

Design Space Analysis as “Training Wheels” in a Framework for Learning User Interface Design

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ABSTRACT

Learning about design is a central component in education for human-computer interaction. We have found Design Space Analysis to be a useful technique for students learning user interface design skills. In the FLUID tool described here, we have combined explicit instruction on design, worked case studies, and problem exercises for learners, yielding an interactive multimedia system to be incorporated into an HCI design course. FLUID is intended as a “training wheels” for learning user interface design. In this paper, we address the question of how this form of teaching might mediate and extend the learning process and we present our observations on Design Space Analysis as a training wheels aid for learning user interface design.

KEYWORDS: HCI education, Design Space Analysis, design rationale, design skills, interactive multimedia

1. INTRODUCTION: A TRAINING WHEELS SYSTEM FOR USER INTERFACE DESIGN

“I think you learn design by apprenticeship. There isn't a recipe we can give but there are some things that everybody picks up, like figuring out what the real problem is, considering the user, ...” [14]

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“Teaching as mediating learning involves constructing environments which afford learning about descriptions of the world...to allow more to be learned than is available from experience alone.” [12]

Learning about design is a central component in education for human-computer interaction [5]. To teach basic design skills we have to provide learners with opportunities to “learn by doing” on concrete projects, and opportunities to “learn by reflecting” [17] on both their own projects and case studies of other user interface designs.

We have found Design Space Analysis (DSA) [13] to be a useful technique for students learning user interface design skills. Design Space Analysis provides a vocabulary of Issues, Options and assessment against Criteria, and a notation to record the current state of a design in shorthand form. In previous research, we have used adaptations of DSA to promote reflection on design case studies [4, 3]. In the FLUID tool described here, we have incorporated explicit instruction on design and problem exercises for learners, yielding an interactive multimedia system to be incorporated into an HCI course. In the course, the students will work in pairs with FLUID as active preparation for studio sessions involving group design projects.

In the spirit of “teaching as mediated learning” as defined above, we use DSA as a description of the considerations emerging in design. For case studies, this allows us to summarize the important design advances in ways that encourage generalization. For the design exercises, it allows us to support design activities by presenting video clips of advice and war stories. We use the

"training wheels"¹ analogy to clarify the role of DSA in the learning context. Here is the explanation given to users of FLUID:

"We will be asking you to construct your design according to a design method called Design Space Analysis (DSA). We use DSA here as a "training wheels" system for learning design. Remember the training wheels on your first bicycle? They helped you to get going and to avoid initial problems. Before long you found you didn't need the wheels any longer because you had internalized the necessary skills. Our requirement that you use DSA is like that: good designers may not have to be so explicit about these steps any more because the processes have become automatic (well, not quite automatic — often we still need to reflect on the design process, so you will find DSA handy later on as well)."

We thus would like to treat Design Space Analysis as a technique for representing design considerations and processes, not as a theory of design practice. However, any notation carries with it implications for the task processes it supports. One interesting aspect of the development of FLUID has been the resulting observations about Design Space Analysis and its implicit model of design.

The case studies in FLUID note that the material has been adapted to serve the training wheels role: the original designers did not necessarily represent their designs in this way. However, design documentation normally rationalizes design history to highlight key decisions [15]. The FLUID tutorial also notes that Design Space Analysis can be useful in other specific roles during design [2].

In the next section we describe a walkthrough of a session with FLUID as a typical learner might experience it. This raises interesting questions about how we learn to design and how teaching might mediate and extend the learning process. In section 3 we discuss the Design Rationale for FLUID, including links to other current research on interactive tutoring systems and reflection about our design based on usability testing. In section 4 we present our observations on Design Space Analysis as a training wheels aid for learning user interface design, including notes on what we learned about DSA through the process of specifying its use in the FLUID Tutorial. The concluding section outlines our current work to deploy and generalize the FLUID system.

¹ Our use of the term was inspired by [2], although our training wheels are both prescriptive and restrictive.

2. A WALKTHROUGH OF FLUID USAGE

In this section, we present typical experiences of a learner working through a design exercise in FLUID, an acronym for "Framework for Learning User Interface Design"².

FLUID is a learn-by-doing system in which the central learning task is a design exercise. Currently, the learner is asked to be the user interface designer of an interface which makes it easy to place, move and rotate furniture objects in a virtual room, using a standard mouse for direct manipulation. This exercise is adapted from a project report by Stephanie Houde of Apple Computer [9].

Initially, the learning task is presented by a team Manager character appearing in a video window. The learner also meets the client (a furniture shop manager), as well as two other characters who will offer advice during the design process — a Tutor on DSA and a senior Designer. Figure 1 shows the Manager and Tutor pointing out various aspects of FLUID that the learner may wish to explore.

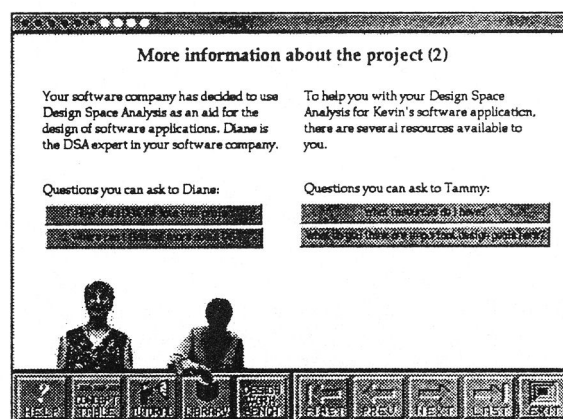


Figure 1. The Tutor and the Manager, introducing the student to the project.

Typically, learners will work through the DSA Tutorial first, although they are free to move back and forth amongst the other components including a Library of worked cases, a Table of Concepts and the design Workbench in which the exercise is carried out (all discussed further below).

The Tutorial introduces the concepts of Design Rationale, DSA, and the DSA notation. In addition, the Tutorial contains some real life "war

² For those interested in technical specifications, the current FLUID system is implemented in HyperCard 2.2, with video clips (about 150) incorporated as QuickTime™ movies through VideoFusion™.

stories”, identifies some disadvantages of DSA, summarizes the different roles that DSA takes on during design, and offers guidelines as to when it is (and is not) advisable to use DSA. The prototype case Library currently contains a single exemplar system, adapted to use the vocabulary and process of DSA. This case is about the design of a device for easy rotation of an object about an arbitrary axis in 3-D space [6]. For the exercise and the worked case, we deliberately chose two related topics to make it easier for the learner to apply the lessons from the case study. Figure 2 shows data from usability testing in the case study (the case study also contains a video clip of a 1981 3-D rotation device [7]).

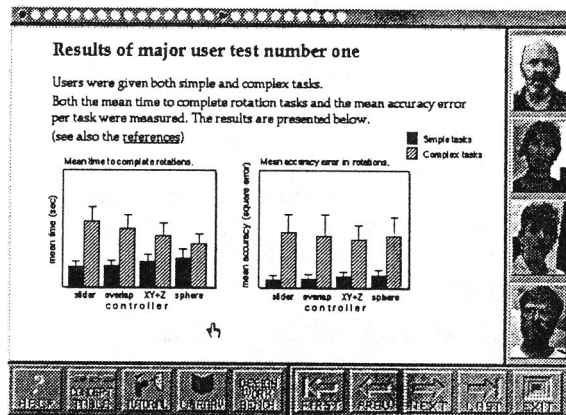


Figure 2. A case from the exemplar Library.

The FLUID design Workbench provides the standard tools of DSA, including a DSA diagram to describe the design Issues³, Options, and Criteria, a usage Scenario to describe typical interactions in narrative form, and a design history log which we can use later to show the learner's actions. In addition to the Tutor, Manager, and senior Designer, the learner can also access a group of Users; they report on the usability of the emerging design. The comments of the users are taken from usage data in the published report [9]. A Demonstration is available, to take the learner step-by-step through the basics of filling in a DSA diagram in the Workbench. Figure 3 shows the various navigation and guidance features.

In the introduction of the design exercise, the Manager presents an initial idea for the interface (corresponding to the starting point in [9]). The initial usage Scenario repeats the Manager's description, and the DSA diagram likewise is seeded with this initial information. If learners

request a user test at this point, the Users⁴ will tell them that more details will need to be filled in about how the interface works. To add detail or change the current design, learners edit the usage Scenario and the DSA diagram. By selecting a set of design choices, the learner can form a new design Alternative and present it to the Users.

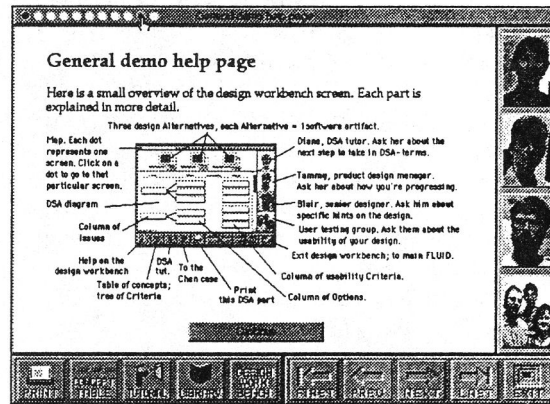


Figure 3. FLUID help screen. The bottom left shows the FLUID components: Table of Concepts, Tutorial, Case library, and Design Workbench.

For example, Figure 4 shows the state of a design after the learner has recognized one of the limitations of the initial idea. In the initial idea (as presented in [9]), a hand-shaped cursor is used to directly manipulate points on the furniture objects, each point corresponding to a different action such as lifting, sliding and rotating. In practice, users had divergent expectations about which part of an object would correspond to a particular movement. The design team introduced “narrative handles”, hands which appeared on an object and indicated, by their orientation, the movement invoked by selecting them.

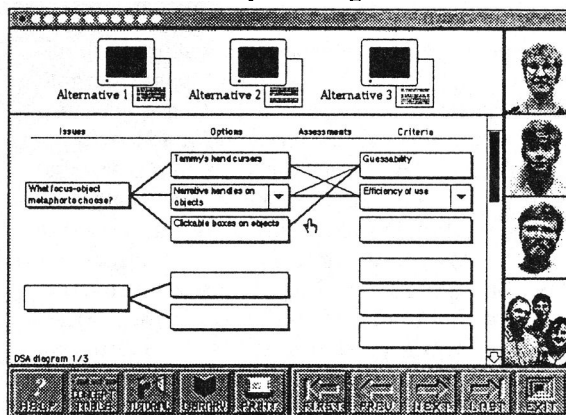


Figure 4. the FLUID Design Workbench.

³ We use the term Issues where DSA uses Questions.

⁴ Technically, it should be a User Test group or a Prototyper returning this information, but for simplicity we chose to have the learner interact directly with the Users.

To add this Option as a possible choice for a new design, the learner must edit the usage Scenario to describe a new style of interaction and then edit the DSA diagram to record this choice (these edits can be in either order). In Figure 4 the learner is adding the Option 'Clickable boxes on objects' as a new solution to the Issue called 'What focus-object metaphor to use?'

Throughout this process, the Tutor, Manager and senior Designer provide help on request. For example, if the learner requests assistance after hearing from the Users that *"the hands don't seem to be in places they expected"*, the Tutor will suggest (in a video clip): *"Think of some other ways to do things (a new Option)"*.

In order to provide this context-sensitive assistance, FLUID must monitor the learner's actions and map them against a state chart which determines what advice to offer. This requires the following features during the process of changing a usage Scenario⁵ or DSA diagram:

- learners enter their name for a new Option or Issue in the diagram;
- FLUID provides a list of likely entries in the current state and asks the learners to identify which one is closest to their idea;
- learners can select a part of the usage Scenario to edit, and type in their desired change; and
- FLUID provides a list of likely changes in the current state and requests a selection as above.

We discuss in section 3 the rationale and effects of these features on the learning process.

At the end of the design exercise, the learner can review the project with the various characters. If the design is incomplete, the characters suggest a return to the design Workbench, otherwise they congratulate the learners upon their exercise and suggest follow up reading before the scheduled group design studio exercise.

FLUID was tested with prospective students of the University of Guelph undergraduate HCI course. Completing their DSA diagrams using the design Workbench took on average 59 minutes with a range from 39 to 90 minutes. This does not include the time taken to work through the Tutorial or Library case.

3. DESIGN RATIONALE FOR FLUID

We outline in this section a number of design issues raised by FLUID, and evaluate the choices we made based on preliminary usability testing.

Objectives

Novice user interface designers have to develop expertise in the following basic design skills:

- judging the adequacy of their task knowledge and task analysis;
- recognizing implicit design decisions;
- anticipating user actions/concepts;
- relating observed usage problems to design alternatives;
- envisioning different design choices;
- understanding and balancing design tradeoffs; and
- managing the design process.

The first and last of these objectives are not addressed in the current version of FLUID. Our use of DSA highlights the other objectives for learners, because DSA requires explicit steps corresponding to each of those skills and the creation of an explicit artifact of DSA as a result. This mapping allows us to offer focused advice based on the DSA constructed at any point.

FLUID Conceptual Model

We based FLUID on the Goal Based Scenario concept of Schank and his colleagues [16, 1]. This approach combines principles of active learning, case-based teaching and expert tutoring. In the Goal Based Scenario architecture, learners experience the learning task through a *cover story* (e.g., you are a designer and your manager is giving you an assignment), a *mission* (e.g., design a way to manipulate the furniture in 3-D with a standard mouse) and a *focus* for actually doing the task (e.g., our Design Workbench).

We observed that FLUID users understood the context of their mission in terms of the cover story and got into their roles. However, we need to reinforce the cover story when they encounter the Workbench, since for typical students, the Tutorial and case Library are used after the mission description and before the Workbench.

FLUID Interaction Style

We incorporated in FLUID interaction elements to provide flexibility in learning styles. A Table of Concepts, still under construction, supports learners who want to develop an explicit conceptual model of the knowledge domain (learners can currently access a concept map of usability criteria, containing definitions and

⁵ The Scenario screen is not shown in this paper.

examples from published usability studies. Figure 5 shows one quadrant of the concept map).

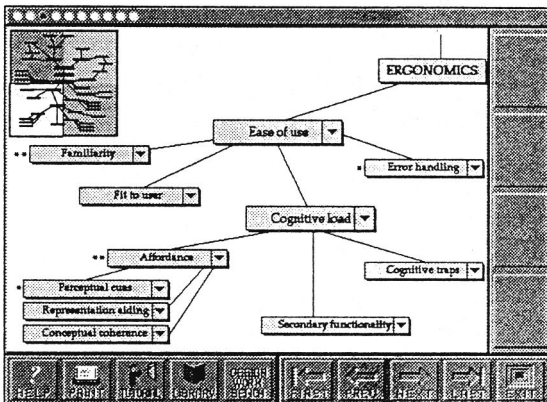


Figure 5. Quadrant of the Table of Concepts.

The Tutorial supports learners who prefer to observe and reflect before launching into a task on their own, and the case Library supports learning by example. In the HCI course, this structure also allows us to relate FLUID to other content: students later do a learning styles assessment and discuss its implications for supporting users with various learning styles.

The Tutorial and case Library appeared to provide users with the background information necessary for learning about DSA. All users explored both interaction elements, suggesting that perhaps these provide complimentary information rather than redundant information. No users referred back to these interaction elements during construction of their DSA in the Workbench.

Choice of Design Exercise

For the exercise which learners would work on, we wanted to adapt a published case study from an industrial environment, so that:

- empirical usage data would be available;
- the design exercise would be perceived as realistic;
- learners would become more aware of the professional literature; and
- learners could read the published paper to contrast the sanitized training wheels version with what actually happened.

We also wanted the design exercise to be novel for the learners, both for motivation and to avoid routine copying from an existing system. Finally, the exercise had to be non-trivial but not require extensive domain knowledge.

The published case study by Stephanie Houde [9] met all of these criteria. A scanned image of the paper is available in FLUID after learners complete the design exercise. The choice of another study to include as a worked case example was largely determined by this choice of design exercise. The study by Chen et al. [6] addressed a similar design problem but with different constraints (i.e., designing a new controller device in [6] versus designing a new way to use an existing device in [9], for similar tasks).

We found that users appreciated the concrete examples provided by both cases. However, there was no evidence that selecting cases from the same domain was advantageous, suggesting that our concern over similarity between cases may have been exaggerated.

Design Workbench

We are not satisfied with the separation between the design Workbench, where learners build a DSA for the exercise, and the other products of design such as the sketches they might make as they work out their designs. The Workbench manipulates DSA, not the entire design. We knew we would not be able to build a design toolkit and also integrate the instructional component, so we accepted the compromise of just developing the DSA Workbench and leaving learners to construct other design products in some other medium (the other activities learners should be doing in parallel with FLUID are described by the senior Designer in the Tutorial). We discuss in section 5 below some of the issues involved in creating a more capable Workbench.

None of the users expressed a need for more creative tools to express their design ideas, although one user took great effort to describe his design idea to the observers of his session with hand gestures. Other users made suggestions for improvement.

Providing Assistance

"For maximum learning to take place, the student should receive just enough of a push or guidance to get past the sticking point without being explicitly told the answer" [8].

It is possible to talk of a future system in which learner input is analyzed for natural content and an appropriate interpretation is made of the meaning of a design choice. There is no such intelligence in the current FLUID system. When users describe a new design Option, they are prompted to identify their choice from a list of

preset labels. This mechanism will fail if the list of available choices is not complete enough — i.e., FLUID does not anticipate the users' choices — or if the list presents choices the user has not yet thought of and thereby pre-empts some of the desired learning.

Through pilot testing we established the likely choices, and then structured FLUID to contain nested lists which expose further choices from 'Other' submenus. The final 'Other' submenu notes that the user has produced a choice not included in FLUID and requests feedback by email to the FLUID developers.

The successful aspect of limiting design Options was that users could eventually build an understanding of the set of Options and formulate a meaningful Issue for the DSA diagram. Issues were not constrained in any way, allowing users to create their own labels for each Issue. The well-constructed set of Options provided an opportunity to guide learning about Issues — from previous work, Issues are known to be a difficult concept to teach.

However, test users commented that they felt constrained by these anticipated design Options. With our initial test users, unanticipated Options generated during usage testing (e.g., a 3-D crane instead of the 2-D hands) could have been allowed without jeopardizing the rest of the design space.

There was great variability in use of characters' advice between users during construction of the DSA diagrams. Some users consistently asked for advice from the characters after each addition to the DSA diagram, while others only sought approval after their DSA diagrams were complete.

Roles for Advisor Characters

Ideally, each of the characters providing input in the design exercise should have a distinctive role, so that learners know who to ask for specific needs, and to provide context-sensitive help [8]. We tried to structure the on-line characters so that the DSA Tutor and project Manager provided generic help about the design process, and the Senior Designer provided specific help about the design domain (and occasional reflections on the role of DSA outside the training wheels setting). This proved to also be a useful distinction in terms of future generalizations of the system: for a new design exercise, the specific hints from the Designer would need to be changed but the Tutor's and Manager's video segments are reusable as is.

We observed that users recognized the differences in the type of advice offered by each of the characters. In general, users preferred the advice from the DSA Tutor for two reasons: the content of the advice seemed most applicable to their task, and the videos for this character tended to be the most engaging. Users consistently commented on the entertainment value of the video clips. These also appeared to be an important motivator for learners to continue to discover new information. However, we noted that in some cases the entertainment value may have been "too engaging" (see also [10]). In some instances the media novelty caused users to miss the important point in the content.

4. DSA AS TRAINING WHEELS FOR USER INTERFACE DESIGN

Issues as Design Dimensions

We found it necessary to emphasize the concept of design Issues in DSA as characterizing dimensions along which designers could look for alternatives. Making this explicit in the Tutorial helped clarify for learners the nature of an Issue in DSA. For example, at a key point in the design exercise, the learners must recognize that their conception of an Issue is too limited: seeing the Issue as "how are users shown selectable parts of an object?" precludes the idea of a manipulable box outside the object itself, which requires the more general conception of the Issue as "how are users shown how to grab the object?"

Role of Scenarios

We had previously found that usage Scenarios were a valuable addition to DSA [4]. Initially, the assumption was made for FLUID that we could easily map changes to the usage Scenarios into changes in the DSA diagram; in the initial FLUID versions this was the only way to change the DSA, to encourage learners to think in Scenario terms. Our assumption proved incorrect — sometimes a new design Option required several changes in the usage Scenario, sometimes a single change in the usage Scenario required alteration of several design Options. We now recognize that the usage Scenarios present a complementary view to the other DSA components. In the current FLUID, users can edit either the Scenario or the DSA diagram. FLUID detects most but not all of the required changes in the other component.

Alternatives Versus Options

We wanted to include usability testing as one of the steps in which learners would engage. Initially, we tried having learners select a set of

Options to present to the users, representing their choices on the various Issues. We found this approach was too abstract, and failed to convey that the design becomes more than just the sum of its parts (see also the point on decomposition below). The explicit notion of an Alternative system design was introduced to fill this gap.

Users were observed to struggle with the notion of an Alternative as a set of selected Options (one from each Issue). This may reflect a weakness in the Case Study and the Tutorial. This will be explored further with students in the HCI design course.

Implications of DSA Notation on Design Processes

As outlined earlier, we found that having to specify the advice to be given to learners in each process step forced us to analyze DSA as a theory of design. We had to develop general heuristics to guide the Tutor's video advice, independent of the particular exercise. For example, in one instance, the tutor says:

"If all your Options are unsatisfactory on a particular usability Criterion, try to identify a new Issue which groups these Options together and suggests a new design dimension to consider."

We also noted the assumption in DSA that an assessment on a specific Criterion can always be related back to the choice of a design Option. This assumption is suitable for the training wheels setting but oversimplifies the design space. For example, in [9] the Option of a hand-shaped cursor satisfies the Criteria of being natural and guessable initially. But once the Option of hands appearing on an object or box is chosen, the assessment of the cursor Options changes. Thus the assessments must be considered on the Alternative system design rather than just the individual Options. The closing section of FLUID uses this example to illustrate how the training wheels experience needs to be extended to cope with more complex situations.

5. CONCLUSIONS AND FUTURE WORK

We found that most learners who were introduced to DSA through FLUID were able afterwards to describe in their own words what DSA is. For example, one user said:

"DSA is a good tool for developing an outline of systematic Options and solutions for most scenarios".

In a pretest questionnaire, we asked test users to describe a previous interface design experience and the decision they made. After the session with FLUID, most were able to suggest ways DSA could have helped them during their design process.

The FLUID system raises questions about what it is that experienced designers know and how others might come to acquire that knowledge most efficiently. We designed FLUID to address particular difficulties which we knew our students encountered as novice designers, in the context of a typical computer science program. The knowledge we gained about DSA in the process of building FLUID was an unanticipated but welcome outcome.

We will be using FLUID in HCI classes in Guelph and Delft in the coming year, probably with pairs of students working together. Further design enhancements are anticipated as we learn more about teaching DSA in this way and more about the usability of FLUID. We have also agreed to distribute versions of the software to other educational institutions and some industrial groups, who agree to furnishing in return both their feedback and additional worked cases and exercises. In this way we hope to accumulate a larger body of exemplar cases. At some point this collection should reach a volume which requires support for learner access to the cases [11], but we do not envision needing this in the short term.

We are also generalizing the FLUID architecture to permit application to additional domains, both within and beyond user interface design. Within user interface design, the next skill to be taught is the design of an evaluation. Outside user interface design, we will be constructing instructional modules for the tasks of problem-based writing and of the role of a field biologist in the Arctic. The key element here is to allow users to engage with the design domain in a way complex enough to seem natural but simple enough to permit monitoring by the environment so that feedback and support can be context-sensitive.

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