Misconceptions of Designing: A Descriptive Study

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ABSTRACT
Our experience in designing and teaching a cross-disciplinary freshman design class has led us to believe that students entering design fields (e.g., computer science or engineering) are saddled with naïve or (mis)conceptions about design and design activity. It is our belief that for students to become effective designers, they must be helped to recognize and overcome these misconceptions through appropriate educational interventions. To better understand the nature and substance of these misconceptions, we conducted a descriptive survey study of 290 freshman in a technological institute. Our findings begin to suggest a consistent profile of misconceptions across declared majors that start to explain observations we have made of naïve designers in our freshman design class. This paper reports on those findings.

Keywords
Design, design education, design cognition,

1. INTRODUCTION
The graduates of most computer science and engineering programs typically have design careers. Yet, too little attention has been paid to educating them in design processes [1]. With the advent of the United States ABET 2000 accreditation criteria for engineering programs, and the new emphasis on design in CSAB accreditation criteria for computer science programs, designing will be integral to most computer science and engineering curricula of the future. Before this can happen, however, it is vital that we understand the best methods for teaching design. We are concerned with the blind application of capstone type design courses to computer and engineering curricula. Capstone courses are intended to be integrative design experiences taught in the student's final year. There is an assumption behind such educational design experiences that students will learn good design practices just by undertaking one team project before they graduate. We believe differently. In fact, it is our contention that design learning, like much complex learning, is developmental and must therefore be integrated and practiced throughout the curricula. In addition, we believe and our experience has shown that computer science and engineering students bring naïve conceptions of design to such capstone experiences that covertly inform their design activities. Sometimes they are lucky and fall upon effective design solutions, but more often than not, they inadequately analyze the design problem so that in the synthesis phase we see failure.

In our research over the last three years, we have been investigating these naïve conceptions of design both through observation in our freshman design courses and more recently through a survey administered to 520 students in an introductory computer science course. The survey study is a preliminary attempt to clarify our understanding of student misconceptions about design, and confirm initially some of our hypotheses of the types of misconceptions students have on entry into a technical institute. This paper reports on findings from this survey targeting only 290 of the responses, which were those of freshman of various majors.

The first section of the paper describes the theoretical background of misconceptions and how it is relevant to designing. The second section defines the problem we were studying, and the third section details the results of our study. The last section summarizes our results, and proposes further research.

2. EMPIRICAL STUDIES OF MISCONCEPTIONS

In recent years, researchers in fields as different as engineering and architecture have investigated the differences between expert and novice designers (for example, [2]). The thrust of these investigations has been to identify how experts act upon and reason about design problems and how these processes differ from those of novices. As might be expected, differences do exist and the cause for such differences is generally assumed: expert designers have more experience doing design and more design cases to draw on, so they engage in activities that are more productive. We accept experience as a partial but incomplete explanation. Our research efforts have been focused on developing a more complete picture of the sources of novice and expert differences in designing.

A resource for our work has been cognitive science studies of expert and naïve reasoning. By and large, this research has analyzed children's naïve or (mis)conceptions about forces, motion, light, heat and simple electrical currents with the aim of uncovering the " substance of the actual beliefs and concepts held by children" [3]. Findings have shown that these misconceptions can be very robust and that changing them is very difficult. The explanation for this difficulty lies in the nature of the naïve conceptions themselves. Often learner notions of a phenomenon and those of a scientist are what philosophers refer to as incommensurable. This has profound implications for learning, for to align naïve conceptions with expert conceptions, a radical reordering or movement of the concept from one ontological category to another is required. As an example, students generally think of electric current as some kind of flowing fluid (object) rather than moving charges (dynamic state). With this conception, they are unable to understand how the intensity of a current is the same throughout the circuit. For conceptual change to occur, they have to shift from an object to a process account of electrical currents, which requires an ontological change in understanding.

Naïve conceptions, however, are not always as "theory-like" or robust as the one cited above. [4] characterizes these naïve conceptions as an "untidy, unscientific collection of meanings" that are not really theories but rather incoherent, disjointed and piecemeal. [5] suggests that these are less intractable and therefore changeable through direct refutation and overt contradiction and correction.

Our survey study begins to investigate the actual beliefs and concepts held by novice designers about the activity of design. Our experience with inexperienced designers leads us to believe that understanding naïve conceptions of design is critical in transitioning students to expert design activity. Thus our research agenda is to answer the following questions: What conceptions do naïve designers have of design? Is this conception consistent across ages and populations? Is this conception theory-like or piecemeal? How intractable is it? What are its sources? In the remainder of this paper, we recount the activities we have undertaken to begin developing preliminary answers to these questions.

3. PROBLEM DESCRIPTION

Our first insight into the issues of misconceptions of novice designers comes from our cross-disciplinary freshman design classes. The class is offered as an elective two-quarter sequence and is taken by 10-20 students per quarter. The class concentrates on students learning design processes by doing design. The problems for the class are purposely selected to minimize a requirement for extensive domain knowledge. Over the three years we have taught this class we have informally collected data on student's misconceptions. A previous paper [6] outlined our methods of assessment for this. One form of assessment we use called for students to develop concept maps of design activity. These maps collected over three years and our interactions with the students began to illuminate their misconceptions of design. The misconceptions manifest themselves as:

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.

From these anecdotal data sets, we developed a survey to more directly target student misconceptions. Our prior data collection techniques were potentially problematic. Our next obvious step was to target a much larger population, and reduce the potential for self-selection and population bias. We constructed a survey targeted at freshmen computer science and engineering students, to overcome our concerns with our previous data.

4. THE SURVEY

The survey was administered on-line to students who are taking CS1501, Introduction to Computing. The course is required of all CS majors as well as many of the engineering programs at Georgia Tech. The survey consisted of choice questions and free response questions. We had independent expert review of the survey, and ran a small pilot of the survey prior to administering it to the full population. The survey is available for review from the authors

4.1 Analysis of Survey Data

520 students responded to the survey. We analyzed the responses from the freshman students (290 respondents). The analysis included extraction of common themes from the free form responses and quantitative analysis of the choice responses. The analysis presented in this paper is based on a subset of the questions in Appendix A.

4.1.1 Examples of Designing

Question: *List five examples of what comes into your head when you think of designing.*

Our analysis of the data showed student responses falling into three categories. These included, product response, e.g., programs, fashion, web pages, or planes; domain response, e.g., mechanical design, interior design; or design activity, e.g., invention, or planning. Our coding scheme allowed for duplicate scoring if the student included product, process, and/or activity descriptions. The coding was not rater reliability tested. The following table summarizes the results of coding the responses.

Response Type	Response Score
Product	140
Domain	163
Activity	77

The results of this portion of the data offer several insights. As we expected, many of the students thought of design as products. In a culture that promotes commercial endeavors, we would expect answers to be informed by media driven notions of design. In contrast, those students who thought of designing as a process, primarily thought of it as a domain description, such as interior design, fashion design, architecture, or graphics. Interestingly, although they are at an engineering institute few of the respondents included engineering design in their lists, which may indicate they don't think of this as a design discipline. Finally, those who described design as activities generally only included activities such as brainstorming, ideation, or creativity. Few responded with normally accepted descriptions of design activities such as iteration, evaluation, planning, etc. The result is of concern as it relates to misconceptions. We find it significant that very few thought of engineering as design, and very few listed what expert designers would consider critical design activities in a free choice question. Finally, many of the respondents listed programming, and not program design or software design. We expected software type of responses since this is a CS class, and if our beliefs of misconceptions are true, then the programming response is appropriate. In other words, the students believe design and synthesis are synonymous.

4.1.2 Relevance and Lack of Relevance of Terms in Designing.

Two more questions in our survey attempted to probe student misconceptions by asking them to rank terms that describe design activities. The first question asked the students to rank from a list of sixteen terms the five they felt most accurately described designing. Similarly, we asked the students to rank from the same list the five terms they felt least accurately described designing. Each set of responses was tested for significance ($p<.05$) using a chi-squared goodness of fit test. The tables below summarize the answers from those two questions.

Top five most important terms describing designing

Ranking	Term Describing Design
1.	Understanding Problem
2.	Using Creativity
3.	Visualizing
4.	Brainstorming
5.	Making Decisions

Top five least important terms describing designing

Ranking	Term Describing Design
1.	Making Trade-offs
2.	Decomposing
3.	Synthesizing
4.	Generating Alternatives
5.	Sketching

We find it interesting and perhaps predictable that terms such as brainstorming, creativity, and visualizing are not activities discussed in most design process descriptions, see for example [3]. We suspect that these notions of design are carried over from high school activities related to writing instruction, and other creative activities. Although these are important in design, they are generally not considered the critical activities of effective design. What was most enlightening was the students responses to the least relevant terms, as they are generally included in most design process descriptions as critical.

These findings, in particular the least relevant responses, begin to explain our earlier observations of how misconceptions manifest themselves in novice design activity. As an example, design fixation could be explained as not understanding the value of generating alternatives, or possibly design arrogance could be explained as originating as failing to understand the decomposing of problems.

4.1.3 Design Problem Analysis

We asked the students to review two problems that characterized simple design processes, and score the problems on a scale as to whether the activities were "good designing". The first problem characterized designing in the form of our misconceptions (single point, fixated, ideated). The second problem characterized designing in the more accepted form (generation and evaluation of alternatives, iteration, etc.). The results of the students scoring of the problems was tested for significance to ensure the two problems were treated independently by the respondents. A paired sample t-test was run on the data with the results of that test in the following table which shows that the two answers were significantly different.

t-Test:Paired Two Sample for Means

	Problem 1	Problem 2
Mean	6.25172414	5.23103448
Variance	3.72534304	3.67308197
Observations	290	290
P(T<=t) two-tail	5.4545E-10	

Though statistically the data reflects little difference between the two responses, practically the results are quite interesting. The students were unable to recognize the differences between the two problems and were interestingly neutral in their scores for both. We can conjecture that the students observed the problem from a solution view. The problems and their solutions were purposely designed to be unexciting in their presentation to minimize the bias of the students picking the "coolest" design. Just as importantly, it is likely that they didn't perceive any differences between the two design scenarios, or they were unable to judge one better than the other. The fact that the judgements about both centered on the middle of the scale indicates indecision and uncertainty, whereas, data congregating on either the high or low end would have indicated a commitment to one design scenario or the other. This indicates to us the students' inability as novices to evaluate effective design processes from ineffective ones.

5. CONCLUSIONS

To be able to better integrate design throughout a computing or engineering curriculum, a deeper understanding of students' naïve conceptions of design is required.

Our goal in undertaking this descriptive study was to begin to better understand the actual substance of students' misconceptions of design. The preliminary results reported in this paper confirm our initial beliefs that we can begin to develop a catalog of students' misconceptions of designing and prescribe interventions to overcome those misconceptions. What we don't know is how robust or theory like these naïve conceptions are, which will make the challenge of learning good design practices more problematic.

We plan on undertaking further research to develop the catalog of misconceptions, in particular, of computer science students. With this kind of knowledge, we can design more effective educational interventions. We also plan on conducting longitudinal studies of subsets of the students we surveyed to understand how or if their misconceptions are being reduced, or modified, as they progress through their education programs.

6. REFERENCES

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