**Session 2225**

# Reverse Engineering or Design Recovery: Two approaches to uncovering designing

**W. Michael McCracken, Wendy Newstetter**
**Georgia Institute of Technology**

Abstract

Many design problems are evolutionary and the need to uncover an existing design is an important part of the design process. Reverse engineering and design recovery are two terms that are often used to describe this process, but in fact the two have very different intentions. Reverse engineering or as we refer to it in this paper, product dissection, is an activity with the goal of recovering the mechanisms of an existing artifact. Design recovery is an activity with the goal of recovering the design processes that went into creating the artifact. Each of these are important elements of designing but we propose that design recovery is the activity students should engage in when learning to design. In other words, product dissection is one of the skills a designer may use in designing, whereas design recovery is a means of discovering design skills.

## I. Introduction

This paper describes the use of design recovery as a vehicle for teaching and learning designing. We use this technique in our introductory design class at Georgia Tech. The technique consists of the deconstruction of artifacts in a manner similar to product dissection[a], courses, but we use the deconstruction as an opportunity to focus the student's attention on the process of design. Unlike many introductory courses in design that emphasize product dissection, we focus on the process and not the product.

In this paper, we clarify the intentionality of product dissection and design recovery as very different vehicles for learning designing. The clarification goes beyond mere definitions buy

extending them into classroom practices and the outcomes of students' engagements in the practices. For this paper, we define product dissection as a process of deconstructing an artifact to discover its inner workings. We define design recovery as the process of deconstructing an artifact to discover the design processes used in its creation. Therefore, product dissection is artifact focused, and design recovery is design process focused.

Instructors often employ product dissection to introduce students to design problem solving. We claim that product dissection, though an important practice in itself does little to illuminate designing to students. An emphasis on deconstructing an artifact gives rise to many learning opportunities for the students. These may include, how the artifact is constructed, how it operates and in some cases, how successful the artifact meets its intended function. Product dissection classes also give faculty an appropriate opportunity to introduce teamwork, effective communications and the ethical issues of design.

What is missing in product dissection classes is the opportunity for students to learn designing as a cognitive activity that emphasizes design thinking. Our research in design learning[1,2] leads us to believe that students come to designing with a set of misconceptions that confound their learning (in whatever milieu) and those misconceptions have to be confronted and dealt with as early as possible. We want the students to uncover design processes and construct their own models of designing.

## II. Misconceptions of Designing

As we previously mentioned students possess a set of misconceptions that confound their learning of design, our work has analyzed in detail the misconceptions[2] and generated the theory of misconceptions of designing[3]. In this paper, we will focus on attacking some of the misconceptions via design recovery. We do not portend that design recovery is the solution to overcoming all of the misconceptions, but we feel it is an important initial step in the process. The misconceptions manifest themselves as student behavior and include:

1. Ideation without substance - Students believe design is coming up with good ideas. Obviously, design has as a constituent element, ideation, but designers also concern themselves with the realizability of ideas and evaluate ideas based on their informed decision-making and analysis.
2. Design arrogance - Students do not place their designs in the context of the environment in which the design will reside. They "arrogantly" ignore the constraints of the user (whether that is a machine or a person).
3. Design fixation - Students tend to focus on single point solutions to problems once beyond the ideation stage. In other words, once they have an idea, they stop considering alternatives and focus all their energy on that one solution regardless of its feasibility.
4. Extreme design - Students have a tendency to operate at only two levels of abstraction. The highest level of general ideas (function), and the lowest level of the structural properties of

the product. They do not move between these spaces in any formal manner, nor do they consider the ramifications of the giant leaps they are taking between those two levels of abstraction.

5. Design serialization - Students have a belief that design is a serial/ linear process, that is, iteration, revisiting past decisions, and evaluating alternatives is not in their process model.

Given that students possess the misconceptions how does product dissection or design recovery help overcome those misconceptions?

## III. Design Recovery and Misconceptions

Our technique is conceptually simple, but labor intensive. It is composed of four steps.

1. Recover the process of designing via an existing artifact. In other words, get the students to describe what the types of activity designers would have engaged in while designing the artifact.
2. Directly discuss with the students their misconceptions and how they color their view of the design space[a].
3. Develop and use models of designing as mechanisms to help students understand why and what they are doing.[b]
4. Apply their understanding of design processes to forward engineer a problem related to the recovered artifact.

The following paragraphs describe an instance of the application of the technique.

In the first class, we ask the students to recover the design of an existing artifact. The artifact is the 3.5" floppy disk. We introduce the floppy disk as a simple yet complex device. It is simple in its actual manufacture but it is technically a complex device with many constraints that often conflict with each other (e.g., durability versus manufacture cost). We ask the students to deconstruct the device and present a first cut at a design specification in the next class. We do not specify the problem more concisely than asking them to produce a specification of the floppy disk.

In the following class, the students present their designs in a pin up[c] session with the faculty member leading the discussion. The first design specifications presented by the students are enlightening (relative to their understanding of the problem). In general they will either present a high level functional specification or a detailed structural specification. We take the opportunity to examine their specifications from a design process view. That is, we are minimally concerned

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[a] We recognize that each student will likely have different misconceptions and interpretations of the design space. We are careful to not generalize a set of "principles" and blindly apply them to the class. The actual technique could be lightly construed as psychotherapy.

[b] It is important to note we are not referring to prescriptive methods of designing but to models that the students may adapt to their increasing understanding of designing.

[c] As an aside, one of the important process elements we are trying to develop in the students is design criticism, both self-criticism as well as criticism of other's designs. We use the studio pin up (borrowed from architectural studios) as a means of engaging students in design criticism. Our approach is to scaffold the learning of criticism over the semester.

with the specification's content, and maximally concerned with how and why they arrived at the specification. Here is an example of a conversation with a student in a recent class.

Instructor – So you presented us with a detailed drawing of the floppy disk.
Student – That's right. I took it apart and drew each of the individual parts of the disk.
Instructor – Why?
Student – I thought that is what a specification is.
Instructor – So what would your specification be used for?
Student – I guess so someone could build it, or maybe so someone could understand what it is made up of.
Instructor – Do you think dimensions might have been important?
Student – Oh, well you can just measure it if you need dimensions.

If we place the student's behavior in the context of misconceptions, it is quite enlightening. The student is exhibiting the characteristics of not understanding what design is and what it is all about. The dialogue reflects the student's design arrogance and extreme design behavior. Though we could assume that their lack of experience is the issue, we feel it is deeper than experience and is the manifestation of these conceptions.

With that entree we expose the students to SBF[3] models of design and initiate the dialogue that will continue through the semester on what designing is. The SBF models allow us to characterize the student's specifications, answer the questions of why such a specification should exist, what questions such a specification answers and most importantly, what are the processes that a designer must go through to develop a specification. Rather than talking about design processes in an abstract form, we use the artifact, its specifications and their growing understanding of design in a dialogical process to uncover what designing really is. The emphasis is on making concrete the tacit knowledge of design[4].

The process continues with the students over the course of several weeks revising their specifications and presenting them in class. These activities are supporting the understanding of design processes and tuning their evaluation skills via the criticisms.

We finalize this phase of the class by opening the design space with a forward engineering problem related to the recovered artifact. For example, we have asked them to design a disk carrier. Their job is to first decide what a disk carrier is, and the intended user(s) of such a device, and then to design it.

At the time of completing the design of their disk carrier, we find they are talking in the language of designers. They speak openly of constraints, structural, behavioral and functional attributes of their designs, and evaluation of alternative solutions. Though encouraging it would be fallacious to believe they are designers and free of misconceptions.

## IV. Product Dissection and Misconceptions

In reviewing the available literature on product dissection classes[5] it is apparent that there are several important goals of these classes. Just a few of those goals are; sketching, communications, team skills, materials selection, design for manufacturing, and design processes[5].

The typical problems in many dissection classes include an internal combustion engine, a bicycle, and a telephone. The dissection process consists of disassembly and then a description of the artifact and relating it to constraints or functional requirements.

A typical dissection class would consist of a design history of the artifact, a component overview, scenarios of use, an overview of the design process and the dissection itself.

## V. Comparing Product Dissection and Design Recovery

We propose a comparison not based on a measure of goodness, but based on a measure of intentions. If we wish a student to understand the workings of artifacts, how they are assembled, some of the decisions that went into their design, and some of the analysis techniques appropriate for the artifact, product dissection is the appropriate pedagogy. If we wish a student to understand the processes of designing, then we feel design recovery is the appropriate pedagogy.

We formed our opinions from four years of experience in evolving our introductory design courses and the research we have conducted on design learning. We originally used dissection as an entry point in our classes but discovered the students were not learning to design but were exhibiting the misconceptions we described in an earlier part of this paper. At the time, we did not recognize them as misconceptions but we identified the behaviors. As we continued the development and teaching of the course we became more focused on design processes and found the students were gaining design skills more readily. A part of our research we then focused on whether or not these behaviors were misconceptions. Once we identified them as misconceptions, we refined our techniques to directly address them.

## VI. Conclusion

We are not advocating the abandonment of product dissection courses. Dr. Sheppard's[6] work at Stanford and others have shown the importance of product dissection as a part of design learning.

We offer another view on design learning that is based on overcoming misconceptions of designing that students walk in the door with. We firmly believe that these misconceptions inappropriately influence a student's ability to learn designing and their design classes have to address them overtly. For example, if a student is behaving as an extreme designer (only thinking at either a high functional or low structural level) they need to experience a design space where they can change that behavior. That is, problems and the evaluation of those problems need to focus on why they need to be concerned with all levels of the design space, and how and why that is important rather than focusing on the artifacts generated at those levels.

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Michael McCracken
Michael McCracken is a Principal Research Scientist in the College of Computing at Georgia Institute of Technology. He is Associate Director of the Software Research Center and a faculty member of the Cognitive Science Program and the EduTech Institute. Mr. McCracken is a co-founder of the Design Learning Lab at Georgia Tech.

Wendy Newstetter
Wendy Newstetter is a Research Scientist in the College of Computing at Georgia Institute of Technology. She is a faculty member of the Cognitive Science Program and the EduTech Institute. Dr. Newstetter is a co-founder of the Design Learning Lab at Georgia Tech.