The 2012 Gordon Prize Lecture:
Engagement and Innovation at Harvey Mudd College

Clive L. Dym
(on behalf of CLD, M. Mack Gilkeson and J. Richard Phillips)
Department of Engineering
Harvey Mudd College
30 September 2012

Engagement and Innovation @ HMC

- Engineering Design @ HMC
- Mudd Design Workshops
- What Have We Learned?
- The Gordon Prize

HMC, “A liberal arts college of science and engineering”:

To educate engineers, scientists and mathematicians so that they may assume leadership in their fields with a clear understanding of the impact of their work on society

<table>
<thead>
<tr>
<th>HMC</th>
<th>Engineering</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAT critical reading (median)</td>
<td>731</td>
</tr>
<tr>
<td>SAT mathematics (median)</td>
<td>770</td>
</tr>
<tr>
<td>HMC enrollment; Engineering majors</td>
<td>765</td>
</tr>
<tr>
<td>FTE faculty totals</td>
<td>89</td>
</tr>
<tr>
<td>FTE faculty totals (F)</td>
<td>32</td>
</tr>
<tr>
<td>Graduates</td>
<td>176</td>
</tr>
<tr>
<td>Graduates (F)</td>
<td>59</td>
</tr>
</tbody>
</table>

Others have said that (and we agree!) . . .

✓ . . . design is the central activity of engineering. Herbert A. Simon
✓ . . . beyond being theoretical carpenters, engineers must be able to synthesize and integrate systems or to design. John H. McMasters

Engineering’s Program Educational Objectives (PEO):

✓ Graduates should be exceptionally competent, broadly educated and technically excellent engineers.
✓ Program should be “hands-on” and reflect engineering judgment and practice.
✓ Prepare students for lifetime of independent, reflective learning.
✓ Graduates should be fully aware of impact of work on society, nationally and globally.
✓ Curriculum must be current, exciting and challenging, and can be completed in four years.

Organizing to Achieve HMC-Engineering’s PEOs:

College Core: Math, Sciences, HSA
Engineering: Engineering Science, Systems, Design and Professional Practice
The HMC Common Core:

- Coordinated, common core for all HMC majors (43.5 credits):
  - Mathematics (9)
  - Physics (8.5)
  - Chemistry (5.5)
  - “Baby Stems” (3)
  - Academic Writing (1.5)
  - Critical Inquiry (3)
  - Free Elective (3)

- Humanities, Social Sciences & Arts (additional 33 credits)

- HMC’s emphasis on HSA is very strong (37.5/128 ~ 29%) and strongly supported by Engineering!

Engineering Science Strand:

- Goal: enable students to acquire a broad framework of fundamental, discipline-specific engineering knowledge

- Five (5) required courses (14 credits):
  - E82: Thermal and Chemical Balances
  - E83: Continuum Mechanics
  - E84: Electronic and Magnetic Circuits and Devices
  - E85: Digital Electronics and Computer Engineering
  - E106: Materials Engineering

Systems Strand:

- Goal: enable students to acquire a unified view of disparate engineering fields and physical systems

- Three (3) required courses (9 credits):
  - E59: Introduction to Engineering Systems
  - E101–102: Advanced Systems Engineering

Design & Professional Practice Strand:

- Goal: ensure students will experience teamwork, client-driven design projects, and demonstrate understanding of open-ended design at conceptual, preliminary, and detailed levels

- Five (5) required courses (16 credits):
  - E4: Introduction to Engineering Design and Manufacturing
  - E60: Experimental Engineering
  - E111: Engineering Clinic I
  - E112–113: Engineering Clinic II–III

HMC design projects are experiences where students:

- work in teams on multidisciplinary design projects;
- work in broader, more ambiguous contexts;
- work with other professionals in teams;
- make qualitative judgments and assessments;
- make oral and written presentations of design results; and
- learn about and identify with what engineers do.

HMC design experiences integrate:

- traditional, experiential approaches, and
- modern, process / methods approaches.
E4 experiences include:

- executing a design process;
- defining (framing) problem, objectives, constraints;
- establishing functions and requirements;
- generating and evaluating design alternatives;
- modeling, prototyping, building proofs of concept;
- team behaviors, dynamics;
- reporting on, documenting design projects;
- mediating conflicting obligations and reinforcing personal responsibility (ethics); and
- managing design projects.

The E4 Design Process:

E4 Projects:

- Client: Danbury (Special Education) School
  Project: Design an Arm Support Device for Student with CP

- Client: University of California, Irvine, Medical Center
  Project: Design of a Microlaryngeal Surgical Stabilizer

Engineering Clinic:

- Some 1000 projects (1500 HMC-wide) since inception; ~ 25 yr.
- Teams of 4–5 students; faculty advisor; sponsor liaison(s).
- Sponsors have included: Aerospace Corp.; Boeing; Broadcom; DirectTV; IBM; Intel; Lawrence Livermore NL; Lockheed-Martin; Los Alamos NL; Mazda; Medtronics; Microsoft; MITRE; Northrop Grumman; ORACLE; Sandia NL; Space Systems Loral; SLAC; SRI; Sun. (Totals of ~ 290 for Engineering, ~ 390 for HMC.)
- Year-to-year return rate ~ 70%.
- Some 10 patent disclosures per year.

Direct Methanol Fuel Cell Corporation

What are Fuel Cell Cartridges?

A direct methanol fuel cell utilizes methanol fuel, stored in cartridges, to provide power. The fuel cartridge must house the methanol and prevent accidental spillage.

Our Project

Students: Kenneth Maples, Michael Bigelow, Wayne Tanaka, Laurel Fulerton, Mike Saltana, Yosuke Sato (Fall)

Advisor: Clive Dym

Liaisons: Manel Arranz, Huyen Dinh

Our Results

We developed a new innovative and safety system which uses a child safety latch and an authentication system. The child safety latch is designed to prevent children from accessing the methanol valve. Additionally, we developed a system for authentication using passive RFID tags. This system allows the fuel cell to distinguish between real and potentially dangerous pirate copies of fuel cartridges.

Students: Kenneth Maples, Michael Bigelow, Wayne Tanaka, Laurel Fulerton, Mike Saltana, Yosuke Sato (Fall)

Advisor: Clive Dym

Liaisons: Manel Arranz, Huyen Dinh
Engineering @ HMC’s founding faculty introduced . . .

- first-year **(cornerstone)** design projects
- engineering students to working in teams
- multidisciplinary design projects
- engagement with industry
- industrially-sponsored senior **(capstone)** design projects
- oral and written presentations by students
- students to the experience of clinical engineering practice

. . . that are now staples of engineering curricula.

Two major starting points were:

- **Engineering Projects** in 1961 by Mack Gilkeson

An ethos and tradition have been maintained (i):


An ethos and tradition have been maintained (ii):

- In **E4**, including Clive Dym (1991– ), Liz Orwin (HMC ‘95, 2001– ), Pat Little (1996– ), Lori Bassman (2000– ), and all of the Engineering faculty:

We say that (and others agree!) . . .

- . . . learning engineering is rather like learning to dance: you have to get out on the dance floor and get your toes stepped on.
  - Jack Alford
- . . . the engineering curriculum is an **artifact** worthy of design.
  - Clive L. Dym
- . . . the engineering curriculum is lean, yet delicately balanced and finely tuned, and its continued success requires continuous attention to detail.
  - Ziyad H. Duran
Engineering's Program Educational Objectives (PEO):

<table>
<thead>
<tr>
<th>Engineering’s PEOs</th>
<th>ABET Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exceptionally competent engineers ... broad and technically excellent</td>
<td>A, C, E, G, K</td>
</tr>
<tr>
<td>“Hands-on” approach ... engineering judgment and practice</td>
<td>B, D</td>
</tr>
<tr>
<td>Lifetime of independent, reflective learning</td>
<td>I</td>
</tr>
<tr>
<td>Graduates fully aware of impact on work on society, nationally and globally</td>
<td>F, H, J</td>
</tr>
<tr>
<td>Curriculum must be current, exciting and challenging, and can be completed in four years</td>
<td></td>
</tr>
</tbody>
</table>

External Assessments of Engineering @ HMC (i):

From the Penn State Studies:

<table>
<thead>
<tr>
<th>Engineering Area</th>
<th>Observation Indicators</th>
<th>HMC</th>
<th>PSU</th>
<th>FSP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fundamental Skills</td>
<td>Design Skills</td>
<td>4.0</td>
<td>3.6</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td>Communication Skills</td>
<td>3.9</td>
<td>3.8</td>
<td>3.6</td>
</tr>
<tr>
<td></td>
<td>Technical Skills</td>
<td>4.1</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>Leadership Skills</td>
<td>4.3</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td>Entrepreneurial Skills</td>
<td>4.6</td>
<td>4.0</td>
<td>4.0</td>
</tr>
</tbody>
</table>

External Assessments of Engineering @ HMC (ii):

From the APPLE Study:

"... HMC students exhibited greater engagement with faculty inside and outside of the classroom... were more satisfied with their teachers and their levels of interaction... reported learning about engineering practice from their school experience in higher proportion than their peers at other schools... Engineering Clinic and E4 likely played a key role in this enhanced engagement and knowledge of practice."

External Assessments of Engineering @ HMC (iii):

- One of best (top 60) engineering design programs in the world (Business Week, 2007), cited for Clinic and MDWs
- Number 1 among private baccalaureate colleges for % graduates who earn PhDs in engineering and science (National Science Foundation, 2008)
- Number 2 “best engineering college by salary potential” (PayPal, 2009)
- Number 1 undergraduate engineering program in the nation (US News & World Report, 2010)
- Bernard M. Gordon Prize (NAE, 2010)

Engagement and Innovation @ HMC

- Engineering Design @ HMC
- Mudd Design Workshops
- What Have We Learned?
- The Gordon Prize
The Mudd Design Workshops:

I. Computing Futures of Engineering Design (1997, 47)
II. Designing Design Education for the 21st Century (1999, 57)
III. Social Dimensions of Engineering Design (2001, 57)
IV. Designing Engineering Education (2003, 44)
V. Learning and Engineering Design (2005, 63)
VI. Design and Engineering Education in a Flat World (2007, 53)
VII. Sustaining Sustainable Design (2009, 57)
VIII. Innovation and Entrepreneurship (2011, 85)

The MDW VIII Organizing Committee:

Alice Merner Agogino (NAE), University of California, Berkeley; Aaron Altman, University of Dayton; Cindy J. Atman, University of Washington; J. Edward Colgate, Northwestern University; Daniel D. Frey, Massachusetts Institute of Technology; Peter Gregson, Dalhousie University; Ahmad Ibrahim, Yorkville University; Larry J. Leifer, Stanford University; Christopher L. Magee (NAE), Massachusetts Institute of Technology; Gregory B. Olson (NAE), Northwestern University; John W. Prados, University of Tennessee, Knoxville; Sheri D. Sheppard, Stanford University; Janis P. Terpenny, Iowa State University; and John W. Wesner, Carnegie Mellon University.

E4 and an MDW in the Parsons Design Studio:

Engagement and Innovation @ HMC

- Engineering Design @ HMC
- Mudd Design Workshops
- What Have We Learned?
- The Gordon Prize

We have learned that (i):

- Design should be both cornerstone and capstone (indeed, the backbone) of engineering education.
- A broad, systems view is more important than depth.
- Content reinforcement is less important because school will not provide all of the answers: Students are (and should be) given an early start on self-learning and lifelong learning.

We have learned that (ii):

- Experiential learning is central to student learning.
- First-year students are motivated by and can do design projects.
- Educational programs succeed over the long term when:
  - the institution is committed;
  - when faculty and staff take ownership; and
  - when leadership is thoughtful, optimistic and sustained.
Engagement and Innovation @ HMC

- Engineering Design @ HMC
- Mudd Design Workshops
- What Have We Learned?
- The Gordon Prize

We want to remember the contributions of:
Jack L. Alford (1920-2006; HMC 1959-1990)
and

Questions, Comments?

Bernard M. Gordon Prize
for Innovation in Engineering and Technology Education

- Inaugurated in 2001;
- recognizes new modalities and experiments in education that develop effective engineering leaders;
- focus on innovations in curricular design, teaching methods, and technology-enabled learning that strengthen students’ capabilities and desire to grow into leadership roles;
- is presented annually; and
- a $500,000 cash award is divided equally between the recipient and the recipient’s institution to support the continued development, refinement, and dissemination of the recognized innovation.

The National Academy of Engineering awarded
The 2012 Bernard M. Gordon Prize for Innovation in Engineering and Technology Education to
Clive L. Dym, M. Mack Gilkeson and J. Richard Phillips for
“Creating and disseminating innovations in undergraduate engineering design education to develop engineering leaders.”
CLIVE L. DYM created the program’s formal design instruction and contributed to a hands-on studio component for the freshman projects class. Dym also advocated the integration of the design and making of tools and prototypes into that class. This helped students learn about manufacturing and design and how to communicate about their work.

Dym is the driving force behind the Mudd Design Workshops, which bring together a wide range of institutions to discuss engineering education and their shared experiences.

Dym is the Fletcher Jones Professor of Engineering Design and director of the Center for Design Education at Harvey Mudd College.

M. MACK GILKESON is the co-inventor and co-founder of the Clinic program, a hands-on approach to teaching engineering in which small teams of students are given real-life design problems to solve from industry partners.

The program was controversial at its outset because this approach defied conventional wisdom and went very much counter to the then-prevailing thinking about engineering curricula.

Thus, while the Clinic program initially faced concerns, even some internally, Gilkeson and his colleagues proved it could work and it became a model for many other institutions.

Gilkeson is Professor of Engineering Emeritus at Harvey Mudd College.

J. RICHARD PHILLIPS was the Engineering Clinic director for 17 years and transitioned the Clinic into a sustainable program that is now integral to the overall Harvey Mudd Engineering curriculum.

He also was directly involved in the establishment of Clinic programs in other colleges and universities. The program has now extended to other departments in the college, influencing fields outside of engineering as well.

Phillips also was instrumental in the development of the Experimental Engineering Lab to give students a deeper and more intuitive grasp of concepts they learn in their theory classes.

Phillips is Professor of Engineering Emeritus at Harvey Mudd College.