A Report on Mudd Design Workshop II: "Designing Design Education for the 21st Century"

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Abstract

This paper reports on a workshop on design education held at Harvey Mudd College (HMC) in May 1999. Mudd Design Workshop II was intended to provide a forum that would bring together design educators, design researchers, and designers from industry, in order to focus exclusively on the teaching of design in engineering education for the next century. Sessions were devoted to (1) design projects in both cornerstone and capstone courses, and metrics for selecting projects; (2) discipline-based and cross-disciplinary design courses; and (3) pedagogy, technology, and assessment in design education. Major emergent themes included the desirability of design throughout the curriculum, focuses on coaching and on learning, roles of projects and interactive learning, and the need to better address the interactions of grading and learning. Participants' specific commitments to future actions are also given.

I. The Origin of the Mudd Design Workshops

The Center for Design Education (CDE) at Harvey Mudd College is an outgrowth of an engineering design center which had as its early focus the development of a network of computing and laboratory facilities that supported Harvey Mudd's design-intensive, unspecialized, general engineering program. While the CDE still maintains an extensive Engineering Computation Facility (ECF), it has evolved into a center that has several additional foci, including:

- a computing design environment to support students' from their freshman design course [1, 2] through their work in Engineering Clinic [3, 4] in their junior and senior years;
- computational tools to further improve students' ability to manage and schedule externally-sponsored freshman and Engineering Clinic design projects in the junior and senior years; and
- an interest in stimulating increased awareness of design by engineering faculty nationally (and even internationally), in part by thinking about design as an integrator of the engineering education environment.

In support of the last focus the CDE organized and hosted the *first* Mudd Design Workshop in May 1997 entitled [5] *Computing Futures in Engineering Design*. This workshop attracted more than forty design educators and researchers (representing, for example, Arizona State, Carnegie Mellon, Florida State, Pittsburgh, Stanford, Washington) and designers (including engineers from Hewlett Packard, MacNeal-Schwendler, McDonnell Douglas) to address various issues in engineering design education. With financial support from both Mudd and Hughes Electronics, the workshop focused on the future roles of computing in *doing* design and engineering and in the *teaching of* design and engineering. It was intended to provide useful insight, advice, and information to educators about how they might think about the future of design and design-related computing, and about the roles for organized centers (of design and related focuses) in engineering education. The meeting was organized as a *workshop*, with the sessions constructed to give *all* participants a chance to be heard as well as to hear and listen.

Workshop sessions were scheduled on: models of design; engineering use of computers in the "real world"; roles of technology in delivering education; and the question, what is learning? Three keynote talks were presented at the workshop. At the opening lunch, C. L. Dym presented a vision of design research and teaching within the HMC context. At the Workshop dinner, N. Mansur and C. Shulstad of Disney presented a visually-intensive view of the roles played by computing in the design, construction, operation, and enjoyment of Disneyland. The final luncheon featured S. J. Fenves, then Carnegie Mellon, as rapporteur who reported on all that had been heard and provided a cohesive summary of the principal threads of discussion [5].

The response to this first Mudd Design Workshop was very positive, and so, supported by both Hughes Electronics and The GE Fund, the CDE organized and hosted a *second* Mudd Design Workshop in May 1999, this time under the rubric [6] *Designing Design Education for the 21st Century*. This workshop brought together sixty design educators and researchers (including Arizona State, Carnegie Mellon, George Mason, Massachsuetts–Lowell, MIT, Northwestern, Stanford, Technical University of Berlin, Tennessee, Tulane, Washington, Worcester Polytechnic, Yale) and design practitioners (including Lucent Technologies and Prescient Technologies) to focus on future directions for

engineering design education. It is this second workshop [6] that is briefly described in this paper by three members of its Advisory Committee.

II. Structure of MDW II and Session Themes

Eight topical workshop sessions were scheduled over two and one-half days on the following topics: themes for design education; design projects as cornerstone; design projects as capstone; metrics for selecting design projects; discipline-based design education; integrated engineering design education; tools and technology in design education; assessment—how are we doing? A final wrap-up session tied everything together. Sessions were initiated with brief presentations by three or four panelists, after which open, moderated, general discussion followed. The panelists' position papers reflected ideas and attitudes about what was being done in engineering design education, as well as on what could be done in the future. Draft position papers were distributed to all participants in a preliminary proceedings volume, and a final, formal volume of the proceedings was later published [6]. In addition, many of the papers presented are contained in a special issue of the *International Journal of Engineering Education* [6].

Four keynote talks were presented at this workshop. The opening lunch featured S. D. Sheppard talking about the compatibility of design and analysis education. Two provocative questions, "Presence or Telepresence? What will Professors Do?" were posed at the second luncheon, by W. C. Flowers. J. J. Shah proposed at the final luncheon that grading criteria be designed to improve students' design skills. And, R. K. Miller, the new president of the new Olin College of Engineering, described the design of this new school at the workshop's banquet.

The first eight working sessions were reviewed at the ninth, wrap-up session at which their chairs—typically Advisory Committee members—summarized the most important issues and themes of their sessions. The session themes and issues identified by each of the (named) session chairs are displayed in Tables 1 and 2.

III. Key Workshop Themes

It is clear from Section II that the session discussions covered a wide range of issues and themes. Interestingly enough, when a somewhat smaller subset of papers was reorganized for the special issue of the *International Journal of Engineering Education* [6], it could be seen that other constructs of issues and themes could be identified, including:

- Design is replete with "people" issues, both personal and social.
- Design educators must stress *collaboration* and work as *team members*.
- *Projects* and *experiential learning* are central to design education, and careful project selection is critical.
- *Assessment* and *evaluation* are important at every level, from project selection, through project and course grading, to curriculum monitoring and accreditation.

Even constructed so compactly, it can be said that a very wide variety of issues relating to the teaching of engineering design surfaced—perhaps too many to be remembered and effectively applied. Since the workshop organizers wanted participants to leave with *action items*—commitments to try in their own classrooms some of the things they had learned during the workshop—a wrap-up session was included as the ninth and final session. The wrap-up session was designed to achieve two goals:

- Identify the *key themes and learnings* brought out during the entire workshop; and
- Elicit *commitments* from the participants, to apply workshop ideas of their own choosing in their own classrooms during the next two years—anticipating the reporting of results at Mudd Design Workshop III.

The *key workshop themes* were identified by the guided application of *affinity diagramming* (a tool for non-numeric decision making; see [7]) during the wrap-up session to review and capture the most important session themes just outlined in Section II. After each session chair stated the most important issues and themes of their sessions, the participants in the wrap-up session gathered all of the session issues and themes into *affinity groupings*, each of which was assigned a *title*. The titles of the affinity groupings became the bases for identifying the *key workshop themes*. This set of key themes or *key learnings* from the workshop—that also represent a synthesis of the individual workshop presentations and countless hallway discussions—is:

- Focus on *Learning* rather than on *Teaching*:

  Coaching rather than *Teaching* as the methodology of the educator.

  Coach rather than *Sage* as the role of the educator.

- Give attention to the *Humanist Engineer*:

  Include *Culture*, *Values, and the notion of Intent* in the academic program.

- Include *Assessment* and *Continuous Improvement* in the program

- Focus on *Projects* and *Experiential Design Learning*:

  Design Projects must be *Designed*.

- *Grading* and *Learning* must be addressed in new ways.

IV. Commitments to Actions and Outcomes

Most of the workshop's participants stayed for the wrap-up session. A good number of them publicly announced a strong willingness to commit to try things they had learned during the workshop. If a good percentage of the large number of commitments that were made are actually met, there will be a lot of quality material to discuss at Mudd Design Workshop III (see below). The commitments were written down, so that people could be reminded of what they said they would do. A representative list of "promises" made includes commitments to:

- ✓ stop lecturing in classes and use more of a *coaching* style;
- ✓ used assessment instrument on the group of participants in this workshop;
- ✓ work on teaching faculty to *coach*;
- ✓ address assessment, guidelines for projects, "humanist engineering," and coaching within their several programs;
- ✓ explore alternate ways of grading the freshman design course;
- ✓ look at the use of *studios* in design education;
- ✓ work to have more computer science faculty and students to realize that they are *doing design*;
- ✓ work with his Human-Computer Interaction Class to design experiments;
- ✓ to work with his university's Learning Laboratory to try to identify what separates Engineering from the rest of the university, from a teaching/learning perspective;
- ✓ explore *values* in design;
- ✓ report back on the growth, progress, and status of the First Competition;
- ✓ look beyond Engineering to the rest of the university for ideas relevant to the workshop learnings; and
- ✓ work with all interested parties on the next workshop.

V. Conclusions

The original announcement of Mudd Design Workshop II incorporated the following three elements:

A vision of a workshop that brought together design practitioners, researchers, and educators who, drawing on their experience and practice, would focus on future directions for engineering design education.

A mission of identifying and proposing 4–6 key ways to improve engineering education for the 21st century.

A process by which some 75–100 participants from academia, industry, and government would work together over two and one-half days discussing the design of engineering design education for the next century

Inasmuch as the sixty (yes, the organizers "failed" here) participants emerged committed to trying a broad variety of ideas from the session themes and issues and the key themes in their own classrooms, it may be justifiably said that this workshop reached its vision and fulfilled

its mission, by a sound and useful process. Participants were enthusiastic about the workshop learnings, were very willing to do undertake their (written) commitments, and expressed a great deal of interest in the prospect of a Mudd Design Workshop III.

VI. Acknowledgments

The authors would like to acknowledge once more the support of the remaining members of Workshop II's Advisory Committee: Steven J. Fenves, Carnegie Mellon University; Woodie C. Flowers, Massachusetts Institute of Technology; George A. Hazelrigg, National Science Foundation; Patrick Little, Harvey Mudd College; Gregory B. Olson, Northwestern University; John W. Prados, University of Tennessee; and Jami J. Shah, Arizona State University. As has already been noted elsewhere, the Advisory Committee's involvement made Mudd Design Workshop II larger, more exciting, and more challenging than its founding (1997) predecessor.

VII. References

1. C. L. Dym, "Teaching Design to Freshmen: Style and Content," *Journal of Engineering Education*, *83* (4), 303–310, October 1994.
2. C. L. Dym and P. Little, *Engineering Design: A Project-Based Introduction*, John Wiley & Sons, New York, 1999.
3. J. R. Phillips (Editor), *Engineering Clinic Issues*, Proceedings of the 30th Anniversary Symposium, Harvey Mudd College, Claremont, California, 25 April 1994.
4. J. R. Phillips and A. Bright, "The Harvey Mudd Engineering Clinic: Past, Present, and Future," *Journal of Engineering Education*, *88* (2), 189–194, April 1999.
5. C. L. Dym (Editor), *Computing Futures in Engineering Design*, Proceedings of a Workshop, Harvey Mudd College, Claremont, California, 2–3 May 1997. See also C. L. Dym (Editor), Special Issue, *Artificial Intelligence for Engineering Design, Analysis, and Manufacturing*, *12* (1), January 1998.
6. C. L. Dym (Editor), *Designing Design Education for the 21st Century*, Proceedings of a Workshop, Harvey Mudd College, Claremont, California, 19–21 May 1999. See also C. L. Dym and S. D. Sheppard (Editors), Special Issue, *International Journal of Engineering Education*, # (#), Date Uncertain.
7. J. W. Wesner, J. M. Hiatt, and D. C. Trimble, *Winning with Quality: Applying Quality Principles in Product Development*, Addison Wesley, Reading, MA, 1994.

List of Tables

1: Themes (Steve Fenves)	teacher's role to progress from *lecturer* to *moderator*; differentiate among teaching, developing, cultivating
	engineers have to decide on how to deal with people
	reuse capstone projects, close experience learning loop
2: Case Studies (Patrick Little)	compelling case-level evidence of the effectiveness of *active learning* of the hands-on, project-based type in engineering education
	project-based learning facilitates introduction of difficult and complex ideas into the curriculum
	trade off between the number of concepts introduced and the retention level of the concepts introduced
3: Case Studies (Richard Phillips, HMC)	integrate the design experience with foreign study
	coaches need to be coached
	grading schemes should motivate students
4: Selecting Projects (Greg Olson)	*general* guidelines: supportive clients (e.g., committed liaisons, creative latitude, concrete goals); *design* projects (not research, development) on non-critical path; projects challenging, clear, compelling to team members; include design *and* fabrication
	cornerstone guidelines: *conceptual* design; multiple solutions; non-profit clients; connect to engineering
5. Discipline-Based Design Education (Jami Shah)	curriculum change to hands-on design, manufacturing team projects; freshman courses; case studies of real, mass-produced products
	holistic view of structural design education situated, integrated, supported by Internet-based environment
	respect emotional logic: work with humanists to develop, cognitive neurophysiology to understand

Table 1: Session Themes for Sessions 1–5.

6. *Integrated Education (Michael Moody, HMC)*	similar philosophical discussions in mathematics community over the "reform" of math teaching; key words/principles for design education evolution: *integrated efforts, authentic learning activities, interdisciplinary course, realistic experience, de-compartmentalize topics, life-long learning, students assume responsibility, vertical integration of material, reinforcement, multiple feedback opportunities, redefinition of instructor's role*
	ideas implied by phrases are very much about process of effective education in a general sense
	suggest inviting one of major figures in calculus reform (e.g., Debra Hughes-Hallet, lead author of influential "Harvard" calculus text) to MDW III
7. *Tools and Technology (George Hazelrigg)*	CAx hard to learn; needs too much time investment
	how will CAx change engineering? reaction will be?
	emergent properties of large, complex systems are not understood; how to address in education?
	uncertainty pervades engineering
	values are a part of engineering design
8. *Assessment (John Prados)*	design and assessment processes are similar; both include continuous improvement feedback loops
	continuous improvement requirement is important, (underestimated?) component of EC 2000
	discomfort with assessment processes perhaps from confusion between *course* and *program* assessment
	formal textual analysis yields characteristics that can be correlated with design report grades

Table 2: Session Themes for Sessions 6–8.

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Sheri D. Sheppard is an associate professor in the Design Division of Mechanical Engineering at Stanford University. Beside teaching design classes, she conducts research on weld fatigue and impact failures, fracture mechanics, and applied finite element analysis. She is particularly concerned with developing effective tools to allow designers to make more informed decisions regarding structural integrity, one of which was recently adopted by the General Motors Corporation as a corporate approach to life estimation. In addition, she was co-PI of Stanford's participation in the NSF Synthesis coalition, and has served as co-director of Stanford's Learning Lab. She is a Fellow of the American Society of Mechanical Engineering (ASME) and the American Association for the Advancement of Science (AAAS). Dr. Sheppard was recently appointed Senior Scholar at the Carnegie Foundation for the Advancement of Teaching where she will lead a major study of U.S. engineering education, as part of a larger Carnegie project investigating education in the professions. Before coming to Stanford Dr. Sheppard held several positions in the automotive industry, including at Ford's Scientific Research Lab. She also worked as design consultant, providing companies with structural analysis expertise. Dr. Sheppard did her graduate work at the University of Michigan (1985).

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