

The Influence of Resource Environments on Product Design and Prototyping: Case Studies from Mexican Universities

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Most technology policy recommendations for improving innovation capacity call for greater investment. A number of research studies on early stage design research have also advocated for greater investment of resources, asserting that building prototypes has a positive impact on student learning and design outcomes. However, there are many places where prototyping resources are limited, greater investment is not immediately feasible, and waste is a large concern. Are there design strategies that could help engineers improve outcomes and provide the highest quality solutions when greater investment is not possible? Could engineers and designers working in these settings actually have an advantage because they are forced to be more adaptable? What are potential implications for engineering curriculum and prototyping laboratory design in universities and firms with lower, equal, or higher levels of prototyping resources?

This research project aims to look at the economics of prototyping, specifically in the context of engineering programs in universities, and its effect on the design decisions and processes of students. This will be done using qualitative and quantitative methods, incorporating broader case studies of each campus and the results of a design experiment conducted with individual engineering students. This study could be conducted anywhere, but Mexico was chosen as the ideal location for this case study because there seems to be a larger range of prototyping resource environments than in the U.S. or developing countries. I chose to start data collection with a particular university system, because it has campuses across the country which have a similar engineering curriculum but variable access to resources.

The main questions this study will address are:

1. How does the prototyping resource environment that students learn in influence their design decisions and processes? (*Individual campus case studies*)
2. Assuming a constrained prototyping resource environment, how does the timing of information about the constraints influence early-stage design outcomes? (*Design experiment*)
3. Does the prototyping resource environment that students learn in influence their designs when they are put into a more constrained environment? (*Cross-case comparison incorporating findings from the design experiment*)

To address the first question, set the context and provide motivation for the experiment and the second question, I will employ a case study method, collecting data through a survey with students, interviews with students, professors, and laboratory technicians as well as site visits. I will use this information to develop a description of the *prototyping resource environment* at each campus. The prototyping resource environment is defined in this study as the combination of available physical resources such as tools and

materials, ease of access (or cost of “time” to obtain access), and culture (where the generally sentiment of a flexible or constrained environment could be caused by cultural factors, budget constraints or both). Given the constraints on data collection due to limited time and resources, this part of the analysis will lean towards a qualitative description of the similarities and differences between the campuses, rather than a detailed quantitative inventory of resources. The cases were selected to provide a large enough difference in prototyping environments so that the resolution of the data will have a negligible impact on the general findings. A case study method was chosen over a general survey because the aim is not to describe product design in Mexico as a whole, but to better understand the influence of the environment on individuals, and to provide a framework that others can adapt to their own setting.

The second level of the study is to look at how students react when they are prompted to design a product when they have limited prototyping resources to work with. The two variables in the experiment are the timing of when students receive information about the resource constraints, and the prototyping resource environment they are used to.

My goal is to use this data to plot the sketches (and by extension research variables) on a cost-benefit curve, which will be especially salient to my target audience, educators and designers who are looking to maximize the impact of limited resources. I will analyze the benefits using standard early-stage design research metrics such as the quantity and novelty of the designs. To reduce the potential effect of researcher bias, I will send out a survey to designers and engineers with experience in Latin America. They will be asked to rate each sketch on novelty, marketability, technical feasibility, appropriateness for the user, and clarity. I will also look at the relative costs for prototype development of the design concepts. This will be based on the materials and tools required to build the prototype, which students were asked to indicate, as well as size and complexity of the designs.

Regardless of what the results end up showing, it will be helpful for stakeholders to have a conceptual framework for evaluating how/if prototyping resources impact their students, in order to help them design laboratories and engineering curriculum. While my thesis is based on a small selection of case studies, it will hopefully provide a new systems model for the impact of resources on design outcomes that could be applied in a variety of contexts.