Good Work Project Report Series, Number 13

Interdisciplinary Research and Education: Preliminary Perspectives from the MIT Media Laboratory

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The Good Work Project
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Since 1995, three teams of investigators, under the direction of Howard Gardner, of Harvard University, Mihaly Csikszentmihalyi of Claremont Graduate University, and William Damon of Stanford University, have been researching the ways in which leading professionals in a variety of domains carry out good work. "Good work" is used in a dual sense: 1) work that is deemed to be of high quality and 2) work that is socially responsible. Through intensive, face-to-face interviews, the researchers have investigated several domains, including journalism, genetics, business, jazz music, theater, philanthropy, and higher education. Pilot studies have been conducted of medicine and the rapidly emerging domain of "cyberlaw", with plans to explore these areas more fully in the future.

In addition to this central line of study, several other related lines of investigation have been launched:

1. The Origins of Good Work project is an examination of teenagers who excel in extracurricular activities.

2. The Dedicated Young Professionals Study focuses on those who have just begun (or will soon begin) promising professional careers.

3. Good Work in Interdisciplinary Contexts. Pilot studies of new arts/science media and of the Massachusetts Institute of Technology's Media Lab have been completed. Plans are underway to study interdisciplinary work at the pre-collegiate, college, and research institution level.

4. The Role of Contemplative Practices investigates the ways in which contemplation/meditation influence how professionals carry out work.

5. Encouraging Good Work in Journalism. This project, carried out in conjunction with the Committee of Concerned Journalists, is currently developing a "traveling curriculum" for use in newsrooms around the country.

6. Good Work as Transmitted through Lineages examines how the principle of doing good work is passed down through continuous generations of teachers to students or from mentors to less experienced professionals.

7. Good Work in Other Societies is a project spearheaded by colleagues at Denmark's Royal Danish School of Education that investigates good work in Denmark and Latvia. In the future, additional international components will be added.

The Project expects to issue a variety of books, reports, and related documentation. The present series, launched in early 2001, includes reports on several of the lines of research mentioned above. For further information on the Good Work Project, contact Professor Howard Gardner's office at 617-496-4929, via email at hgasst@harvard.edu, or through regular mail at 201 Larsen Hall, Harvard Graduate School of Education, Cambridge, MA, 02138.

Papers On Good Work
February 2001

1. The Project on Good Work: A Description (April, 2000), Howard Gardner, Mihaly Csikzentmihalyi, and William Damon.

2. The Ethical Responsibilities of Professionals (July, 1998), Howard Gardner

3. The Empirical Basis of Good Work: Methodological Considerations (June, 1997), Howard Gardner, Anne Gregory, Mihalyi Csikzentmihalyi, William Damon, and Mimi Michaelson.

4. Good Work in Business (August, 2000), Kim Barberich and Howard Gardner.

5. Good Work Among Dedicated Young Professionals (July, 2000), Becca Solomon, Greg Feldman, and Marcy LeLacheur.

6. Contemplation and Implications for Good Work in Teaching (August, 1998), Laurinda Morway, Jeff Solomon, Mimi Michaelson, and Howard Gardner.

7. Good Work in a Complex World: A Cross Cultural Comparison (November, 1998), Hans Henrik Knoop and Howard Gardner.

8. Opportunities and Obstacles for Good Work in Medicine (August, 2000), Jeff Solomon, Jennifer DiBara, Sara Simeone, and Dan Dillon.

9. New Media Art: A New Frontier or Continued Tradition? (January, 2001), Kaley Middlebrooks.

10. The Origins of Good Work (April, 2000), Wendy Fischman and Grace Lam.

11. Good Work among Albert Schweitzer Fellows (April, 1999), Wendy Fischman, Becca Solomon, and Deborah Shutte.

12. High Abilities and Excellence: A Cultural Perspective (2000), Jin Li

13. Interdisciplinary Research and Education: Preliminary Perspectives from the MIT Media Laboratory (January, 2001), Dan Dillon.

14. Good Work in Cyberlaw (August, 2000), Evan Zullow.

15. Getting Kids, Parents, and Coaches on the Same Page (2000), Becca Solomon and Howard Gardner.

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I. Introduction

At universities and research institutions today, interdisciplinarity is a hot topic. A number of areas of study boast of an interdisciplinary approach (e.g., cognitive neuroscience, bioinformatics, and urban planning) and are attractive to large numbers of young people, in part because these blended areas are frequently publicized as being at the forefront of research and professional practice. Such disciplinary mixing seems impressive, and surely some combinations of previously separate areas of study are necessary for forward progress. However, the epistemological, educational, and practical implications of combining disciplines have rarely been considered in depth.

Important questions that have not been addressed in sufficient detail include:

- Which components need to be in place for interdisciplinary approaches to work?
- Which types of individuals are drawn to doing interdisciplinary work?
- How might the tensions between different disciplines (in terms of content, methodology, and standards) be resolved?
- Which attitudes or skills does an interdisciplinary education develop in a student and how do they differ from those developed in a single discipline?
- Which organizational structures facilitate interdisciplinary research, and which structures hinder it?

As more academic and research programs espouse interdisciplinary approaches, securing an answer to these questions becomes increasingly important.

II. The Challenges of Combining Disciplines

The challenges associated with combining two or more disciplines are not obvious. A good illustration of the subtle difficulties associated with interdisciplinary work comes from the domain of cognitive neuroscience—the combination of cognitive psychology and neuroscience. Today, cognitive neuroscience is a flourishing area of study. However, for years cognitive psychology and neuroscience existed separately, each with its own complement of practitioners, unique practices (e.g., reaction time measures in cognitive psychology and cell recordings in neuroscience), and institutions. Though the integration of the two disciplines is by no means complete (there still exists a multitude of "strict" cognitive psychologists and neuroscientists), the challenges faced (and successfully met) in creating the discipline of cognitive neuroscience illuminate the difficulties that may be encountered in doing quality interdisciplinary work in general.

The key tension revolves around differing conceptions of mind and brain. Cognitive psychologists attempt to study the mind. The discipline is based on the notion that human beings engage in the mental manipulation of representational symbols, and cognitive psychologists study these mental activities as distinct from neural functions. Traditionally, at least, cognitive psychologists have not been interested in the brain. To use a metaphor from computation, they study the software (thoughts, mental processes—the mind) without much regard for the hardware (the brain).

For a neuroscientist, on the other hand, the notion of "mind" is likely to be a contentious issue. Continuing with our computer metaphor, neuroscientists are concerned with hardware—the brain. Dealing strictly with biological data, many

neuroscientists are loath to posit a supra-physical structure—a mind—in order to explain behavior. Indeed, for some neuroscientists the entire foundation upon which cognitive psychology is built is suspect. Obviously, in order to "put together" cognitive psychology and neuroscience the tensions which exist between each discipline must be resolved; without some shift, the two, though topically similar, are at odds[1].

Fortunately, in the case of cognitive neuroscience the gaps between each discipline are now frequently bridged. Due largely to improved neuroimaging techniques, many scientists have begun to couple behavioral measures (associated—at least for cognitive psychologists—with the workings of the mind) with neural activity. For this growing number of researchers, cognitive and neuroscientific efforts have become complementary rather than irrelevant or even antagonistic to each other. While the definition of mind continues to evolve, the discipline of cognitive neuroscience rests on a solid intellectual foundation.[2]

The result of this happy confluence has been an outpouring of scientific work. Studying the mind/brain from a variety of different perspectives has given researchers new insights into topics such as memory, perception, and language use. As a consequence, several journals and institutions devoted to cognitive neuroscience have been created in the last several years and many are flourishing. Furthermore, an increasing number of researchers who were initially trained in cognitive psychology or

[1] For an informed discussion of this issue, see the Journal of Cognitive Neuroscience interview with Martha Farah, Professor of Psychology and Director of the Center for Cognitive Neuroscience at the University of Pennsylvania (available online at ccn.upenn.edu/pr/JOCN_interview.html).

[2] See Gazzaniga, M. S., Ivry, R. B., Mangun, G. R., (1998). Cognitive neuroscience: the biology of the mind. New York: Norton.

neuroscience (or related disciplines like linguistics or radiology) have acquired the additional skills necessary to conduct cognitive neuroscientific work. In sum, the formation of cognitive neuroscience has constituted a small (and very useful) scientific revolution.

III. Our Project

At Project Zero, a basic research center at Harvard University's Graduate School of Education, we have completed several studies of the scholarly disciplines. With interdisciplinary work growing dramatically in popularity and a number of interdisciplinary endeavors reaching maturity, the time is right to begin a study on the merits and weaknesses of interdisciplinary approaches to research and education. Consequently, we are embarking on a large-scale study of several of the nation's leading interdisciplinary institutions. Our ultimate goal is to identify the components consistently present in quality interdisciplinary efforts, so that more informed decisions about educational and research practices can be made.

We began our work by investigating the MIT Media Lab. Over the course of several months, we conducted semi-structured, one-to-two hour interviews with 13 Media Lab professors, asking them about their backgrounds, the projects they are currently involved in, and the institution as a whole. In this paper I summarize the findings from this initial phase of the project.

IV. The MIT Media Lab: Factors Crucial to its Foundation

The MIT Media Laboratory is a very unusual institution. It was founded by architect Nicholas Negroponte and former MIT president Jerome Wiesner in 1980 to explore the future of media and human-computer interactions. The Media Lab has since blossomed into an organization with a worldwide reputation for attention-grabbing invention. The lab now commands a yearly budget of over $30 million, nearly all of which is the product of the lab's extraordinarily successful model of corporate sponsorship. Although change is definitely on the horizon[3], the Media Lab will probably remain an important intellectual resource for years to come.

Given the Media Lab's special nature, it is worth asking a broad question before moving on to more specific ones: What factors contributed to (or allowed for) its establishment?

Three Keys to Success

Three environmental conditions stand out which helped the lab get started and contributed to its interdisciplinary character: vision, support, and a lack of intra-institutional competition.

First, the most obvious necessity for the Media Lab's successful instantiation was a desire for the kind of work it would do. Nicholas Negroponte filled this prerequisite himself, with his vision of the future. In 1980, the computer, broadcast, and publishing

[3] For an overview of the changes that may be in store for the lab, see Freedman, D. H. (2000). The Media Lab at a Crossroads. Technology Review: MIT's Magazine of Innovation, 103 (5) (available online at www.technologyreview.com/magazine/sep00/freedman.asp).

industries were distinctly separate entities. Negroponte argued that by 2000 the three would converge (as they indeed have), and he convinced a number of people in major corporations that his vision was plausible. As a result, not only did Negroponte and Wiesner begin to receive funding for their new institution, they also obtained a mandate to work in an interdisciplinary fashion. In order to anticipate and streamline the merger of the computer, broadcast, and publishing industries, it was necessary (at a minimum) to bring members of each industry together to work on new technologies which would help effect the oncoming shift. Ultimately, because the task of developing media technologies for the future could be broadly construed and because the work produced was considered by many to be interesting and important, the Media Lab attracted researchers with varied backgrounds.

Second, in a recent interview with us Negroponte stressed that the presence of MIT was absolutely crucial to the establishment of the Media Lab. In addition to being one of the world's foremost technical universities, MIT also has an entrepreneurial bent. As a result, new initiatives like the Media Lab tend to be welcomed as opportunities for growth, rather than frowned upon as breaks from tradition: Negroponte and Wiesner were not impeded as they put together plans for their organization.

Furthermore, MIT is not a university with strong disciplinary boundaries. Negroponte pointed out that this is evident even in the institution's architecture. At MIT, many departments are represented on the same hallway, rather than in different buildings, so that in a few yards a student can walk from one department into the next. Similarly, departments at MIT all share the same financial system; this differs from the

situation at many universities, where each department has its own financial methods. Negroponte opined that simple facts like these foment open-mindedness at MIT—students and faculty members who come there are willing to work across divides that personnel at other institutions might regard as unbridgeable. Negroponte credited some of the interdisciplinary success of the Media Lab to the prevailing attitude of openness at MIT.

Third, Negroponte mentioned that the lack of several schools at MIT that might exist in a more typical university—e.g., an art school or an education school—meant that the Media Lab could begin exploring issues like film, art, and education without encroaching on anyone else's territory. The Media Lab encountered less intra-institutional competition than it might have had it not been at MIT.

The Dynamic Duo

Negroponte is largely responsible for turning these three components into foundations for the Media Lab's success. His vision and ability to articulate with clarity the lab's value to society have been instrumental in the lab's rise. Today, the Media Lab is staffed with a large number of talented and hard working faculty members who continue to build upon Negroponte's ideas. As a consequence, it would be easy for an outsider to overlook the importance of another person in the Media Lab's good fortunes: Jerome Wiesner.

When Nicholas Negroponte began laying the groundwork for the Media Lab he was a young professor. He had founded the Architecture Machine group at MIT; the group

did important work that provided the foundation for much that was to follow at the Media Lab, and Negroponte had big ideas for the future. As impressive as those ideas were, the young professor's budding enterprise benefited greatly from the *gravitas* provided by Wiesner.

When the two men began their collaboration in the late 1970s, Wiesner was the past president of MIT and a distinguished scientist; he had previously been dean of MIT's School of Science, a leader at MIT's famous Radiation Laboratory, and a science advisor to Presidents Johnson and Kennedy. However, Wiesner provided the Media Lab with more than personal and intellectual heft. He had, in some ways, anticipated Negroponte's vision for the future of media some 20 years earlier.

In 1952 Wiesner became the director of MIT's Research Lab of Electronics (RLE). Thirty-five years later, commenting on the activities of RLE to Stewart Brand (author of the popular 1987 book The Media Lab: Inventing the Future at MIT[4]), Wiesner said:

> The Research Laboratory of Electronics was probably the most exciting place in the world for anyone interested in communications. We were doing research on neurophysiology, we were studying electrical noise problems, we were doing coding, we were following Shannon's work on information theory, we were even thinking about computers (Brand, p. 134).

As evidenced by this quote, Wiesner was passionate about studying communications, and he was clearly very comfortable with an interdisciplinary approach. The Research Lab of Electronics was very successful, and in time Wiesner

[4] Brand, Stewart, (1987). The Media Lab: inventing the future at MIT. New York: Viking.

attempted to parlay the RLE's success into an even bigger venture – a Communications Sciences Center at MIT. Though the idea was well-received, plans for the Center eventually fell through. Shortly thereafter, Wiesner left academia for three years to serve in President Kennedy's administration.

Wiesner soon returned to MIT, and as the 1970s came to a close Wiesner saw another opportunity to explore communications and the interactions between humans and machines in Negroponte's idea for the Media Lab. Wiesner joined Negroponte as a sort of partner in establishing the institution, and his experience, insight, and practical knowledge proved invaluable as the Media Lab took root.

Certainly the Media Lab benefited from a number of unique conditions which were in place as it was created. In fact, Negroponte suggested to us that the lab could really only have taken shape

1. at MIT;
2. in the early 1980s;
3. with a certain cast of characters.

We have reviewed MIT's special contributions to the Media Lab's existence above, and the early '80s were an opportune time for the Media Lab in large part because the personal computer industry was just beginning—this industry would open the doors for the media convergence predicted by Negroponte. Also as noted above, Negroponte and Wiesner were crucial to the Media Lab's foundation. But what about the rest of the initial members of the Media Lab? Who were they, and what made them unique? Relatedly, what type of person does the Media Lab attract today?

V. The People of the Media Lab

The founding members of an organization play a critical role in its success or failure. Consequently, it was surprising to hear Negroponte, as well as other Media Lab professors we spoke with, refer to the early Media Lab as a "*salon de refusé*". However, according to Negroponte several of the Media Lab's founding faculty—for example, Marvin Minsky, Seymour Papert, and Negroponte himself—arrived there because they were regarded as "misfits" in their home departments. Of course all the lab's initial faculty were talented, and many had already achieved great successes before coming to work with Negroponte. By the time they reached the Media Lab, however, their ideas, goals, and / or methods apparently diverged from existing norms at MIT.

Minsky, Papert, and other early Media Lab faculty went on to contribute greatly to the institution and helped solidify its position as an important research laboratory. Even as the lab grew more stable, however, its policy of hiring "renegades" never changed. As Sandy Pentland, the Academic Head of the Media Lab, told us, "Most of the people who are here are people who were not accepted by their more traditional homes." Negroponte pointed out that the first students and faculty who applied to work at the Media Lab were unusual simply by virtue of their applications: when the Media Lab was young and not well-known, an application implied a certain willingness to take intellectual risks. Nowadays, of course, the Media Lab is well-established, but its search for original thinking and individuality continues.

Negroponte described the mark of a successful Media Labber as a combination of intelligence, extroversion, and open-mindedness. Accordingly, when he and other faculty members evaluate candidates for admission to the lab's graduate program they do not rely solely on indicators of academic performance. Perhaps more than any other institution in the United States, the Media Lab is in search of candidates who are well-rounded in a special sense. Applicants' chances of admission are significantly increased if they have a varied and interesting list of extracurricular activities—playing in a rock band, turning an avocation into an entrepreneurial pursuit, etc.—because in the mind of Negroponte and other lab professors, how a person uses his or her unstructured time is indicative of how passionate and curious a thinker and doer he or she is (and may be a more accurate measure of their potential than performance in the classroom). Likewise, extensive travel is a big positive on an applicant's resume; Negroponte speculated that seeing the world is likely to provide prospective members with the sense of perspective and broad-mindedness the institution values.

In a more traditional research setting, this focus on extracurriculars over academics would likely be considered exotic. After all, most graduate students are trained as scholars, and academic performance as an undergraduate is likely to be more predictive of success as a scholar than participation in a rock band. Success at the Media Lab, however, seems to depend more on personality or cognitive style than on a specific area of interest or even a unique technical ability. The Media Lab is not an organization where groups of researchers from different disciplines pursue distinctly separate agendas, using different skills, and then combine their results in the end. Instead, the

lab tends to be an open environment. Students move from research group to research group, borrowing ideas from one project and applying them to another. Faculty members, as well as students, work with corporate sponsors in an effort to locate and solve problems which affect a broad range of industries and endeavors, rather than one area in particular. As a consequence of this working style and the shifting arena of new media technologies, the Media Lab puts a premium on researchers' ability to move laterally among research topics, guided by problems often discovered through interpersonal interactions. This is not to suggest that Media Lab students and faculty are not intelligent in a conventional sense; they are, usually exceptionally so. But the Media Lab relies on much more than grades (or analogous measures for faculty members) when making admissions decisions for students, and, as a consequence, academic perfection is not necessarily the ticket to Media Lab admission or success.

To illustrate the differences between the lab and a more "normal" academic environment, Negroponte told us the story of an excellent young Media Lab scientist who ultimately ended up leaving the organization. This particular researcher did marvelous scholarly work and was recognized throughout the university as outstanding. However, he did not interact extensively with other Media Lab faculty, students, or sponsors. Also, he preferred exploring a few ideas in depth as opposed to working laterally, across several areas of inquiry. In short, he fit the traditional definition of a scholar, working as an individual to push the boundaries of a single scientific area.

As a result, though his work was exceptional, this researcher did not fit in at the Media Lab. He eventually left (on good terms), and quickly obtained a tenured position elsewhere at MIT, where he was welcomed as a great addition to another department. Clearly, excellence in a scientific field and the skills that predict success in many parts of academia (or industry) are not the only keys to success at the Media Lab. While intelligence is critical, the Media Lab also relies heavily on researchers' openness, flexibility, and ability to work in teams, as opposed to their specialized skills or propensity to doggedly pursue particular topics.

VI. The Media Lab philosophy: Shifting Bodies of Knowledge

The movement across disciplinary boundaries that characterizes the Media Lab is not unconsidered. Rather, it is part of a distinctive approach to research and education. Sandy Pentland gave us an overview of the organization's philosophy with respect to the differences between disciplinary and interdisciplinary approaches.

Historically, Pentland observed, people confronting challenges have made investigations, documented findings, and developed solutions. Occasionally the accumulated knowledge was deemed important enough to be codified so that it could be passed on and replicated with ease: the initial problem was set apart, along with its solution, and regarded as a unique area of inquiry. Particularly important and expansive topics that were so treated have become "the disciplines"—organized topics of study that have served as the lynchpins of Western education for centuries.

In Pentland's estimation, the codification necessary for the formation of a discipline tends to generate an unnecessarily rigid mindset in disciplinary learners: many disciplines come to be regarded as finished products, as subjects frozen in time. As Pentland told us, with most disciplines "[I]t's a static body of knowledge, or static in the sense that the base is static—you may be able to add on to it. And the main, deep problems are in some sense fixed forever. Not quite true, but that's the general attitude."

According to Pentland, the result of such rigid codification is frequently constrained, narrow work. Researchers and students revisit many of the same problems time and

time again, sometimes after the problems have been "largely solved or shown [to be] irrelevant", simply because they were important when the discipline was formed. Accordingly, this type of disciplinary work (which involves refining existing concepts) is often of little relevance outside the discipline. Pentland summed up his position on the propensity of disciplinary study to become stale by saying, "And that's what they mean when they say 'academic' in the bad sense. . . . Irrelevant. Who cares?".

The Media Lab proceeds in an altogether different way. Rather than adhering to the issues as delineated by the disciplines, Pentland said, "our view is that there are good basic science problems anywhere, in virtually anything. In fact, there's too many to choose from." Consequently, while (for example) a biologist draws his or her inspiration and focus from the relatively stable issues that comprise the problem space biology addresses, a Media Lab researcher tackles problems that cross several disciplinary boundaries. In addition, as noted above, researchers at the lab frequently develop research topics as a result of conversations they have with corporate sponsors—an additional source of intellectual input absent in most disciplinary settings. Pentland described Media Lab personnel as working in this manner in order to solve "deep problems that are shared among lots of different places". To the extent that lab researchers are successful in this goal, they can make practical contributions to society and have an impact usually unavailable to discipline-based researchers.

This focus on synthetic, practically-relevant work infuses all the Media Lab's activities. One such activity is of particular interest to us: the lab's educational practices. The Media Lab is the only MIT laboratory that also confers academic degrees.

As a consequence, Media Lab researchers are not only doing interdisciplinary work; they are also directly responsible for training their students to become interdisciplinary workers. Thus, the lab provides an excellent chance to investigate interdisciplinary education as well as research.

A caveat

Having discussed the general nature of our project, the foundation of the Media Lab, the characteristics of its members, and the lab's basic philosophy regarding the disciplines, I now move to a more detailed review of research and education at the Media Lab. Before I begin, I wish to point out that my colleagues and I did not carry out a case study of the Media Lab. Accordingly, the point of this paper is not to assess the quality or relevance of the Media Lab's research projects or educational practices. Instead, my goal is to investigate a few key questions with regard to the interdisciplinary nature of the lab, questions whose answers can provide insight into the basic challenges associated with an interdisciplinary institution.

One more point to note is that my colleagues and I did not interview current students at the Media Lab, and thus can hardly claim to have obtained a comprehensive picture of its educational program. Furthermore, because this is the first interdisciplinary institution we have studied, it is not possible to directly compare educational outcomes between the Media Lab and other institutions. However, we did receive useful information regarding the lab's educational practices by addressing the topic with each professor to whom we spoke.

VII. A Review of Interdisciplinary Research and Education at the Media Lab

A. Interdisciplinarity at the Media Lab: Approach and Content

The Media Lab currently consists of 30 different research groups, each run by a faculty member and usually staffed with a handful of graduate students (in addition, a large number of undergraduates participate in various research projects). The groups span a variety of topics of interest: group names like "Electronic Publishing," "The Future of Learning," and "Aesthetics and Computation" hint at the diversity of projects presently in progress. However, though the nature of the work the research groups do varies widely, each one is devoted to affecting the way humans interact with technology in some way. For example, the "Tangible Media" group is developing technologies which will allow humans to make use of more of their senses (e.g., touch and hearing) when interacting with computers. Meanwhile, the "Lifelong Kindergarten" group is exploring the ways in which digital technology can be used to augment educational practices. Every group in some way works on the intersection between people and machines.

The organizational structures at the Media Lab are few and fluid. Currently, three consortia—entitled "Digital Life," "News in the Future," and "Things That Think"—serve as loose categories into which the research groups fit, as well as access points for sponsors (for example, a publishing company sponsoring the lab might hone in on the News in the Future consortium and the groups affiliated with it). However, according to the professors we spoke with the consortia are so loosely organized that the

fundamental unit of organization at the Media Lab is actually the research groups themselves, as run by individual faculty members.

Media Lab faculty pursue their research interests with a great degree of freedom. Negroponte believes in a hands-off managerial style and directs the lab by helping to provide financial support and broad guidance rather than by micro-managing. Also, lab researchers do not depend on individual grants for support: when a corporate sponsor donates money, it is shared equally among the Media Lab's faculty members. As a consequence, individual lab members do not have to justify their particular line of work to funding agencies (although of course sponsors hope to reap intellectual benefits from the Media Lab as a whole). This arrangement further frees lab personnel to pursue whatever line of work they deem important, and their ideas and efforts set the tone for the lab.

B. The Strength of Interdisciplinarity, As Seen at the Media Lab

The foremost benefit to working at the Media Lab seems to be increased creativity. In part this stems from a lab-wide belief that "new" is better; Media Lab members are focused on inventing, rather than on refining or studying existing entities. As Professor Deb Roy put it: "we always have this, almost, mantra against incrementalism . . . if what you're doing is producing the next—you know, version 2.0—it doesn't belong here in the same way as looking for some radical recombination of ideas, where on a meta level you're shifting / recombining things rather than on a microlevel." Given the

focus on discovering new areas of inquiry and creating new things, it is no wonder that Media Lab faculty and students are often successful.

However, Roy went on to say that, "[w]hen you make that recombination 'meta' enough you're talking about mixing disciplines, which quite often happens here." Of course, it is the mixing of disciplines that I am primarily concerned with in this paper, and such mixing appears to be equally crucial to creativity at the Media Lab. Although of course it is possible to be creative in any setting, including a discipline-based one, the combination of computer programmers, engineers, scientists, and artists present at the lab allows individuals to invent in ways they simply might not think of in another environment.

For example, consider the work done in the Synthetic Characters group. Led by Professor Bruce Blumberg, the group creates cartoon-like digital characters which are self-directed and able to learn from their digital environment (as well as aesthetically pleasing). The more complex characters the group has developed are guided by sophisticated and flexible computational models which account for the characters' needs, desires, and affect, but which do not determine behavior in advance. One of the group's goals is to use the characters' behavior as a test to determine the strengths and weaknesses of various theories of motivation and intelligence (which inform the computational models that guide the characters). While many simulations in various disciplines have this goal, the work of the Synthetic Characters group is unique in that many facets of intelligence and behavior are evaluated simultaneously within a single, life-like character, rather than in isolation. This is a significant advance, because a

model of intelligence, for example, that runs seamlessly in isolation may fail to work when a large number of behaviors are dependent upon it.

In order to build their models and characters effectively, Blumberg and his students have combined principles and techniques from a variety of disciplines. Many sources are unsurprising: artificial intelligence, cognitive science, and graphic design, for example. However, one discipline that figures very heavily in the work of the Synthetic Characters group is not usually found in technologically-oriented institutions like the Media Lab: ethology. Blumberg derives many of his ideas from work done by animal trainers (not surprisingly, the characters the group has developed in the past include dogs, raccoons, and chickens). In fact, when we interviewed Blumberg and asked what he was currently working on, he had this to say:

> I spent the last two days with a dog trainer, and had all our group go to a dog training facility to actually train dogs. So we take ideas and observations from animal behavior and animal learning, we go out training, and then build complete, if simple, systems, and see what we learn from that, and iterate through the process. So what we're trying to do right now is build an animated dog that thinks for itself whose behavioral complexity is that of a real dog, who can be taught using traditional dog training techniques, and who you could then put in, say, a virtual world to do sheep-herding, train it how to do sheep-herding, or scent detection, or be a seeing-eye dog or whatever.

Blumberg's willingness to look outside of the usual disciplines associated with machine intelligence has enabled him to draw on the wealth of knowledge present in ethology. Not surprisingly, therefore, he described an openness to interdisciplinarity as invaluable when tackling intellectually tough problems, saying, "you really have to pull from all the shelves in the library. Because there's a reason why there are all the shelves

in the library . . . it really behooves you to pay attention." Finally, the ethological principles imbedded in Blumberg's work make it interesting to a wider audience. As Blumberg said:

> The ethologists who have seen the work and read my thesis by and large were very intrigued, because it was really interesting for them to see, because most of them aren't computational kinds of people. So it was interesting to see these ideas that they had read about in [work by the famous ethologist Konrad] Lorenz implemented in a computer model where they could test it.

Other groups are pursuing similarly unusual research projects. Consider, for example, Professor Roz Picard's Affective Computing group. Picard and her students are working on a variety of projects designed to make digital devices responsive to humans' emotional states. In attempting to do so, the members of Affective Computing have had to draw from a number of disciplines. Like their counterparts in the Synthetic Characters group, members of the Affective Computing group have studied and incorporated a number of psychological theories of emotion and motivation into their work. However, Picard's group has also developed an appreciation for the physiological indicators of emotion in humans. Picard and her students have designed interfaces that feed biological data from the user into the computer, and are creating programs that can:

1. recognize the data;
2. translate the physiological data into a representation of the user's feelings (with enough subtlety to distinguish between different gradations of emotions—e.g., distinguishing irritation from anger);

3. store the data such that a long-term emotional profile of the user can be created (for instance, the computer might notice emotional patterns the user habitually displays—e.g., a tendency to follow anxiety with frustration);

4. adapt the computer's behavior so that working with it is a more pleasant (and useful) experience.

Clearly, Picard has moved into realms far from her "home" discipline of electrical engineering. The extent to which this statement is true can be ascertained in part by the variety of disciplines represented by her students in the Affective Computing group. Picard told us:

> I had two [students] recently come from a human-computer interaction discipline . . . Some of them have come from electrical engineering, one came from physics and immediately did graphics and interaction stuff, it was great . . . The most common has probably been an engineering discipline or computer science. I have one from psychology.

On its own, this variety is impressive. In keeping with the Media Lab's special emphasis on a cognitive style characterized by flexibility, however, Picard described a willingness to branch out into new intellectual areas as the key to success for a student in her group:

> Somebody who comes from a particular area and wants to stay in that area worries me a little bit, especially if they are not open to at least investigating what's around the areas they are familiar with. I see that as a sign of a lack of adventurousness. Maybe that's not quite the spirit we want.

The Synthetic Characters and Affective Computing groups are simply two example of the team-driven interdisciplinary work done at the Media Lab. The drive to combine disciplines pervades the institution. In fact, one Media Lab professor we spoke with

feels he has hit upon the ideal number of disciplines to be combined. He tells his students that the key to useful creativity is to look at how three disciplines have approached a problem, determine what has been missed, and then use some combination of the three disciplines to fill in the gaps. Of course, he might add, this is easier said than done!

Such cross-disciplinary mixing is supported by the Media Lab's emphasis on movement: students are encouraged to work with and learn from research groups other than their own. Professor Ken Haase went so far as to describe the students at the Media Lab as the "glue" holding the various research groups together by transferring information from group to group. This movement between groups is commonplace at the Media Lab, because, as Deb Roy mentioned:

> the environment is set up to really make it easy to have a conversation with a musician, or someone who writes operas, or someone who studies children's learning, and then connect it with something you're doing in a completely new way . . . that's the sort of work that is certainly most appreciated and, really, the environment is most conducive to.

In fact, Roy's current work at the Media Lab evolved from his own wanderings as a student: he was able to combine topics investigated by two groups and create a novel and important synthesis.

Roy's work (discussed in the next section) sheds light on another aspect of the Media Lab environment that differentiates it from other institutions: the focus on creating physical artifacts as opposed to writing papers. While personnel at

some discipline-based institutions also create products, every member of the Media Lab creates objects as an integral part of their work. This point of view is partly a legacy of the Media Lab's origins: as noted, Negroponte was trained as an architect, and the Media Lab is still officially housed in the School of Architecture. As a consequence, the architectural notions of building and the design studio have always been central to the Media Lab's research practices, and the "demo" (demonstration) is an essential form of output at the Media Lab. Also, one of the disciplines that undergirds a great proportion of the work done at the lab (as well as at MIT in general) is engineering. The combination of architectural and engineering influences means that working in an interdisciplinary fashion at the Media Lab is bound up in creating physical objects. These objects nearly always involve digital technology, but can take on a tremendous variety of forms: software agents, computerized toys, and technologically augmented instruments are three examples of objects that have issued forth from the Media Lab.

C. Constructive Interdisciplinarity: An Example

At the Media Lab, faculty and students are expected to do more than simply mix and match ideas—they are expected to produce objects which embody those ideas. One of our subjects, Deb Roy, was a student at the lab before joining the faculty, and his thesis work (as well as subsequent modifications he made before

becoming a professor) is an excellent example of what can be produced in the Media Lab's catalytic environment.

Roy studied computer engineering as an undergraduate, but during his graduate years at the Media Lab he developed an interest in speech and the processes underlying language learning. For his doctoral thesis, Roy began an investigation into how multisensory processing leads to the development of a lexicon. He observed that while humans do not learn language in the absence of multisensory stimulation (i.e., they build a vocabulary while being exposed to sights, tastes, smells, etc.), most "current spoken language recognition and understanding systems are not grounded"[5]. That is, most language recognition systems today only receive written and/or spoken words as input.

Roy decided to use his observation to improve machine language recognition and production. He developed a computer system called CELL (for Cross-channel Early Lexical Learning), which he subsequently embodied in the form of an active, aviatically-inspired robot (which he built) dubbed Toco the Toucan. Toco learns vocabulary by interacting with natural human speech and the environment simultaneously. The system works as follows: the human "teaching" Toco vocabulary describes an object into a microphone that inputs verbal information into Toco's auditory system. Meanwhile, Toco apprehends the described object via a camera in one of his eyes. For example, in a video on

[5] Professor Deb Roy's research is described online at dkroy.www.media.mit.edu/people/dkroy/research.html

the Media Lab's webpages[6] Roy presents Toco with a red cup and says, "Look, it's a red cup." Toco is able to associate Roy's spoken phrase with the physical object in front of him, and parrots back the phrase "Look, it's a red cup" when he has the relation down.

Toco does more than simply remember objects and their verbal labels, however. When analyzing an object, Toco encodes color and shape separately, and he also processes color and shape words separately. Consequently, after being exposed to a number of objects of various shapes and colors, Toco can describe novel objects correctly. In the aforementioned video, for example, Roy began by presenting Toco with a red cup and a yellow ball; Toco was subsequently able to identify and describe a yellow cup placed before him, even though he had never seen one before. In short, Toco learns a flexible vocabulary, rather than simply storing descriptions about individual items. Furthermore, Toco learns from natural, connected speech and regular objects, not from specially inputted data.

Roy's work with Toco is impressive: he has effectively combined a model of early language acquisition with computer engineering and robotics. It is also important work, as Roy has developed a system that stands to make contributions to developmental psychology, cognitive science, and artificial intelligence, and which would be of acute interest to industries involved in speech recognition and processing systems. Finally, Roy sees his work as having

[6] The Toco video is available online at dkroy.www.media.mit.edu/people/dkroy/toco.html

a practical purpose. As he said, "I'm starting to realize, from talking to people in the speech field now, that this will be relevant and I expect to have an impact."

Furthermore, the work is an example of the Media Lab's strengths as a research and educational institution in general. Roy approached his education with curiosity and a focus on invention. He was expected to create, and he succeeded in dramatically expanding existing efforts in speech recognition, processing, and generation. Roy told us, "a lot of these ideas that I talked about—grounding words in our spoken languages—simply have never been addressed; it's completely wide open." Furthermore, in developing his project Roy made connections between separate areas of investigation around the Media Lab. During our interview, he described his movement from a group that focused on speech to one that focused on vision, and how that contributed to his project:

> the good thing is this whole issue of grounding, which has to do with—it started off with connecting vision with speech, which is what happens when you bring a speech person into a vision group . . . I was in a unique situation; I was doing work in a group that didn't do that kind of work. And it influenced me, and I ended up thinking about relations between visual and auditory input in a way that people haven't before.

D. Weaknesses of Interdisciplinarity, As Seen at the Media Lab

1. Depth and Time

The Media Lab's strengths do not come without drawbacks. As mentioned earlier, in order to augment its creativity and innovative potential, the Media Lab has de-emphasized studying history and working on refining past work. Media Lab researchers are always looking to the future, much more so than most of their academic peers. Some of the ways in which this philosophy manifests itself are rather shocking. For example, as one subject told us, "in general [Nicholas Negroponte's] advice to incoming faculty is to drop what they're doing and change fields right as they walk in the door." Needless to say, this differs tremendously from the practice at most academic institutions, where faculty members are hired precisely because of the potential for continued productivity in their particular area of expertise.

Because of the emphasis on change at the Media Lab, it has often been suggested that faculty and their students do not deal with issues in great depth. A former Media Lab student lent support for this notion, telling us:

> the Media Lab is a place that, of course, has some boundaries, but in general if your philosophy is to let people try things, crossing boundaries and not paying attention to boundaries, you haven't necessarily staked a particular piece of turf and one, claimed it as a discipline; and two, explained what the key tenets of that discipline are so that you know what is encompassed by it and what is not encompassed by it. It makes it difficult to push deeper, because you don't have the framework . . . .

Concerns about depth and the sustained investigation of a few topics at the lab are reflected by debates lab professors have over whether or not to implement an undergraduate major in MAS (no such major exists at present). Professor Mitch Resnick told us he currently argues against the Media Lab developing an undergraduate major because "right now I feel that there's not enough of a discipline here. I think that it is good for an undergraduate to get more of a grounding in a particular disciplinary area." Another subject also told us that he did not think the Media Lab should allow undergraduates to major in Media Arts & Sciences (MAS). The problem, he said, is not that the content the Media Lab researches is unworthy of a major. On the contrary, he opined that MAS would be an excellent course of study because students would get an "introduction to a lot of basic concepts in society". For this professor, the problem with a Media Lab undergraduate major stems from the fact that lab researchers do not probe the same areas with enough consistency for a sustained program of undergraduate education. As he told us, "I think that to have an undergraduate major you do need to be a place that says, 'Well, we really do teach this class every year. We don't lose interest in it and stop teaching it.'"

Clearly, this professor and Resnick are articulating the need for a solid grasp of basic concepts before one moves on to experimentation with new ideas. Both suggested that there is presently not enough stability and focus on a few key ideas for them to feel comfortable with MAS as a major course of study for undergraduates (although nearly all the professors we interviewed spoke

glowingly about the Media Lab's ability to augment an undergraduate's education through research opportunities). However, the Media Lab has never billed itself as a place designed to educate undergraduates. Furthermore, as mentioned several times throughout this paper, the Media Lab explicitly focuses on lateral thinking as opposed to "burrowing in" on a few topics. Therefore, the critical question is whether or not the Media Lab's lack of disciplinary grounding poses problems for the research and / or development of its faculty and graduate students? Does the Media Lab take its anti-disciplinary stance too far?

A statement by Resnick indicates that he does not think so, provided an adequate disciplinary foundation is already in place; as he put it, "when someone has that [disciplinary] background I think this is a good place to come to graduate school." Other statements made by Media Lab professors suggested other points of view, however. For example, a quote from Bruce Blumberg suggests that the answer to this question is, "sometimes". Blumberg told us:

> even though the Media Lab prides itself on being sort of out there and on the cutting edge, just because you're on the cutting edge doesn't mean that you shouldn't know the classics, if you will. And I think that sometimes, people don't do their homework. And that they would do well to.

Professor Tod Machover sounded a similar note. He suggested that if the Media Lab has an educational flaw, it is the tendency of students to move too quickly from one project to another. Once a demo has been built, many students do not take the time to evaluate its strengths and weaknesses thoroughly in an

attempt to improve the work. Instead, they move on quickly to another project, another idea. The result, Machover said, is that often products do not achieve their full potential and their quality is not as high as it could be.

While the Media Lab has done pioneering work moving across boundaries, lateral thinking does not necessarily mean that one needs to move from topic to topic exceptionally rapidly. Indeed, Machover would like to see the Media Lab adopt a somewhat slower pace with regard to innovation, so that new ideas could be explored in greater depth: there is no need to come up with five new ideas each week. As he suggested during an interview, if an individual really is inventing five things a week, then many of those things simply are not going to be very good.

An important question is: to what extent are any problems with depth and quality at the Media Lab due to interdisciplinarity, and to what extent are they simply due to the rapid pace of work? This question is very difficult to answer: Machover clearly ascribed problems to the speed of turnover from project to project, while Blumberg's comment highlights the importance of having a solid grounding in the particular area of interest. In truth, at the Media Lab interdisciplinarity and quick movement from topic to topic are somewhat confounded: one feeds the other.

2. Problems with Standards

One conundrum that has emerged at the Media Lab is due solely to the lab's interdisciplinary methodology—it is the question of standards. In a discipline, at least ideally, there are common standards of quality that must be met before a product is accepted as finished. As indicated by Tod Machover's statements, paraphrased above, there are fewer rigorous standards for demos at the Media Lab than might be ideal. However, this problem certainly does not exist because the Media Lab has abandoned standards altogether. Instead, it appears to be the consequence of several different disciplines with different standards mixing together, without a clear consensus being reached as to what universal standards of quality for Media Lab work might be.

As Professor Roz Picard told us:

> The lab has had these different cultures: some people don't value publication at all, some people value performance, some people value demos . . . When you bring such diverse people together they also have diverse values, they have diverse ways of measuring success, and some of these really conflict. We have to figure out how to get along with that . . . When you don't succeed, when there is real conflict, then that becomes a weakness, people get stressed, and there is a loss of productivity because people don't understand what they are supposed to be doing: maybe a student who really believes publications are important winds up working for an advisor who doesn't value that and they wind up really not doing so well. Because the status quo is so hard to figure out it's a little tricky to navigate. If you do it well it works fabulously, but if you don't I think it becomes a real detriment.

Another Media Lab professor described an incident where a student did not internalize a set of standards during his education at the lab: the student had an extremely trying oral qualifying exam in part because he was making claims

without providing evidence to support them. The student's troubles caused his advisor to think, "I haven't trained him right. I haven't taught him what a standard of evidence is". The same professor wondered, "Can I train them in every field? Am I training them for any field?".

Because of these types of concerns, this particular Media Lab professor makes a concerted effort to spend time teaching students about meta-science, the overarching ideas that form the basis for sound experimentation and scientific practice. Other Media Lab professors, instead of trying to teach their students general ideas about what constitutes quality work, simply require their students to display their work in a variety of ways and to meet the varying standards of each discipline from which their work draws. Unfortunately, of course, this means that for one project a student could be required to produce a demo, run experiments, and write a number of papers. One faculty member spoke about the difficulty of balancing the need for both demos and papers in her own work, saying, "it's hard, truthfully, to find the hours in the day to do both".

As an institution, the Media Lab has resisted creating a set of standards with respect to faculty members and has instead opted to "offload" judgment of faculty work to the wider world. Nicholas Negroponte told us, very frankly, that the prerequisite for advancement as a Media Lab professor is world fame. Negroponte was very clear that he did not mean fame in the public sphere, necessarily. Being on "The Tonight Show" will not automatically get you ahead at the Media Lab (though it might not hurt!). The key for faculty members is to be famous among those qualified to judge the quality of

the work they are doing—primarily academics or industry members who work in a related field (because Media Lab faculty do particularly unusual research, finding someone in precisely the same field is often difficult; this may be a challenge faced by interdisciplinary workers in general).

However, this model obviously cannot be put to use with students. Also, it does not help Media Lab personnel judge their efforts before they send them out of the lab. Finally, being the "best in the world" can be a false indicator of talent if the type of work being pursued is extremely unusual. Presumably, one could become famous as the only person to master an esoteric area of inquiry, but because of the lack of qualified judges it would be foolish to put much stock in such an person's work simply because they were famous as "the best at X".

We asked Negroponte if he had ever considered implementing a lab-wide standard of quality at the Media Lab, and he replied by saying he has always tried his hardest to make as few lab-wide rules as possible. When issues like this come up, Negroponte admonishes his charges to enjoy their freedom instead of asking for more rules (though he said he understands why the lack of rules makes many people uncomfortable). He believes that multiple ways of doing things—multiple insights, multiple disciplines, multiple standards—lead to a richer final product.

However, it seems that the lab could benefit from a common (minimally restrictive) set of standards. A set of clear guidelines outlining the requirements for student work at the Media Lab might help students work through the

strengths and weaknesses of their demos. Also, guidelines could make it easier for students to move amongst faculty members who favor different forms of output.

Finally, regularized standards could help keep Media Lab faculty honest with respect to their own areas of specialized knowledge. Several Media Lab faculty commented that because of the lab's reluctance to hire several faculty members with training in the same background, there is often only one person at the lab who really understands a particular area. As a result, as Professor John Maeda put it, "you talk to people who know nothing about your field, so you can invoke all these fancy terms, and suddenly you can realize that, 'I'm so smart' or, 'I think I'm so smart, I'm so special.' And, that's a primary weakness, I believe." Deb Roy made similar comments:

> I think the weakness also comes from the same environment, which is: we have to constantly look outwards—outside—to get proper criticism of our core areas. I work in a certain area of spoken language technologies and multilingual processing, and nobody else does . . . and it's difficult for my colleagues to assess my work; they basically believe what I tell them . . . and so we have to keep ourselves honest by going out and—so that's a danger: the onus is on you, whereas I think if you're in an environment where everyone's doing similar things you push each other and there's a lot of internal competition. Competition here is of a different sort; it's not at that technical level. By definition, it can't be.

Perhaps a regularized set of standards for use within the Media Lab would help alleviate concerns like those of Maeda and Roy: lab researchers could use the standards as guides when evaluating work too specialized for others to grasp. Tod Machover intimated that he hopes to use standards more rigorously

in the Center for Future Arts (one of three centers now being developed at the Media Lab) in order to improve the quality of the lab's artistic achievements.

VIII. What About Intellectual Tensions at the Media Lab?

Earlier, we noted the intellectual differences between cognitive psychology and neuroscience. In order for people to begin practicing what is now regarded as cognitive neuroscience, those differences had to be addressed. Melding the two disciplines required a re-evaluation of each one's key notions, and also required intellectual flexibility on the part of scientists. It seems likely that researchers at successful, boundary-breaking institutions would have to go through the same intellectual steps as those initial cognitive neuroscientists. After all, disciplines are separate for a reason; traditionally, at least, one did not need the same skills to study physics that he or she needed to study biology, for example, because the two disciplines were geared to ask and answer different questions, and used different methods. To combine different disciplines is (often) to reformulate the central ideas of each.

At the Media Lab, where the research focus changes on a regular basis, people have to exercise their intellectual flexibility repeatedly as they seek to make connections between different research areas. To perform such mental gymnastics is no small task. Moving seamlessly and productively from discipline to discipline requires (at a minimum) a fundamental openness to new ideas, impressive intellectual assets, and a willingness to spend lots of time

working with materials and notions that are initially foreign. A great deal of skill and thought is required to bring separate disciplines together effectively.

How do Media Lab researchers go about making the intellectual connections between disciplines? How do they bring together engineering and the arts, for example, which have such divergent notions concerning subject matter, working style, and criteria for success?

Unfortunately, at this point, the answers to these questions are unclear. Media Labbers are obviously combining disciplines in a useful way, but most of the professors we spoke with did not talk specifically about how they deal, intellectually, with disciplinary contradictions. There are probably two reasons for this:

- We did not ask about this issue specifically enough;
- It is very possible that Media Lab researchers have been combining disciplines for so long that they no longer think much of it—they are beyond considering the differences between areas of inquiry.

Neither of these reasons is very satisfying. In our future work, we intend to be much more direct in questioning subjects about the intellectual tensions between disciplines in hopes of eliciting more responses on this issue. Also, we expect that researchers at a more "typical" interdisciplinary institution—e.g., a genomics center—might be more self-conscious regarding the disciplinary combinations they are involved with than researchers at the Media Lab. It is

important to find out how disciplines are being combined, even if subjects no longer spend a great deal thinking about how they are doing the combining, because the degree to which the compatibility of two disciplines has been thought through is likely to determine the value of the resulting interdisciplinary work.

Although they did not speak directly about resolving the underlying tensions between disciplines, Media Lab professors did have interesting things to say about closely related topics. For example, Roz Picard told us about the challenges she has faced from fellow engineers as she has imported ideas from psychology into her work:

> I did a bunch of computer chip design, computer architecture design, the VLSI design... and switching from that to image analysis, which are both different fields of electrical engineering, felt like a big switch at the time... Switching and adding in collaboration with artists and working with psychologists and cognitive scientists on affect stuff has been a much harder thing, because the core values of the engineering community suddenly raised their eyebrows, people raised their eyebrows and said, wait a minute, this is sissy science, what's going on here? Is there science here?

John Maeda mentioned a different concern. He lamented the fact that finding students who are willing and able to mix disciplines is difficult, and he ascribed the problem to discipline-based education:

> our educational institutions can only create two types of people . . . one person can think scientifically or logically, and one person can think illogically or more about in relation to the world . . . it's a sad commentary on the fact that our institutions can't create modern day Da Vincis. Why is

> it this doesn't happen? And, it's very simply because the disciplines are stuck in ruts, essentially.

Maeda's goal is to produce modern day Da Vincis—students who can use all aspects of their minds equally effectively. He told us:

> I'm working on . . . figur[ing] out how to make people who are very fluent in technology and also have an ability to think about what they would do with that voice of technology. Mainly, the ability to combine thoughts of creativity with technology as a natural reflex. These people are very few, and I recruit these people; I'll go everywhere, find these people who don't really fit in, don't fit in either side very well because people like to classify you and therefore it's very difficult. You can see they're very troubled in this, so I provide an environment for them to all be together and act like it's normal, I guess.

"Acting normally" may mean very different things for people in different areas, however. The traditions and practices of different disciplines, as well as the cognitive abilities required to work in them, vary widely. For example, Roz Picard was very upfront about the different levels of rigor she has found in engineering, psychology, and the arts:

> I'm not at all impressed with the level of cognition I see in the psychology camp. There are some outstanding people, but there is also a lot more rotten thinking than I've seen in the engineering community . . . I think I take it for granted that people there are very logical and rational and they make their arguments and support them with data. I've run into some people who are very frustrating to deal with in this other community . . . The arts people I've been working with are such a pleasure. Maybe I don't expect them to think in the same way as I expect engineers to think, whereas I sort of expected the psychologists to, and maybe because I go with a different set of expectations, I'm much more open to whatever they bring to the table . . . .

Based on Picard's comments, one would not necessarily expect a seamless interface between psychologists, artists, and engineers. In fact, Picard told us that doing research in psychology and engineering means she has to expend twice as much effort to meet the standards and address the questions of each discipline:

> There have been people from the psychology community questioning some of our methods; not understanding our pattern analysis methods: too many variables, not enough data, why didn't she run the standard ANOVA analysis, and what is P and all that stuff . . . so the burden is on me to really sit down and get a deeper understanding of their methods and show them how their methods do and don't relate to our methods. In a sense I feel like I have to do my work and then their work . . . it's harder and I'm willing to take that on, it's just that it takes me a little bit longer to get around to doing that.

As revealing as these comments are, it is still not clear how Media Lab professors go about reconciling the underlying differences between disciplines: it is one thing to adjust standards, and another to rework a discipline's basic questions. As suggested earlier, however, the Media Lab seems to be rather unreflective regarding the disciplinary boundaries being crossed in particular pieces of work. In fact, Maeda's comments appear to sum up the Media Lab's theory on how best to combine disciplines: simply provide an environment for intellectually inquisitive people to work together and productive interdisciplinary work will issue forth.

Many Media Lab professors told us about the value of being able to speak with colleagues from a variety of different specialties—maybe the differences

between disciplines are reconciled during these conversations. Unfortunately, because we did not ask directly about how the underlying intellectual tensions between disciplines are addressed, we cannot ascertain the degree to which that statement is true. This is a topic which we will investigate further in future research.

IX. Organizational Structures Which Support or Hinder Interdisciplinary Work

The Media Lab, as noted earlier, has very few clear organizational principles. However, three, loosely-defined structures or factors have led to the Media Lab's interdisciplinary success:

1. the leadership's managerial style;
2. the lab's commitment to having interdisciplinarity at its core;
3. the structure of the research groups.

Each element has contributed to the Media Lab's interdisciplinary work in a unique and important way.

First, there is the matter of the Media Lab's leadership. As anyone even remotely familiar with the Media Lab knows, Nicholas Negroponte has been an absolutely indispensable part of the institution's rise. What is less well-known is how his hands-off managerial style (really an organizational "anti-structure") has contributed to the lab's work. Nearly every Media Lab professor we spoke to testified to the fact that Negroponte's policy of giving researchers the resources

to do their work and then leaving them alone contributed massively to their creative success.

For example, Tod Machover described how he came to the Media Lab for an interview as a young researcher in the early 1980s, full of ideas to pitch to Negroponte. Over lunch, Machover mentioned potential project after potential project to the Media Lab's founder, expecting to hear words of approval or disapproval: Machover received, instead, only polite nods and neutral responses. Slightly unsettled by the end of lunch, Machover asked Negroponte directly: "Do any of those things seem particularly interesting?". Negroponte replied by saying that Machover was asking the wrong sort of question: if he decided to come to the Media Lab, then he would be directing his research, not Negroponte. Negroponte made it clear that his role was simply to find excellent, inquisitive researchers and provide them with the materials to do their work. Machover was impressed, and the world has been impressed with Machover's work at the Media Lab in the ensuing years—a testament to Negroponte's methods.

Second, Negroponte's laissez-faire style has been supported by the lab's explicit commitment to interdisciplinarity. Many other interdisciplinary institutions, organized without such an explicit commitment to interdisciplinarity, have suffered because of this misstep. Ken Haase described contrasting structures at other such institutions beautifully:

> When Nicholas and Jerry [Wiesner] first started the Media Lab in the late '70s / early '80s, they expected that within a few years there would be a lot of competitors and they were surprised when this didn't happen.
>
> One of the reasons it didn't happen is if you look around at the different programs that might be competitors, they are either one of two structures. One of the structures has something which is a center that is between departments . . . people from different departments are a part of it, but essentially you're getting their marginal energies and not their core energies.
>
> The second case is: some existing department declares a part of itself to be a media center or a media laboratory or whatever—so it's a part of computer science or it's a part of arts or it's a part of literature or what have you . . . and in that case it's part of the department and it's not really interdisciplinary. In addition, it also . . . may get more marginal energy than core energy.
>
> What the Media Lab did that was unique was that it was an interdisciplinary center where people were based in the Media Laboratory, so that their primary affiliation was in the Media Laboratory, which meant that it was getting core energy and not marginal energy. And I think that there's a lot to be said for that kind of structure.

Third, Negroponte and the lab's founders did not simply set up a general interdisciplinary space and leave it wide-open. Instead, they encouraged the formation of a large number of research groups with varying interests, which would feed off each other and synergistically move forward. This is the organizational scheme that is still in place today, and as we saw in the work of Deb Roy, movement between various research groups indeed does lead to new ideas, new connections, and increased creativity. In addition, several professors cited the flow of students between research groups as one of the most important stimulants for their own work as well.

There are only a few elements related to interdisciplinarity that hold back work at the Media Lab. One, already mentioned, is the presence of so many interdisciplinary workers with different backgrounds, which makes it hard for individuals to get an informed critique on what they have done (because they may be the only lab members trained in their area).

There is a key point to note before taking this shortcoming too seriously, however. Several Media Lab researchers said that although the trouble with getting an informed critique from inside the lab was definitely a problem, it is far from devastating and well-worth the benefits that come from having so many different people from such disparate areas working together. For example, when we asked Mitch Resnick whether this situation constituted a problem or not, he replied:

> Yes. The question of how big a problem it is is a hard thing to gauge. Is it worth the tradeoff? Yes. Do I sometimes wish that I had more people within the building who were more focused on issues about learning and education? Yeah, I think that would be helpful to me; I would like that. Would I want to trade so I would be at a school of education where I would have many more people surrounding me with interests in learning and education but missing the other things? No.

Other Media Lab professors made similar statements, and some even suggested that the lack of disciplinary colleagues at the Media Lab forced them to be more connected to like-minded researchers outside the institution than they would be otherwise.

Another problem that subjects mentioned is a bit more invidious and relates to the lack of defined identities at the lab. While the freedom to do research across a number

of different areas is liberating, it can also result in a struggle for distinctiveness. One subject told us that collaboration at the lab is not as easy for junior faculty as it might seem, as the desire for unique, distinctive research (necessary for a successful tenure review) squelches the impulse to work with others pursuing similar projects. The possibility for a person's individual strengths to get overlooked may indeed be higher when the distinctions between different researchers are made less clear; this particular subject cited a hesitancy on the part of others to work on common problems as evidence supporting this hypothesis.

X. Interdisciplinary Research at the Media Lab: Summary

The Media Lab is well-designed to support interdisciplinary work: Nicholas Negroponte sets a tone that embraces free, open-inquisition, interdisciplinary work is expected and supported, and the presence of a variety of interacting but unique research groups ensures that novel ideas will be spread around the lab. The two major structural problems are:

1. the lack of bodies of experts who can judge work that draws from specific disciplines (however, as we have seen, this is the result of the lab's focus on interdisciplinarity, and it is a trade-off many Media Lab professors are happy to make);
2. the problems associated with (too) close collaboration, noted above.

Interestingly, the Media Lab is undergoing two dramatic changes that figure to alter its structure significantly. First, Nicholas Negroponte is stepping down as the lab's director, and it is unclear at the moment as to how the lab will replace him. Second, the

lab has grown so large that a decision has been made to split it into three centers: one devoted to technology and the arts, one to technology, children, and developing nations, and one to "bits and atoms" (a lab effort to embed digital technology—"bits"—into everyday physical objects—"atoms"). It will be interesting to see how the three centers interact, and whether or not the presence of distinct units will make the lab more disciplinary than it is today (most Media Lab professors hope that it will not). In fact, a follow-up study of the Media Lab in a few years might yield a much clearer picture as to what factors are necessary for an effective interdisciplinary institution.

XI. Conclusion

The Media Lab is a place that has espoused an interdisciplinary approach and achieved singular success. Though there are some weaknesses associated with the lab's method of combining disciplines, the results of that method have been twenty years of ground-breaking research, hundreds of students with inquisitive minds and the skills to match, and an international reputation for excellence.

Paradoxically, all those strengths keep us from drawing general conclusions based on the way interdisciplinary work is carried out at the Media Lab: the institution is simply too unusual to serve as a template for how interdisciplinary work, in general, gets done. Few other organizations have the same resources or intellectual capital that the Media Lab has, and even fewer have the good fortune to exist in partnership with a university like MIT. Furthermore, as mentioned earlier, most interdisciplinary institutions have a narrower focus than the Media Lab.

In order to get a more accurate picture of the value of interdisciplinary research, as well as the components that contribute to it, we intend to examine a handful of other outstanding interdisciplinary institutions in the near future. We also plan to investigate collegiate and pre-collegiate interdisciplinary programs, to complement the preliminary look at interdisciplinary education that we have obtained at the Media Lab.