Introducing Students to Engineering Design through the Sophomore Clinic
## The Engineering Clinics

<table>
<thead>
<tr>
<th>Year</th>
<th>Fall</th>
<th>Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Freshman</strong></td>
<td><strong>Spring</strong></td>
</tr>
<tr>
<td></td>
<td>Intro to the profession Measurements</td>
<td>Reverse engineering Statistics</td>
</tr>
<tr>
<td></td>
<td>(2 CR)</td>
<td>(2 CR)</td>
</tr>
<tr>
<td>Sophomore</td>
<td>Intro to design Technical Writing</td>
<td>Engineering design Public Speaking</td>
</tr>
<tr>
<td></td>
<td>(4 CR)</td>
<td>(4 CR)</td>
</tr>
<tr>
<td>Junior</td>
<td>Sponsored projects (2 CR)</td>
<td>Sponsored projects (2 CR)</td>
</tr>
<tr>
<td>Senior</td>
<td>Sponsored projects (2 CR)</td>
<td>Sponsored projects (2 CR)</td>
</tr>
</tbody>
</table>
Sophomore Engineering Clinic

- Technical Writing & Public Speaking
- Engineering Design
- Team taught by engineering & communication faculty
- Two 75-min writing classes and one 3 hr lab per week
- Semester-long design projects
Diverging-Converging Model

- Published by Dym, et. al., 2005
- Models design as alternating series of diverging and converging steps
  - Divergent thinking is generation of alternative solution strategies.
  - Convergent thinking is zeroing in on a “right” or “best” answer.
  - Typically engineering courses emphasize convergent thinking
Design and build truss that will support at least 420 pounds lifted to height of 24 inches and return to starting location.
Successfully lifting 1400 lbs
Failure at 1400 lbs
Project Grading

“Technical Merit”: 20% of course grade

$$Performance = \left( \frac{W}{420} \right) \left( \frac{3.5}{LCA} \right) \left( \frac{435}{PW} \right) \left( 1 - \left| \frac{t_m - t}{t} \right| \right)$$

W=Weight, LCA=Lifecycle Score, PW=Present Worth, t=actual lift time, t_m=time measured by team

Written deliverables:
Individual progress reports (10% course grade)
Team final report (20% course grade)
Observations from 2003/2004

- All 47 teams lifted at least 420 pounds, over 75% lifted 1400
- Over half of Progress Report #1 didn’t even mention performance equation, yet many stated a final design had already been chosen.
- Important decisions made without quantitative analysis, and often never revisited despite faculty feedback.
- Good knowledge of statics and failure analysis, but not always used to inform decisions
Diverging-Converging Model

- Published by Dym, et. al., 2005
- Models design as alternating series of diverging and converging steps
  - Divergent thinking is generation of alternative solution strategies.
  - Convergent thinking is zeroing in on a “right” or “best” answer.
- Rowan sophomores were good at both but not at connecting them
Changes for Fall 2005

- Add a 4 week startup project on bottle rocket design

- Design reports for both projects refer explicitly to diverging-converging model of design
Bottle Rocket Design Project

- 2-L soda bottle
- Water propellant
- Clay on front
- 3 wings made of foam board
Rockets launched at 45 degrees using pressurized air. Unlimited test launches over three lab periods. Goal: Maximize perpendicular distance travelled.
## Student Evaluation of Course

<table>
<thead>
<tr>
<th>Question</th>
<th>2004</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>This course assisted me in developing teamwork skills</td>
<td>3.82</td>
<td>4.32</td>
</tr>
<tr>
<td>This course assisted me in developing multidisciplinary engineering design skills.</td>
<td>3.70</td>
<td>4.06</td>
</tr>
<tr>
<td>This course assisted me in developing project management skills.</td>
<td>3.93</td>
<td>4.24</td>
</tr>
<tr>
<td>This course helped me make the link between engineering design and writing.</td>
<td>3.89</td>
<td>4.02</td>
</tr>
</tbody>
</table>
Comparison of 2003-2005 cohorts
Sophomore Engineering Clinic II

- Spring 2005 and 2006 offerings featured:
  - Identical faculty teams
  - Same semester-long project (energy audit of campus buildings)
  - No further discussion of Diverging-Converging design model

<table>
<thead>
<tr>
<th>Cohort</th>
<th>Spring 2005</th>
<th>Spring 2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average SAT</td>
<td>1232</td>
<td>1230</td>
</tr>
<tr>
<td>Average HS class rank</td>
<td>Top 17%</td>
<td>Top 18%</td>
</tr>
</tbody>
</table>

- Final reports evaluated using rubrics published previously
## Evaluation of Final Reports

<table>
<thead>
<tr>
<th>Desired Outcome</th>
<th>2005</th>
<th>2006</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apply knowledge of mathematics, science, and engineering</td>
<td>2.48</td>
<td>3.11</td>
</tr>
<tr>
<td>Acquisition and interpretation of experimental results</td>
<td>2.19</td>
<td>2.60</td>
</tr>
<tr>
<td><strong>Design and conduct appropriate experiments</strong></td>
<td>2.00</td>
<td>2.73</td>
</tr>
<tr>
<td><strong>Identify, formulate and solve engineering problems</strong></td>
<td>2.31</td>
<td>2.90</td>
</tr>
<tr>
<td>Understanding of contemporary issues</td>
<td>1.44</td>
<td>2.25</td>
</tr>
<tr>
<td>Fundamental principles of engineering</td>
<td>2.17</td>
<td>2.83</td>
</tr>
<tr>
<td>Modern engineering tools</td>
<td>2.22</td>
<td>2.83</td>
</tr>
<tr>
<td><strong>Experience in undergraduate research</strong></td>
<td>2.28</td>
<td>2.94</td>
</tr>
<tr>
<td>Global/societal context of engineering problems</td>
<td>2.11</td>
<td>2.50</td>
</tr>
<tr>
<td><strong>Oral and written communication skills</strong></td>
<td>2.04</td>
<td>2.83</td>
</tr>
</tbody>
</table>
Dixon’s Taxonomy

- States of knowledge
  - Perceived Need
  - Function
  - Physical Phenomena
  - Embodiment
  - Artifact Type
  - Artifact Instance
  - Feasibility

Real design projects have an “initial state” and a “final state.”
States of knowledge

- Perceived Need
- Function
- Physical Phenomena
- Embodiment
- Artifact Type - Initial
- Artifact Instance – Final
- Feasibility
States of knowledge
- Perceived Need
- Function
- Physical Phenomena
- Embodiment - Initial
- Artifact Type
- Artifact Instance – Final
- Feasibility
Successor to Crane Project
Example Wind Turbine

- Plastic hub and dowels supplied to students
- Blades from foam board
Entrepreneurial Design Project

- States of knowledge
  - Perceived Need
  - Function
  - Physical Phenomena
  - Embodiment
  - Artifact Type
  - Artifact Instance
  - Feasibility
Timeline

- **Week 1**: Students choose between Entrepreneurial and other design project
- **Week 3**: Students give “elevator pitch” proposing an entrepreneurial project to their classmates
- **Week 4**: Faculty announce project teams
- **Finals Week**: Final reports and presentations
Elevator Pitch

- Each student has 90 seconds to present their proposed project
- Each student ranks projects (besides own) that they would like to work on
- 2/3 of grade determined by faculty evaluation of pitch (NOT idea itself)
- 1/3 of grade determined by popularity with students
Project Selection

- Projects ranked in order of popularity
- Projects screened for feasibility
- Students assigned to highest ranked project that runs
- If too many students on project, preferences of sponsor used
Project Deliverables

- 10 minute presentation
  - Evidence of market
  - Evidence of feasibility
  - Case for funding
- Comprehensive final report- 3 graders
  - Reads entire report
  - Reads entire report excluding appendices
  - Exec. Summary, Conclusions, Figs. & Tables
Project Outcomes

- Excellent synergy with public speaking goals
  - Quality of elevator pitch affected project selection and grade
  - 18 final presentations on a wide variety of topics

- “Case for funding” meant expectations relatively uniform despite wide variety of projects
Informal survey of residents showed most wished for better way of cooking than firewood.
Collecting firewood time consuming & sometimes unsafe.
Contributes to deforestation.
Example: Briquette Production in The Gambia

- Annual peanut production
- Combustion properties of husks before and after compaction
- Infrastructure in The Gambia
Example 2: Retractable Plane Sign

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BizarroComix.blogspot.com


Plot. 19 King Features
Plane Sign: Retractable Sign

States of Knowledge
Perceived Need
Function
Physical Phenomenon
Embodiment
Artifact Type
Artifact Instance
Feasibility

Team already had preliminary sketches at start of project
Change Signs Without Landing

States of Knowledge
- Perceived Need
- Function
- Physical Phenomenon
- Embodiment
- Artifact Type
- Artifact Instance
- Feasibility

Team went to top and brainstormed other ways of meeting the goal.
Example 3: Inflatable Water Wheel
Inflatable Water Wheel

States of Knowledge
- Perceived Need
- Function
- Physical Phenomenon
- Embodiment
- Artifact Type
- Artifact Instance
- Feasibility

Team had preliminary sketches at start of semester
Inflatable Water Wheel

States of Knowledge

Perceived Need
Function
Physical Phenomenon
Embodiment
Artifact Type
Artifact Instance
Feasibility

Team’s written description of “perceived need” still included the word “inflatable.”
Inflatable Water Wheel

States of Knowledge
- Perceived Need
- Function
- Physical Phenomenon
- Embodiment
- Artifact Type
- Artifact Instance
- Feasibility

Final design was essentially identical to preliminary sketch and included fatal flaw.
Portable Aspects of SEC I and II

- Diverging-Converging Design Model
- Dixon’s Taxonomy
- Individual Design Projects
  - Bottle Rocket
  - Crane
  - Wind Turbine
  - Student-driven Entrepreneurial project

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