Media Matters:
Nudging digital media into a manual design process (and vice versa)

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ABSTRACT
This paper reports on a media class offered during the 1995-96 academic year at the University of Oregon. This course, a renovation of an existing ‘manual’ media offering targeted intermediate level graduate and undergraduate students who, while relatively experienced design students, were relatively inexperienced users of digital media for design. This course maintained a pedagogical emphasis on design process, a point of view that media are powerful influences on design thinking, and an attitude toward experimentation (and reflection) in matters of media and design process. Among the experiments explored were fitting together digital with manual media, and using digital media to collaborate in an electronic workspace. The experience offers opportunity to consider how digital media might be more widely integrated with what remains a predominantly ‘manual’ design process and media context for many architecture schools and practices.

PREAMBLE
I have studied, practiced or taught architecture with an emphasis in design process and design media for the past 20 years. For many of those years I learned, practiced and taught these subjects deeply rooted in a traditional architectural culture of diagramming, drawing and model-making as a means to design thinking and frequently, a measure of design quality. I have an active interest in what I (and others) consider a reciprocal relationship between design media and design thinking (the mental processes designers use to understand and solve a design problem) — especially in early phases of design process. Common to much of my work and thinking in this arena is the notion that throughout their education and careers, designers cultivate and continually refine a diverse media repertoire that both propels and influences their design thinking (Kellett 1990a and b, for example). LeCorbusier’s phrase the “indispensable, practical and beneficient relation between the hand and the head” (LeCorbusier, 1963) aptly captures for me this fundamental interdependence between design media and design thinking.

Although I am not academically or professionally centered in computing or digital media per se, I am deeply interested in the compelling, powerful and influential tools they bring to design process. I hold a fascination for the processes of adoption of new media and technologies into the mainstream of design practice and teaching with a particular interest in the many accommodations and adaptations that accompany them. The recent past has been personally instructive on this point — consider that it has been but the span of one generation that T-squares and ruling pens became parallel bars and mechanical pens and then became CAD; slide rules became pocket calculators became engineering software; carbon paper became photocopy machines became scanners and image manipulation software and so on. Arguments could be made (in another time, another paper) that each innovation, to some extent, changed us, our work processes, our teaching, our workplaces, our studies and our architecture.

At the same time, I would also argue that new processes and technologies do not fully displace (at least not right away) established processes and practices. Instead the new initially co-exist with those that came before — sometimes in parallel, sometimes in series — until eventually they find their own place and role perhaps displacing one or more existing processes and practices no longer as necessary or as effective. This closely parallels my recent experience as a teacher and an architect observing how the hardware and software of digital media and processes develop so much more quickly than the practices and people who use them. So, while I am, for the most part, enthusiastic for the practice as well as the promise of digital media tools in architectural education, I also recognize that the digital media future is functionally, culturally and conceptually entangled with the present. We are, for the
time being (and as some might argue — continually) in transition. And, over the short term, until a generation of teachers, practitioners, administrators and clients change or retire, opportunities to diffuse the use of digital media beyond 'specialists' and 'early adopters' will emerge in part from a more incremental and piecemeal adoption and displacement of tasks that computers can support demonstrably 'better' than manual means. A question of some interest to this paper is where, when and how will that be the case for a cohort of students of architecture less than fully invested or fluent in digital media.

![Diagram of one cycle](Image)

**Figure 1: Cycles of Design Thinking and Media in Design Process**

Each large loop represents a design process phase (concept formation, for example) within which are focused media studies that mark or characterize a design decision-making cycle within that phase (how might this building be shaped or sited, for example). With acknowledgment to Faruqee (1984) and Zeisel (1981).

I might start with the hypothesis that designers cultivate a media 'repertoire' — a palette of tools and techniques (Kellett, 1990a) that they deploy in sequences or series against the many tasks of a design process (Figure 1). Other authors have argued that design process is comprised of linked series of visual thinking cycles (Zeisel, 1981, for example) characterized and marked by particular media types and sequences (Faruqee, 1984 and Herbert, 1993, for example). I would add to this figure the observation (as yet unmeasured) that designers continually grow and evolve their repertoire as they learn and gain experience with design. New techniques and media, are added to and integrated with the existing where and when they add design process value — typically in the form of speed, clarity, scope of inquiry or quality of idea. Prior media are never 'unlearned' and rarely displaced, but incrementally adapted or redefined to a more appropriate and effective role in the repertoire. Facile designers cultivate an ability to 'switch' seamlessly back and forth (in parallel, or in series) among as many techniques and media as needs, situations and opportunities demand.
About three years ago, I began to integrate digital media into my design studios and media classes. First as a topic of discussion and demonstration, eventually a fraction of a syllabus and finally, this past academic year, the primary focus of a course and a substantial component of a design studio. As this process unfolded, I became interested in where I and my students would seek and find those points of value that would bring a digital media technique into the middle of their design process. While this inventory undergoes continual review and redefinition — I currently consider the following characteristics among the greatest immediate value to new and partial users of digital media:

- access to images and data of the Internet
- inexpensive, quick, multiple iterations of alternative ideas
- instantaneous, effortless shifts of point of view
- ability to quickly and accurately appropriate and manipulate images (cut, copy, paste, scale, overlay and so on.)
- sophisticated measurement and instantaneous calculation of complex quantitative operations
- storage of complex images and models (and their many variations)
- the collaboration opportunity of distributed and asynchronous networks

And, among the manual media characteristics of greatest existing value I would identify:

- ability to work with coarse and imprecise design information
- fluidity and speed (thinking and simple image making at roughly the same rate)
- integration and cross reference of diverse studies
- intellectual stimulation of ambiguity and random cross-reference
- creative vitality of direct physical experience with 'making'

TEACHING THE COURSE

Winter term 1996 provided an opportunity to prototype a media course for intermediate level design students seeking to upgrade their digital media skills and bring them more strategically into their design process. At the University of Oregon, this audience is typically in the ‘middle’ of an undergraduate or graduate degree and partial, in some instances tentative, adopters of digital media. Of the 3 graduate and 6 undergraduate students who enrolled, most had completed four or more design studios. All had basic manual media skills (perspective, axonometric, model-making and so on). A few had basic digital media skills (the Department’s basic software — Design/Workshop™, Adobe Photoshop and ClarisWorks). Two had advanced digital media skills.

My agenda for this course was to create opportunities for these students to:

1. 'See' and manage an interdependence between design thinking and design media (both manual and digital) in design studio-like situations.

2. Become more fluent, confident and creative integrating the standard digital and manual media taught in the Department into their own design process and working methods.

3. Learn to work in teams in electronic workspace.

The course highlighted issues associated with media choice and promoted experimentation with the combinations of media different students might employ given equal access and encouragement to both manual and digital alternatives. Of particular interest were experiments that emphasized collaboration and utilized manual and digital media in parallel — that is within on design studio or a single cycle of design thinking represented in Figure 1. To these ends, students worked primarily in small teams and were encouraged to seek any combination of manual and digital media appropriate to the assignment, their level of skill or experience and the time available. In order to focus explorations and simulate the ‘real time’ compression of most design studio situations, a self-imposed limit of 5 hours per team member per week was adopted.

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The syllabus

The syllabus paralleled beginning design process tasks of:

- **PROBLEM DEFINITION**: drawing out design implications from the words, numbers and images of program and site information
- **CONCEPT GENERATION**: finding, analyzing and extracting design concepts from precedent and other sources
- **FORM GENERATION**: exploring the creative leap from concept to form and its schematic development

Within each segment were weekly readings, presentations, assignments and critiques that explored combinations of manual and digital media in the context of a design task.

ASSIGNMENTS

A common design problem — an Associated Collegiate Schools of Architecture competition brief for an orientation center of exhibits and culture for international visitors attracted to the Sydney, Australia Olympic Games of 2000 — linked the seven assignments of the course. The site for this competition is a prominent waterfront pier immediately adjacent to and below the Sydney Harbor Bridge and across Circular Quay from the Sydney Opera House.

Each assignment maintained qualities of a typical design situation. These included principles of open-endedness (design goals are defined by the designer), iteration (understanding through repetitive cycles), cumulative work (scope and complexity builds on the results of prior iterations), presentation and critique. Work in process as well as final products were presented for critique in studio-like electronic 'Hack-ups' via an LCD panel and overhead projector. At no time, however, were students directed or encouraged to solve the problem in its entirety or converge the results into a coherent, unified design solution. Instead, the emphasis was a more piecemeal but guided probing of each student’s design process and media repertoire with mandated periods of reflection from which written comment on issues and questions concerning process and product were compiled and presented for discussion with the class. Discussion and verbal evaluation was a part of every presentation, followed by written comment from class members and formal evaluation from the instructor delivered via electronic mail.

Below is a summary of the principal assignments illustrated with examples from student work, and accompanied by discussion of the design thinking and media agendas within, and reflection on the results.

Getting started

**Assignment 1: Postcards from Cyberspace**

Duration: 4 days Example: Figure 2

Working in teams of three, students were to locate digital images relevant to the term project (from the WorldWideWeb) and 'hard copy' images relevant to themselves, their work and interests (from prior studios, sketchbooks, scrapbooks etc.). Each team was to edit and compose a selection of these images via the University network and send it to the course file server as an 'digital postcard' and retrieve it for presentation in class.

Design thinking agenda: This was fundamentally a field test of the electronic file server, communications, presentation and team organization systems established for the course. Accordingly the design thinking agenda was modest — a rather simple task of collaborative information gathering and graphic composition in Photoshop.

Design media agenda: This assignment was also a field test of the digital media savvy of the students in the class. Although all had completed a survey seeking to inventory their experience and fluency with various computing applications, this assignment sought to calibrate that self-assessment and test the degree to which those with expertise would be able and willing to share it with others. A secondary agenda was to experience the difference between media attributes (color, contrast, scale, complexity and so on) that communicate well on paper in a lighted room and those that communicate well through an LCD panel in a darkened room.
Reflection: The 'Postcard' assignment proved to be a fast, energetic, effective and somewhat entertaining introduction to the course. Students not only learned the basic protocols of teamwork, assignments, communications and presentation but were also presented opportunity to introduce themselves, their skills, past work and interests to each other.

Problem definition

Assignment 2: Transformations of Design Information
Duration: 7 days Example: (Part A program information — Figure 3; and Part B context information — Figure 4).

Figure 3: Problem Definition: Program Example
Program information teams were asked to sort through the spatial requirements of the assigned competition program, supplement them where appropriate and design an effective visual summary of the results. Excerpts from the work of Steven Lee and Corey Meeks

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Working in pairs, two teams were assigned the task of expanding the program portion of the competition statement and the other two teams were assigned the task of compiling information about the project site and architectural context. In both cases, teams were charged with providing their classmates with 'what they need to know' about the program and site to initiate a thoughtful and creative design process. The final product, a public presentation and 'stand-alone' electronic document was made available to the class via the course server. Class members would use any portion or combination of this work in subsequent assignments.

Design thinking agenda: The design thinking priority of this assignment to collect and sort through information relevant to the program, draw out crucial physical form implications within that information — much of which comes in the 'non-physical' form of words and numbers — and then edit the content, sequence and form of that information to support initial design studies. Design media agenda: The design media priority of this assignment was transformation of this information into 'design useful' formats that anticipate how and where it might be used in design process. Also, like the first assignment, there was a parallel objective of learning to communicate this information effectively using projection.

Reflection: The problem definition task embedded in this assignment has consistently been a difficult one to teach. This class, like many before it, had difficulty anticipating and sorting which design issues and information were likely to be more crucial influences on design. They also struggled with this as their first design opportunity to integrate digital and manual media, opting instead to undertake the assignment with one media or the other. Those issues aside for a moment, the site and context analysis portion was the more successful of the two from a digital media point of view. This was at least in part attributable to the observation that site analysis is well suited to the rich quantity of site related information and images available via the Internet as well as the image manipulation, modeling and animation capabilities of Photoshop and DesignWorkshop™ respectively. In the discussion that followed, a suggestion was made that the class missed an interesting digital media opportunity to link spreadsheet-like descriptions to comparative volumetric and part-to-whole analyses of form.
Generating concepts

Assignment 3: Houses of Glass
Duration: 7 days Example: Figure 5

Teams of three were assigned the task of abstracting design concepts (via graphic analysis) from at least two project precedents—one a 'house of glass', and the other, their choice of any example pertinent to a programmatic, contextual or architectural design issue in the project. Teams were to then apply these extracted concepts to the program and site of the Sydney Visitors Center project in a 'judgment suspended' sketch design study.

Design thinking agenda: The design thinking context for this assignment is the quick, initial, highly thematic concept generating probes that typically follow problem definition and precede more systematic and comprehensive form generating studies associated with schematic design. Often such concepts are extracted from precedent and analogous design situations and then transformed or adapted to the specific requirements and circumstances of the problem at hand.

Design media agenda: The media emphasis of this assignment was an appropriate combination of techniques to 'extract and make vivid' relevant design concepts in the examples selected for analysis. The class was provided technique examples that exhibited vivid correspondence between media technique and design content. These included examples of diagramming, volumetric analysis and animation of experience over time and motion.

Reflection: This assignment directly benefited from the experience and some of the struggle with the design thinking agenda of Assignment 2 (the program portion, Figure 3, in particular). Two teams saw an opportunity to use a scanner and the image manipulation capability of Photoshop (like a sophisticated photocopy machine) to undertake a comparative scale and organizational analysis of programmatically similar buildings. Images of these buildings were pulled from books and the Internet, supplemented with freehand analytic diagrams and composed into a single illustration. Another team developed a three dimensional model of a glass pavilion by tracing a photograph of its dome using CAD and modeling media (Figure 5).
Generating form

Assignment 5: The Machine-Assisted Perspective (Digital to manual)
Duration: 7 days Example: Figure 6

Working individually, students were assigned the task of creating perspective explorations of alternatives for an interior space or spaces with an emphasis on quantity and speed. The alternatives explored could be design variations of a particular volume or a series of volumes experienced in sequence.

Design thinking agenda: The design thinking context for this assignment is those coarse-grained form generating studies typically encountered at the very beginning of a schematic study. The approximate shape and location of a form or volume alternative are tentatively set and there is need to intuitively develop and test the architectural opportunity of that alternative through a quick sketch or series of sketches.

Design media agenda: This assignment reversed the manual to digital media sequence of the previous assignment and explores the degree to which the 3-dimensional modeling capabilities of an application such as DesignWorkshop™ could be "leveraged" to facilitate quick, expressive and accurate freehand sketch studies. Parallel to this assignment a workshop was given in one-point perspective and methods of locating perspective construction points in a wireframe view of a CAD model. Discussion considered issues and timing of transition between the digital media (how much information and time to put into the CAD model) and the manual media (how much depth and form development cues were needed to facilitate an individual's perspective sketching skills).

Reflection: This assignment was arguably the most vivid and effective demonstration of value-added from both digital and manual media. With very little instruction and minimal time investment on a computer, even the most tentative of perspective skills were elevated to confident, expressive explorations of form and space.

Assignment 6: The Model-assisted Photograph (Manual to digital)
Duration: 7 days Example: Figure 7

Teams of three were assigned the task of testing on-site the appropriateness of two conceptually different massing and organization studies for the Visitor Center project. These massing and organization studies were to originate in the simplest, quickest physical model possible, photographed with a QuickCam digital camera and placed into an aerial (a view to) and ground level image (a view from) the site.

Design thinking agenda: The design thinking context for this assignment is those quick studies of massing and organizational strategy one might visualize by way of rough, quickly fabricated and intuitively altered physical

Figure 6: Machine Assisted Perspective Example
Excerpts from the work of Steven Lee

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models — not unlike the rapid prototype techniques common to contemporary product design process. The notion is that a highly interactive, hands-on physical model (which might be developed for other design process purposes) could be adapted to on-site, in context assessments of massing and organizational ideas.

Design media agenda: This assignment explores the degree to which the quick, intuitive modeling capabilities of a manual physical model could be "leveraged" to simulate the approximate appearance of a whole building idea without incurring the time investment associated with an appropriately detailed digital model of a building and its site. Among the strategies explored by the class were: using a quick model of a "part" and digitally repeating or expanding it to simulate a "whole"; modifying a model made for another purpose and scale (a structural concept, for example); and recording the many different massing strategies created from an interchangeable kit of model parts.

Reflection: With one important caveat, this assignment was an effective experiment. Arguably its effectiveness comes in no small part from the creative stimulation many find in working with physical models one can see, touch and experience directly and from multiple points (Cheng 1995 and Wilson 1995 speak to this point). Additionally the ability to experience that model transported to a different, more complex context of a digital site model and site photographs only broadened the experience. The caveat concerned the inexplicably large scale and fine level of detail at which most students chose to make their 'quick' model. Few seemed to recognize that the time and process opportunity would be greater with the smallest, least detailed model possible using digital media to adjust its scale and rendering. Most exceeded their 5 hour time budget significantly and voiced some disappointment with the technical shortcomings of a process that failed to capture their models subtleties in digital images.

Figure 7: Model Assisted Photograph Example
The model illustrated is a large (about 3/4" scale) but crude assembly of boxes and textures quickly (and iteratively) taped together and photographed with a black and white QuickCam for later scaling and manipulation in one of the digital site models of Assignment 2. Excerpts from the work of Corey Meeks

Course retrospective

Assignment 7: A Design Methods and Media Retrospective
Duration: 12 days (with a hiatus for term end design studio reviews) Example: Figure 8

The final assignment for the course asked each student to reflect on the term’s experiments and prepare a self-running digital diary or storyboard of what they learned and took away from each syllabus segment. The intent

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is to systematically capture an inventory of how each student's design thinking and media repertoire had been impacted by the course. Students were encouraged to interpret this as a creative, editorial opportunity and conceive their report to comment on their unique interests, values and attitudes about design, digital and manual media, working in teams and thinking about design media and process. Each selectively drew from any of the work produced over the term (including that done with or by other classmates). Final products were posted to the course server and students were invited (via e-mail) to view each other's work and reflections over the network.

Reflection: This assignment represented an important process of closure and consolidation of the diverse themes and experiments of the course. Most students saw it as an opportunity to reconsider their work chronologically, reflecting on their successes and failures, in a few instances redoing the assignment with the benefit of hindsight or to take advantage of a technique acquired since the work was completed. On balance, there appears to have been much positive impact from the several opportunities to systematically record and evaluate one's working methods, media tools and design thinking strategies. Taken the recorded comments at face value, most considered the media work broadening, interesting and confidence building but not profound. Most seemed to appreciate the opportunity to discover their own fluency and creative comfort level with digital media in a design focused context. Several remained skeptical that the digital media experiments they had undertaken were adequately robust and sustainable to acquire a lasting role in their working methods. It is too early to evaluate the degree to which that will really be the case over time.

![Image](image1.png)

![Image](image2.png)

**Figure 8: Media and Methods Retrospective Example**

Excerpts from the work of Jake Bigham

**POSTSCRIPT**

At this writing about three months have passed since the last assignments were submitted and evaluated and this paper brings my own opportunity for 'mandated reflection'. As I look back on the experience and consider its lessons for the future, I am struck by the diversity of ideas and observations nine weeks and eight students have brought forward. I am equally struck by the very few illusions of profound insight and breakthrough that (so far) accompany them. Mostly I see this work as a 'very rough cut' on a few very good opportunities. Although I place

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great confidence in situational learning, the breadth of syllabus topics and the open-endedness of the assignments were perhaps too much of an otherwise good strategy and will aspire to 'do less better' in future iterations. Among the lessons I will take forward are:

The diversity of people, their work and methods

Despite their relatively comparable standing in the program (roughly in the late middle of the design studio sequence), the knowledge, experience and skill with design, design thinking and design media ability of the student enrolled in this course was uneven. Most had little formal and mostly informal, ad hoc experience with digital media. A similar assessment could be made of their fluency and confidence with manual media as well as design process skill and maturity.

As design educators it is important for our teaching and methods to recognize that we are only beginning to see the new habits and expectations of mind and practice that digital media add to mainstream practice and discussion. Manual and digital media will be side by side for some time to come and we need more explicit pedagogical ideas and practices for building links and bridges between. The challenge will be to cultivate strategies that acknowledge the 'messy mix' of tools and techniques to match the unique needs and circumstances of people, be they students, clients, colleagues or collaborators — as we have developed for other subjects and technologies.

Media and design pairs

Media courses offer effective venues to explicitly consider and work on issues of process, tactic and technique. The more focused investment of time and effort and generally reduced performance anxiety that accompanies such classes can be better suited to their purpose than a design studio. It is possible in these settings to step away from the complex demands and expectations of studio to concentrate on specific skills and processes or experiment with new work settings, teaching and learning strategies and working relationships between students and students and faculty. Students (and faculty) are perhaps more open to explore higher risk but potentially beneficial approaches to design outside the context of more complex studio projects.

At the same time, teaching about media is only partly about teaching design and the obligation to forge complex, integrated whole designs is simply not as pressing. A structured relationship between the two, however, is highly desirable and, based on the experience of this course, it ought to be sequential — the media course as a process focused preparation for a related design project to follow.

Time bounded experimentation

A 5 hour per student per week rule was adopted to help manage a diverse set of issues and to help students suspend their fear of failure and gain confidence knowing that a time limit would legitimately intervene if things got out of hand. Each time-bounded experimentation mandated the class to cycle through these assignments very quickly and introduced an inherent tension between process and product. Because assignments were short, intense and transient, most students quickly gained a degree of confidence and generally positive regard for taking, what would in other situations, be considered unacceptable risks. This, I believe, was very positive and cultivated a vitality of inquiry that helped many see tremendous opportunity to bring new digital as well as traditional manual tools into their own work. The initial cost, however, is quality of product — many of the experiments were less than elegant in conception and / or execution. One has to start somewhere.

Collaborative teaching and learning

With a little care and attention to process (notably on working in teams and maintenance of teamwork skills and processes), the small team format was a good way to share the diverse knowledge and experience available in any given class. The students and I taught each other a great deal about process and media with relatively few formal demonstrations and presentations. I also have untested reservations about the equity of some of these exchanges and

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am particularly concerned that there is enough to attract and sustain the more capable and highly motivated in any one aspect.

Three team members seemed to represent an effective balance between an acceptable range of skills and work sharing ability and overhead associated with team management and coordination. This perception is in no small part influenced by the relatively short, intense pace associated with teams that form and disband every week. In this course, students were able to outlast or 'work around' most teamwork problems that arose. Had teams been longer-lived or the assignments more complex, I suspect that a team size of 3 would have been more problematic were conflict or problems to arise were a team's life expectancy longer. In addition, undergraduates tended to have less experience and lower expectations for working in groups than do graduates and in retrospect I see greater need to balance or mediate that experience.

The network as an electronic file cabinet

All course materials were made available via a World Wide Web site as well as from a course file server. It was fortuitously instructive that the class (because of the administrative complexity associated with multiple levels of file security) agreed to share read and write access to all the work produced during the term. The opportunity created was being able to retrieve and copy any image or digital model created by another student or team. Students were given sanction (with fair use guidelines) to pursue this opportunity and did so frequently but, to my knowledge, did not abuse the privilege. Without exception the software was cited and ultimately enriched by the contributions of successive students. The experience modified my definition of shared resources and authorship. The network in this case presents interesting parallels to the 'drawing or detail file' maintained in many professional offices which brings a surprisingly acceptable notion of collective authorship that one does not frequently encounter in academic situations.

The network as communication

Electronic systems and communications (the World Wide Web, e-mail and the course server) were welcome and effective strategies once the work was underway. Most students have not the necessity, the experience, or the desire, to conduct more complex business over a network. They found it especially awkward to plan work and make decisions without meeting two or more times. Given the small enrollment of the course and the proximity of many students to each other most working days, these systems must seem cumbersome contrivances that at best save phone calls and travel time and at worst displace opportunities for more substantive interaction with their peers. I would not disagree as one who values the culture of face-to-face learning of this many other architecture schools. It is also increasingly the case that the daily schedules of students are becoming complex and difficult to coordinate. The most obvious solution is to use both -- building some regular team meeting time into the class schedule and sustaining communication out of class via the network.

Teaching venue

Electronic classrooms which, as configured at this institution, are dark, machine dominated environments that do not support teacher to student and student to student communication, collaboration or presentation functions that did not center around a computer screen. In an attempt to improve the environment for traditional media and communication, I added a second venue in a conventional classroom in another building. The problem was, no matter what the venue or topic, the class was more often than not in an ineffective setting for one medium or the other. As we seek to move forward with a growing set of tools and working relationships, design education needs to create a model of working environments that consider manual and digital media as well working individually and working in groups more as both and less as an either/or proposition.
Administrative 'overhead'

Considering the enrollment, the overhead — planning, maintenance and troubleshooting and so on — associated with this course was dramatically out of line with that of comparable traditional media courses. While some of this is legitimately attributable to the learning curve associated with new ways of working, I have had similar experiences in other settings and am about to concede that it has not and probably will not likely disappear anytime soon. The overhead appears to be inherent to the complexity of computers, software and networks and will be a factor to manage and build into expectations of effort and performance for some time to come and perhaps indefinitely.

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