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# Engineering Design @ HMC: A Testament to Innovation and Entrepreneurship*

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This paper elaborates and formalizes the opening remarks made by the chair of the organizing committee at a recent workshop on innovation and entrepreneurship. Held at Harvey Mudd College in May 2011, and supported by HMC's Center for Design Education and the National Science Foundation, Mudd Design Workshop VIII provided a forum for engineers and designers—in their roles as educators, researchers, and practitioners interested in learning and in design—to identify and articulate important aspects of innovation and entrepreneurship in design and engineering education. The remarks summarized below were intended to bring to the community's attention the entrepreneurs who developed and implemented some truly innovative ideas in engineering education. Many of these ideas are now 'best practices,' yet the innovators themselves are largely unrecognized. The story of these ideas and their originators also serve to remind us, as members of engineering faculties, that all too often we are remiss in maintain our institutional memories and passing down our own history.

**Keywords:** innovation; entrepreneurship; engineering education; Harvey Mudd College

## 1. Introduction

This eighth Mudd Design Workshop (MDW VIII), held 26–28 May 2011, was titled, 'Design Education: Innovation and Entrepreneurship.' At the previous seven MDWs, as chair of the organizing committees, I tried to provide a personal reflection on each workshop's specific theme. This year, I focused the opening remarks (and this paper) on Harvey Mudd College's design-intensive Engineering program, for a variety of reasons. One is that while HMC's engineering program is quite visible and highly regarded, it is also the case that not very many people know exactly what we do here or why and how we do it. Given the record number of attendees at MDW VIII, it seems like a good opportunity to highlight HMC's Engineering program for the broader community.

A second reason for this paper's focus on HMC Engineering relates to this MDW's theme, innovation and entrepreneurship. Simply put. The 'founding fathers'—and they were all men—of our Engineering program were visionaries, innovators, and entrepreneurs who put together a curriculum that was well ahead of its time. Inasmuch as these folks were 'doers' rather than talkers or writers and publishers of papers, they did not receive much personal recognition for what they did. Similarly, in a failing all too common in many institutions, even my younger and newer HMC colleagues don't really know the story of how and why we came to do what we do, because we haven't told it to them. (Perhaps we need to imitate the Passover Seder tradition and tell the story annually, to educate our 'children'!) My brief exposition is not a comprehensive, authorized history. Rather, I intend it as a testament to three men who really got this program off the ground: Jack Alford, who started the first-year course Engineering Projects in 1961, and Mack Gilkeson, who revived it in 1973; Jack and Mack again, for starting Engineering Clinic in 1965; and Tom/Ted Woodson, who was our first real Director of Engineering Clinic.

One more note. It is generally a good idea to talk and write in a common vocabulary, yet it became clear during the MDW VIII discussions that the meaning of two key terms might not be universally shared. Thus, for my purposes, I will rely on the venerable 'OED,' the Oxford English Dictionary [1] for our definitions:

- **innovate** (*v*) to bring in or introduce novelties; to make changes *in* something; to introduce innovations
- **entrepreneur** (*n*)the director or manager of a public musical institution; one who undertakes an enterprise; a person who takes the risk (of profit or loss)

## 2. Engineering @ HMC: when and why

In the aftermath of World War II and based on partial readings of the Grintner Report [2], engineering curricula strongly emphasized the rigors of engineering science at the expense of 'hands-on' experiences and certainly at the expense of engineering design. In the early 1960s at newly-formed Harvey Mudd College (which was founded in 1955), a conscious effort was made to develop a curriculum that would, as stated in the first HMC



* Accepted 20 August 2011.

catalog, seek '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' [3]. From 1962–64, the HMC engineering faculty developed a novel engineering curriculum based on the Herbert A. Simon premise [4] that 'design is the distinguishing feature of engineering . . .' Thus emerged the Harvey Mudd Engineering approach:

- choose *breadth* over disciplinary narrowness, and
- place *experiential learning* (long before the term came into use) on an equal footing with book learning.

## 3. Engineering @ HMC: how

The Harvey Mudd Engineering curriculum sits on a strong foundation that is provided by the HMC coordinated, common core that is required for *all* HMC majors (Table 1).

The 'Baby Stems' course listed in Table 1 is the first course in Engineering's engineering systems and signals sequence emphasis (Table 3 below), and, even though it is a tough and rigorous engineering class, it is required of all HMC students. (The other HMC majors are Biology, Chemistry, Computer Science, Mathematics and Physics, as well as two combined majors: biochemistry and quantitative biology.) One of the features of the HMC common core is that every HMC student takes at least one course in every HMC major.

Two hallmarks of a Harvey Mudd education are the structure of its common core, which requires each HMC student to take at least one course in each of the College's majors, and our very strong emphasis on Humanities, Social Sciences and Arts (HSA). This dual emphasis on breadth is consistent with our current mission statement (with emphasis added[1]), as illustrated in Table 1. In fact, HMC's Engineering curriculum requires 128 credits overall with 37.5 (~ 29%) in HSA. This emphasis on HSA is almost unheard of in U.S. engineering programs generally, and yet here at HMC it is very strongly supported by Engineering!

The Harvey Mudd Engineering major is built around three stems that reflect its core values and goals, as displayed in Tables 2–4:

- a *foundational stem* of five *engineering science* courses (Table 2);
- an *integrative stem* of three *engineering systems and signals* courses (Table 3); and
- a *design and professional practice* stem that implements and realizes professional engineering design results (Table 4).

[1] It is interesting that the original formal mission statement did not include this emphasis, although it was clearly part of the thinking when the curriculum was first envisaged [3].

**Table 1.** College-Wide Requirements of HMC Curriculum: Common Core (43.5 credits) and Humanities, Social Sciences and Arts (33 credits)

**Goal**: 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* (from the current HMC mission statement, *emphasis added*)

| **Required courses** | |
|---|---|
| Mathematics (9 credits) | Physics (8.5 credits) |
| Chemistry (5.5 credits) | Biology (3 credits) |
| 'Baby Stems' (3 credits) | Computer Science (3 credits) |
| Academic Writing (1.5 credits) | 'Choice Laboratory' (1 credit) |
| Critical Inquiry (3 credits) | Physical Education (3 credits) |
| Free Elective (3 credits) | |
| Humanities, Social Sciences & Arts (33 credits) | |

This last stem, design and professional practice, more than any other, sets HMC's engineering program apart from all others. Beginning in their very first year, students pursue a graduated sequence of project-based design experiences that allows them to function as engineers, gaining both technical expertise and the skills attendant to sound professional practice. The sequence focuses on work in teams on open-ended, externally driven design projects that, over the course of the curriculum, encompass conceptual, preliminary, and detailed design. The required curricula elements of the design and professional practice stem are listed in Table 4.

Engineering Clinic is the manifestation of the success of the design and professional practice paradigm: Teams of students carry out design, development and research projects for paying corporate and government sponsors. The design stem includes other elective courses as well, but those listed above represent the innovative curricular model developed and nurtured by Jack Alford and Mack Gilkeson, and consistently maintained and nourished at Harvey Mudd for some 50 years.

Note that both in the first-year design class, E4, which we teach in studio mode, and even more so in Clinic projects, our students take the initiative in organizing, defining problems, and in setting deadlines. The faculty teaching E4 and advising Engineering Clinic teams do not function as team

**Table 2.** HMC Engineering Curriculum: Engineering Science

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

**Five (5) required courses**
E82: Thermal and Chemical Balances (3 credits)
E83: Continuum Mechanics (3 credits)
E84: Electronic and Magnetic Circuits and Devices (2 credits)
E85: Digital Electronics and Computer Engineering (3 credits)
E106: Materials Engineering (3 credits)

**Table 3.** HMC Engineering Curriculum: Engineering Systems

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

**Three (3) required courses**
E59: Introduction to Engineering Systems (3 credits)
E101–102: Advanced Systems Engineering (6 credits)

**Table 4.** HMC Engineering Curriculum: Design and Professional Practice

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

**Five (5) required courses**
E4: Introduction to Engineering Design and Manufacturing (4 credits)
E80: Experimental Engineering (3 credits)
E111–113: Engineering Clinic I, II and III (9 credits)

members. Rather, we are coaches and advisers who teach and emphasize 'the rules of the game.'

By working in teams on open-ended design problems, students must conceptualize and articulate their goals, draw upon information, apply knowledge practically, and manage projects collaboratively—*they must learn to be engineers.* The first three years of study, including a one-semester Clinic experience in the junior year, are preparation for the senior-year, capstone Clinic experience. Team members meet and communicate regularly with the sponsor's representatives and usually travel to the sponsor's corporate site for an orientation to the project. Teams are responsible for managing a project budget, making oral presentations on campus and to the sponsor, and producing deliverables, which may include written reports, software or prototype devices, on time.

## 4. Engineering @ HMC: testament to innovation

This experiential, design- and project-oriented curriculum is as old as HMC:

- Jack L. Alford (Fig. 1) instituted our first-year projects class for all HMC first-year students, E4, in 1961, and M. Mack Gilkeson (Fig. 1) revived and institutionalized it in 1973; it was originally called *Engineering Projects*.
- Jack Alford and Mack Gilkeson launched *Engineering Clinic* in 1965.

Both experiences are required for an HMC Engineering degree in engineering; all engineering majors take three semesters of Clinic. In the modern implementation of E4, since I revived and restructured the course in 1992, some 150 design projects have been completed for schools, hospitals, NGOs, etc. Over 1,000 Engineering Clinic projects have been completed since its inception; nowadays we complete about 25 Engineering Clinic projects annually.

> **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*

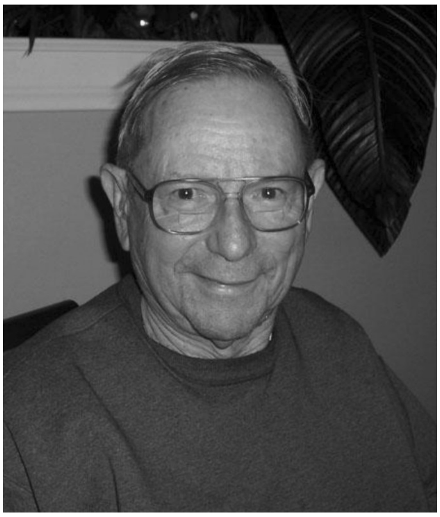
Today experiential learning is widely touted, and it is accepted that project-based design experience helps produce self-confident students who function *as* engineers armed with both technical expertise and the skills attendant to sound professional practice, which is, communication, teamwork and leadership skills, along with a clear understanding of professional ethics. Thus, *since the 1960s* the Harvey Mudd Engineering paradigm has included:

- *Open-ended, ill-structured design problems* that are matched to the students' levels of sophistication from their first year (*cornerstone*) to their last (*capstone*), that require students to be inventive and to deal with large and unfamiliar volumes of information, and that help students to 'learn to think (and perform) in a world of noise.' Further, those design problems are 'real,' that is, they are not made up by faculty: the cornerstone projects come from not-for-profit clients and sponsors, while the capstone projects are fee-based and provided by industrial or government clients.
- *Team deliverables*, including oral and written proposals, reviews and reports, as well as models and/or prototypes, to real, external clients who set forth their own (and their users') needs and wishes. These deliverables foster not only teamwork skills, but also communication skills because all the projects require oral and written reporting.
- *Team effort*, with student-selected team leaders, peer evaluations of team member performances, along with discussions about and faculty feedback on team dynamics.

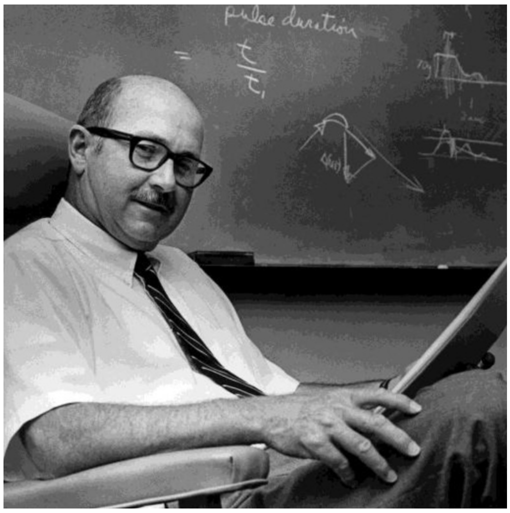
As a result of HMC's project-based Engineering curriculum, our students acquire a broad and interrelated set of skills that are distilled in the following set of capabilities:

- apply technical knowledge in the solution of technical problems;
- work with colleagues as a member of a goal-oriented team; and
- communicate processes and results, clearly, effectively, *on time*, *within budget*, and orally and in writing.

This is a very modern view of the skills that engineering students ought to develop, encompassed in ABET goals [5] and notably captured by the late



M. Mack Gilkeson (1922– )
@ HMC (1961–87)



Jack L. Alford (1920–2006)
@ HMC (1959–90)

**Fig. 1.** Mack Gilkeson and Jack Alford, the founders of Engineering Clinic.

John H. McMasters as the *soft skills* of engineering practice [6]. Yet for all their currency, we must recognize and pay homage to Jack Alford and Mack Gilkeson, who started enabling students to experience and acquire these skills at Harvey Mudd College in the 1960s! Talk about innovation! Talk about having the entrepreneurial spirit to advocate and initiate something that must have seemed orthogonal to the 'engineering science' currents that were sweeping U.S. engineering curricula in the wake of Sputnik. It is also interesting to credit Warren E. Wilson [7], briefly an HMC faculty member in the early 1960s, with encouraging the advocacy of design and of a systems approach [8].

> The engineering curriculum is an **artifact** worthy of **design**. *Clive L. Dym*

As a department, Engineering has learned some things about engineering curricula that anchor every curriculum discussion we have:

- A broad, systems view is more important than depth.
- Content reinforcement is less important because . . . school will not provide all of the answers (and so we also give students an early start on self-learning and lifelong learning).
- Experiential learning is central to engineering education.
- First-year students are motivated by and can do design projects.

Perhaps John McMasters has best summarized our perspective on the practice of engineering, which clearly informs our view of engineering education [9]: 'Beyond being *theoretical carpenters*, engineers must be able to *synthesize and integrate systems* or to *design*.'

We close this section by noting that there are more than a few indicators that Alford, Gilkeson, and their colleagues and heirs got it right. Among other accolades, HMC's Engineering program has been recognized as[1]:

- Number 1 undergraduate engineering program in the nation: *US News & World Report,* 2010.
- Number 1 among private baccalaureate colleges for % graduates who earn PhDs in engineering and science: *National Science Foundation*, 2008.
- Number 1 'best college—across *all* majors—by salary potential': *PayScale*, 2009.
- One of best (top 60) engineering design programs (cited for Clinic and MDWs) in the world: *Business Week,* 2007.
- The program at which Clive L. Dym, M. Mack Gilkeson and J. Rich Phillips were awarded the NAE's 2012 Bernard M. Gordon Prize for 'Creating and disseminating innovations in undergraduate engineering design education to develop engineering leaders.'

## 5. Engineering @ HMC: keeping the faith

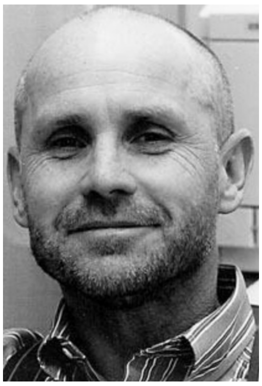
I had earlier described some features of the Engineering Clinic program. It is worth noting that typical Clinic sponsors include companies such as Amgen, Boeing, Hewlett-Packard and Raytheon as well as smaller companies and federally funded

[1] Last entry added in proof.

T. T. Woodson (1910–2010)
1970–75

J. Richard Phillips
1975–92

Anthony Bright
1992–97



Joseph A. King
1997–2002


Patrick Little
2002–2010

R. Erik Spjut
2010–

**Fig. 2.** Harvey Mudd College Directors of Engineering Clinic.

agencies such the Aerospace Corporation, the national laboratories and the U.S. military. Nearly all Clinic projects cut across the boundaries of scientific and technical disciplines, and many call upon students to take marketing and other economic considerations into account. We typically get about 25 paid Engineering Clinic projects each academic year, and we work at that so as to keep Clinic team sizes small. In an ideal world, a team would have four members: two seniors over the whole year and two different juniors in each of the two semesters. We want small teams because that requires each member to assume responsibility and leadership for particular aspects. Personal growth is an inevitable by-product of the Clinic experience.

But having said that, and notwithstanding our continuous record of having done more than 1,000 industrially-sponsored projects for almost 50 years, these projects do not show up, magically, on their own. Indeed, it takes continuous, thoughtful, and at times stressful, hard work, led by a faculty member who upon election by Engineering colleagues serves as Director of Engineering Clinic. We show in Fig. 2 the full-time Engineering Clinic Directors. We note especially the service of the late Tom/Ted Woodson who was the first to serve in that role, and the sustained service of Rich Phillips who advocated and recruited for Engineering Clinic for seventeen years!

In a similar way, our first-year project experience has also been nurtured and grown over the years. In 1992, at a time when the conventional wisdom was that first-year students didn't know enough to be able to do design, I restructured HMC's E4 course to formally incorporate design methodology—as well as the 'soft skills' and ethics—into the experience [10]. The course has been sustained over the years by two Engineering commitments: First, every faculty member in the department teaches E4 when they arrive. Second, there has been a core of Engineering faculty that has led the evolution of this team-taught design class over the years, including (Fig. 3): Patrick Little, my collaborator on the

> The engineering curriculum is lean, yet delicately balanced and finely tuned, and its continued success requires **continuous attention to detail**. *Ziyad H. Duron*

Clive Dym Pat Little Liz Orwin Lori Bassman

**Fig. 3.** The Core E4 Teaching Team.

text and in introducing the studio approach [11]; Elizabeth J. Orwin[2] who has taken the lead in introducing the realization—the making and manufacturing—link into E4; and Lori M. Bassman, who for several years taught the course with infectious enthusiasm.

It is also a source of pride to me and my colleagues that, like Engineering Clinic, E4 is being replicated in varying forms across the U.S. engineering landscape. For example, schools as diverse as Northwestern and Arizona State (@ Mesa) Universities have adopted first-year design courses that are modeled very much along E4 lines. Similar courses have appeared in both engineering and engineering technology programs across the country. The Dym-Little textbook for E4 and similar courses [12] has been adopted by more than 80 U.S. schools, sold more than 36,000 copies, been translated into Spanish, Korean and Portuguese, and is now headed for a fourth edition.

## 6. Mudd Design Workshops

I have already noted that this is the eighth in the series of biennial Mudd Design Workshops [13–29], a complete list of which is shown in Table 5. In 1997 HMC's Department of Engineering instituted a biennial program of Mudd Design Workshops to bring together design educators, practitioners and researchers to discuss issues in design and engineering education. The MDWs have become a highly desirable meeting place with important intellectual content on design pedagogy for engineering faculty. Registrants represent a wide range of U.S. engineering schools, including Arizona, ASU, BYU, CMU, Clemson, Cornell, George Mason, Georgia Tech, Idaho, MIT, Minnesota, Missouri, Northwestern, Olin, Penn State, Pittsburgh, RPI, Smith, Stanford, Tennessee, Tulane, USC, Utah State, Virginia Tech, Washington, and Yale. Overseas participants have also been plentiful, representing Aalborg, Budapest University for Technology and Economics, Hong Kong U of Science and Technology, Institutt for Informatikk (Oslo), KAIST, Maastricht, Singapore Polytechnic, Technion, TU Berlin, TU Delft, TU Lisbon, TU Denmark, Tel Aviv, Universidad Politécnica de Valencia, and the new Singapore University of Design and Technology (SUTD) in 2011. Practitioners have come to the MDWs from Attenex, Boeing, IDEO, Lucent, Northrop, and Sapient.

Recent MDW keynote speakers include William A. Wulf, then-president of the National Academy of Engineering (2003), James W. Pellegrino, Distinguished Professor of Psychology and Education at the University of Illinois at Chicago (2005), Chris Scolese, Chief Engineer of NASA (2007) and Malcolm Lewis, President of Constructive Technologies Group (2009). Featured banquet speakers have

**Table 5.** The Eight Mudd Design Workshops (Year, Registration)

| | |
|---|---|
| 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) |

**Table 6.** The Honor Roll of Mudd Design Workshops Advisory/Organizing Committees (showing the number of committees that these folks have served)

| | |
|---|---|
| Seven (7): | Greg Olson, John Prados, John Wesner |
| Six (6): | Sheri Sheppard |
| Five (5): | Larry Leifer |
| Four (4): | Alice Agogino, Cindy Atman |
| Three (3): | Ed Colgate, Phil Doepker, Chris Magee, John McMasters (dec.) |
| Two (2): | Aaron Altman, Ahmad Ibrahim, John Lamancusa, Pat Little, Janis Terpenny, Michael Wald (dec.) |

[2] It is also a pleasure to note that Liz Orwin, then Liz Cornelius, was a first-year student at HMC when I introduced E4 in spring 1992, and I was chair of Engineering when we recruited Liz, HMC'95, back to HMC as an Engineering colleague!

Holly Hauck (II, III, IV) Sue Lindley (VI) Sydney Torrey (VII, VIII)

**Fig. 4.** The 'True Organizers' of the Mudd Design Workshops.

included presidents of two emerging institutions who introduced their new endeavors to the MDW community: Richard K. Miller talked about Olin College in 1999, and Thomas L. Magnanti described the Singapore University of Technology and Design in 2011. Workshop audiences have generally included 50–60% repeat registrants from previous workshops, with the balance being 'first timers.'

The MDWs were initially supported by HMC and a few industrial partners, including Boeing, Hughes, and Raytheon. They have become largely self-supporting, perhaps an indication that the MDW series is regarded as an excellent investment in the vast free market of conferences and meetings. Ironically, my 2001 proposal to the NSF was rejected in part because the series of workshops was regarded as 'too successful' to warrant further support—although it must be noted that the NSF did support MDW III (2001) and is supporting this year's MDW VIII. As a result of that support, we have participants from under-represented groups and minority-serving institutions, and we are building an 'MDW Community' web site.

I have chaired all eight MDWs, undertaking the task as part of being the inaugural holder of the Fletcher Jones Professorship of Engineering Design at HMC. Over the years I have also had the benefit of valuable support and contributions from a collection of Organizing and Advisory Committees with several members who have served on such a committee more than a few times. I list the 'honor roll' of advisory/organizing members in Table 6 and thank them for their continuing exceptional support.

This MDW, the eighth is a poignant one for me, partly because the tremendous interest in this workshop is a very vivid reaffirmation of assessment results found after previous editions: respondents have almost uniformly found that the MDWs provided important intellectual content on design pedagogy and have created 'a vibrant community' of design educators and design practitioners. But it is also poignant because MDW VIII is the last edition that I will solely chair because I am phasing out my HMC appointment, intending to retire fully in December 2012. Harvey Mudd College will commence a search for the next Fletcher Jones Professor of Engineering Design in summer 2011, hoping to fill the post for the academic year 2012–13.

Harvey Mudd College, its Department of Engineering and the MDW VIII Organizing Committee all intend that the biennial series of MDWs will continue, and it is my hope that my planned overlap with the next Fletcher Jones Professor will help in that regard.

Finally, in the context of organizational support, I cannot adequately thank the 'true organizers' of the MDW series (Fig. 4): Holly Hauck, Sue Lindley and Sydney Torrey. Without their unfailing efforts and sense of responsibility, the MDWs would simply not have happened.

## 7. Concluding thoughts

Innovation and entrepreneurship seem to have become extremely popular buzzwords in engineering education these days, perhaps even in college and university education generally, and the foregoing remarks will not add very much to the buzz. From the author's view, it seems rather clear that people should not self-identify as innovators, and perhaps not even as entrepreneurs except in the most narrow and obvious of circumstances. On the other hand, it seems very important that context and history mean everything here, so the lesson to be drawn is that we often are simply unaware of the work of those who've gone before us. We owe it to our predecessors, to ourselves and to our students and successors to pay attention to and recognize and celebrate true educational innovation and entrepreneurship.

*Acknowledgments*— I am grateful to Harvey Mudd College for its continuing support of the MDW series, in particular the Chair of Engineering, Ziyad H. Duron, and the Dean of Faculty, Robert J. Cave. I am also grateful for the financial support provided by the National Science Foundation under Grant EEC-1102663.

I am also very grateful for the continuing, enthusiastic support of the MDW VIII Organizing Committee: Alice M. Agogino, 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; Christopher L. Magee, Massachusetts Institute of Technology; Gregory B. Olson, Northwestern University; John W. Prados, University of Tennessee–Knoxville; Sheri D. Sheppard, Stanford University; Janis P. Terpenny, Virginia Polytechnic Institute and State University; and John W. Wesner, Carnegie Mellon University.

I am also grateful to the staff of the Department of Engineering at Harvey Mudd College for their continuing support, including first and foremost Sydney Torrey, who once again undertook administrative responsibility for virtually all of the event logistics. She was organized, thorough, thoughtful and always on a decidedly even keel. As I said above, this workshop simply would not have happened without Sydney.

Ray Hurwitz, a rising sophomore at HMC has provided invaluable help in many ways during and after MDW VIII, including assessment, the wrap-up paper [21], and the creation of an MDW website (http://mudddesignworkshop.com).

Finally, I want to acknowledge the helpful reviews and comments provided by my Harvey Mudd colleagues Ziyad H. Duron, M. Mack Gilkeson (Emeritus), Jeffrey R, Groves, and J. Richard Phillips (Emeritus).

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