

# On Designing Engineering Education: Lessons Learned at Mudd Design Workshop IV\*

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*This paper reports on the Mudd Design Workshop IV held at Harvey Mudd College (HMC) in July 2003 to discuss a broad variety of issues on engineering education. Sessions were devoted to: ABET's EC 2000; barriers to change; learning and motivation; the many roles of design; and the ethos of and ethics in both education and practice. Major emergent themes included: the need for engineers to educate the public and their policy-makers about the processes of engineering; that research into engineering learning must be conducted by (at least in part) and recognized by engineering faculty; that design can motivate and enhance the place of values and ethics in undergraduate curricula; and that positive change is emerging in engineering education, notwithstanding the formidable and enduring barriers to such change. Before leaving, participants converged on a set of goals that they would try to advance—both individually and collectively.*

## INTRODUCTION

CALLS FOR CHANGE in engineering education abound, emanating from government agencies (e.g. NSF, NAE), professional societies, industry, academe and the public at large. Forty-four (44) engineering educators and practitioners came together in July of 2003 for Mudd Design Workshop (MDW) IV, the fourth biennial workshop on engineering design education organized by the Center for Design Education at Harvey Mudd College, to talk about 'Designing Engineering Education.' Over three days they talked, listened, discussed and learned a great deal about the American engineering education enterprise. This article summarizes some of that discussion and learning.

## STRUCTURE AND THEMES OF MDW IV

MDW IV was organized much like its predecessors [1–2]. All participants took part in seven topical workshop sessions over two and a half days, covering various views of engineering education. The session format featured brief presentations by three or four panelists, followed by open, moderated, general discussion.

An eighth session synthesized what participants

had experienced at the workshop and looked forward by eliciting and identifying commitments to new 'change actions' by participants. The ninth session, over a final lunch, summarized what was heard and looked forward, tying everything together and making new commitments.

Discussion was further stimulated by several keynote talks:

- A brief challenge was cast at the opening lunch by C. L. Dym, suggesting that the design of the enterprise of engineering education needed to be approached from both the *design* and *systems* perspectives.
- William A. Wulf, President of the National Academy of Engineering (NAE), elaborated 'Some Thoughts on Engineering as a Humanistic Discipline,' suggesting among other things that the engineering profession was not fulfilling its responsibility of ensuring that America's Jeffersonian democratic society understood the roles, challenges and achievements of engineering (and engineers).
- Thomas R. Chase joyfully illustrated how the 'Large Scale Manufacturing of Tiny Particles' resulted from the application of engineering design principles to the physicists' problem of finding Neutrinos.
- In 'Engineering Design: The View from Mars,' Erik K. Antonsson described the complex design issues in various Mars missions as seen from his current role as Chief Technology Officer of NASA's Jet Propulsion Laboratory (JPL).

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## THE PEOPLE

A majority of MDW IV's 44 participants were engineers from academe, including some deans and some NAE members. Industry was also represented (Boeing, Ford, Northrop Grumman), as were experts in education, philosophy, and religion. The programs and institutions represented included both small (Harvey Mudd) and large (Berkeley and Penn State), private (Stanford, MIT) and public (Tennessee, Washington), and old (Virginia) and new (Olin, Smith). Although mostly American, participants and co-authors included faculty from the Delft University of Technology, the University of Leeds, Ecole Central de Lyon and Universidad de Navarra (in Spain). The conversation throughout was lively, earnest and enthusiastic, often humorous, and frequently inspiring. One particularly inspiring feature of MDW IV was the attendance and participation of a significant number of younger, untenured faculty, who displayed an avid interest in and commitment to improving and enhancing engineering education.

## THE SESSIONS

The seven working sessions addressed:

- EC 2000: A Change Agent for Engineering Education?
- Drivers and Rewards in Engineering Schools
- Motivating Student Learning and Growth
- New Designs for Engineering Education
- Design as Integrator Across the Curriculum
- Multi-Scale 'Reductionism' versus 'Synthesis'
- Ethos, Ethics and Design Engineering Education

In each session, speakers took individual questions related to their own papers and then returned to serve on a panel for more general discussion. Shared concerns and common themes emerged in these energetic discussions.

## THE KEY LESSONS AND 'LEARNINGS'

Several interesting and important lessons or 'learnings' emerged during this workshop, some of which had also been articulated at prior MDWs. They are outlined below.

### *Engineers must reach out to society*

From the outset, the audience heard and echoed the sentiments that the public does not understand technology and engineers, and that public policy-makers are dangerously ignorant of engineering and technology. For example, there are only six engineers in the US Congress, and only two had been practicing engineers; the other four were patent attorneys. For an example with a more local perspective, engineers are most likely designated as

the 'person I'd most want on a desert island,' but least likely to be 'someone I'd want to talk to at a cocktail party.' A third example was the relative paucity of responses to the challenge: 'Name ten engineering heroes.'

Perhaps the most important facet of this lack of understanding is that it reaches beyond an insufficient knowledge of scientific and technical facts: it is an ignorance of the *processes* by which engineers and scientists accumulate and use evidence. Society and its policy-makers may be unwilling to trust technical judgments, because they do not understand the processes by which such judgments are reached.

Speakers and participants agreed that engineers should not wait to be asked the right questions by the public or its government, but should initiate corrective action. Engineers and educators have an urgent responsibility to address this lack of understanding, and to demonstrate the relevance of engineering and design to an often-indifferent society.

One suggestion to this effect was that engineering faculty need to develop new engineering courses aimed at students in the humanities and the social sciences. Further, engineering faculty must *themselves* work toward ensuring that engineering students can connect engineering and science both to the humanities and to humanity. Many students go into engineering wanting to help mankind, but they need reinforcement and pride, which are best provided by engineering faculty.

The attitudes expressed in this context captured and extended perceptions that had emerged strongly at MDW III [2], where the question 'Can engineering be "re-humanized"?' was heard, as was an 'exciting new word, "techmanities",' that most immediately referred to a Northwestern freshman design course co-taught by Engineering and Writing faculty. Similarly, engineering and design are paths to get to the spiritual side—the soul—of engineering practice and to raise ethical concerns.

### *ABET's ec 2000 may already be producing meaningful change*

The new ABET approach embodied in EC 2000 is viewed as very positive, because of its new focus on learning outcomes rather than its traditional focus on auditing curricula. Thus, the emphasis on attitudes and skills, the requirement of meaningful assessment aimed at continuous improvement and the use of rubrics in course assessment were lauded. At the same time, it was recognized that it is very hard to measure curricular impact on graduates' long-term careers. Furthermore, a formal assessment of the early results attributable to EC 2000 is only just underway.

### *The engineering education system is resistant, but change is happening*

Familiar frustrations were aired about obstacles to change in engineering education:

- misdirected faculty rewards that stress engineering science research;
- a missing sense of urgency; and
- the lack of visible positive drivers.

The engineering education system or establishment is viewed as too attached to (and in awe of) ‘the science’ approach to conducting, reporting and assessing research. One possible ‘cure’ for this malady, also aired at MDW III [2], is that a National Engineering Foundation might better represent the values of the engineering community than does the National *Science* Foundation. However, it is not clear that there is a unified view of this among the professional societies or with such bodies as the NAE. On the other hand, the NAE appears determined to play a greater role in engineering education and to influence faculty reward systems in ways which will enhance design education.

Adding to the difficulties is the lack of a universally accepted functional definition of what engineering is and what engineers do. Several were proposed during MDW IV, including, ‘Engineering is design under constraint.’ With thanks and apologies to both Theodore von Karman and Robert F. Kennedy, we suggest:

*Scientists* see things as they are and ask, Why?  
*Engineers* see things as they could be and ask, Why not?

Notwithstanding the obstacles and difficulties, meaningful change is occurring in positive directions and in a variety of settings. One widely appreciated instance is the University of Colorado’s design-based outreach aimed at K-12. New programs at Olin (integrative, design project-centered) and Smith (engineering as the synthesizer and integrator of science and the humanities) colleges were described.

There were several reports that reported data on the degree to which motivation could be successfully imparted to engineering students, especially in the context of design projects and courses. While instilling motivation in students was viewed as essential to teaching and learning, it was not evident that the successes here also translated into comparable success in learning content. This in turn also reinforced the need for further research—to be conducted by and with engineering faculty—on learning in engineering education. Such research would perforce need to have clear-cut communicable goals, to be rigorous and scholarly, and to be accepted within existing evaluation and reward structures in engineering schools and colleges.

It was also noted that capstone design courses appeared too late in the curriculum to serve as effective motivators or curriculum integrators. The idea that design should be the cornerstone of engineering education [3] was reinforced, as was the sense that it should clearly address social and cultural issues.

## THE EXPECTED IMPACT

Each participant was asked to answer eight questions after the second day of the workshop, the answers to which were collated and organized for the wrap-up session and the final luncheon. Aggregate answers to the first two questions were reported by the co-chairs of the wrap-up session:

- *What is the most interesting thing you have heard in the last two days?* Colorado’s K-12 outreach program; the call for a National Engineering Foundation (NEF); the (Carnegie Foundation) effort to establish a common functional definition of engineering; the new programs at Olin and Smith; and the design community’s involvement in meta-level design of engineering education.
- *What is the most doubtful thing you have heard in the last two days?* That a graduate degree would be the first professional degree; that engineers will lead the integration of science and the humanities; that faculty reward structures will change; and that there will be an NEF.

Participant responses from the other six survey questions were clustered into three questions by the wrap-up session chairs and used as the basis for a design assignment during the final wrap-up session. Teams of participants were then asked to ‘design’ answers to one of the three questions and present their candidate solutions during the concluding luncheon, as summarized below:

*How might you improve/increase recognition, appreciation and promotion of engineering design activities by deans?* Ideas presented included compiling quantitative data related to design activities (e.g. number of sponsored design projects in courses) that the dean could use in presenting design work, inviting the dean to high-profile student design presentations, and working to increase the role that design plays in institutional rankings.

*How might you improve/increase recognition and appreciation of scholarship of teaching activities?* Among the suggestions received were: raise awareness of the scholarship of teaching by trumpeting the field’s heroes and by making the scholarship itself accessible (e.g. including the *International Journal of Engineering Education* in the Science Citation Index (SCI)); encourage faculty to look at the classroom as a research opportunity, and facilitate this research by holding workshops on methods for teaching-related research and strategies for including research results in one’s teaching; effective research about education is rigorous research that addresses a fundamental question, and should meet certain standards, so that it should be possible to develop explicit criteria to assist in the evaluation of its evidence in promotion and tenure reviews.

*How might you improve/increase understanding of engineering?* One proposal was to introduce young readers to an engineer hero in children’s literature,

perhaps by recasting a character like Tom Swift in more modern clothes. The influence of such a character—'Alice Swift' was suggested as her name—could be tremendous, even if it did not reach Potteresque proportions. Advertising campaigns and projects that dovetail with current NAE efforts were suggested. Although such media saturation would be advantageous, it was also recognized that each engineer and each educator could take small steps in each personal interaction toward this goal. From crafting cocktail party chatter more cognizant of a current project's relevance to daily life and society, to offering engineering classes to non-engineers, every engineer can help to educate the public.

## CONCLUSIONS

MDW IV was, in many ways, a call to action. Participants were urged to consider the following:

the ways in which their work is (or is not) conveyed to and understood by outside audiences; to advance the scholarship of teaching by continuing to innovate, and to evaluate and communicate their innovations; and to use *engineering design* as an integrator of disciplines, peoples, and ideas.

The full proceedings of MDW IV were published on a CD that is available from the corresponding author, and a special issue of the *International Journal of Engineering Education* devoted to MDW IV will appear in 2004.

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## REFERENCES

1. C. L. Dym, S. D. Sheppard and J. W. Wesner, A report on Mudd Design Workshop II: Designing design education for the 21st century, *International Journal of Engineering Education*, **90**(3) (2001) pp. 291–294.
2. C. L. Dym, J. W. Wesner and L. Winner, Social dimensions of engineering design: Observations from Mudd Design Workshop III, *International Journal of Engineering Education*, **92**(1) (2003) pp. 105–107.
3. C. L. Dym, Learning engineering: Design, languages, and experiences, *International Journal of Engineering Education*, **88**(2) (1999) pp. 145–148.

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