Development of a Questionnaire to Test the Impact of Scarce Materials on Design in Developing Countries

by

Edward Grinnell

Submitted to the Department of Mechanical Engineering in Partial Fulfillment of the Requirements for the Degree of

Bachelor of Science

at the

Massachusetts Institute of Technology

June 2011

© Massachusetts Institute of Technology 2010
All Rights reserved

The author hereby grants to MIT permission to reproduce and to distribute publicly paper and electronic copies of this thesis document in whole or in part in any medium now know or hereafter created.

Signature of Author ..........................................................

Department of Mechanical Engineering
May 10, 2011

Certified by ..........................................................

Maria Yang
Assistant Professor of Mechanical Engineering and Engineering Systems
Thesis Supervisor

Accepted by ..........................................................

John H. Lienhard V
Collins Professor of Mechanical Engineering
Chairman, Undergraduate Thesis Committee
Development of a Questionnaire to Test the Impact of Scarce Resources on Design in Developing Countries

by
Edward Grinnell

Submitted to the Department of Mechanical Engineering on May 10th, 2010 in partial fulfillment of the requirements for the Bachelor of Science Degree.

ABSTRACT

The objective of this thesis is to create a questionnaire that tests how designers in developing countries design with scarce resources. The questionnaire will be given to mechanical engineering students in Mexico and will ask them to design and sketch ideas for several products that would help physically disabled shopkeepers. However, each student must use only materials provided on a specific list to manufacture their products. The list of materials has very basic items like plywood, aluminum bars, and springs. Along with these materials, found objects were also added to the list of materials. These included things that can be found rather easily in a developing country like an iron or a tire. Making the students design using only these sparse raw materials and found objects should simulate designing in a developing country with limited resources. The questionnaire and materials list underwent several revisions before it was sent to Mexico, wherein American engineering students took the questionnaire and then gave feedback that was used to make changes to the questionnaire. After three rounds of revising, the questionnaire and materials list were finalized and then sent to Mexico where they were taken by engineering students at local universities.

Thesis Supervisor: Maria Yang, Assistant Professor of Mechanical Engineering and Engineering Systems
Acknowledgements

The author would like to thank Lisa Schlecht for her mentorship. Ms. Schelcht was consistently available for consults during the development of this questionnaire and provided information about the typical design conditions in developing countries.

The author would like to thank the brothers of Phi Sigma Kappa for their assistance in revising the questionnaire over several drafts. Each person who took the questionnaire had insightful ideas about beneficial changes that could be made.

The author would like to thank Professor Maria Yang for her advice and for her help in creating this thesis project.
# Table of Contents

ABSTRACT ................................................................................................... 2  
Acknowledgements ................................................................................. 3  
List of Figures .......................................................................................... 5  
List of Appendixes .................................................................................. 6  
Chapter 1: Introduction .......................................................................... 7  
Chapter 2: Background .......................................................................... 8  
  Developing vs. Developed Countries ..................................................... 8  
  Building with sourced parts ................................................................. 10  
Chapter 3: Thesis Objectives .................................................................. 13  
Chapter 4: Creating the Design Questionnaire ...................................... 14  
  First Questionnaire Iteration ................................................................. 14  
    Time Limit .......................................................................................... 14  
    Different Design Groups ..................................................................... 14  
    Developing the Initial Prompt .............................................................. 15  
  Second Questionnaire Iteration ............................................................ 16  
    Surveys and Questionnaires ............................................................... 16  
    Layout of the Questionnaire .............................................................. 17  
  Third Questionnaire Iteration ............................................................... 17  
    Changing the Prompt .......................................................................... 17  
    Reordering the Surveys ....................................................................... 18  
Chapter 5: Results of the Preliminary Questionnaires ........................... 19  
  First Questionnaire Iteration Results ................................................... 19  
  Second Questionnaire Iteration Results ................................................. 19  
Chapter 6: Creating the Materials List ................................................... 20  
  Materials First Draft ............................................................................. 20  
  Materials Second Draft ....................................................................... 21  
    Letting the Designers Choose Found Objects ..................................... 21  
  Materials Third Draft .......................................................................... 21  
    Changes to the Raw Materials ............................................................ 21  
    Changes to the Found Parts ............................................................... 22  
Chapter 7: Conclusions and Final Thoughts .......................................... 23  
References ............................................................................................... 24
List of Figures
Figure 1: Human Development Index of Countries in the World ..................................................8
Figure 2: Gross Domestic Product per Capita of the World, 2005 (in US$) .................................9
Figure 3: Countries of the World Shown as Developed or Developing ....................................10
Figure 4: A Guatemalan woman uses a pedal-powered grinder made from old bicycle parts ....11
Figure 5: A Guatemalan man pedals a bicycle powered water pump ......................................12
List of Appendixes

Appendix A. Design and Manufacturing Parts Kit ................................................................. 25
Chapter 1: Introduction

This paper details the steps taken to develop a questionnaire that tests how people in developing countries design products with limited resources. Being citizens of a wealthy country, American designers have access to a larger supply of raw materials and better equipment than designers in developing countries. Due to this difference, it is expected that designers in developing countries would use different methods than designers in wealthier countries. The goal of this project is to develop a questionnaire that allows researchers to take qualitative and quantitative data about the methods of designers in developing countries. This project will specifically discuss conditions in Mexico because this is where the questionnaire is going to be first implemented.

Chapter 2 presents the background material for this thesis. It describes all of the difficulties currently facing designers in developing countries and how these difficulties affect their design methods.

Chapter 3 discusses the objectives of this thesis and the specific requirements that the questionnaire needs in order to correctly simulate conditions in a developing country.

Chapter 4 describes the process of creating and revising the questionnaire.

Chapter 5 analyses the results of the three trial runs of the questionnaire and how they changed different features of the questionnaire.

Chapter 6 describes how the materials list that was used to simulate the scarcity of materials in a developing country was developed and revised.

Chapter 7 presents closing remarks and discusses what changes will be made to the questionnaire before being used in developing countries and proposes future steps for the questionnaire.
Chapter 2: Background

Developed vs. Developing Countries

While there is currently no universally agreed upon definition as to what defines a county as either developing or developed, the UN uses several different statistics to decide which countries it considers developed and which are developing. Life expectancy, education level, and per capita gross national income (GNI) are three such statistics. The UN takes these three statistics and uses them to create a Human Development Index (HDI) number for every country. The HDI is a measure of a country's standard of living and is used by the UN to decide which countries are considered developed and which are considered developing. The UN creates a list of all the countries and orders them by HDI and then splits the list into four categories. The countries with the highest HDIs are in the category “Very High Human Development,” and then in decreasing order of HDI, “High Human Development,” “Medium Human Development,” and finally “Low Human Development (Human Development Index (HDI) – 2010 Rankings).” The UN refers to the first category of countries (Very High Human Development) as developed countries and refers to the other three categories as developing countries.

Human Development Index (HDI)

Figure 1: Human Development Index of Countries in the World
Not everyone agrees with the UN's distinction however. Many believe that the countries with the highest income per capita should be considered developed countries. However, as seen in the map below, the countries with the highest GDPs per capita are also the countries with the highest HDIs assigned by the UN. Also the spread of GDP over the rest of the countries in the world seems closely correlated to the spread of HDI over the world.

Figure 2: Gross Domestic Product per Capita of the World, 2005 (in US$)

Even though these two examples use different criteria, they show similar results as to which countries are developed and which are developing. Even though the specifics of the matter are constantly in dispute, the generally accepted separation between developed and developing countries are shown in the map below.
Because there is such a large variation between the different levels of industry in developing countries, this thesis will mainly focus on Mexico. Because Mexico is a more advanced developing country, it will be easier to compare its conditions to a developed country like the US.

Building with Sourced Parts

Like most developing countries, Mexico doesn’t have the resources to spend on raw materials and newer equipment for manufacturing. According to the World Bank, Mexico’s GDP per capita is $8,143, while the US on the other hand has a GDP per capita of $45,989 (Report for Selected 2011). Since Mexico like most other developing countries doesn’t have the resources to support a large industrial force, most large scale manufacturing and industry in these regions is supported by funding from wealthier nations who want the benefits of cheap labor. To deal with this lack of resources, the practice of using found objects in designs has become common amongst designers in developing countries. By using objects that have already been manufactured to design new products, people in the developing world are able to lower costs of having to order fresh raw materials and buying expensive equipment.
The photo above shows a woman in Guatemala working a machine that grinds blue agave to make shampoo. The machine in the photo is mainly made of found bicycle parts reassembled to make a new machine. This is just one example of how people in the developing world are using found objects to create new, cheap, and useful machines. Bicycles especially are popular objects for making machines because pedal-power is so easy to find and because it is relatively easy to transfer the power from a bicycle to a useful output. The usefulness of bicycles in developing countries goes on to include applications like bicycle powered:

- Water pumps for irrigation
- Mills to grind corn
- Machines that manufacture concrete tiles
- Electricity generators that can charge car batteries
- Coffee pulping machines
- Trikes and trailers for transport
- Three cycle washing machines (Olson 2010)
Figure 5: A Guatemalan man pedals a bicycle powered water pump.
Chapter 3: Thesis Objectives

The goal of this thesis is to develop a way to gather quantitative and qualitative data about design in developing countries. In wealthy developed countries like the United States, designers have the luxury of readily available materials and easy access to sophisticated machinery. Designers in developing countries however, have to use limited resources and older and possibly even broken machinery when designing products.

This thesis attempts to create a questionnaire that simulates these conditions that exist in developing countries. The questionnaire calls for each designer to come up with and sketch possible products while only using materials from a provided list. This list of materials will be carefully controlled so that each designer will have enough freedom to create unique products and yet will still be sparse enough so that it accurately simulates the scarcity of materials that is native to developing countries.

Another aspect of the materials list is that it should contain found objects. One way that designers in developing countries deal with scarce materials is by using found objects in their designs. To properly simulate this however, it’s important that the found objects that are added to the list be things that are commonly found in the developing country. If some objects are too specialized then the results of the questionnaire might be skewed if all of the designers decide to use those objects. Finding the right amount as well as the right kinds of found objects is a crucial part of this project.

Deciding upon the time limit for the questionnaire is another important factor. The time limit should be short enough so that the designers taking the questionnaire feel a sense of urgency to complete it. A shorter time limit also allows for more questionnaires to be filled out in a shorter amount of time. However, the questionnaire should also be long enough so that everyone taking the questionnaire has sufficient time to complete it and brainstorm enough ideas. In the end five minutes were allocated for brainstorming physical disabilities, five minutes were allocated for brainstorming possible products to aid each disability, ten minutes were allocated for sketching out design ideas, and ten minutes were allocated for annotation and describing how the product would be manufactured from the materials in the list. This plan gives each designer thirty minutes to complete the questionnaire, not counting time to fill out the entry and exit surveys.
Chapter 4: Creating the Design Questionnaire

First Questionnaire Iteration

The goal of this thesis is to create a design experiment for mechanical engineering students in developing countries that will test their designing abilities. In the initial draft of the experiment, the designers (students) taking the questionnaire were asked to design a single product that would aid a physically disabled shopkeeper living in a developing country. The profession of shopkeeper was chosen because it is one that is highly recognizable to people in developing countries, and because the duties and responsibilities of shopkeepers are generally well known. Shopkeepers also perform a relatively large number of tasks on a daily basis (lifting, sorting, counting, interacting with customers, etc.) so there would be a large number of areas for potential products.

Time Limit

An appropriate time limit for the experiment was the first design factor set. In the first iteration of the questionnaire, the designers were asked to design only one product and then describe how they would manufacture their product using a list of provided material. We estimated that each designer would take about five minutes to brainstorm different physical disabilities that a shopkeeper in a developing country could have, five minutes to brainstorm different ways of aiding their chosen disability, ten minutes to sketch their design, and ten minutes to explain in a short paragraph both how their product works and how they would manufacture their product using the provided materials. These initial estimates resulted in giving the designers 30 minutes to complete the test.

Different Design Groups

One of the factors of this experiment is testing how the availability of materials affects the way that students design for a problem. In order to simulate designing with limited resources, the students taking the test were given a list of specific materials that they could use to design and manufacture their products. Half of the students would be given the list of materials at the start of the test and the other half would get the list of materials when half of the allotted testing time had passed. The test takers were split up into two groups in hopes that a difference would be seen between the products designed by the two groups. The designers who received the materials list halfway through the examination were expected to think of more creative physical disabilities and more creative products since they wouldn’t be constrained by the materials list when they were brainstorming. Then once these designers had their ideas in mind they would be able to pick one that could feasibly be made out of the materials provided.
When deciding the correct time to hand out the materials list to the second testing group, we also reasoned that the test takers would use about five minutes to brainstorm ideas and five minutes to brainstorm possible products. However, we decided to split the ten minutes of sketching time into one five minute segment without the materials list, and one five minute segment with the materials list. With this schedule, the designers would be able to use the first five minutes to begin sketching out what their chosen ideas could possibly look like and then use the second five minutes to finish sketching what their final design would look like when made out of the provided materials.

**Developing the Initial Prompt**

In the first iteration of the questionnaire, the prompt presents the problem to the designers in the form of a “role” that each designer should play. The first iteration prompt is shown below:

You are a newly hired product designer working for a firm on projects in developing countries. Your firm is interested in designs for new and innovative products that will aid physically disabled shopkeepers. Your task is to design and sketch a potential product that will aid a disabled shopkeeper in a developing country. You will be given 30 minutes and a list of raw materials that you will be allowed to use to build your design. Don’t stress over detail in your sketches but be sure to use only materials found in the kit for your designs. Make sure to designate what specific disability you are designing for and give a short description of how your product works. Good luck. (A good way to start is to come up with as many disabilities and products as possible and then narrow down your choices from there)

In this prompt, each designer is placed in the role of a product designer working at a firm that is trying to create innovative products for the developing world. The designers taking the questionnaire were placed in this role so that they would become more engaged in the questionnaire and hopefully brainstorm more creative ideas. The designers were also told to not stress about specific details of their designs because this iteration of the questionnaire was more focused on the creativity of each designers’ ideas rather than the specifics of how the products were put together. As long as the designers could explain which parts from the materials list made the different pieces of the product their idea was generally acceptable.

The last sentence of the prompt gives advice to each designer in the event that they hadn’t had much experience with product design before taking this questionnaire. While being developed, the questionnaire was given to students from different backgrounds and technical expertise. This was done to gain better perspective on what people besides mechanical engineers thought about the questionnaire. However, those people who weren’t from an engineering or designing background could have had trouble completing the questionnaire. To help these people, a short sentence of advice was given to them at the end of the prompt suggesting that they proceed in the direction that most designers would in the same situation (i.e. coming up with as many ideas as they can and then narrowing down their ideas from there).
Second Questionnaire Iteration

After finishing the first iteration of the questionnaire, it was sent out to several people in order to get feedback about what could be improved. The people who took the questionnaire were all male and also all college students, with most being mechanical engineering students, which was ideal because these students would have the most experience designing products. Those who took the questionnaire that were not mechanical engineers varied between computer scientists and aeronautical engineers. Upon receiving feedback, it became very apparent that several issues with the questionnaire needed to be resolved.

Surveys and Questionnaires

The first problem with the questionnaire that needed to be fixed was the method of collection data about each designer. The first questionnaire didn’t have a designated location for each designer to describe his or her own design background. The first questionnaire also didn’t have any specific questions asking the designers questions about the difficulty of the questionnaire or if they had any suggestions for improvements to the questionnaire.

To fix these problems, two different questionnaire sections were added to the questionnaire, one to be taken before reading the design prompt and one to be taken at the end of the questionnaire. The first questionnaire began by asking the designer what major they were studying in college, what year of college they were in, and what University they were attending. The next question asked each designer to list all of their previous experience designing and building prototypes. All four of these questions were aimed at gaining information about the experience level of each designer so that a correlation could be drawn between the design experience of each student and the quality of their product. The next two questions in the entry questionnaire asked the students to rank how strongly they used various methods of prototype building and information gathering when they designed products. Only those students who had actually done designing and prototyping before were able to answer these questions, but they still helped to gauge what methods each student who answered the questions used to go about designing their products.

The second questionnaire was supposed to be filled out when each student was done with the design questionnaire, and asked them to rank their feelings about several questions related to their designs. The questions asked them to ranks from one to seven how:

- Difficult was the questionnaire
- Frustrated did they feel during the questionnaire
- Confident did they feel during the questionnaire
- Satisfied they were with the outcome of their designs
- Engaged did they feel during the activity
- Whether or not they felt that they had enough time to finish the questionnaire
These questions were all asked in order to get feedback about the structure of the questionnaire. The answers to these questions became very helpful when developing the third iteration of the questionnaire. Following these questions were two more that asked the students whether or not this questionnaire would affect how they approached future design problems, and if they had any additional comments about improvements that could be made to the questionnaire. The first of these two questions was an attempt to see how the students felt about the realness and rigor of the questionnaire, while the second questions was more of an open ended question that was there to let the students express any outstanding ideas they had for the questionnaire that didn’t fit anywhere else in the surveys.

**Layout of the Questionnaire**

Another problem with the questionnaire was that many of the students taking the questionnaire didn’t know where there drawings and descriptions should go. To fix this, specific areas of the questionnaire were designated to be for the students to sketch their designs, for them to describe what their chosen disability was, and for them to annotate how their design worked and how it would be manufactured from the parts on the materials list. Denoting where their design should go greatly improved the neatness of the returned questionnaire s, and even improved the overall sketching quality of the designs and the amount of annotation that came with each design.

**Third Questionnaire Iteration**

After revising the questionnaire to make the second iteration, it was given to more people to take in another attempt to gain feedback about possible improvements. This time not all of the people taking the examination were male, however only about two of the fifteen people who took the second iteration were female. These people were again all college students, however, their majors varied much more than the last group. Instead of just mechanical engineers, computer scientists, and aeronautical engineers, the test group now had physicists, biologists, and even one student who’s major was hospitality. The feedback from this round of students revealed more problems with the second iteration of the questionnaire. However, most of these problems were issues of formatting and presentation, so not much of the questionnaire changed except for the number of designs asked for in the prompt.

**Changing the Prompt**

In the third iteration of the questionnaire, the prompt was split into three parts. The first of these three parts is presented on one page and explains to the designers that they will be participating in an idea generation exercise. It explains that the designers will be generating concepts of products from a constrained list of materials. At this point half of the prompts explain that the designers will receive the list of materials halfway through the questionnaire, while the rest of
the prompts explain that the designers will get the materials list right away. The first part of the prompt next explains that the designers must come up with three ideas instead of one and that they must choose one to explain how to manufacture from the materials list. The first part of the prompt ends by asking the designers to sketch every idea on a separate sheet of paper, to annotate as much as they can for each sketch, and that they will have thirty minutes to complete the questionnaire.

The second part of the prompt explains to the designers what kind of products they will be specifically designing. Before this page the designers had no information about what kinds of products they would be designing. They only knew that they would need to make three sketches of something and then annotate them. This page is where they can begin brainstorming ideas and is also when the thirty minute timer begins. Again this part of the prompt presents the designers with a role as a product designer working with a firm on products for developing countries, which was an attempt to make the questionnaire more engaging for the students.

The third part of the prompt only exists for the half of the designers who received the materials list after half the allotted time was over. This page explains that the firm the students are supposed to be working for has decreased funding to their project so they now need to only use materials from a specific list. This page of the prompt goes on to say that the designer may choose to go on with the three ideas they had before receiving the materials list, or choose to come up with entirely new ideas.

In this iteration of the questionnaire, the designers were asked to make three different sketches and then choose one to make a detailed drawing of and describe how to build using the materials provided. The reason for this change was largely in order to try to make the designers more creative with their final design by making them sketch out more than just the one idea. This iteration of the questionnaire also strongly told the designers to annotate as much as possible because there were many instances when running the questionnaire in the past that the designers hardly annotated at all, which made understanding their designs difficult.

**Reordering the Surveys**

In this iteration of the questionnaire, the physical order of the surveys in the packet of papers was rearranged so that the entry questionnaire was placed before the design prompts and the exit questionnaire was placed after the design prompts. In the second iteration, the prompt came before both of the questionnaires in the packet of papers. To get unbiased answers on the initial survey questions about methods of prototyping and brainstorming, the entry questionnaire was moved to be first in the questionnaire packet.
Chapter 5: Results of the Preliminary Questionnaires

First Questionnaire Iteration Results

After having several people take the first questionnaire, certain trends could be seen in the products that were designed. Most of the products that the initial group of designers came up with involved devices that lifted and moved objects for shopkeepers who were either in wheelchairs or in some other way unable to lift boxes of goods. Lifting and moving was a common theme in the first iteration results as there were forklifts, plastic grabber-arms that could extend and grip items, and wheelchair attachments that helped carry and maneuver heavier objects. One rather unique product was an analog to digital converting scale that when it was loaded with an object would extend a certain number tabs. By counting the number of tabs that extended, one could figure out how heavy something was.

Another interesting result of the first questionnaire's was the organization of the papers that were returned. Almost every one of the designers had a list of five to ten disabilities and possible solutions at the top of the questionnaire, which means they probably spent time brainstorming before they began designing or sketching parts. Noticing this trend was one of the reasons that the second iteration of the questionnaire had designated locations for the designers to write down brainstormed ideas and to sketch their ideas.

Second Questionnaire Iteration Results

The products designed in the second questionnaire iteration almost exclusively helped shopkeepers move or lift objects. There was a pulley system to lift heavy objects, carrying bags that attached to crutches, wheel chair extension bars to hold hangers of clothing, and a grabber arm to reach far away items to name a few. The majority of the people who took this version of the questionnaire were engineers, so expectedly, most of the sketching and annotating done on this questionnaire version was well done. The organization of the sketching and annotating however, was still a little bit erratic, which is why for the third iteration, the instructions are very explicit about where to sketch and annotate.

The surveys and questionnaires that were put into the second iteration of the questionnaire were extremely helpful when it came time to revise the questionnaire again, especially the open ended questions that asked for additional comments and how the designer felt about the questionnaire. The designers had suggestions for changes to the materials list, the amount of time allotted to the questionnaire, and also about the theme and setting of the role they were presented with at the beginning of the questionnaire. Most of the suggestions presented were useful and help with revising the second iteration of the questionnaire.
Chapter 6: Creating the Materials List

Materials First Draft

Deciding what materials to give the students for their designs was crucial to the experiment. The list had to be large enough to keep the designers from feeling constrained to the point that they couldn’t brainstorm any ideas, or to keep all the designers from having the same design. For the first draft of the list of provided materials, the previous year’s Design and Manufacturing class’s list of provided materials was used as a starting point and then materials and parts were added and removed over time.

The Design and Manufacturing class calls for students to use a kit of provided parts to build robots that compete in a competition at the end of the year. Their kit of materials had a large amount of stock parts like sheets of plywood, aluminum extrusions, and various rods and pipes. These kinds of materials seemed applicable to many different products, so most of them were kept for the experiment materials list. The next item on their list was wheels, which were kept on the questionnaire’s list to allow people to build things that moved. However, many of the wheels on the old list were small plastic wheels that mated onto servos. These wheels were removed since they would be rather hard to find in developing countries and were only useable with specific electric servos. The caster wheels that were in the kit were kept in the questionnaire’s materials list since they would be rather easy to find in developing countries and offered a significant amount of mobility. The old kit contained several different electric components like servos, microcontrollers, and DC motors. However, since these components would be expensive and difficult to acquire in developing countries, they were left out of the questionnaire’s materials list. All of the different kinds of springs from the old kit were kept in the questionnaire’s materials list, which included: extension springs, compression springs, torsion springs, and constant force springs. There were a large number of gears in the old kit; however, since motors and servos were removed from the materials list, only one of the larger gears was left in the questionnaire’s materials list in case someone wanted to use the gear with a hand crank or some similar mechanism. The remaining components in the old kit were various fasteners like glue, pop-rivets, and e-clips, which were left in the materials list since they are needed to build a variety of products. Besides these items that were found in the old kit, rope and pulleys were also put into the materials list because they would be useful to anyone trying to make a product that lifts objects.

In the first iteration of the questionnaire, there were no found objects placed in the list of allowable materials. This was done in order to gauge how people designed using only the raw materials that were provided in the old Design and Manufacturing kit. However, many of the people who took the first iteration felt that there were too many materials in list but not enough of the right kinds of materials. In other words they didn’t need four different kinds of sheet metal or five different sizes of tubing.
Materials Second Draft

The second draft of the materials list was much more streamlined and concise than the first draft list. All of the materials that were of similar type to other materials in the list were removed so that there was only one kind of sheet metal, pipe, etc. A few very basic found objects were also added to the materials list this time like plastic wrap, an electric fan, pots and pans, and light bulbs. The list of odds and ends and fasteners was also removed and instead the list just said that the designers could use whatever kinds of fasteners they wanted to assemble the various parts of their design.

Letting the Designers Choose Found Objects

In this draft of the materials list, the end of the list stated that the designers could use any commonly found objects in their designs as long as they explained what each item was and where they would find it. This was done in order to increase the flexibility that the designers taking the questionnaire would feel while brainstorming. As long as the objects they found were actually easily found in developing countries then it would be fine for them to use the objects in their designs. However, this was not the case, and a few of the designers used parts in their designs that wouldn’t be very easy to find in a developing country while others didn’t use any found objects at all. Because of these results, the statement was removed for the next and final draft of the materials list.

Materials Third Draft

A large number of changes were made to the second draft when it was revised to make the third and final draft. Many of these changes were suggested by the people who had made suggestions, however the parts that were added to the found objects section were all thought of in brainstorming sessions held by the authors.

Changes to the Raw Materials

Up to this point, the previous drafts of the materials lists had both the names of the objects and a small picture of each one. For this draft however, the size of the pictures on the page were varied so that larger objects would have a larger picture next to them. For example a picture of a piece of plywood takes up half a page, while a picture of rope only takes up an eighth of a page. This was done to give the designers a sense of scale of each of the objects. Also, the description of the size of each part was changed. In the second draft, dimensions were given to denote how large each part in the list was. However, several people who took the second iteration of the questionnaire stated in their comments section that not enough of certain parts were offered. To
fix this, the dimensions describing the size of parts were changed so that only the critical
dimension was told to each designer. For example, the tag under the plywood in the second draft
said that it was 16” x 16” x 3/8” while in the third draft the tag said only that it was 1/2” thick
(the thickness of the plywood was increased in order to allow for more robust products). Making
this change gave the designers the freedom to choose how much of the plywood they wanted to
use while still informing them that it is 1/2” thick.

The relative grouping of the materials was also changed in this draft. The pictures of the sheets
of raw materials (plywood, sheet metal, plastic sheet, rubber sheet) were placed on the same two
pages and put first in the list. The different kinds of bars and rods were placed on the same page
and all of the springs were placed on the next page. Organizing the materials this way was done
in order to help each designer order the materials into groups so that they would be easier to
remember and think of while designing.

Changes to the Found Parts

This draft of the materials list had a much larger found objects section. One of the designers that
took the second iteration of the questionnaire took apart the iron that was provided in the
materials list and used its heating element in her design. In order to allow other designers the
opportunity to do similar things with found parts, more kinds of objects were included in the list.
Some of the newly added found parts were a Walkman, a washing machine, speakers, and
various car parts. Besides these objects, a tarp, a hydraulic door closer, bungee cord, and a lawn
chair were all added in order to increase the number of possibilities for each designer.
Chapter 7: Conclusions and Final Thoughts

After three different revisions, the questionnaire and the materials list were brought to a level where they could be used to test actual students in Mexico. In the end more things about the questionnaire and materials list could have been improved, but due to time constraints a fourth revision was not possible. Some things that could have been improved more were the questions in the entry and exit surveys, the organization of where the designers were supposed to sketch and annotate, and the parts in the found objects part of the materials list. Also more testing could have been done with the time limit and the number of requested sketches. If the time limit were increased to forty five minutes then would each designer have been able to make five sketches instead of three, and if so would they be better than the three they could make in thirty minutes? Also, before the questionnaire can be used in Mexico it must first be translated to Spanish so that the students at the university can understand the instructions.

Overall, this was a very rewarding and interesting project. Designing questionnaires for designers presents a very unique set of challenges that were both difficult to overcome and interesting to think about. Observing the large variety of ideas and sketches that the designers came up with using the same materials was very interesting. Also, although many of the sketched products followed similar themes, no two were extremely alike, which is an excellent example of both how creative product designers can be and that there is usually more than one solution to a problem.
References

<http://www.theecologist.org/how_to_make_a_difference/recycling_and_waste/532101/reusing_bike_parts_to_power_water_pumps_corn_crushers_and_more.html>

## Appendix A. Design and Manufacturing Parts Kit

### 2.007 - Design and Manufacturing I

#### Spring 2009 Kit List

<table>
<thead>
<tr>
<th>#</th>
<th>Picture</th>
<th>Q</th>
<th>Item Description</th>
<th>SW File/Info</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stock (provided in storage container)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td>1</td>
<td>Plastic storage container (Rubbermaid Roughneck 14 gal 2212)</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>1</td>
<td>Captop - Digital</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td>1</td>
<td>Birch plywood - nominally 1/8 x 1/8 x 1/8&quot;</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td>1</td>
<td>6061-T6 Box Extrusion - 1&quot; x 1&quot; x 12&quot; - 1/8&quot; thick</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td>1</td>
<td>6061-T6 Box Extrusion - 1&quot; x 1&quot; x 12&quot; - 1/8&quot; thick</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>1</td>
<td>6061-T6 Box Extrusion - 1&quot; x 1&quot; x 12&quot; - 1/8&quot; thick</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td>1</td>
<td>6061-T6 Bar - 1/2&quot; x 1/2&quot; x 1/4&quot; thick</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td>1</td>
<td>6061-T6 Angle Bar - 1/2&quot; x 1/2&quot; x 1/4&quot; thick</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>2</td>
<td>Al Angle Iron 1&quot; x 1&quot; x 1/8&quot;</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>1</td>
<td>6061-T6 Rod - 1/4&quot; x 12&quot;</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td></td>
<td>2</td>
<td>6061-T6 Rod - 5/16&quot; x 12&quot;</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>2</td>
<td>560-H132 Sheet - 1/16&quot; x 1/16&quot; x 18&quot;</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
<td>2</td>
<td>2011 Hex Rod - 1/2&quot; x 12&quot;</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td>1</td>
<td>Inverted steel rod - 1/4&quot; 3/16&quot; 1/2&quot; length</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td>1</td>
<td>24&quot; Steel steps - 1&quot; x 0.5-0.5&quot; (not in container, too big, as needed)</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
<td>1</td>
<td>Steel Sheet - 18&quot; x 18&quot; x 1/2&quot;</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td></td>
<td>4</td>
<td>1/8&quot; diameter x 1/8&quot; welding rod (not in container, too big, as needed)</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td></td>
<td>1</td>
<td>Drivn Rod 1&quot; Diameter x 6&quot; length</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td></td>
<td>1</td>
<td>Drivn Rod 2&quot; Diameter x 6&quot; Length</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td>2</td>
<td>ABS Sheet 1/8&quot; x 1/4&quot;</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td></td>
<td>2</td>
<td>Small PVC pipe - 1/2&quot; x 10&quot; x 12&quot;</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td></td>
<td>2</td>
<td>Large PVC pipe - 1 1/4&quot; x 10&quot; x 12&quot;</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td></td>
<td>2</td>
<td>Square HDPE Bar 1/2&quot; x 1/2&quot; x 6&quot;</td>
<td></td>
</tr>
<tr>
<td>Wheels (provided in storage container)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td></td>
<td>4</td>
<td>Polypropylene Wheel 3&quot; x 13/16&quot; 1/4&quot; Axle</td>
<td>McMaster Part #</td>
</tr>
<tr>
<td>25</td>
<td></td>
<td>2</td>
<td>Low-Profile Castor Wheel 1-1/4&quot; X 9/16&quot;</td>
<td>McMaster Part #</td>
</tr>
<tr>
<td>26</td>
<td></td>
<td>2</td>
<td>Sotarobotics 2-5/8&quot; Diameter Servo Wheel</td>
<td>Sotarobotics Part #</td>
</tr>
<tr>
<td>Electrical (spares limited)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td></td>
<td>1</td>
<td>Parallax Homework Board</td>
<td><a href="http://www.parallax.com">www.parallax.com</a></td>
</tr>
<tr>
<td>28</td>
<td></td>
<td>2</td>
<td>Parallax Continuous Rotation Servos</td>
<td><a href="http://www.parallax.com">www.parallax.com</a></td>
</tr>
<tr>
<td>29</td>
<td></td>
<td>1</td>
<td>Hexa Standard Servo HS-311</td>
<td><a href="http://www.hitecrd.com">www.hitecrd.com</a></td>
</tr>
<tr>
<td>30</td>
<td></td>
<td>1</td>
<td>Hitec Low Profile Servo HS-77BB</td>
<td><a href="http://www.hitecrd.com">www.hitecrd.com</a></td>
</tr>
<tr>
<td>31</td>
<td></td>
<td>1</td>
<td>Hitec HS-805BB Mega 1/4 Scale Servo</td>
<td><a href="http://www.hitecrd.com">www.hitecrd.com</a></td>
</tr>
<tr>
<td>32</td>
<td></td>
<td>1</td>
<td>9V Battery</td>
<td></td>
</tr>
<tr>
<td>Springs (stocked in storage closet)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td></td>
<td>4</td>
<td>Constant force spring (small)</td>
<td>special order from Vacum</td>
</tr>
<tr>
<td>34</td>
<td></td>
<td>4</td>
<td>Compression spring</td>
<td>M604101</td>
</tr>
<tr>
<td>35</td>
<td></td>
<td>4</td>
<td>Extension springs (small)</td>
<td>M6044K4</td>
</tr>
<tr>
<td>36</td>
<td></td>
<td>4</td>
<td>Extension springs (medium)</td>
<td>M604890</td>
</tr>
<tr>
<td>37</td>
<td></td>
<td>4</td>
<td>Extension springs (large)</td>
<td>M6050369</td>
</tr>
<tr>
<td>38</td>
<td></td>
<td>4</td>
<td>Torsion spring (small)</td>
<td>M2713042</td>
</tr>
<tr>
<td>39</td>
<td></td>
<td>4</td>
<td>Torsion spring (large)</td>
<td>M2719039</td>
</tr>
<tr>
<td>Gears (stocked in storage closet)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td></td>
<td>4</td>
<td>Nylon spur gear, module 1, 12 teeth</td>
<td>Hitec Part #</td>
</tr>
<tr>
<td>41</td>
<td></td>
<td>4</td>
<td>Nylon spur gear, module 1, 24 teeth</td>
<td>Hitec Part #</td>
</tr>
<tr>
<td>42</td>
<td></td>
<td>4</td>
<td>Nylon spur gear, module 1, 30 teeth</td>
<td>Sotarobotics Part #</td>
</tr>
<tr>
<td>43</td>
<td></td>
<td>1</td>
<td>Nylon bevel gear, 24 diametral pitch, 24T</td>
<td>Sotarobotics Part #</td>
</tr>
<tr>
<td>44</td>
<td></td>
<td>4</td>
<td>Nylon bevel gear, 24 diametral pitch, 48T</td>
<td>Sotarobotics Part #</td>
</tr>
<tr>
<td>45</td>
<td></td>
<td>1</td>
<td>Length 12&quot; x 24 Diametral Pitch, 1/4&quot; Face, 1/4&quot; Height</td>
<td>Sotarobotics Part #</td>
</tr>
<tr>
<td>Long Bits (stocked in storage closet)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>46</td>
<td></td>
<td>as need</td>
<td>Spring pins</td>
<td>96290A133</td>
</tr>
<tr>
<td>47</td>
<td></td>
<td>as need</td>
<td>1/4&quot; Nylon bushing</td>
<td>63990527</td>
</tr>
<tr>
<td>48</td>
<td></td>
<td>as need</td>
<td>5/16&quot; Nylon bushing</td>
<td>63990526</td>
</tr>
<tr>
<td>49</td>
<td></td>
<td>as need</td>
<td>E clip for 1/4&quot; shaft</td>
<td>97431A300</td>
</tr>
<tr>
<td>50</td>
<td></td>
<td>as need</td>
<td>E clip for 5/16&quot; shaft</td>
<td>97431A310</td>
</tr>
<tr>
<td>51</td>
<td></td>
<td>as need</td>
<td>1/8&quot; Flat push-on retaining clips</td>
<td>984070A04</td>
</tr>
<tr>
<td>52</td>
<td></td>
<td>as need</td>
<td>1/4&quot; Flat push-on retaining clips</td>
<td>984070A02</td>
</tr>
<tr>
<td>53</td>
<td></td>
<td>as need</td>
<td>5/16&quot; Flat push-on retaining clips</td>
<td>984070A00</td>
</tr>
<tr>
<td>54</td>
<td></td>
<td>as need</td>
<td>1/8&quot; Washer - 3/4&quot; ID, 29&quot; OD, 054&quot;, 070&quot;, 097&quot;, Thk</td>
<td>96290A300</td>
</tr>
<tr>
<td>55</td>
<td></td>
<td>as need</td>
<td>1/4&quot; Washer - 292&quot;, 097&quot;, 094&quot;, 097&quot;, 070&quot;, Thk</td>
<td>96290A160</td>
</tr>
<tr>
<td>56</td>
<td></td>
<td>as need</td>
<td>5/16&quot; Washer - 3/4&quot;, 097&quot;, 094&quot;, 097&quot;, 070&quot;, Thk</td>
<td>96290A160</td>
</tr>
<tr>
<td>Odds n'Ends (stocked in bins)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>57</td>
<td></td>
<td>as need</td>
<td>1/8&quot; x 48&quot; Burns-N rod, 70 durometer</td>
<td></td>
</tr>
<tr>
<td>58</td>
<td></td>
<td>as need</td>
<td>3/8&quot; x 24&quot; x 1/16&quot; Burns-N shaft stock</td>
<td></td>
</tr>
<tr>
<td>59</td>
<td></td>
<td>as need</td>
<td>25' of braided nylon twine, 0.045&quot; dia, 95 lb strength</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td></td>
<td>as need</td>
<td>Alcohol wipers</td>
<td></td>
</tr>
<tr>
<td>61</td>
<td></td>
<td>as need</td>
<td>10 past epoxy packets</td>
<td></td>
</tr>
<tr>
<td>62</td>
<td></td>
<td>as need</td>
<td>Zip ties - 4&quot; length</td>
<td></td>
</tr>
<tr>
<td>63</td>
<td></td>
<td>as need</td>
<td>Cable zip ties mounts</td>
<td></td>
</tr>
<tr>
<td>64</td>
<td></td>
<td>as need</td>
<td>Rubber bands</td>
<td></td>
</tr>
<tr>
<td>Standard Lab Supplies</td>
<td></td>
<td>as need</td>
<td>Propagate as grown, others possible</td>
<td></td>
</tr>
<tr>
<td>as need</td>
<td></td>
<td>other supplies provided by Poppiardos staff as needed</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

25