common in software engineering and which are encouraged in scenario-based design [14].

5. USER STUDY

5.1 Purpose

The purpose of the study was to validate that the central role of the system image, combined with the addition of IRC values within a stage of action framework, supported the design of notification systems. We also expected to encourage the development of claims so as to contribute to a knowledge repository. In addition, the study was intended to highlight any difficulties novice or inexperienced users may have in using the LINK-UP system to design an interface.

Design model IRC values

Very Desirable ← Not Important → Very Undesirable

5	4	3	2	1	0	-1	-2	-3	-4	-5

Stage of Action	Perception	Interpret	Make Sense	System Goal	Action Plan	Execute
Interruption	3	-2	-3	-3	0	-5
Reaction	-2	2	0	-3	1	5
Comprehension	2	3	5	3	1	3

User Model IRC Values

Very Desirable ← Not Important → Very Undesirable

5	4	3	2	1	0	-1	-2	-3	-4	-5

Stage of Action	Perception	Interpret	Make Sense	System Goal	Action Plan	Execute
Interruption	3	-4	-3	-3	-4	-1
Reaction	-2	0	0	0	0	0
Comprehension	1	4	4	3	2	1

Figure 3. Example IRC charts from an evaluation. The user model IRC chart is shown below the design model IRC chart.

5.2 Procedure

Participants for this study were nine computer science graduate students in an upper-level graduate HCI course. Participants had little to moderate amount of HCI knowledge and had little to no experience applying that knowledge to interface development. The study was run as a series of two week-long project-based homework assignments.

For the first assignment, participants were asked to define aspects of a problem situation to motivate the design of a notification system. First, they developed a problem scenario, to describe a problem situation in terms of one task flow through the stages of action. Second, they defined the requirements for their system in terms of the IRC critical parameters for each stage of action (see figure 3 top). Third, they extracted a set of problem claims from the problem scenario based on the requirements they defined. The statement of design requirements and problem claims represented the *design model* for their prototype.

For the second assignment, participants were asked to develop a system image for their design based on a nonfunctional prototype they developed. First, participants wrote a scenario describing the use of their prototype in terms of one task flow through the stages of action. Second, they extracted a design claim from their design scenario that corresponded to each of their problem claims. The nonfunctional prototype, which consisted of a series of screenshots or sketches, combined with the scenarios and claims made up the *system image* for the design. Third, participants exchanged system images and evaluated each other's prototypes. They evaluated the prototype by specifying whether the interruption, reaction and comprehension levels were desirable at each stage, based on what they deduced from the system image (see figure 3 bottom). Evaluators provided written explanations for the values in each stage of action. The written explanations in addition to the completed User Model IRC chart formed the *user model* for each design. Last, participants were asked to compare the user and design models for their prototypes, and look for possible improvements to their design based on the results. They then completed a series of discussion questions that focused on:

1. The process each pair of participants followed in evaluating a system image.
2. Their effectiveness in evaluating a prototype using the system image and accuracy of the system image in representing the goals of their systems.
3. The potential of the system image to apply to other aspects of design.
4. Problems they encountered in using the method and the causes for those problems.

6. RESULTS

The results below are derived from the set of discussion questions that participants were instructed to answer after completing the assignment. Results were gathered from seven of the nine original participants. Two of the participants failed to complete the assignment in the time allotted. There was one group of three participants.

6.1 Evaluation Process Followed

Participants were asked to explain the process they followed in evaluating each other's prototypes.

The group of three participants met in the same room to evaluate each other's prototypes. They first read over the system image materials (i.e. the scenarios, claims and IRC values), and then asked each other questions to clarify or explain aspects of each other's prototypes.

One pair of participants exchanged their respective system images, recorded in Word documents and email, and conducted their evaluations separately. However, they did maintain contact with one another by exchanging several emails while they evaluated each other's system images. They discussed issues concerned with the system image and the evaluation process in general so that their evaluations were consistent with one another.

One group of two participants exchanged their respective system images over email but did not exchange any additional emails during the evaluations.

6.2 System Image Effectiveness

Participants were asked to discuss whether the system image aided in the design process.

All of the participants agreed that the system image was helpful in effectively capturing critical design goals and tying them to design aspects of their prototypes. Four of the students gave specific examples where the evaluation of the system image led directly to a design improvement. Evaluator feedback and the designer's rationale for making the change were stated in terms of the critical parameters and stages of action. For example, one participant that was designing an alarm system decided to shorten the duration of the alarm because the evaluator indicated that the continuous alarm may lead to too much interruption across all of the stages of action. Improvements were not confined to the design of the interface. As an example, one participant was designing a vehicle navigation system that automatically reroutes the user if he or she encounters traffic. After looking at the design model side of the system image, an evaluator noted that a user may not want to be automatically rerouted by the navigation system because it may be too *interruptive.* Thus, the evaluation resulted in the designer changing the system requirements, rather than the design of the prototype itself.

6.3 System Image Applicability

Participants were asked to discuss whether the system image could be applied to other stages of the design process and how useful it would be in later design iterations.

Five of the seven participants agreed that the system image as it was presented in the study would be useful in other stages of the design process. One student noted that "reviewing and comparing those values to those other system images would be much easier and faster than using standard comparisons of prototypes." Another student noted that the system image could be useful in participatory negotiations with clients since it could serve as a "reference when determining if aspects of a design can be accepted or rejected."

Two of the seven participants thought the system image would be useful earlier in the design process, but would decrease in importance after a working prototype was developed.

6.4 Problems Encountered

Participants were asked to discuss any problems encountered during the evaluation process.

The participants did not encounter significant problems in the creation of the system image which included the prototype screens, scenarios and claims. However, six of the seven participants encountered problems using IRC values for each stage of action in the evaluation. The participants stated that they had differing interpretations of what the critical parameters, interruption, reaction and comprehension signified and how values should be assigned for each. One participant mentioned that he and his evaluator had a differing concept of what reaction was, making any comments from the evaluator concerning reaction useless to him. Participants also had differing conceptions of how critical parameters applied to each stage of action. One participant noted that it was not clear whether the interruption, reaction and comprehension values for a particular stage indicated the amount needed to progress through the stage or whether it indicated the amount gained by being in the stage.

7. DISCUSSION

The study demonstrated the value of making the system image a central part of the LINK-UP system and making it the communication point between the designers and evaluators. The scenarios and claims, which were sorted by stage of action, allowed evaluators to give targeted feedback to designers that helped them identify areas for improvement in their prototypes. The system image supports a similar kind of interaction in other stages of the design process such as in participatory negotiations between designers and clients. This is because it encourages discussion of the most important features of a design, using a common language, or *common ground,* which is critical for efficient communication between parties [2].

In addition, the majority of the participants agreed that the system image would be useful later on in the design process even if a functional prototype were available, because the system image presents only the most important aspects of the functional prototype in the form of claims and critical parameters. The system image supports efficient changes to both the design and to the requirements of the system since it ties the design and user model together within the stages of action. This is important in practical, iterative design processes where changes may affect any aspect of a system's design.

The key problems encountered during the evaluation process were caused by differing understand of the critical parameters and their application to the stages of action. Scenarios and claims are largely written in the form of narrative text, which allows for explanations and elaborations. Indeed, the claim itself elaborates on design decisions presented in the scenarios and in the prototypes. On the other hand, critical parameters are quantitative in nature and their effectiveness is dependent on a universal understanding of what they mean and how they should be used. This common understanding was not established between the participants in this study. As a result, the differing interpretations rendered the IRC values within the stages of action ineffective. Instead, participants relied primarily on the prototype screenshots, scenarios and claims, and on communications between the designer and evaluator.

All of the participants were given the same explanation for the critical parameters and stages of action. They were also given presentation-based examples of the LINK-UP process in action. In addition, all participants read and discussed a set of research papers related to the different HCI concepts within LINK-UP and about LINK-UP itself [1][3][9][14]. The results of the study suggest that traditional presentation of these HCI concepts may be insufficient for students to understand and apply them. This has implications both for the successful application of these HCI concepts to practical design and to the development of knowledge repositories that contain a structured, internally consistent body of knowledge. Chewar et al. developed a web-based questioning system for estimating IRC parameters that was shown to consistently generate IRC values among different users [3]. An adaptation of this tool that incorporates Norman's theory of action could serve as an educational resource resulting in a consistent understanding of IRC parameters among LINK-UP users.

8. CONCLUSIONS AND FUTURE WORK

Overall, we can report that the system image, acting as a central component of design, supported the design process presented in LINK-UP. Participants encountered problems in applying IRC values within the stages of action framework because of incongruent understandings of those HCI concepts. Since knowledge development for use in the repository depends on the application of LINK-UP to design systems, users must consistently apply the HCI concepts embedded in it to ensure that the generated knowledge is widely understandable and reusable. To summarize the major findings:

- A design process centered on the *system image*, which represents the current design prototype in terms of scenarios, claims and critical parameters, allows designers to iteratively improve designs by having evaluators give targeted feedback.

- The system image supports communication between different stakeholders (designers and evaluators) by providing common ground based on the critical aspects of design.
- The ability of novice HCI designers to use critical parameters and stages of action within a design and evaluation environment depends on a process or tool that supports the development of a common understanding of those topics within a realistic situation of use.

LINK-UP is being redeveloped to make the system image a central component through which all of the other modules communicate. This will allow it to more efficiently support highly iterative design processes. Supporting quick iterations will allow designers to both improve their designs and to reflect on their use and application of the LINK-UP system. If a user does not understand a particular HCI process or idea the first time, he or she will be able to go back and change the system image. Also, the system image will allow designers to append notes to different parts of the image. Designers will be able to use these notes to provide rationale for design decisions and explain why or how certain changes were made. This will support the mutual understanding of concepts between designers and evaluators and allow designers to keep track of the reasoning behind design decisions.

As shown, teaching novice designers HCI topics requires more than simple instruction or reading assignments. LINK-UP will provide specific instructions at each stage of the design process to make the steps involved in using each module more linear. This will provide some of the guidance and structure necessary to promote the development of mutual understanding of HCI concepts among its users. The next version of LINK-UP will be evaluated by having introductory HCI students use the system to design interfaces and to generate knowledge in the form of claims. In part, we will be validating that the use of consistent knowledge derived from design projects which use a common set of HCI practices and theories results in a rich body of reusable design knowledge.

9. ACKNOWLEDGMENTS

We'd like to thank The Virginia Tech ASPIRES program and our study participants for their valuable feedback.

10. REFERENCES

[1] Carroll, J.M., Singley, M.K., Rosson, M.B. Integrating theory development with design evaluation. *Behavior and Information Technology, 11*, (1992), 247-255.

[2] Clark, A. *Common Ground in Electronically Mediated Communication: Clark's Theory of Language Use. In Carroll, J. M. HCI Models, Theories, and Frameworks: Toward a Multidisciplinary Science,* Morgan Kaufman, San Francisco, CA, 2003.

[3] Chewar, C. M., Bachetti, E., McCrickard, D. S., and Booker, J. Automating a Design Reuse Facility with Critical Parameters: Lessons Learned in Developing the LINK-UP System. In *Proceedings of the 2004 Intl Conference on Computer-Aided Design of User Interfaces (CADUI '04)*, (Island of Madeira, Portugal, January 2004), 236-247.

[4] Chewar, C. M. and McCrickard, D. S. Links for a Human-Centered Science of Design: Integrated Design Knowledge Environments for a Software Development Process. In *Proc of the 2005 Hawai'i Intl Conference on System Sciences (HICSS '05)*, (Waikoloa HI, January 2005), to appear.

[5] Chewar, C. M., McCrickard, D. S., Sutcliffe, A. G. Unpacking Critical Parameters for Interface Design: Evaluating Notification Systems with the IRC Framework. In *Proceedings of the 2004 Conference on Designing Interactive Systems (DIS '04)*, (Cambridge MA, August 2004), 279-288.

[6] Fabian, A., Felton, D., Grant, M., Montabert, C., Pious, K., Rashidi, N., Tarpley, A. R., Taylor, N., Chewar, C. M., McCrickard, D. S. Designing the claims reuse library: Validating classification methods for notification systems. *41st Annual ACM Southeast Conference*. Huntsville, Ala — April 2-3, 2004, 357-362.

[7] Hobby, L., Booker, J., McCrickard, D. S., Chewar, C.M. Facilitating and Automating Empirical Evaluation for Education. *43rd Annual ACM Southeast Conference.* Kennesaw, GA. March 18-20, 2005, to appear.

[8] Lee, J. C., Lin, S., Chewar, C. M., McCrickard, D. S., Fabian, A., Jackson, A. From Chaos to Cooperation: Teaching Analytic Evaluation with LINK-UP. *In Proceedings of the World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education (E-Learn '04),* (Washington DC, November 2004), Vol. 2004, Issue. 1, 2004, 2755-2762.

[9] McCrickard, D. S. & Chewar, C. M. Attuning notification design to user goals and attention costs. *Communications of the ACM 46*(3), March 2003, 67-72.

[10] Ndiwalana, A., Kampanya, N. McEwan, I., Chewar, C. M., McCrickard, D. S., & Pious, K. A tool for participatory negotiation: LINKing-UP participatory design and design knowledge reuse. In *Proceedings of the 8th Biennial Participatory Design Conference (PDC '04)*, volume 2, (Toronto Canada, July 2004), 118-122.

[11] Newman, W. Better or Just Different? On the Benefits of Designing Interactive Systems in terms of Critical Parameters. In *Proceedings of the 1997 Conference on Designing Interactive Systems (DIS 1997)*, ACM, 239-245.

[12] Norman, D. A. *Cognitive engineering. In D. A. Norman & S. W. Draper (Eds.) User Centered Systems Design: New Perspectives on Human-Computer Interaction,* Lawrence Erlbaum Associates, New Jersey, 1986.

[13] Payne, C., Allgood, C. F., Chewar, C. M., Holbrook, C., and McCrickard, D. S. Generalizing Interface Design Knowledge: Lessons Learned from Developing a Claims Library. In *Proceedings of the 2003 IEEE International Conference on Information Reuse and Integration (IRI '03)*, (Las Vegas NV, October 2003), 362-369.

[14] Rosson, M. B. and Carroll, J. M. *Usability Engineering: Scenario-Based Development of Human-Computer Interaction*. Morgan Kaufman, New York, NY, 2002.

[15] Sutcliffe, A. G. and Carroll, J. M. Designing claims for reuse in interactive systems design. *International Journal of Human-Computer Studies 50*, (Mar. 1999), 213-241.