IDENTIFYING NEW DESIGN PROBLEMS: OBSERVATIONS FROM SENIOR UNDERGRADUATES

Young Mi CHOI
Georgia Institute of Technology, USA

ABSTRACT
A good body of literature exists that examines the process of problem solving as it is an important activity in many fields from design, engineering or management to name a few. Much less has been written about the process of identifying and articulating problems to be solved. This paper examines some of the challenges encountered by undergraduate students in the formulation of design problem statements based on observations of senior Industrial Design and Mechanical Engineering students in their final semester. Though the students come from different disciplines, they all encountered similar difficulties. Identifying a design problem and boundaries was a new experience for most students. It required students to synthesize and filter information from different knowledge domains. Human factors issues were observed such as cognitive limitations related to short term memory: the need to process a large number or variables simultaneously, and long term memory: efficiencies that can be gained though prior experience with a topic. The stress associated with the need to find a topic as well as the motivation level of individual students appeared to play a role in their success. These issues and other observations will be discussed in light of existing literature on the process of identifying problems.

Keywords: Design problem definition, design research

1 INTRODUCTION

The goal of this paper is to look at some of the issues encountered by undergraduates in identifying and defining a problem statement to be used as the basis for a design project. This is motivated from observation and student comments of the difficulty associated with this task. Much has been written on the process of solving problems. However outside of the field of management, little has been written about the process of identifying and articulating problems to be solved. While they share some similarities, the two processes are distinctly different.

A problem can be said to be made up of two parts [1]. The first is that there must be some unknown variable in a given situation. This unknown is the difference between a current state of affairs and the desired situation. The second part of a problem is that there must be some value in finding the value of the unknown variable. This simply means that solving for the unknown must be worthwhile in some way; otherwise there is arguably no actual problem to be solved.

The difference between the current and desired situation can be viewed in a few different ways. Mintzberg, Raisinghani and Theoret describe these as opportunities, problems or crises [2]. They describe a model to help improve the formulation process for all types of problems that is made up of four stages: Gap Identification/Problem Recognition, Problem Diagnosis/Formulation, Alternatives Generation, and Alternatives Selection. The first two phases are relevant to the topic of this paper. Problem Recognition is realizing that an opportunity, problem or crisis exists. In the Problem Diagnosis step, information that is relevant to the recognized issue is collected so that the problem can be more specifically identified. An interesting observation made was that when studying descriptions of organizational decisions described by the managers in the study, the authors found that an explicit problem identification stage to diagnose the issue was carried out for the majority of problem issues. Problem identification was explicitly carried out far less often for issues that were either opportunities or crises. A couple of reasons were suggested for this. In the case of opportunities, only an improvement to a current state is needed rather than some kind of correction. In the case of crises, time and cognitive pressures can discourage a formal diagnosis [3].

Getting a good initial formulation of a problem is of course also important in planning and design since it can have an effect on all design activities that follow [4]. Time must be dedicated to understanding the problem and issues to ensure that the eventual solution is appropriate and is not addressing the wrong or less important issues. Gathering all of the issues, identifying what is important and understanding the relationships between them can itself quickly turn into a very complex task.

As the number of variables involved in the problem increase the limitations of human cognition have an increasing effect. The number of items that can be considered at any one time is limited by the capacity of short term memory. In ideal circumstances without external stresses, pressures or other factors, short term memory can hold between 5 to 7 items at once [5]. Problems often involve more variables than this which means that one person will not be able to consider the entirety of a problem all at once. This can have obvious consequences to the way that a person formulates a problem. For example, while searching for information related to a problem during Problem Diagnosis, the determination of whether a new fact being considered is actually relevant to the problem at hand will be largely determined by the particular known factors of the problem that it is being compared with. A new detail that could actually be important may be discarded simply because known issues related to the problem weren't being considered at the time.

We know from human factors that knowledge stored in long term memory can help relieve the load on short term memory. This happens through a process known a chunking and happens all of the time. When you read for example, whole words are processed rather than each individual letter that make up the word. In terms of short term memory load, the word "something" would take up only one spot rather than nine. The specific sequence of letters "s-o-m-e-t-h-i-n-g" has a learned meaning. "Oemihtgn" would be much more difficult to remember even though it is made up of the same letters because it has no inherent meaning and remembering each letter is beyond the typical limit of short term memory.

Chunking happens not just with things like letters and words, but also with known situations or scenarios. The process of retrieving chunks of meaning from long term memory happens very quickly. The drawback in relation to either problem formulation or problem solving is that this only happens from knowledge gained from learned experience. As with the reading example, the more experienced one is with a particular subject or with dealing with certain types of problems, they will be better able to process issues related to a particular domain or scenario. One description of the differences in information processing based on experience is the Skill, Rule, Knowledge (SRK) model [6]. At the Skill level a person is able to react to the available raw information in an automatic manner to situations with which they are highly familiar. At the Rule level a person may be familiar enough with a situation to recognize possible actions and then follow a series of rules or scripts. The Knowledge level represents the least experience. At this level, a person must analyze all of the incoming raw information before even recognizing that there may be an issue to react to. Then an assessment of the desired goal and plan of action must be made before action is taken.

Although the SRK model describes problem solving, experience plays a similar role in problem formulation. At the least experienced level (Knowledge), many more variables must be considered and analyzed simultaneously. If there are more factors to consider than can be reliably held in short term memory, errors are more likely. With greater experience less raw processing is needed to recognize that there is a problem or actions that should be taken. This can be seen in the identification of management problems where managers are more aware of problems or certain types of problems through recognizing familiar patterns. However, the ability to recognize the patterns comes through personal experience and because of this and other reasons, is not something that is easily passed on to others in the organization [3].

The ability to identify problems is an activity that can be improved through experience, yet it is also a skill that is not necessarily taught formally. Designers and Engineers typically learn and practice their skills by solving well structured problems with defined boundaries. While useful in a class setting these do not always reflect the challenges of real world problems which often have less well defined boundaries. The following sections will examine some of the challenges encountered by undergraduate students in the formulation of design problem statements.

2 METHOD

Industrial Design (ID) students and Mechanical Engineering (ME) students were observed in the final design studio course required for graduation. The basic goal of both classes was similar: to identify and clearly state a design problem for which they would develop a functional prototype solution by the end of the term. Students in both classes experienced difficulties with the problem statement task in previous semesters so the goal was to try to identify some of the specific issues.

Projects from 37 total students were examined: 17 ID students each working on an independent project and 20 ME students (two teams of 5, two teams of 3 and one team of 4) with each team working on a different project. Data was collected from the course deliverables. For the ID students, the deliverables were three separate assignments related to problem identification. For the ME students, the deliverables were made up of the first of three reports along with weekly updates turned in by each team detailing progress and issues that were encountered.

There were some differences in how the two classes were organized. In the ID class, a special focus was placed on research and topic selection (the actual problem formulation phase) at the beginning for the semester before beginning typical design activities. These initial activities consisted of three main deliverables. The first was for each student to general topics of interest to them that would likely have an appropriate scope for a semester long project. The next two deliverables focused on gathering details of the issues and needs related to a specific problem of interest. The goal was to focus on one topic, define the boundaries of a related problem, identify stakeholders and gather their needs, investigate the market and competing products, and finally to define design success criteria. If a student's first choice of topic turned out to be a dead end they were instructed to immediately move to their next choice. This could happen in cases where needed information was not readily available or where addressing an issue would be beyond their resources. At the end of the first three deliverables, each student was responsible for producing a design statement that clearly described their problem, its importance and communicated the specific issues that would be addressed by their design solution.

In the ME class, the special focus was placed on the level of technical innovation provided by the functional prototype as well as the market potential of the solution. Students in this course worked on a mix of sponsored and un-sponsored projects. Sponsored projects consisted of a real world engineering design problem currently faced by company. These students could almost immediately begin solving the problem as it is already defined. Often only about half of the students get to work on sponsored projects due to the size of the class. The rest work on un-sponsored projects which are topics selected and defined by the students themselves. Students working on unsponsored projects provide weekly updates on the selected topic and problem boundaries as they are defined. The first of three reports is used to formally present the problem, its importance and implications, and design criteria which must be satisfied by a design in order to solve the problem.

3 OBSERVATIONS

Students in both classes who had to define their own design problem seemed to encounter some similar issues. The initial phase of listing areas of interest which we might refer to as Topic Research is of course necessarily general in nature. However, it should still provide enough detail to suggest a definite direction. One of the more difficult things for students to do at this stage was identifying topics that were specific enough to begin work. In the ID class, students were tasked with researching and stating 10 general problems they found interesting and to summarize the references they had found that described them. Some examples were:

- Due to the harsh and unpredictable weather outside; it's generally advised not to change DSLR camera lenses outside.
- A year after the devastating earthquake in Haiti, victims still struggle to survive often lacking proper nutrition, shelter and clean water.
- Cigarette smoke in the home is harmful and cigarettes are a leading cause of house fires.

The problems generated could be classified into three main groups. The first group consisted of problems that identified a fairly specific topic with some outstanding issue and where a number of potential design issues might be involved. These types of general problems were encouraged. Initial ideas that were extremely broad, such as the second example made up another group. In these cases there were undoubtedly problems which could be solved through the design of a product but they were too big to actually indicate any sort of direction. Attempting to solve the issue as stated would clearly be beyond a student's available time and resources. The last group, such as the third example, had a fairly specific focus but defined the problem in terms of economic or social problems. These problems might benefit from the design of a product but it was not clear what it might do or how it might even be approached in a single semester. The class was instructed to avoid topics that would likely require a large change to a society or directly changing a user's behaviour. This was done to try to get out of a 'change the world' mindset and more focused on topics with a more appropriate scope. Students with very broad ideas were instructed to go through another iteration of Topic Research to identify an issue that described a more tangible problem (similar to the lens example) either by narrowing the scope of one of their current topic ideas or by identifying a new one.

Once an appropriate Topic was identified, more detailed research was conducted to begin gathering more specifics and to develop a formal problem statement. The goal was to identify precisely what issue(s) would be addressed and why (and to whom) it is important. This is much like defining a research question. The students were given the following formula, adapted from Booth, Colomb and Williams [7] to help in structuring their statements:

1. Topic: I want to design a product to solve the problem ________
2. Issue: This problem is caused by __________
3. Significance: Solving this problem is important to _______ because _________

Assigned tasks during this phase were to specifically define the user group(s) and their demographics, determine specific user needs based on tasks and the use environment, identify user preferences and expectations, identify pertinent laws or regulations, and finally to understand market needs (competition, price, advantages/disadvantages of competing products). Students were encouraged to gather some of this data directly from end users if possible. All of this information combined to allow each student to state their problem, the specific issues and causes related to the problem that would be addressed and the importance of solving it for the end users. This phase might be called Detailed Problem Analysis lasted for two weeks. It was highly iterative; many students updated and refined the specifics of their problem statement multiple times during each of the two weeks.

The students from the ME class who had to identify their own problems ran into very similar issues. Initial problem statements were not specific but in a different way. In this case, instead of stating a very broad issue without much direction or other information, the problem statements tended to contain a lot of facts without convincingly defining an issue, such as the example below:

> Whether it is the ritualistic morning or afternoon pick me up coffee, many students and professionals are reaching for cups of coffee throughout the day. Coffee drinking Americans on average drink 3.1 cups per day, commuting, walking to class, or running errands and currently there are no mobile coffee sources to supply this need. We hope to propose a solution which will allow busy coffee drinkers access to coffee where and when they want it.

The statements that many people are on the go and that there are no mobile coffee sources seem to correlate but don't make a problem on their own. In fact the target users appear to be drinking a good bit of coffee already from some source. Though users and a scenario were described, no significance or impact to the user group is identified, and if it doesn't matter to anyone then any designed product would be a solution looking for a problem. The ME teams were given similar instructions for refining their problem statements as the ID students. In addition to the patent and market research tasks that were already built into the class, they were encouraged to spend more time researching the user group and use scenarios, including gathering data from actual target users.

A number of issues cited in literature were observed. Familiarity with a particular topic appeared to be quite helpful in formulating the final problem (i.e. the effect of Skill, Rule or Knowledge). One of the best examples of this was a student who designed a sustainable and locally producible school desk for schools in Haiti. This project was from the same student who listed the earthquake problem from the example earlier in the paper. In this case, the student had been personally involved in aid work in Haiti even before the earthquake. This provided more familiarity about things such as locally available materials as well as actual problems encountered within Haitian schools. In addition, the student had resources available in the form on contacts with members of the aid organization both in the US and Haiti. The student's own knowledge along with the ability to gather additional relevant data allowed the problem to be focused very quickly from impossibly broad to specifically focused on a significant issue to the target users.

In cases where the student was less familiar with the topic, the problem definition process typically took longer with more iterations/updates. An example of this is a student who designed an equipment butler for use in restaurant kitchens. The student began with no background knowledge. Different iterations of the problem statement reflected the changing understanding of the important factors related to the problem as they were discovered and the ways in which they were related.

In addition to gaining a good understanding of the problem, other factors appeared to play a role in the quality of the problem statement. Most students, particularly the ID students at the very beginning, were very anxious about being sure to pick the "right" topic. Among other things, this was because they would be working on the project for the whole semester and because they wanted to produce something of high quality for their final class. In a couple of cases students were unable to actually decide on a topic that they liked and were essentially assigned to a design problem. A couple of possible reasons were observed for this. First, the wide open nature of the task of picking a problem was overwhelming. Much like sensory overload, too many things to consider at once could have prevented them from being able to focus on a single topic long enough to refine it. Another possibility is the motivation of the student. Most were highly driven though others were content with doing the minimum required to get through. Much like satisfying when problem solving (where the first solution that satisfies the minimum requirements is taken), the same effect can happen with problem definition where only the very minimum of issues are uncovered or considered.

4 RECOMMENDATIONS AND FINAL THOUGHTS

An interesting difference between the ID and ME students observed is the way that the task of defining the problem was approached. Stereotypically one might say that the ME students took the approach of jumping as quickly as possible to making solutions before a problem was fully defined. It is impossible to say if this was the case. There is an important difference in the way that the tasks were presented between the classes. For the ME students the primary goal was in showcasing a technical solution at the end of the semester. From the outset, ME students generally treated most activities as problem solving opportunities. The ID students were presented with the same task but they were instructed to find a real world issue that represented a design opportunity. Much like a manager who may not spend the same time for a formally analyzing an opportunity or crisis as they would a problem, the way that the task was presented may have made it more difficult. The ID students were much more comfortable (and less stressed) once their problems were set and they were able to enter 'problem solving' mode to design a solution. It may be helpful to initially present problem definition strictly as a search for problems. Even if the goal is to identify design opportunities, the activities are similar and the semantics will make it seem more familiar.

In both classes there was a goal to be sure to cover important issues such as research methods, market analysis, patent searches, etc. While important focusing on particular topics in such a way may not necessarily help a student in their task of formulating a problem. Instead of covering specific topics on their own in the future, it might be helpful to present them within a framework primarily intended to help reduce the complexity of this task. MacCrimmon and Taylor described four strategies for reducing the complexity of problem diagnosis and formulation [8]. They are

- Determine the problem's boundaries
- Analyze changes in the decision environment that may have caused the problem
- Break complex problems into sub-problems
- Focus on the components of a situation that are controllable

With this in mind, a problem's boundaries will often cross disciplines and be defined by user needs, marketing or business realities, engineering constraints, etc. Attempting to define a problem by simply covering these topics in sequence may not be the most effective.

A wide open format where a student can choose anything they can think of may be much too broad for a first real encounter with problem formulation. Though picking a general problem of interest to refine seems simple enough, it is in fact quite stressful. A possible solution to this might be to provide a list of pre-defined topics to choose from. This would be similar to the approach in the ME class with sponsored projects, but the topics would still require the research steps to properly formulate them into workable design problems. This would give students a kind of initial boundary so that they won't have to search through an infinite sea of possibilities. Of course a list of topics would need to cover a wide range of subjects since students should ideally work on a topic of interest to them. This would take some effort to build as each topic would need to be vetted before hand for things like complexity, scope, etc. Another option might be to allow a wide open topic selection, but for a shorter duration project. This would help reduce the stress of picking the topic but would also lead to less complex design problems (which might not be appropriate for a capstone type course).

Finally, 'teaching' problem formulation requires a great deal of support and feedback from the instructor. Students were mostly eager and viewed the formulation process as a challenge. However, they can become easily frustrated, stuck or discouraged. This can easily lead to disengagement from a task which requires a lot of effort on their part for success.

REFERENCES

[1] Jonassen, D. (2000). Toward a Design Theory of Problem Solving. Educational Technology Research and Development, 45(1), 65-94.

[2] Mintzberg H, Raisinghani D. and Theoret A (1976). The structure of 'unstructured' decision processes. Administrative Science Quarterly. 21, 246-275.

[3] Schwenk, C.,Thomas, H. (1983). Formulating the Mess: The Role of Decision Aids in Problem Formulation. Omega, 11(3), 239-252.

[4] Volkema, R. (1983). Problem Formulation in Planning and Design. Management Science, 29(6), 639-652.

[5] Wickens, C., Lee, J., Liu, Y., Gordon Becker, S. (2004). An Introduction to Human Factors Engineering; 2nd Edition. Pearson Education, Upper Saddle River.

[6] Rasmussen, J (1983). Skills, Rules and Knowledge; Signals, Signs and Symbols and other Distinctions in Human Performance Models. IEEE Transactions on Syetems, Man and Cybernetics, 13(3), 257-267.

[7] Booth, W., Colomb, G, Williams, J. (2008). The Craft of Research. The University of Chicago Press, Chicago.

[8] MacCrimmon, K and Taylor, R. (1976). Decision Making and Problem Solving. In Handbook of Industrial and Organizational Psychology, M. Dunnette (ed). Rand McNally College Publishing Company, Chicago.