Seeking New Perspectives: Engineers Experiencing Design through Creative Arts

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SEEKING NEW PERSPECTIVES: ENGINEERS EXPERIENCING DESIGN THROUGH CREATIVE ARTS

Abstract

The engineering curriculum of necessity focuses heavily on technical subjects—mathematics, chemistry, physics, and the large body of discipline-specific material. The arts are frequently present only in vestigial form and are regarded as tangential at best to the real engineering curriculum. However, an experience of the creative arts beyond the superficial might reveal that the artist and the engineer are not as different as is usually supposed. The University of Texas at Tyler has conducted an experimental project in which engineering students were encouraged to experience the design process afresh from the perspective of the creative arts. Juniors in electrical engineering worked under the mentorship of arts faculty in a chosen medium (studio art, writing, or music) to produce legitimate works of art that were displayed, performed, or read publicly, and documented how their experiences of design in the arts have informed and shaped their perspectives as engineers. The structure, expectations, and results of this course are described in this paper.

A pedagogical crisis presents an opportunity

The BSEE and BSME curricula of the University of Texas at Tyler include a required course entitled "Design Methodology in Engineering." The course's catalog description states that it is "an overview of design activity in engineering" and includes "the product design process; project planning; quality function deployment; design specifications; concept generation and selection; system and subsystem design." This course would appear to have *prima facie* relevance and value to engineering students; however, its reception among EE students has been lukewarm at best. Thirty-one graduating EE seniors between 2011 and 2013 (the latest years for which data have been compiled) assessed the usefulness of Design Methodology as 2.65 on a scale of 1 – 5 with 1 representing "Little Usefulness," 3 representing "Useful," and 5 representing "Essential." (Eight students chose the extremes of this scale, with six choosing "Little Usefulness" compared to two choosing "Essential").

Design Methodology had traditionally been taught by Mechanical Engineering faculty to mixed classes of EE and ME students. However, circumstances in the fall of 2015 disrupted this longstanding comity. The large number of ME juniors enrolling in the course outstripped the available faculty resources (both the EE and ME Departments had faculty vacancies) and provoked a decision in fall, 2015, to limit enrollment in Design Methodology in the spring of 2016 to ME students only. However, rather than simply finding someone to teach Design Methodology for its students, the EE Department challenged its faculty to find creative solutions to the crisis. Two proposals were eventually put forward. One proposal was to create an additional technical elective involving Matlab, Simulink, and LabVIEW. The other was an exploration of the design process *through participation by engineers in the creative arts.* The genesis of this particular proposal is described in the following paragraphs.

Insights from Gustave Flaubert

One of the authors of this paper has long harbored Francophile tendencies and approximately a year ago undertook as a personal goal to read Gustave Flaubert's masterpiece *Madame Bovary* in the original French. This particular edition of the text [1] included an appendix that described the genesis of the novel, including Flaubert's development of detailed scenarios for the events of his novel in which Flaubert described the setting, characters involved, and outcomes of these events. The level of detail and planning seems remarkable to an engineer; Flaubert even drew a simple map of the fictional village of Yonville-l'Abbaye in which much of the story takes place. Many pages include cross-outs and marginal notes related to the plot. Faculty in the arts, however, are used to seeing such careful mapping of setting, plot, and characters in imaginative texts, especially in longer works such as novels. Similar plans were made by Charles Dickens and Jane Austen for their novels, and by William Wordsworth and John Keats for their poems. Figure 1 shows images excerpted from Flaubert's original manuscript (which is now available on-line). [2]

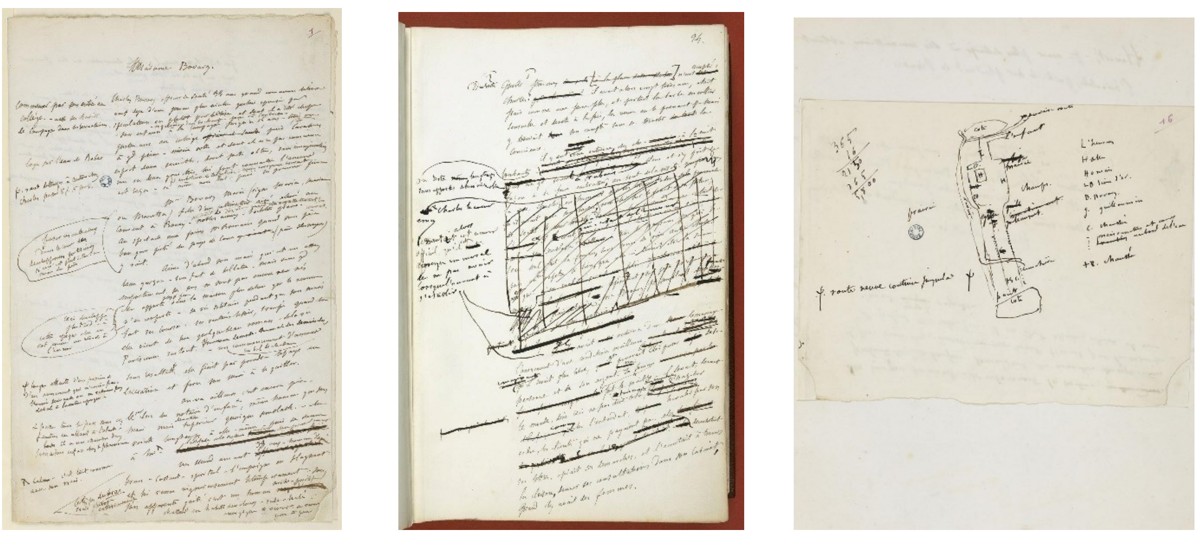

Fig. 1. Excerpts of Gustave Flaubert's manuscript of *Madame Bovary*.
Left: opening page. Marginal notes about characters and settings appear on the left-hand side of the page.[3] Center: chapter 1, folio 24 of Flaubert's manuscript, showing extensive editing. [4]
Right: Flaubert's hand-drawn map of Yonville-l'Abbaye.[5]

Flaubert's meticulous detail, planning, and documentation evident in the artifacts he created are reminiscent of the detail, planning, and documentation in engineering design. Flaubert, like other imaginative writers, evidently employed a structured *process* by which he brought his work to fruition. This encounter with the artifacts of Flaubert's creative process posed the following question: *what sorts of structured design processes do other artists use—and could engineers learn from them*?

Engineering—a straitjacket curriculum?

The process of answering this question began with a survey of literature; and, somewhat surprisingly, there does exist a body of literature bearing on the relationship of engineering and the creative arts. But some of that literature concluded that the engineering curriculum has little room for engagement with the arts.

Lichtentstein et al [6] have performed an extensive analysis of data from the National Survey of Student Engagement (NSSE) and have drawn conclusions regarding the engineering curriculum. They conclude that the tightly-packed engineering curriculum leaves little room for studies for personal development; as a consequence, engineering students report the least engagement among all majors in foreign languages, study abroad, and independent study. The perceived benefits of the liberal arts component of the engineering degree are consequently low. They speculate that a narrow curriculum may discourage students from continuing in engineering or enrolling in engineering in the first place:

> "Might students who leave engineering (or who never enroll who might otherwise have considered the degree) enter STM [Science, Technology, and Mathematics] and Business believing that they can still acquire practical skills that make engineering so appealing, while giving themselves curricular breathing room for enriching educational activities that are difficult or impossible to pursue when enrolled in engineering?"

The rigid curriculum would appear to be an impediment to the education of the socially-aware, humanistically-competent graduates envisioned in *The Engineer of 2020* (among whose traits is "the creativity of Pablo Picasso"). [7]

These observations prompt the question, *could engineers draw benefits from a curriculum in which they have greater exposure to the arts?*

Loosening the straitjacket—the benefits of arts training for engineers and scientists

The engineering curriculum is indeed bursting at the seams with technical subjects; however, a number of authors make the case that engineers and scientists would reap much benefit from including the creative arts in their education.

Root-Bernstein and Root-Bernstein [8] make extensive observations about the benefits of arts education to scientists and engineers. They state that arts and crafts develop skills of observation, visual thinking, manipulation, and the ability to discern patterns. Drawing and painting, they observe, also contribute to fine-motor skills. Albert Einstein, Luis Alvarez, Richard Feynman, and Hans von Euler-Chelpin (winner of the 1929 Nobel Prize for Chemistry) are cited as scientists whose arts avocations enabled their success in science. The Root-Bernsteins further observe that scientists who have achieved at the highest levels in their fields are significantly more likely than their peers to practice an avocation in the arts. In their view, arts education is not a dispensable luxury.

Kellam et al, [9] drawing upon their experience with an interdisciplinary (engineering/art) design studio program, state that "deliberately engaging students in creative thinking processes is thus critical to their development as innovative thinkers who are able to work across multiple knowledge domains."

Shuster [10] argues that exposure of engineering students to the liberal and the fine arts is important not just because it will make them better members of society, but because it will make them better engineers. Shuster proposes further that creation in art and creation in engineering have much in common, and that the study of the liberal arts and the fine arts requires creative participation on the part of the student in ways that the engineering curriculum does not. The author contends that "the activity of research in engineering has far more in common with artistic creation or even with the appreciation of a work of art than anything which we usually teach in our engineering classes."

Root-Bernstein [11] emphasizes the roles of observation, empathy, and envisioning in scientific discovery and states that all are strengthened by artistic training. He cites the work of anthropologist and painter Desmond Morris (author of *The Naked Ape*) to support his contention that "scientific insight and inspiration stem from empathy, feelings, dreams, visions or, more simply, what Max Planck (himself a concert-caliber pianist) has called the 'artistically creative imagination.' "

Laplante and Flaxman [12] invoke the concept of aesthetics to explain the preference for "elegant" proofs in mathematics and science. They state that information presentation must include considerations of aesthetics and that developments in video and computer technologies are creating niches where computer, video, and audio technologies are converging with art forms like music, painting, sculpture, and theater.

This literature points to the following: (1) greater exposure of engineers to creative arts would potentially enrich their educational experiences; and (2) avocations in the arts correlate strongly with creativity in the sciences and engineering. These ideas have been tested in a number of engineering/arts initiatives as summarized below.

Loosening the straitjacket: art initiatives with engineering students

Mirth and Findley [13] have attempted to broaden the experience of engineers with a course entitled "Enduring Design—the Art of Engineering." In this course, engineering students are exposed to concepts of both *form* and *function*, studying subjects ranging from the art of public spaces to design of web sites to the design of household objects. In this course, students are given challenges to improve the design of common objects (e.g., a stapler). At the outset, students' ideas focus chiefly on improving function; toward the end of the course, students' ideas include a greater proportion of improvements in form. Student response to this course appears to be enthusiastic.

Pezeshki et al [14] have documented the experience of engineering students as they brought into being the artistic visions of a sculptor in projects entitled *Umbrellaship* and *Machinescape*. The chief perceived benefit of these projects was the development of *cognitive empathy* on the part of engineering students as they attempted to comprehend the motivations of the artist and to mesh the engineering project design process with the artist's creative vision.

Recruitment, engagement, and retention of engineering students are benefits reported by Carnegie et al [15] in a mechatronics program that creates sonic objects (e.g., mechanically-played stringed musical instruments that mimic real instruments). They describe this project as "a recruitment dream—skilled engineers/musicians, performing to an open audience using devices they have constructed." The authors report improvements in communication skills in addition to those in student performance, engagement, and retention.

The program *ElectrizArte* [16] described by Yu et al involves electrical engineering students in the design and implementation of projects involving electrical engineering (analog electronics, digital electronics, programming) to create artistic effects (e.g., photonic harp, LED cube). Completed projects were displayed publicly.

Freeman et al [17] describe *EarSketch*, a programming environment and accompanying curriculum that allow students to create their own music mixes. This project's chief goal is to recruit new students into computer science.

Loosening the straitjacket: interdisciplinary art/engineering initiatives

Herzberg et al [18] describe a course in which teams of engineers and artists (video and photography) collaborate to produce photographs of fluid flows that are legitimate works of art while illustrating engineering principles. This course is designed such that "the engineers are expected to be artists, with aesthetic control over their work, while both the art students and the engineers are expected to preserve the scientific utility of their images of fluid flow by providing accurate documentation of the flow and imaging process."

Schoner et al [19] paired engineering and art students at the University of Waterloo in a course called "FINE392: Technology Art Studio." In this course, engineers and artists work together to create technologically-mediated sculptures which are displayed publicly at the end of the course. The course is team-taught by engineering and fine arts faculty, and the course includes subjects from each, including formal sculptural concepts, user-centered design, electricity and electronics, microprocessors, and technology art history.

Costantino et al [20] have used support from the National Science Foundation to establish design studios involving both art and engineering students within the scope of an environmental engineering curriculum. Reported benefits to engineering students included learning to see problems from multiple perspectives and gaining an appreciation of aesthetics.

Thus there appears to be ample evidence of initiatives introducing engineering students to artistic concepts (*Enduring Design*), having engineers contribute to the development of objects of art (*Technology Art Studio*), and engaging engineers as performers (the sonic objects described by Carnegie et al). These initiatives, however, do not appear to engage engineers *as artists*.

Introducing the Leonardo Project

The circumstances in play in the EE Department in the fall of 2015 were these: (a) a replacement for Design Methodology was imperative; (b) Flaubert's detailed notes and frameworks from *Madame Bovary* provided a hitherto-unappreciated perspective on the design process in the arts; (c) a review of literature pointed toward benefits of the confluence of engineering and the arts. These elements were the genesis of an idea to replace Design Methodology with an experiment in which engineers would experience the design process *through direct participation in the arts as artists* in multiple fields of artistic expression.

The idea of an arts/engineering experiment as a substitute for Design Methodology was floated to EE juniors in fall, 2015; twelve students in a class of twenty-five expressed interest. Arts faculty were then approached informally to assess their willingness to participate; responses ranged from curiosity to enthusiasm tempered by trepidation: "how much time is this going to cost me?" Ideas generated in these conversations with EE students and arts faculty were incorporated in an outline that was presented first to the EE Department Chair, who gave his support. It was subsequently presented to the Dean of Engineering and the Dean of Arts and Sciences, who also gave their backing. Support from the latter was crucial, because arts faculty understandably wanted assurances that participation in this experiment would be recognized as a legitimate component of their academic duties.).

Arts faculty were assured that they would have autonomy to set their own schedules and determine how many EE students they would take on. Three arts faculty eventually agreed to participate (one each in writing, music composition, and studio art). EE students interested in participation were required to have an interview with one of the cooperating arts faculty and obtain permission to enroll. Of course, no initiative is complete without a catchy title, and "The Leonardo Project" was the obvious choice.

Structure of the Leonardo Project

The Leonardo Project was structured in a way that sets it apart from previous art/engineering ventures chiefly because students would be working *directly in the arts*. Students could use science or engineering as inspiration for their projects, but this was not mandatory. The Leonardo Project also includes creative writing, which appears to be a novel innovation.

Expectations of students were organized as follows:

1. Meet regularly during the spring semester of 2016. Meetings will initially be informative; subjects relative to creative processes in the arts will be introduced. In subsequent meetings, students will read, show, or demonstrate their work and contribute as critics of their peers' work.
2. Create a portfolio of samples of the artistic or literary form in which the student plans to work.
3. Present a design plan for an arts project including a description of the project goal (what expression of human experience is intended?) and a description of the solution space boundaries of time, budget, skill, knowledge, and available technology. This is to draw an explicit parallel between engineering design and design in the arts:

- Design in engineering: solving a problem or fulfilling a need within the constraints of budget, knowledge, time, and available technology;
- Design in the arts: to solve a problem in human expression within the bounds of time, budget, skills, knowledge, and available technology.

4. Create and maintain a weekly journal that records the design and development processes (this journal serves a purpose analogous to an engineering laboratory notebook).
5. Meet periodically with engineering faculty to talk about the aesthetic design process and how it appears to relate to engineering design.
6. Create drafts or preliminary versions of the work of art.
7. Create a final version of the work and attend its display, performance, or exhibition.
8. Create a video explaining what was done and what insights relating engineering and the arts were gathered.

The eventual enrollment was ten students—three pursuing writing, two composing music, and five pursuing various phases of studio art. The themes of each artwork were left to the discretion of the students and their mentors. Themes related to science and engineering (such as Charles Sheeler's industrial art) were encouraged but not mandatory.

The three authors chose individual themes (street poetry, young adult fiction, and science fiction). Both students who chose music composition are brass players and wrote music for brass instruments. The studio artists include one who worked in collage, one who designed stained glass, one who worked in digitally-enhanced photography, and two who initially planned to do photography but switched to work in 3D forms

Participants in the Leonardo Project were required to negotiate specific schedules with their mentors. Participants also met weekly as a group throughout the project. The first meetings were devoted to discussions of the creative process led by arts faculty; subsequent meetings were used for critiques and focus groups. A video presentation by each individual participant was the culmination of the project.

It has been suggested that recruiting students having prior experience in the creative arts skewed the results of the Leonardo Project since the participants, all of whom were volunteers, were already predisposed to the creative arts. However, this does not seem like a fatal weakness in the design of the project since the Leonardo Project was intended as a preliminary inquiry, not a definitive study.

Grading rubric for the Leonardo Project

The grading scale for components of the Leonardo Project was as follows:

1. Attendance 10%
2. Portfolio 10%
3. Art project design plan 20%
4. Draft or preliminary work 20%
5. Journal 10%
6. Final version 20%
7. Video 10%

Public exposition of student works

A public exposition of student works was held on April 19, 2016, in connection with the annual College of Engineering awards dinner. A gallery of visual arts projects was set up; these included a sculpture, an architectural model, a 3D stained-glass project, digitally-enhanced photographs (some of which were presented in a three-dimensional format), and digitally-created collage (accompanied by music). Figures 2, 3, 4, and 5 below are photographs taken at the public exposition.

Fig. 2. Digitally-enhanced photography by student Kathryn Stout. The photograph on the left has been divided into tiles and presented in a three-dimensional format.

Fig. 3. Digitally-produced collage by student Islombek Karimov.

Fig. 4. Student James Costlow reading from his original creative writing.

Fig. 5. Students Colin King (left) and Zachary Tunnell (right) preparing to perform their music compositions.

Results of the Leonardo Project

The small number of participants and the varied experiences made it difficult to draw statistically-valid quantitative conclusions. Findings were of necessity chiefly subjective. They were extracted from required weekly journal entries and focus group discussion. Video presentations are pending at this writing.

Results from these sources (except videos) are presented below.

Insights from journal entries

Most journal entries were prosaic descriptions of weekly progress. However, among the journal entries were the following on the intrinsic artistic component of engineering:

- "…engineering is the marriage of creativity and knowing what's possible."
- "One cannot simply negate the fact that engineering, science, and math is (*sic*) art with structure."
- "Honestly, the issue isn't increasing the arts in engineering, the problem is accepting that engineering is already a form of art that most people do not realize they appreciate."

Insights from a mid-course focus group

The first of two planned focus groups was conducted at mid-course; discussion questions and responses are summarized below.

Q. The initial enrollment of the course seems to be those engineering students who need it the least. What need (other than replacing Design Methodology) does the Leonardo Project meet for *you*?

- "Cool to do something that is not strictly logical or based in mathematics; not all of engineering is mathematical"
- "Engineering has its artistic dimensions"
- "Makes us adaptable—gets us out of a strictly mathematical mindset"
- "Gets us away from the idea that engineering is the rote application of known techniques"
- "Good opportunity to appreciate art more"

Q. To what extent do you see yourself as atypical among your peers?

- "Possibly more artistic than peers?"
- "There seems to be a new stereotype of engineers—they all play guitars. We don't fit that stereotype."
- "We may have greater dislike for rote learning—too confining."

Q. How do we re-structure this experiment to draw in more engineering students?

- "Form partnerships with arts students; arts students are encouraged to "get out there," build résumés, and gain exposure through extracurricular activities."
- "Show that we are not expecting symphonies or works at that level. The art we are doing should be good, but not daunting."
- "Other students may have chosen to participate if they had not been required to have a basic competence beforehand."

Q. One outline of the engineering design process comprises four identifiable stages:

a) Problem Definition (requirements, specification, identification)
b) Diverge (identify alternative solutions, articulate decision criteria)
c) Converge (apply criteria to select best solution, make trade-offs, decide)
d) Implement (work out details of solution, which might be iterations on the other stages)

How has your experience in the Leonardo Project fit within this framework?

Authors:

- “Mentor required students to generate multiple ideas by writing for 30 minutes without stopping.”
- “Mentor had students identify useful plotlines and develop supporting backstories.”
- “Mentor asked questions to poke holes in the narrative, asking why particular details were as they were.”
- “Mentor has shown that poetry has a structure and form, and writing poetry is *hard*.

Studio artists:

- “Mentor is pressing students with experience in 2-D media (stained glass, photography) to think of implementing them in 3-D forms.”
- “One student is using computer graphics to create preliminary designs for collage, mentor is pushing him to create tangible objects which can be held in one’s hands.”

Musicians:

- “Students developed many musical themes, mentor is helping focus the compositions (e.g., repeat theme rather than introduce entirely new theme).”
- “Mentor has chiefly taught *organization* rather than mechanics of composition.”

One additional focus group was held at the end of the course. Public exposition of the works created in the Leonardo Project took place on April 19, 2016.

Course wrap-up: insights from the end-of-course focus group

A course-ending focus group was held on the last class meeting of the semester (one week after the public exposition of the students’ work). Seven of the ten student participants were present. They were asked to answer questions regarding their experiences with the course and recommendations for future directions for engineering and the arts.

Q. What were your expectations for the Leonardo Project? How well (or how badly) were they met?

Six of seven focus-group participants thought their expectations were met satisfactorily or better.

- “I expected to be working with the writing department to compare the engineering design process of engineering with that of writing. It went well, I enjoyed it and I learned a lot.”
- “My expectations were to try something different and something new besides equations. Project went well, I really like[d] it.”

- "I was expecting a clear connection between engineering and arts, and this course did all right in that respect."
- "I was expecting something that would make the engineering degree plan more interesting and bring some fun to the studies. The expectations were met pretty well."
- "I expected to be able to be immersed in the creative process and learn some parallels between engineering and the creative arts. This project did a great job of letting us explore the creative process."

One expressed frustration that he did not learn more about the techniques of his intended medium.

- "My expectations were that I was going to learn more about my chosen medium and how to work with students from a different degree. Expectations were not met."

Q. How would you describe your interaction with your mentor? What new insights or aesthetic appreciations did you gain from working with him or her?

Four of seven participants reported positive experiences with their mentors; three reported relationships involving various degrees of frustration or conflict, particularly in artistic vision. Among the comments were the following:

- "My mentor helped me expand upon my original ideas. I gained new insights into the design process of making works of art from my mentor."
- "I thought the interactions with my mentor were very positive. I learned a new way of writing, and [my mentor] was very helpful in encouraging our creativity."
- "I personally didn't gain anything from my mentor because they didn't give any contribution to my ideas and plans but only wanted what they wanted."

Q. What is your opinion of the value of studying the arts to engineers? What, if any, were the benefits to *you*?

All seven participants reported that they saw benefits to the engineer from participation in the arts. Among the representative comments were the following:

- "Studying arts in [the] engineering degree plan shifts the mindset and the monotonic design process a little bit to the creative side."
- "I believe there is a lot of value, students get to apply the engineering design process to the arts, areas where they aren't experts. I was able to benefit because to produce anything you have to follow the design process, there is no getting around it."

Q. If we were to institute an arts-and-engineering course, where would it best fit in the curriculum? Should it be something like the Leonardo Project (where engineers work as artists) or should it be a hybrid (where engineering is used to enhance arts projects)?

Two participants recommended following the model of the Leonardo Project. One recommended either, but felt that engineering students would gain more from creating their own works rather than enhancing the works of others. One recommended the hybrid approach:

- “I would say that this course needs to be and taught by faculty.” [Arts faculty?]

Most participants felt that a good place for an arts-and-engineering course would be to replace the freshman-level Introduction to Engineering course. These sentiments, however, appear to be motivated at least in part by dislike for that course.

Q. What would be your final summary of the Leonardo Project?

No participant reported an overall negative experience with the Leonardo Project, even those who reported tension in the relationships with their mentors. A representative sampling of their comments follows:

- “I think that overall this project was a great new experience. I hope to see this project implemented as a permanent fixture in the curriculum. I hope my peers saw the benefit of stimulating the creative side of the brain that I did.”
- “This course was fun and it was something I was looking for! This course and my project (photography/collage) inspired me for (*sic*) an idea for my Senior Design project!”

Conclusion

Arts and engineering faculty cooperated in a project whose aim was that engineering students would gain insight into creative design processes through the arts. This project included unique innovations: the engineering students were themselves the artists; engineering students worked under the direct mentorship of arts faculty; and multiple types of artistic expression were supported (including creative writing).

The project could be termed a moderate success. The experiences of the students were chiefly positive, although there were some cases of artistic tension between students and mentors.

Participants (both students and mentors) were supportive of the idea of explicit involvement of engineers in the creative arts. However, a number of ways for improvement have become apparent. Among these are:

- Arts faculty should be involved in an explicit instructional role, not simply in an *ad hoc* mentoring role. This would permit the inclusion of concepts of aesthetics and insights into cognition which are beyond the competence of engineering faculty.
- Improved structure is necessary. It appeared that students often let the Leonardo Project slip when hard deadlines appeared in other courses.
- Better recruitment is necessary to draw in students who were not already predisposed toward combining engineering and the arts.

Future directions are under discussion at the present time.

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