The Design Development and Implementation Process for Assistive Devices

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&

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Workshop Goals

“The goal of this workshop is to present and discuss structured approaches to design, develop, and implement customized assistive devices. The presenters will focus on processes that leads the device development team (designers, engineers, healthcare professionals, and users) to clearly identify problems; define needs; create design specifications; research existing solutions; develop new solutions; evaluate multiple preliminary design concepts; fabricate and evaluate prototypes; and communicate results. Examples of each step will be presented.” - Goals stated in Workshop Proposal

• These processes apply to student design projects, design solutions for a single individual, and for general commercial product development in assistive technology.

• Workshop content suitable for both engineers and non-engineers.
Workshop Introduction

• What are your backgrounds?
  – Students
  – Engineers
  – Therapists
  – Educators
  – Users
  – Other
Modules

• Module 1 – Structured Design Process  25 minutes
  – Introduction to the Design Process – Allen
  – Brainstorming - Dave
  – Selecting Design Concepts - Dave

• Module 2 – Prototyping – Allen  10 minutes

• Module 3 – The Role of the User – Dave  10 minutes
What is Design?

- “...making something that has not existed before”  
  (Petroski)

- “...the process of applying the various techniques and scientific principles for the purpose of defining a device, a process or a system in sufficient detail to permit a realization”  
  (Norton)

- “To design is to invent... usually employing familiar elements in a new combination to accomplish a particular purpose”  
  (Ferguson)

- Using a structured process increases the odds of success
“Simplified Design Process?”
(Niku, 2009, Figure 5.1)
The Design Process

Identify the Problem

• Define the problem
• Identify the customers / stakeholders
• Identify resources including internal and external constraints
The Design Process
Understand the Problem

• Clarify goals and objectives
  • Incorporate users’ perspective and standards of care

• Gather information
  • WWW, library (research)
  • Product catalogs (existing products)
  • Benchmarking

• Team organization - who will do what?
The Design Process

Goal (Aim) Statement

• Exactly what are you trying to achieve?

• How will you know when you are done?
Example 1: Project Goal Statement  
(approved by Profs. Ault and Hoffman)

This project was originally proposed by the Rehabilitation Engineer at the Massachusetts Hospital School. Four WPI senior students spent 1/3 of their senior designing and building the device.

Design and build a battery powered modular mobility device for a 2 year old patient with quadriplegic cerebral palsy requiring pre-wheelchair independent mobility.

Where did we go wrong?
What We wish We had Said

Design and build a battery powered modular mobility device for the family of a 2 year old patient with quadriplegic cerebral palsy requiring pre-wheelchair independent mobility.
The Design Process

Design Specifications

• These define what your device (or system) must do and how it must perform

• The primary causes of design failures can be traced to faulty, inadequate or missing design specifications
Design Specifications

• Design specifications define what the system must do or be able to do.
• Design specifications **MUST** be measurable and specific
• All design specifications are not created equal.
  – Must be satisfied
  – Should be satisfied
  – Would be nice to satisfy
Requirements Checklist

Pick the categories that are relevant

- Performance
- Size, weight constraints
- Environment
  - during use, transport, manufacture, storage
- Ergonomics, safety
- Aesthetics, appearance
- Customer preferences
- Service life, reliability
- Cost
- Installation, disposal
- Manufacturing
  - available facilities, materials
  - quantities, product life span
  - testing
- Packing, shipping, storage
- Maintenance
- Standards
- Legal issues, liability, patents
- Time scale of project
- Market constraints
- Company policies

MUST HAVE
Functional Decomposition

A technique for decomposing any problem into smaller, more easily managed parts by working to understand the functions required of the device and/or user and treating each function as a separate subsystem.
Example 2
Functional Decomposition

A former senior design project involved a woman with Muscular Dystrophy who relied on an overnight caregiver only to assist her in transferring between her bed and her wheelchair. She desired to live independently during the overnight hours.
The Technical Problem

- To design a system to allow her to independently arise from her bed and access her wheelchair and vice versa.
- Function decomposition yielded a 43 step process which included her inputs and system inputs.
- Several commercial components were part of the system design.
Example 2 - Result

• In 2 of the 43 steps, her ability to provide the required system input was marginal.

• Meeting 95% percent of the functional requirements does not always guarantee success.
The Design Process

Ideate

• Idea Generation
  ❖ Morphological charts
  ❖ Brainstorming
  ❖ Others

• Develop multiple preliminary ideas
Morphological Charts
Design of a Table Lamp

(After Voland, 2004, Table 7.3)

<table>
<thead>
<tr>
<th>Desired Functions</th>
<th>Concept 1</th>
<th>Concept 2</th>
<th>Concept 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stability</td>
<td>Large Base</td>
<td>Weighed Base</td>
<td>Tie Down Straps</td>
</tr>
<tr>
<td>Adjustable Height</td>
<td>Flexible Neck</td>
<td>Sectional Design</td>
<td>Adjustable Legs</td>
</tr>
<tr>
<td>Lightweight</td>
<td>Use lightweight Materials</td>
<td>Use less Material</td>
<td>-----------</td>
</tr>
</tbody>
</table>
Module 1b - Dave

- Prerequisites for Brainstorming
- Brainstorming Design Concepts
- Selecting Design Concepts
Prerequisites for Brainstorming

• Identify the Problem
  – Ethnography, observation, discussion
• Describe the Problem
  – What, not how
• Understand the Problem
Understand the Problem

• Often called “Empathy”
• Find out as much as you can
• Talk to people with disabilities and older adults, family members, friends, neighbors, health care professionals, RESNA colleagues, researchers, engineers, product suppliers
Understand the Problem

- Research current solutions
  - Published research
  - Articles in popular media
  - Previous student projects
  - Input from users, healthcare professionals, computer listservs (RESNA AT-Forum)
Understand the Problem

• Research current solutions
  – What products currently address the problem?
  – What products are commonly used?
  – What is the standard of care?
  – You don’t want to reinvent what already exists or has already been tried

“Sometimes the only problem is a lack of awareness of a suitable existing solution.” Dave
Understand the Problem

• Determine why current “solutions” don’t work
  – Important to find limitations of current products:
    • High cost, weight, reliability, etc
    • Ineffectiveness
    • Non-compliance or non-use
    • Poor aesthetics, functionality, durability, fit
    • Does not take advantage of current technology

• Why a new solution may not work
  – “The old shoe is more comfortable.”
Define the Problem - 2

• Judge what is needed from a full understanding of the problem
  – Compose a written problem statement that includes:
    • Background
      – Information on the population affected
      – Information on the health condition
    • Problem – describe what, not how to solve
    • Aim – what project effort seeks to achieve:
      – Explore designs that address the problem
      – Not how to address the problem
    • Design criteria – basic capabilities of prototype
      – What is absolutely necessary?
      – What would be “nice to have”?
    • Other information
    • Links to current products, research literature
Brainstorming

• Also know as “Ideation”
• Rules: You can’t brainstorm alone
  – Defer judgment – do not critique
  – Go for lots of ideas
  – One person talking at a time
  – Be visual – draw something quickly
  – Build on ideas of others
  – Stay on topic
  – Express wild ideas, including suspending reality
    • What would they do in Star Trek?
    • Contemplate violating the Laws of Physics
    • Use Harry Potter’s magic wand
    • Use “The Force”
Brainstorming
Selecting Design Concepts

• Select best design concepts using a Pugh Chart
  – Plot design concepts vs features
    • Ability to meet objectives
    • Cost
    • Complexity (consider skill level of fabricators)
    • Ability to complete within allotted time and budget
    • Caregiver issues
  – Weights – which features are most important?

<table>
<thead>
<tr>
<th>Criteria for Success</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
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</thead>
<tbody>
<tr>
<td>Common Theme</td>
<td>7</td>
<td>7</td>
<td>49</td>
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<tr>
<td>Expands Knowledge</td>
<td>5</td>
<td>5</td>
<td>25</td>
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<tr>
<td>Accurate Info</td>
<td>9</td>
<td>8</td>
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<td>Appealing</td>
<td>8</td>
<td>6</td>
<td>48</td>
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<tr>
<td>Unique</td>
<td>10</td>
<td>9</td>
<td>90</td>
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<td>3 different forms of media</td>
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<td>9</td>
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<td>Reflects Rauschenberg</td>
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<td>7</td>
<td>28</td>
</tr>
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</table>

TOTAL: 402, 371, 388
Selecting Design Concepts

• Don’t forget aesthetics and coolness factor
  – Users won’t buy or use a product that identifies them as disabled
  – Users want to look cool
  – You want to work on something cool
## Selecting Design Concepts

<table>
<thead>
<tr>
<th>Concepts ⇒</th>
<th>Concept 1</th>
<th>Concept 2</th>
<th>Concept 3</th>
<th>Concept 4</th>
<th>Weight</th>
</tr>
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<tbody>
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<td>Criteria ↓</td>
<td></td>
<td></td>
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<tr>
<td>Cost</td>
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<td>0 / 0</td>
<td>3</td>
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<tr>
<td>Coolness</td>
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<td>0 / 0</td>
<td>5 / 25</td>
<td>5</td>
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<tr>
<td>Other criteria</td>
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<td>3 / 18</td>
<td>2 / 12</td>
<td>1 / 6</td>
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<td><strong>Totals</strong></td>
<td><strong>12</strong></td>
<td><strong>7</strong></td>
<td><strong>21</strong></td>
<td><strong>51</strong></td>
<td></td>
</tr>
</tbody>
</table>

“Everything is a prototype.” Dave
Questions and Discussion for Module 1
5 Minutes
Prototypes - An early physical or virtual embodiment of a design concept
Why Build a Prototype?

- **Learning**
  - Develop design ideas
  - Can/will it work?
- **Communication**
  - Users / customers, management, vendors
- **Integration**
  - Compatibility of subsystems
- **Milestones**
  - Demonstrate progress
Prototypes

- Are of lower quantity by definition
- Use stock shapes as much as possible
- Use easily formed materials
- Use purchased parts where possible
- Need sufficient accuracy to prove design
- Simple models often useful to prove principle
- Zero generation prototypes are valuable
- **Rapid Prototyping** is coming of age
Developing Prototypes

• 0 dimensions: Thinking, visualizing
• 2 dimensions: Sketching, CAD drawings
• 3 dimensions: Quick prototyping with low cost materials
• Critical function prototypes, failing fast, testing, analyzing, redesigning, fabricating
• Form, function, and aesthetics are all important
• Iterate until you & stakeholders are satisfied or decide to abandon the project (for now?)
0th Generation Prototypes

• Demonstrate only the most important features.
• Allow a better understanding of geometry issues and kinematics
• Crudely constructed
  – Popsicle sticks
  – Wood and duct tape
  – Legos, Knex’s
Example of 0\textsuperscript{th} Order Prototype

(Cane with a folding seat)
1\textsuperscript{th} Generation Prototypes

- Suitable for evaluation by the client. Generally a full scale working model.
- Evaluated using the same testing procedures as the final product.
- Demonstrates all but the least important functional features.
  - Aesthetics may still be lacking
  - Components may be of lower quality and durability than final product
Spray Can Holders

ES 1020 Prototypes
Other Resources for Building Prototypes

- Vocational Technical High Schools
- Maker Spaces
- Universities and Community Colleges
- Volunteer Groups
Where to get stuff?

• Hardware and lumber stores
  – Home Depot, Lowe’s

• Industrial suppliers
  – MSC, Grainger’s, etc.
  – 101 uses for duct tape
Questions and Discussion for Module 2
5 Minutes
Module 3
The Role of the User
10 Minutes

Dave

Who are the Users?
Testing and evaluation of prototype design(s)
Design Iterations
Who are the Users?

- Work **with** real users, clinicians, caregivers, healthcare professionals, mentors, experts, TAs throughout the process
  - You, your project team, and users have a very limited perspective
Roles of the Users

• Get input from family members, clinicians as well - to help identify and further understand the problem as well as evaluate a series of prototypes. This caregiver input is vital.

• Users certainly know the problem, but may not be helpful in identifying a solution due to lack of a full understanding of the capabilities and limitations of current technology.
Design Iterations

• Test with user, consider usability, get real data
• Test, measure, analyze, consider, iterate
Not Included

• What we didn’t cover:
  – Final testing
  – Aesthetics
  – Design for manufacturing
  – Patents
  – Getting a prototype to market
  – Product liability insurance
  – FDA approval
  – Medicare issues
  – Etc

*batteries not included*
Discussion Questions

15 minutes

in the future everybody will be world famous for fifteen minutes.
Backup Material

• Project Examples:
  – Allen – Cane with a Folding Seat (2014)
Enhanced Visibility Project

- **Background:** The WHILL Model A is a mobility device meant to give wheelchair users a sleek alternative to standard products, which often lack aesthetic appeal and thereby reinforce stereotypes of weakness or helplessness.

- **Problem:** While the WHILL has built-in lights that are designed into the rear wheel cover, they are insufficient to provide adequate visibility (to see and be seen) at night.

- **Aim:** Explore designs that will enhance the night time visibility of the WHILL and thereby increase user safety.

- **Design Criteria:** The design should:
  - not alter or permanently deface or damage the physical structure or operation of WHILL
  - integrate well with WHILL's appearance
  - provide forward illumination (like a car’s headlights)
  - enhance both side and rear visibility
  - automatically operate based on sensed ambient lighting
  - include a manual override
  - optionally include a light show mode
Enhanced Visibility Project

Explore designs that will enhance the nighttime visibility and safety of the WHILL.
Enhanced Visibility Project

Before

After
Cane with a Folding Seat
Cane with a Folding Seat
Contact Information

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