CAN DESIGN BE TAUGHT?

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Department of Mechanical Engineering
University of Minnesota
(www.me.umn.edu/labs/hmd/)

Haptic interfaces for virtual product prototyping,
smart knobs for cars

Rehabilitation engineering
- Tele-rehabilitation
- Stroke rehab
- Driving simulators

Human assist machines
- Compact power sources
- Powered exoskeletons
- Natural control

Medical device design
- Evaluation of surgical tools

Muscle mechanics

Stimulated Muscles = Power
Brace = Trajectory guidance
Brake = Control, stability

Smart orthotics + electrical stimulation
for gait restoration
Some provocative statements
(for an academic)

- Design **defines** the engineer
- Design **deserves its place** as a legitimate activity in a university
- Teaching design is **different** from teaching engineering sciences
- We don’t do a good job producing design **leaders**
- Faculty must **do** design
- I **enjoy** design
Face the facts

- Most of your students go on to industry
- Industry wants good designers
- Engineering sciences tasks are now done by specialists or computers
- You can’t do professional training in 4 years, so you might as well turn out some good designers
A successful design program requires:

- Buy-in from the top
- Buy-in/participation from a critical mass of faculty
- Faculty are rewarded
- Multiple opportunities for students (DaC)
- Industry/client participation
- Connections to research
- Access to resources
- A buzz
Typical design courses

- Intro to design (frosh/soph)
- Capstone design (senior)
- Projects in a course (all levels)
- Graduate product design
Design is...

- A process
- Ability to think about the system
- Ability to gather information
- Practical fabrication knowledge
- Planning
Basic design

- The sense of process
- Design thinking
- Basic design covers 99% of what is done in industry
- Focus on what can be done to help novices improve their design skills
- Advanced design includes optimization, axiomatic, genetic,..... that’s later on
Basic design process

- Understand the problem/need
- Ideation
- Selection
- Detail
- Build/test
- Envision the future
Learn design by *doing* design

A series of *creative, successful* experiences
Hands-on design

- Directly involve students in the process
- Binds analysis to actual
- Seeing what works reinforces the basics
- Gain respect for design process
SERIOUS PLAY
HOW THE WORLD’S BEST COMPANIES SIMULATE TO INNOVATE

THE ART OF INNOVATION
Lessons in Creativity from IDEO, America’s Leading Design Firm

Tom Kelley
with Jonathan Littman

foreword by Tom Peters
THE SIX ANTI-”HANDS-ON” ARGUMENTS

1. Costs too much
2. Classes too big to consider fabrication projects
3. Our machine shop can’t handle all the students
4. Not enough faculty
5. I don’t know how to teach hands-on
6. Difficult or impossible to grade projects
The old UMN MechE design program

<table>
<thead>
<tr>
<th>Level</th>
<th>Course</th>
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<tbody>
<tr>
<td>Freshman</td>
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<tr>
<td>Sophomore</td>
<td></td>
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<tr>
<td>Junior</td>
<td></td>
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<tr>
<td>Senior</td>
<td>Capstone design</td>
</tr>
<tr>
<td>Graduate</td>
<td></td>
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</table>
Areas targeted for IMPROVEMENT

- Introduce design earlier
- Hands-on design through fabrication/prototyping
- Design across the curriculum
- Opportunities for graduate students
- Links with other departments/colleges
- Involve local industry
- Improve resources for student designers
Highlights

- **Introduction to Engineering**
  - Freshman/sophomore

- **Design Projects**
  - Senior capstone course

- **Student activities**
  - Vehicle competition projects

- **New Product Design and Business Development**
  - Graduate level
Introduction to Engineering (1)

- Required 15-week course
- Art and practice of engineering
- Hands-on approach
- Introduce M.E. and a few basic skills
  Excite and retain students
- Minimal use of resources (staff, shops)

HANDS-ON AT LOW COST
Introduction to Engineering (2)

Skills:
- Communication (visual, oral, written)
- Fabrication/prototyping
- Information gathering
- Software (Pro/E, Excel,....)
- Estimation/analysis
- Innovation
- Project management

Disciplines:
- Forces and motion
- Energy
- Materials
- Manufacturing
- Mechanisms
Learning from everyday objects

Full cans are strong

Empty cans are not
Mechanical dissection
Participatory lectures
In-class critique
Visual communication
Sketchbooks
HOW to BRUSH your TEETH

1. 

2. 

3. 

4. 

5.
HOW TO MAKE A CUP OF COFFEE

WHAT YOU'LL NEED

PLACE FILTER IN FILTER HOLDER

STEP 1

STEP 2

FOLGERS

ONE SCOOP COFFEE

STEP 3

SPREAD COFFEE EVENLY, REPLACE HOLDER

STEP 4

FILL COFFEE POT WITH WATER

STEP 5

Pour water into back of coffee maker

STEP 6

Place coffee pot on burner, turn on.

STEP 7

When brewing stops, enjoy a fresh cup!

BILL KLEVE 10/13/98
HOW DOES A MECHANICAL PENCIL WORK?

FIRST LET'S LOOK INSIDE

- Sleeves (Metal)
- Spring
- Lead advancing mechanism (Metal)
- Lead guide (Rubber)
- Pencil tip (Metal)
- Tube - holds lead (Clear plastic)
- Pencil housing (Blue plastic)
- Eraser (Blue plastic)

LED COMES OUT HERE.

PUSH HERE
How A DC Drill Works

1. DC Motor.

2. Electric switch, activates motor, reverses polarity for opposite rotation.

3. NiCd rechargeable batteries.

4. Plug-in to charge batteries from an AC outlet.

5. Reverse button tells switch to reverse direction of rotation.

6. Drill chuck - holds drill bits.

7. System of gears - steel (hardened) in a ratio that has torque & speed.

8. Trigger - plastic - molded.


11. Case - injection molded plastic.

12. Ball bearing - metal.

13. Key holder.

Aaron Pickels
3-15-00
Presentations and reports
ME 1012 assignment 2

Beam Bending Experiment

Ron Boltik
1503021

Description of Experiment

This experiment involves a simply supported beam with a load at the center. Based on the load added versus deflection, and the physical characteristics of the beam, Young's Modulus can be calculated.

I setup my apparatus in the least likely of places, the back yard. I had a piece of lath that was 36 inches long. The soap dish and a glass resting on the toilet supported the other end of the beam with an empty water bottle. I suspended the beam from the center of the beam by a rubber band and hung it up with water 4 ounces at a time. I test trials with 4 ounces of water and record the deflection of the beam. I was only at about 9/16 inch when I stopped. I used a ruler to measure the deflection and a teaspoon of water.

Interpretation of the Results

The next page shows the results. I got approximately the same amount of deflection with the same load. I tried to fit a linear line to the data using the procedure of linear regression. My "r" value of .9981 is quite good. I do not know this material. Gere & Timoshenko, p.170 gives this range. I am quite satisfied with the results.

<table>
<thead>
<tr>
<th>Load (kg)</th>
<th>Deflection (in)</th>
<th>Young's Modulus (GPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.20</td>
<td>0</td>
<td>785.5 ± 12</td>
</tr>
<tr>
<td>0.75</td>
<td>0.3125</td>
<td>1024 ± 17.5</td>
</tr>
<tr>
<td>1.25</td>
<td>0.8275</td>
<td>1024 ± 17.5</td>
</tr>
<tr>
<td>1.75</td>
<td>1.3425</td>
<td>1024 ± 17.5</td>
</tr>
<tr>
<td>2.00</td>
<td>1.855</td>
<td>1024 ± 17.5</td>
</tr>
</tbody>
</table>

Material Characteristics

- Pine: 0.64215 GPa, 1.2168 MPa, 59.0020 ksi, 0.6149, 0.00441
- Oak: 0.72215 GPa, 1.4448 MPa, 92.0020 ksi, 0.6812, 0.00528

Graph:

- Linear regression
- Equation: y = 0.0965x + 0.0228
- R² = 0.9861
HOW TO EVALUATE AN ORAL PRESENTATION

This brief guide will help you to evaluate a presentation when the purpose of the evaluation is to assess the quality of the presentation itself, rather than to assess its technical content. In providing a critique, be gentle in your comments. Find at least two positive things to state before launching into a list of negatives. It does the speaker no good to be ruthlessly hammered on their presentation style to the point where they are fearful of presenting again. Also, remember that when you are on the receiving end, hearing constructive, respectful criticism is the best way to hone and improve your presentation skills.

In a good talk, the speaker understands his or her audience and the topic. The presentation is well organized, delivered so all can hear clearly, supporting visuals.

In evaluating the presenter's foundation for success:

<table>
<thead>
<tr>
<th>PRESENTER'S NAME</th>
<th>Delivery</th>
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</thead>
<tbody>
<tr>
<td>Poor</td>
<td>Made eye contact</td>
</tr>
<tr>
<td>Poor</td>
<td>Spoke to audience</td>
</tr>
<tr>
<td>Poor</td>
<td>Good posture</td>
</tr>
<tr>
<td>Poor</td>
<td>Good use of hands</td>
</tr>
<tr>
<td>Poor</td>
<td>Good vocal habits</td>
</tr>
<tr>
<td>Poor</td>
<td>Good introduction</td>
</tr>
<tr>
<td>Poor</td>
<td>Each point clear</td>
</tr>
<tr>
<td>Poor</td>
<td>Held my interest</td>
</tr>
<tr>
<td>Poor</td>
<td>Professionalism</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Voice</th>
<th>Art. Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>Varied rhythm of tone changed.</td>
</tr>
<tr>
<td>Poor</td>
<td>Proper speed: Not too fast...but not too slow either.</td>
</tr>
<tr>
<td>Poor</td>
<td>Text big enough</td>
</tr>
<tr>
<td>Poor</td>
<td>Cluttered</td>
</tr>
<tr>
<td>Poor</td>
<td>Helpful graphics</td>
</tr>
<tr>
<td>Poor</td>
<td>Good use of color</td>
</tr>
<tr>
<td>Poor</td>
<td>Did not “read”</td>
</tr>
</tbody>
</table>

Organizational skills:

- Each point clear
- Held my interest
- Professionalism

Overall:

- Each point clear
- Held my interest
- Professionalism

Comments:

- Varied rhythm of tone changed.
- Proper speed: Not too fast...but not too slow either.
From: "Kristi Bonin" <Kristi.A.Bonin-1@tc.umn.edu>
Date: Tue, 1 Oct 96 16:05:06 -0500
To: William K Durfee <wkdurfee@maroon.tc.umn.edu>,
    wulfman@me.umn.edu,
    James Holroyd <holr0001@gold.tc.umn.edu>,
    John F Macklin <John.F.Macklin-2@tc.umn.edu>
Subject: Assignment 1

Hi my name is Kristi Bonin and this summer i sold beer on a beverage cart
at a golf course by my home in White Bear Lake, Minnesota. I also had a gall
bladder operation at the end of the summer, that's it! I'm interested to
see if this course is really what i'm looking for in a major, we'll see.

John Sculley's new product is called Imaging for the Internet which
capitalizes on FlashPix. Nicely hidden!
DESIGN PROJECTS

- Need not be “serious”
- The more the better
- Students experience concept generation, selection, design/build/test
- Goal: Get students thinking like a designer
An aside on teams

- **Team skills**
  - Working with and appreciating skills of others
  - Managing a self-directed work group
  - Helps to train the teams

- **Teams are good…but you don’t have to do everything in a team**
An aside on projects

Made-up projects

These are OK!

Serious, client-driven projects

Must deliver

Results sometimes are serious (no matter what the marketing says)
Tools for building and testing

We loan them this
Distributed shops...build in your dorm

They can purchase this
Intro Eng design projects

Tower of Books

Tip-A-Can

Edible Scale
“Design and construct an autonomous machine that does something interesting for 45 seconds”

Rules

- Fits on 34 x 28 inch base
- Has at least one moving part
- Controlled by a microcontroller
- Costs no more than $30 beyond parts provided (microcontroller, motors, battery)
- Is safe
Robot project components

Plus.......$30 of your own parts

Garages, dumpsters, junkyards, “Ax-man” surplus
BASIC Stamp Microprocessor

- 8-bit
- 16 digital I/O lines
- Custom BASIC programming language
- Program retained after power off in EEPROM
- Develop code on any PC, link to Stamp via serial port
- Simple, inexpensive
Start out with

• Ideation
• Sketching concepts and designs...
1. HOLE DIA. TO FIT LED

2. ALUM. TUBE

3. FILL WITH HOT GLUE
The ideas get crisper...
CAN CRUSHER

When gear box begins to apply pressure on can, arm will swing down to dent the can.

Place can here.

Start button.

Conveyor driven by pulley system.

Gear box coupled to threaded rod.

Microswitch (reverse direction).

Stationary rods.

Stationary nut.

Thrust bearing.

Crush plate.

Trash.

Aaron Feckels
4-4-00
One week before...
LOTS OF ROBOTS!

THE FOURTH ANNUAL ME 2011 ROBOT SHOW

Wednesday May 3, 2:40-4:30 PM
Gateway Center
University of Minnesota

For the past six weeks, 210 college students in an introductory design course in Mechanical Engineering have been designing and building robots. Their task was to create a machine which “does something interesting”. The results of their efforts will be on public display at the Robot Show. It should be one of the largest collections of robots ever assembled in the Twin Cities and will be fun for kids of all ages. We invite you to join us for this exciting event. The Gateway Center is at 200 Oak St. S.E., Mpls, on the East Bank campus of the University of Minnesota. For more information please contact Prof. Will Durfee (625-0099, wkdurfee@tc.umn.edu)
Design Projects (ME4054)

- The benefit to companies: You get 4-6 very bright MechE seniors working on your project for 15 weeks for free. You come up with the project.
- The tax: No fee, but company provides a project advisor who meets with the student team at the University every Tuesday or Thursday afternoon for about 90 minutes
- New projects start each semester: Sept-Dec and Jan-May
- Details at www.me.umn.edu/courses/me4054
- Visit the Design Show: Tues Dec 14, 2-4 pm

Where else can you get smart engineers working on your project for free for 15 weeks?
Capstone design projects course

- Common expectations
- Focus on process
- Many industry projects
- Prototypes expected
- Juried Design Show
Student activities

- Vehicle competition projects
  - Solar car
  - Hydrofoil
  - SAE Formula race car
  - SAE Baja Buggy
- Independent / co-curricular
- Department support
  - Dedicated faculty
  - Seminar courses
  - Space
U of M Solar Car

- **Aurora II**
  - Sunrayce 95 (Indianapolis to Colorado, 1100 miles in 9 days): 2nd place
  - Fastest day (50.5 mph)
  - Best aerodynamics

- **Aurora III**
  - 35 students, 5 depts
  - $150K outside funding
  - Top speed: 78 mph
  - Sunrayce 97: 11th
  - World Solar-Car Rallye, Junior Division: 1st

- **Aurora IV**
  - Sunrayce 99: D.C. to DisneyWorld in 10 days
NEW PRODUCT DESIGN AND BUSINESS DEVELOPMENT

Business and engineering students join with industry to develop new products

www.npbd.org
WHY

- New products drive successful businesses
- Product development is more than design
- Faculty from several schools within the university interested in new products
- Need to train students in a multi-disciplinary setting
- New partnerships with industry
WHAT
• Graduate level course offered by CSOM, ME, BME
• Work with client firms to design a new product and create a business plan
• Teams of 4-8 grad students (1/2 business, 1/2 engineering) + faculty + marketing and engineering company reps
• Nine months (Sept - June)
• Deliverables: Working prototype, comprehensive business plan

FEATURES
• Real projects
• Companies commit to manufacture
• Cross-functional teams
• Engineers do marketing and vice-versa
• All patents assigned to companies
• All team members sign confidentiality agreements
• Strong university/company collaboration
## Projects (1995-2005)

<table>
<thead>
<tr>
<th>Year</th>
<th>Company</th>
<th>Technology or Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>1995</td>
<td>3M, Home and Commercial Care Division</td>
<td>2nd generation Twist 'N Fill container</td>
</tr>
<tr>
<td>1995</td>
<td>Toro, Consumer Division</td>
<td>Powered, hand-held gardening tool</td>
</tr>
<tr>
<td>1995</td>
<td>Micro-Medical Devices, Cleveland OH</td>
<td>Endoscope technology</td>
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<tr>
<td>1995</td>
<td>Reel Precision Manufacturing</td>
<td>New market hinge product</td>
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<tr>
<td>1995</td>
<td>Horton Manufacturing</td>
<td>Smart clutch/brake</td>
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<tr>
<td>1995</td>
<td>Irwin Publishing</td>
<td>CD-ROM textbook supplement</td>
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<tr>
<td>1995</td>
<td>Donaldson</td>
<td>Engine noise control product</td>
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<tr>
<td>1995</td>
<td>Molecular Diagnostics Lab, UMN</td>
<td>Blood collection system</td>
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<tr>
<td>1995</td>
<td>Aetrium, Inc.</td>
<td>Motion platform for Integrated circuit testing machine</td>
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<tr>
<td>1995</td>
<td>Spinal Designs International</td>
<td>Low-back pain care for people in wheelchairs</td>
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<tr>
<td>1997</td>
<td>Augustine Medical</td>
<td>Skin care product</td>
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<tr>
<td>1997</td>
<td>Horton Manufacturing</td>
<td>Web control product</td>
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<tr>
<td>1998</td>
<td>Soil Sensors</td>
<td>Next-generation soil moisture sensor</td>
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<tr>
<td>1998</td>
<td>Honeywell, Home &amp; Building Control</td>
<td>Residential ventilation system</td>
</tr>
<tr>
<td>1998</td>
<td>Select Comfort</td>
<td>Improved-comfort sleet system</td>
</tr>
<tr>
<td>1998</td>
<td>Sulzer Medica, Winterthur Switzerland</td>
<td>Hip surgery instrument</td>
</tr>
<tr>
<td>1998</td>
<td>3M, Stationery and Office Supply Division</td>
<td>Improved Post-it Flag dispensers</td>
</tr>
<tr>
<td>1999</td>
<td>Augustine Medical</td>
<td>Nursing home market for Augustine technology</td>
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<tr>
<td>1999</td>
<td>Medtronic</td>
<td>Catheter product</td>
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<tr>
<td>1999</td>
<td>Enhanced Mobility Technology</td>
<td>Biorehab product</td>
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<tr>
<td>1999</td>
<td>Lincages</td>
<td>Windows version of CAD mechanicsm software</td>
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<tr>
<td>1999</td>
<td>Shepherd Medical</td>
<td>Male contraceptives</td>
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<tr>
<td>1999</td>
<td>Rust Architects</td>
<td>Ice-palace cooler</td>
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<tr>
<td>1999</td>
<td>Sulzer Medica</td>
<td>Arthroscopy product</td>
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<td>2000</td>
<td>SpineTech</td>
<td>Artificial disk product</td>
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<td>2000</td>
<td>EnduraTEC</td>
<td>Tissue test grips</td>
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<tr>
<td>2000</td>
<td>Scimed</td>
<td>Smart catheter product</td>
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<tr>
<td>2000</td>
<td>Medtronic</td>
<td>Visible Heart CD-ROM</td>
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<td>2001</td>
<td>Andersen Windows</td>
<td>Novel window technology</td>
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<td>2001</td>
<td>Hormel Foods</td>
<td>Food safety sensor</td>
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<tr>
<td>2001</td>
<td>Introspective</td>
<td>Medical catheter</td>
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<tr>
<td>2001</td>
<td>Geodigm</td>
<td>Dental scanner</td>
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<tr>
<td>2001</td>
<td>Medtronic</td>
<td>Electrode impedance monitor</td>
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<tr>
<td>2001</td>
<td>VivaCare</td>
<td>Emergency call system</td>
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<td>2002</td>
<td>3M</td>
<td>Multifunction electrode</td>
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<td>2002</td>
<td>Newco</td>
<td>EEG biofeedback</td>
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<td>2002</td>
<td>Comedicus</td>
<td>Imaging in the pericardial space</td>
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<td>2002</td>
<td>Hearing Components</td>
<td>Soundproof headphones</td>
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<td>2003</td>
<td>Pando</td>
<td>New sports field technology</td>
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<tr>
<td>2003</td>
<td>Medtronic</td>
<td>Visible Heart technology</td>
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<td>2003</td>
<td>Scimed</td>
<td>New catheter product</td>
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<td>2003</td>
<td>3M</td>
<td>Smart electrode product</td>
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<td>2003</td>
<td>Probus</td>
<td>Timers and nightlights</td>
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<tr>
<td>2003</td>
<td>3M</td>
<td>Wound care product</td>
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<tr>
<td>2004</td>
<td>3M</td>
<td>DVT prevention</td>
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<tr>
<td>2004</td>
<td>Arctic Cat</td>
<td>Snowmobile accessory</td>
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<tr>
<td>2004</td>
<td>IMI Vision</td>
<td>Food dispense machine</td>
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<tr>
<td>2004</td>
<td>Pneumedics</td>
<td>Device for controlling surgical bleeding</td>
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<td>2004</td>
<td>Unisys</td>
<td>Security application</td>
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<tr>
<td>2004</td>
<td>Venturix</td>
<td>Ablation catheter</td>
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<td>2005</td>
<td>Medtronic</td>
<td>Lead implant device</td>
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<tr>
<td>2005</td>
<td>IMI</td>
<td>Fluid power</td>
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<td>2005</td>
<td>Tennant</td>
<td>Cleaning product</td>
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<td>2005</td>
<td>Devicix</td>
<td>Spine surgery</td>
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<tr>
<td>2005</td>
<td>StarFire Medical</td>
<td>Aneurysms</td>
</tr>
<tr>
<td>2005</td>
<td>Pando Technologies</td>
<td>Sports training</td>
</tr>
</tbody>
</table>
OUTCOMES

• 45 projects, 36 companies since 1995
• 5 patents, several commercial products
• 200+ students, 8+ faculty

SELECTED COMPANIES
Medtronic, Scimed, Honeywell, 3M, Comedicus, Geodigm, Hormel, Andersen, EnduraTEC, SpineTech, Augustine, Sulz
Select Comfort, Horton, Spinal Designs, Aetrium, Donaldson, RPM, Toro
FLAG RINGS

Flag dispenser for office desk drawer.
(in paper clip holder)

Flag dispenser taped on velcro

Self-forming dispensed

You fold & line tabs on the display cardboard cabinet...to make this really neat.

Flags/Notes -- for Book Lover

How to get away

Flag dispenser

Flag holder slips over your pencil

Post-it® Bookmarks 50 + a few flags & notes
PROJECTS

- Careful selection
- Known area, but not completely defined
- Business challenges
- Engineering challenges
- Typically mechanical, electromechanical
- Many medical products
- 4-6 projects/year
LESSONS LEARNED

- Engineering and business must lead program equally
- Creating appropriate agreements takes time and effort
- Requires didactic component on product development process
- Advantage if company is nearby
Some final words

- Protect hands-on
- Multiple opportunities for students
- Reward your faculty!
It’s worth it because...

We have bright, energetic students who are ready to be challenged and who are turned on by design!
Bot show
That’s all folks!