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What We Have Learned at Mudd Design Workshop VII: 'Sustaining Sustainable Design'*

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This paper summarizes and highlights the presentations and discussions that took place during a workshop on sustainable engineering design in both practice and education. Supported by Harvey Mudd College's Center for Design Education, Mudd Design Workshop VI, 'Sustaining Sustainable Design,' was held at Mudd during 29–31 May 2009. This paper describes both the key ideas that emerged from the presentations and discussions of the participating engineering design educators, practitioners and researchers, and the methodology used to capture and retain those ideas.

Keywords: design education; sustainable design; sustainability

1. INTRODUCTION

AS HAS BECOME a standard product of the Mudd Design Workshops, this paper presents the results of the seventh of this biennial series, MDW VII, 'Sustaining Sustainable Design,' held at Harvey Mudd College, in Claremont, California, during 29–31 May 2009 (Fig. 1). The Workshop was organized in much the same ways as its six prior implementations [1–6]. After remarks by the Chair of the Workshop's Organizing Committee at the opening luncheon, Dr. Malcolm Lewis, Founder and CEO of The Constructive Technologies Group of Irvine, California, gave the keynote talk on 'Sustainable Design From a Practitioner's Perspective'. The key ideas developed in the Workshop Chair's opening remarks are that:

- Sustainable design choices are not technical; they are often driven by economics.
- Some resource scarcities are mediated by market forces (e.g., oil) and some by advances in technology (e.g., wireless replacing copper land lines), but some resources are irreplaceable or irretrievable (e.g., soil, water, ecological diversity).
- Resource productivity is important.
- Good design uses less energy and fewer resources.
- Both private and social costs and benefits must be accounted for in design evaluation and assessment.
- Engineers have a responsibility, indeed a duty, to design for sustainability.

The keynote speaker positioned these key ideas very clearly and succinctly:

- Sustainable design meets present needs without compromising the ability of future generations to meet their needs.
- All aspects of a design must be considered *ab initio*, up front.
- Investment at the community scale radically reduces costs at the (individual) building or project scale.
- The larger the system being designed, the more it demands sustainable solutions for the systems with which it interacts.
- Design decision making must incorporate *right brain* (or 'squishy') thinking and attributes, as well as *left brain* (or analytical) habits of thought.

The seven following sessions were devoted to various aspects of sustainability in engineering design education and practice. Each session started with four 10-minute 'position talks' that were followed with about 75 minutes of vigorous open discussion. The Workshop ended with the convening of a formal 'Wrap-Up' session and a subsequent closing luncheon.

The next section of the paper describes the methodology used to pull together the key 'Learnings' of MDW VII. It is followed by Sections (3) What Have We Learned?; (4) The Core Concepts and Key Ideas; and (5) Input From the Workshop Presentations.

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Fig. 1. The Parsons Design Studio, designed for HMC's first-year design course, *E4: Introduction to Engineering Design*, was once again the venue for an MDW.

2. THE METHODOLOGY

Before the Workshop sessions started, each session moderator was charged to capture what he or she believed to be the three or four *most important* or *key* ideas or issues brought out in their session, either from the presentations or from the ensuing discussion. The moderator of the Wrap-Up session (JWW) did the same for the keynote talk and other non-session presentations. These key ideas are collected in Part II below, organized according to the sessions from which they were gathered.

These key ideas were compiled as a PowerPoint® presentation and also copied onto Post-it® notes (one key idea per note) prior to the Wrap-Up Session. The Wrap-Up Session started with a presentation of all of the captured 'most important' ideas and issues, with some discussion, mostly for clarification. The Workshop participants were then challenged to gather the key ideas and issues in common categories or affinities according to common themes, in order to obtain a compiled set of major concepts on which participants might choose to work after the Workshop. The challenge was structured in that the participants were asked to construct *affinity diagrams* [7, 8]. The construction of affinity diagrams by teams is a silent exercise in which everyone on a team works together to group related items (affinities), and then choose names for the assembled categories:

> The purpose of this exercise is to identify natural groupings of items by silently and simultaneously, everyone working at the same time, placing the Post-it notes with other Post-it notes that belong together. No discussion is allowed. Anyone can continue to move Post-it notes around until everyone is content with the groupings (or tired, whichever comes first).

Since having some fifty participants working together on a single affinity diagram seemed an unwieldy prospect, the audience was divided into four teams, each of which was given an identical set of Post-It notes and challenged to group all of the key ideas and issues (Fig. 2). This did complicate the final analysis since each team grouped items somewhat differently and assigned different titles to each of the affinity groups it formed.

Commonality was sought using a spreadsheet with the key ideas and issues as the rows, and the team groupings as the columns. Columns were brought together according to the number of ideas and issues they had in common, and new 'Learnings' or overall headings were applied that seemed to capture the ideas of the several team group titles. These 'Learnings' are the six *most important core concepts* listed next in Section 3.

3. WHAT HAVE WE LEARNED?

The theme for MDW VII, 'Sustaining Sustainable Design,' was extremely broad, yet it has the potential for great impact if applied properly and expansively. The breadth made finding commonality among the ideas brought forth in the varied sessions difficult. Based upon input from the Workshop participants as described above, the *key ideas* gleaned from the first seven sessions were used to identify the most important *core concepts*, which were further refined into the following MDW VII 'Learnings' (ordered from most abstract to most concrete/least abstract:

- Sustainability may be thought of as a philosophical concept that can be used as a basis forunderstanding and application.

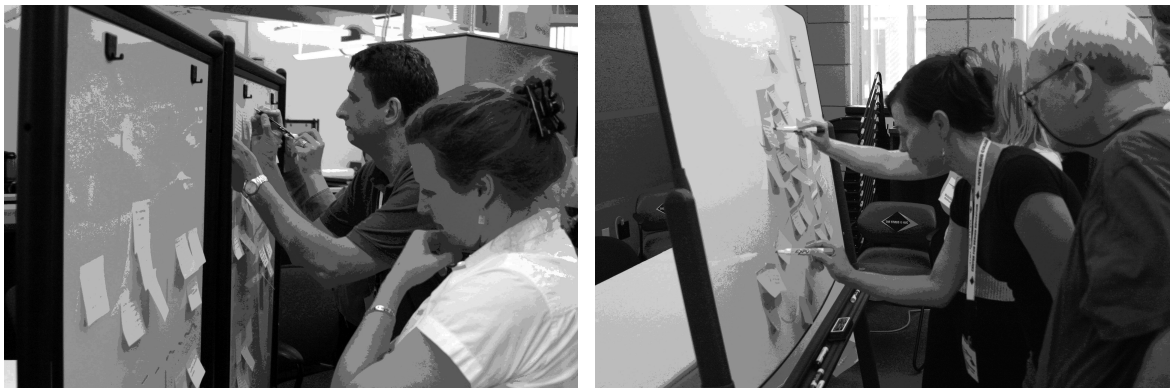

Fig. 2. Scenes from a typical MDW affinity diagramming exercise.

- Thinking about sustainability requires clear definitions and terminology in order to foster and support fruitful discussion.
- Sustainability must be considered in context.
- There are both methods and tools that can be wielded to do sustainable design.
- Sustainable design has many non-engineering aspects.
- Sustainability issues are myriad in the engineering curriculum in many dimensions.

None of these Learnings leads directly to actions that Workshop participants can take to improve their work or teaching performance. The *key ideas* that make up each of them provide suggestions to help improve the profession's understanding of sustainability, and to help maintain a focus on incorporating concepts of sustainability in programs and activities in both industry and academia. The *key ideas* that support each Learning are presented in the next section.

4. THE CORE CONCEPTS AND KEY IDEAS

The following paragraphs delineate the Learnings, the *core concepts* that were combined into each, and the *key ideas* that they shared. Here they are listed together with their underlying with their component ideas:

4.1 Sustainability as philosophy—as a basis for understanding and application

This is the merging of three *core concepts*: Values, Spiritual IQ, and Sustainable Products. The first two seem to go together; the third appears to be an outlier. But the criterion for merger was shared *key ideas*. It is not possible to re-create the team dynamic that led to the name of the third *core concept*.

The *key ideas* that comprise this Learning are:

- Good designs use less energy and fewer resources. (3)*
- Sustainable design meets the needs of the present without compromising the ability of future generations to meet their own needs. (3)
- Sustainability should be viewed as a constraint, rather than as an objective. (2)
- We often thoughtlessly push non-sustainable thought (e.g., 'quick and dirty'). (2)
- Students should learn that beyond function, form is important in sustainability design (2)
- Apply sustainability to our own practices ('physician heal thyself'). (2)

4.2 Thinking about sustainability—needing definitions and terminology for discussion

This, too, is the merger of three *core concepts*: Change in Perspective, Internal Resonances, and Ways of Thinking and Knowing. These fit together well, and assigning a Level II title was rather straightforward.

The *key ideas* included in this Learning are:

- Sustainability-focused design education is, at some deep level, about caring in the natural, ethical and human realms. (3)
- Creativity is more than 'just another tool' for engineering design. Rather, it is a core idea or capacity in reducing the unsustainable remainder ('dross') spoken of by the keynote speaker. (3)
- We design products we don't need, that we pay for with money we don't have, in order to satisfy people who don't care. (2)
- We need to re-orient or mental models, our views of reality, to convert our means to make them our ends. (2)
- Sustainability is both a process issue (i.e., an intrinsic attitude, much like ethics) and a content/substance issue (e.g., technical, economic, etc., domain knowledge). (2)
- Sustainable buildings are spiritual places. (2)

4.3 Sustainability in its appropriate context

The three *core concepts* that were merged into this Learning are Holistic Systems, What is Sustainability?, and Diverse Perspectives and Abilities Required.

The key ideas that form this are:

- All aspects of a design need to be considered up front. (3)
- The larger the system being designed, the more it demands sustainable solutions for the systems with which it interacts. (3)
- There are substantial differences of how sustainability is treated in various disciplines, for example, could EEs be taught to think about reusing/recycling processors across a range of products? (3)
- Investment at the community scale radically reduces costs at the building scale. (2)
- Systemic (i.e., broad scale, wide boundaries) thinking is important. (2)
- Should sustainability be mainstreamed? (2)

4.4 Methods and tools for sustainable design

This was a natural fit for these *core concepts*: Tools/Methods, Tools, and Sustainable Tools.

The included *key ideas* are:

- Laptop tablet computers can reinforce (paperless) sustainability. (3)
- Note public availability of databases on sustainability (UC Berkeley) and ethics (Penn State). (3)
- Clean Air Cool Planet (CACP) Carbon Calculator is a valuable tool. (3)

4.5 Non-engineering aspects of sustainable design

This, too, is an easily-recognized collection of

* Numbers in parentheses indicate how many of the teams put this *key idea* into the clusters collected into this Result.

core concepts: Economics, More than Technical, and Resources are Key Consideration.

The three shared *key ideas* are:

- Sustainability design choices are not just technical; they are often economic. (2)
- Some resource scarcities are mediated through market forces (e.g., oil prices) and some by technology advances (e.g., wireless replacing copper land lines), but some are irreplaceable or irretrievable (e.g., soil, water, ecological diversity). (2)
- Resource productivity is important. (2)

4.6 Sustainability in and of the curriculum.

All four teams identified *core concepts* relating to educational curricula: Curriculum Pros/Cons, Logistics of Student Projects, Sustainable Courses, and Teaching Sustainable Design (Solutions).

There were many shared *key ideas*:

- Incorporation of sustainability in students' design experience requires explicit stimulus either within the design course or within a prior course. (4)
- Sustaining adequate staffing for large-enrollment design courses requires strong institutional commitment (e.g., KIAST) or through support of a department of engineering education (e.g., Purdue, VA Tech). (3)
- Although effective sustainable design requires a large-scale systems perspective, projects for first- and second-year students are realistically limited to smaller system components. (3)
- Design methods are best suited for novel projects. (3)
- Students learn best through examples, although product/design fixation is an outcome to be guarded against. (3)
- Students who take detailed courses are strongest in understanding, but that level of understanding does not change much over the years they're in school. (2)
- Even for students with strongest understanding it was difficult (if not impossible) to do sustainable design in/for real projects when the client does not raise it. (2)
- Emphasis on sustainability in first- and second-year design experiences will lead more students to incorporate sustainability in their capstone design projects. (2)
- Case studies, including those derived from co-op design reports, can be a very valuable tool for teaching (sustainable) design across the curriculum. (2)
- Need 'hands-on' sustainability projects for design courses. (2)
- Sustainability projects increasingly present in design courses. (2)
- Student projects can have a big impact: lead to technological and behavioral changes to improve sustainability. (2)

5. INPUT FROM THE WORKSHOP PRESENTATIONS

The following brief outlines present the key thoughts presented in the 28 'position' talks' organized by the sessions in which the talks were given. Note that the surnames of the first authors of the papers in this session are listed after each session title.

Session 1: Paradigmatic issues (Lau, Corson, Ameta, Lande)

- Sustainability-focused design education is, at some deep level, about caring in the natural, ethical and human realms.
- Creativity is more than 'just another tool' for engineering design. Rather, it is a core idea or capacity in reducing the unsustainable remainder ('dross') spoken of by the keynote speaker.
- Students experience difficulty in framing sustainability design problems from a wide variety of sources, including failure or unwillingness to include non-engineering sources.

Session 2: Sustaining sustainability (Johri, Cardenas, Linder, Oliver)

- Systemic (i.e., broad scale, wide boundaries) thinking is important.
- Work and organizational practices can have a big impact on sustainability, as well as on work-life balance.
- Achieving sustainability requires attitude that both focuses on long-term goals (e.g., zero resource consumption) as well as working on shorter-term immediately achievable gains.
- Sustainability should be viewed as a *constraint*, rather than as an *objective*.
- There are substantial differences of how sustainability is treated in various disciplines, for example, could EEs be taught to think about reusing/recycling processors across a range of products.
- Sustainability is both a *process* issue (i.e., an intrinsic attitude, much like ethics) and a *content/substance* issue (e.g., technical, economic, etc., domain knowledge).

Session 3: What are the students thinking? (Kilgore, Gerber, Adams, Stobel)

- Students reflect society: they know sustainability is important, but they actually understand very little about it.
- Students who take detailed courses are strongest in understanding, but that level of understanding does not change much over the years they're in school.
- Even for students with strongest understanding it was difficult (if not impossible) to do sustainable design in/for real projects when the client does not raise it.

- Students perceive a conflict between life cycle assessment (LCA) and engineering.
- We often thoughtlessly push non-sustainable thought (e.g., 'quick and dirty').

Session 4: Curricula matters I (Goff, Thompson, Cardella, Stiver)

- Incorporation of sustainability in students' design experience requires explicit stimulus either within the design course or within a prior course.
- Sustaining adequate staffing for large-enrollment design courses requires strong institutional commitment (e.g., KIAST) or through support of a department of engineering education (e.g., Purdue, VA Tech).
- Emphasis on sustainability in first- and second-year design experiences will lead more students to incorporate sustainability in their capstone design projects.
- Although effective sustainable design requires a large-scale systems perspective, projects for first- and second-year students are realistically limited to smaller system components.

Session 5: Curricula matters II (Morris, Rhee, Lambert, Williams)

- Students should learn that beyond function, *form* is important in sustainability design.
- Design tools/methods can be used to design sustainable courses, but we also need development of metrics for 'soft' or 'squishy' issues.
- Case studies, including those derived from co-op design reports, can be a very valuable tool for teaching (sustainable) design across the curriculum.
- Need 'hands-on' sustainability projects for design courses.
- Laptop tablet computers can reinforce (paperless) sustainability.
- Note public availability of databases on sustainability (UC Berkeley) and ethics (Penn State).

Session 6: innovation (Tate, Bremer, Vanasupa, Linsey)

- Transdisciplinary approaches to engineering are needed in order to successfully address societal needs.
- We design products we don't need, that we pay for with money we don't have, in order to satisfy people who don't care.
- Need to re-orient or mental models, our views of reality, to convert our means to make them our ends.
- *Economic* domain embedded within *social* domain, which is embedded within *environment* domain; they are not separate domains with coincident (i.e., Venn diagram) portions.
- Design methods are best suited for novel projects.
- Students learn best through examples, although product/design fixation is an outcome to be guarded against.

Session 7: Sustainability projects and products (Paretti, Doepker, Fleischmann, Oehlberg)

- Sustainable design requires bringing everyone to the table. How does that happen when 'the table' is only a metaphor (i.e., what's difference between *co-located* and *distributed*)?
- Sustainability projects increasingly present in design courses.
- Clean Air Cool Planet (CACP) Carbon Calculator a valuable tool.
- Student projects can have a *big* impact: lead to technological and behavioral changes to improve sustainability.
- Can use *content* in human-centered, sustainable product design to enhance diversity (i.e., women, under-represented minorities) and to develop confidence in meeting ABET A-K criteria. There are gender differences in students' project preferences, as well as in skill improvements.

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