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ABSTRACT

A digital project undertaken last year at Yale (Connecticut) offers an opportunity to explore productivity matters. The project aimed at improving the quality of library support and of student learning in one of the most heavily enrolled undergraduate courses at Yale, "Introduction to the History of Art, from Prehistory to the Renaissance." The Scully Project was Yale's first effort to demonstrate what it could mean to move from film-based to digitally-based systems to support teaching in art history. Student comments on the Scully Project emphasized the convenience of the Web site employed, which contributed significantly to visual memory training. This paper describes the Scully Project and discusses productivity gains subject to administrative control; productivity gains subject to reader control; and productivity as an urgent concern of higher education. The cost model for the Scully Project is appended. (AEF)

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Information Based Productivuty

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INFORMATION-BASED PRODUCTIVITY

Convenience is a key word in the library lexicon. As service organizations, libraries give high priority to enhancing the convenience of their operations. Readers themselves regularly use the word to describe what they value.[1] By contrast, when NEXIS-LEXIS describes itself as a sponsor of public radio, it emphasizes not convenience but productivity for professionals. Does NEXIS-LEXIS know something that we are missing?

I think so. Talk about productivity is unambiguously grounded in the discourse of economics, whereas talk about convenience rarely is. Quite notably, the Andrew W. Mellon Foundation has self-consciously insisted that its programs in scholarly communication operate within the realm of economics. Foundation President William G. Bowen explains this focus, in speaking of the Foundation's JSTOR project, by observing that "when new technologies evolve, they offer benefits that can be enjoyed either in the form of more output (including opportunities

for scholars to do new things or to do existing tasks better) or in the form of cost savings . . . . In universities electronic technologies have almost always led to greater output and rarely to reduced costs . . . . This proclivity for enjoying the fruits of technological change mainly in the form of `more and better' cannot persist. Technological gains must generate at least some cost savings."[2] In its JSTOR project and the other scholarly communication projects it supports, the Foundation calls for attention "to economic realities and to the cost-effectiveness" of different ways of meeting reader needs. The Foundation wishes to promote change that will endure because the changes embody "more effective and less costly ways of doing [the] business" of both libraries and publishers.[3]

Productivity is the underlying measure of such effectiveness, so I want briefly to recall what economists mean by the word and to reflect on the problematic application of productivity measures to higher education. I will then describe a modest project recently undertaken to support one of the most famous of Yale's undergraduate courses. I will conclude with some observations about why the productivity of libraries and of higher education must command our attention.

PRODUCTIVITY

Productivity is one of the most basic measures of economic activity. Comparative productivity figures are used to judge the efficiency with which resources are used, standards of living changed, and wealth created.[4] Productivity is the ratio of what is produced to the resources required to produce it, or the ratio of economic outputs to economic inputs:

$$\text{Productivity} = \frac{\text{Outputs}}{\text{Inputs}}$$

Outputs can be any goods, services, or financial outcomes; inputs are the labor, services, materials, and capital costs incurred in creating the output. If outputs increase faster than inputs, productivity increases. Conversely, if inputs increase faster than outputs, productivity falls. Technological innovation has historically been one of the chief engines of productivity gain.[5]

Useful indicators of productivity require that both inputs and outputs be clearly defined and measured with little ambiguity. Moreover, the process for turning inputs into outputs must be clearly understood. And those processes must be susceptible to management if productivity increases are to be secured. Finally, meaningful quality changes in outputs need to be conceptually neutralized in measuring changes in productivity.

One need only list these conditions for measuring and managing productivity to understand how problematic they are as applied to higher education.[6] To be sure, some of the least meaningful outputs of higher education can be measured, such as the number of credit hours taught or degrees granted. But the outputs that actively prompt people to pursue education--enhanced knowledge, aesthetic cultivation, leadership ability, economic advantage, etc.--are decidedly difficult to measure. And while we know a great deal about effective teaching, the best of classroom inputs remains more an art in the hands of master teachers than a process readily duplicated from person to person. Not surprisingly, we commonly believe that few teaching practices can be consciously managed to increase productivity and are deeply

suspicious of calls to do so.

Outside the classroom and seminar, ideas of productivity have greater acceptance. Productive research programs are a condition of promotion and tenure at research universities; and while scholars express uneasiness about counting research productivity, it certainly happens. The ability to generate research dollars and the number of articles and books written undeniably count, along with the intellectual merit of the work. There is little dispute that many other higher education activities are appropriately judged by productivity standards. Some support services, such as the financial management of endowment resources, are subject to systematic and intense productivity analysis. Other academic support activities, including the provision of library services, are expected to be efficient and productive, even where few actual measures of their productivity are taken.[7]

In many cases, discussion of productivity in higher education touches highly sensitive nerves.[8] Faculty, for instance, commonly complain that administration is bloated and unproductive. Concern for the productivity of higher education informs a significant range of the community's journalistic writing and its scholarship.[9] This sensitivity reflects the truly problematic application of productivity measures to much that happens in education and the tension between concerns about productivity and quality. But it also reflects the fact that we are "unable and, on many campuses, unwilling to answer the hard questions about student learning and educational costs" that a mature teaching enterprise is inescapably responsible for answering.[10]

THE SCULLY PROJECT

A modest digital project undertaken last year at Yale offers an opportunity to explore productivity matters. The project aimed at improving the quality of library support and of student learning in one of the most heavily enrolled undergraduate courses at Yale. We wished to do the project as cost-effectively as possible, but initially we gave no other thought to productivity matters. To echo Bowen's words, we wanted to take the fruits of digital technology in the form of more output, as "more and better." But the project provided an opportunity to explore possibilities for cost savings, for reduced inputs. The project, in spite of its modest objectives and scale (or perhaps exactly for those reasons!), became an instructive "natural experiment" in scholarly communication very much like those supported by the Mellon Foundation.

For years, Emeritus Professor Vincent Scully has been teaching his renowned Introduction to the History of Art, from Prehistory to the Renaissance. The course commonly enrolls 500 students, or about 10% of the entire undergraduate student body at Yale. Working with Professor Mary E. Miller, head of the History of Art department, and with Elizabeth Owen and Brian Allen, Head Teaching Fellows with substantial experience in Professor Scully's course, Max Marmor, the head of Yale's Arts Library, and his colleague Christine de Vallet undertook to provide improved library support for this course. Their Scully Project was part of a joint program between the University Library and Information Technology Services at Yale designed to offer targeted support to faculty as they employ digital technologies for teaching, research, and administration. The Scully Project was also our first effort to demonstrate what it could mean to move from film-based to digitally-based systems to support teaching in art history.[11]

The digital material created for Professor Scully's students included:

- An extensive and detailed course syllabus, including general information about the course and requirements for completing it.
- A roster of the 25 Teaching Fellows who help conduct the course, complete with their e-mail addresses, and a schedule of section meetings.
- A list of the four required texts and the six journal articles provided in a course pack.
- A comprehensive list of the works of art discussed in the course, along with detailed information about the artists, dates of creation, media and size, and references to texts that discuss the works.

Useful as this textual material is, it would not meet the course's key information need for images. The Scully Project therefore includes 1,250 images of sculptures, paintings, buildings, vases, and other objects. These images are presented in a Web image browser that is both handsome and easily used, and accompanied by a written guide advising students on study strategies to make the best use of the Web site.[12]

How did the Scully project change student learning? To answer that question, I must first describe how the library used to meet the course's need for study images. The library traditionally selected mounted photographs closely related to, but not necessarily identical to the images used in Professor's Scully's lectures. We hung the photographs in about 480 square feet of study gallery space in the History of Art department. Approximately 200 photographs were available to students for four weeks before the mid-term exam and 400 photographs for four weeks before the final exam. In those exams students are asked to identify images and to comment on them. With 500 students enrolled, and with the photos available in a relatively small space for just over half of the semester, the result was extreme crowding of students primarily engaged in visual memorization. To deal with the obvious imperfections of this arrangement, some of Professor Scully's more entrepreneurial students made video tapes of the mounted photos and sold them for study in the residential colleges. Less resourceful students simply stole the photos from the walls.

The Scully Project employed information technology to do more and better.

- Students can study the slide images Professor Scully actually uses in class, rather than frequently different photographs that are often in black-and-white rather than color and sometimes carry out-dated identifying labels.
- The 1,250 digital images on the Web site include not only those that Professor Scully uses in class, but also other views of the same object and still other images the Teaching Fellows refer to in discussion sessions. Students now have easy access to three times the number of images they could see in the study gallery space. For instance, where before they had one picture of Stonehenge, they now have eight, including a diagram of the site and drawings showing construction methods and details.
- Digital images are available for study throughout the semester, not just before term exams. They are also available at all hours of day and night, consistent with student study habits.
- The digital images are available as a Web site anywhere there is a networked computer at Yale. This includes the residential colleges, where probably three-fourths of undergraduates have their own computers, as well as computing clusters at various locations on campus.

- The images are usually of much better quality than the photographs mounted on the wall; they read to the screen quickly in three different magnifications; and they are particularly effective on 17" and larger monitors.
- The digital images cannot be stolen or defaced. They are always available in exactly the form intended by Professor Scully and his Teaching Fellows.

Student comments on the Scully Projects emphasized the convenience of the Web site. Comments like "convenient, comfortable, detailed all at the push of a button," and "fantastic for studying for exams" were common, as were grateful comments on the 24-hour a day availability of the images and the need not to fight for viewing space in the study gallery. One student told us "it was wonderful. It made my life so much easier." Another student said "it was very, very convenient to have the images available on-line. That way I could study in my own room in small chunks of time instead of having to go to the photo study. I mainly just used the web site to memorize the pictures like a photo study in my room."[13]

Visual memory training is a key element in the study of art history, and the Scully web site was used primarily for memorization. Reports from Teaching Fellows on whether the digital images enhanced student learning varied, and only two of the Fellows had taught the course before and could make comparisons between the photo study space and the Web site. The following statements represent the range of opinion:

- Students "did think it was `cool' to have a web site but [I] can't say they wrote better or learned more due to it."
- "I don't think they learned more, but I do think it [the Web site] helped them learn more easily."
- The head Teaching Fellow for the course reported that student test performance on visual recognition was "greatly enhanced" over her previous experience in the course. Another Teaching Fellow reported that students grasped the course content much earlier in the semester because of the earlier availability of the Web site images.
- One Teaching Fellow expressed an unqualified view that students learned more, wrote better papers, participated in class more effectively, and enjoyed the course more because of the Scully Project.[14]
- Another Teaching Fellow commented, I "wish we had such a thing in my survey days!"

The Web site apparently contributed significantly to at least one key part of Professor Scully's course--that concerned with visual memory training. We accomplished this at reasonable cost. The initial creation of digital images cost about $2.25 an image, while the total cash outlay for creating the Web site was $10,500. We did not track computing costs or the time spent on the project by permanent university staff, but including these costs might well drive the total to about $17,200 and the per image cost to around $14. Using this higher cost figure, one might say we invested $34 for every student enrolled in the course, or $11 per student if one assumes the database remains useful for six years and the course is offered every other year.

This glow of good feeling about reasonable costs, quality products, improved learning, and convenience for readers is often as much as one has to guide decisions on investing in information technology. Last year, however, Yale Professor of Cardiology Carl Jaffe took me up short by describing the criterion by which he judges his noteworthy work in instructional media.[15] For Professor Jaffe, improved products must help solve the cost problem of good education. One must therefore ask whether the Scully Project passes not only the test of educational utility and convenience set by Professor Scully's Teaching Fellows, but also the productivity test set by Professor Jaffe. Does the Scully Project help solve cost problems in higher education? Does it allows us to use university resources more productively?

ACHIEVING INFORMATION-BASED PRODUCTIVITY GAINS

For more than a generation, libraries have been notably successful in improving the productivity of their own operations with digital technology. It is inconceivable that existing staff could manage today's circulation work load if we were using McBee punch cards or--worse yet--typewriter-written circulation cards kept in book-pockets and marked with date stamps attached to the tops of pencils. While libraries have an admirable record of deploying information technology to increase the productivity of their own operations, and while there is more of this to be done, the most important productivity gains in the future will lie elsewhere. The emergence of massive amounts of textual, numeric, spatial, and image information in digital formats, and the delivery of that information through networks, is decisively shifting the question to one of teacher and reader productivity.

What does the Scully Project tell us about library, teacher, and reader productivity? To answer that question, I will comment first on a set of operational issues that includes the use of library staff and Teaching Fellows to select and prepare images for class use; the preservation of the images over time; and the use of space. I will assess the Scully Project both as it was actually deployed, with little impact on the conduct of classroom instruction, and as one might imagine it being deployed as the primary source of images in the classroom. The operations I will describe are more or less under the university's administrative control, and savings achieved in any of them can at least theoretically be pushed to the bottom line or redirected elsewhere. I will also comment on student productivity. This is a much more problematic topic because we can barely imagine controlling or redirecting for productivity purposes any gains readers might achieve.

Productivity gains subject to administrative control

The comparative costs of selecting images and preparing them for instructional use in both the photographic and digital environments are set out in the four tables that follow. These tables are built from a cost model of over three dozen facts, estimates, and assumptions about Professor Scully's course and the library support it requires.[16] Appendix 1 presents the model, with some information obscured to protect confidentiality. I do not explain the details of the cost model[17] here but focus instead on what it tells us. One cautionary word is in order. The cost model generates the numbers given in the tables, but these numbers are probably meaningful only to the nearest $500. In the discussion that follows, I round the numbers accordingly.

The first table compares the cost of library support for Professor Scully's course in its

former dependence on photos exhibited in the study gallery and in its present dependence on digital images delivered in a Web site.[18]

TABLE 1, "AS DONE" CONDITION: 1,250 images used primarily for memory training

1st Year and Cumulative 6-Yr Expenses	400 Photos		1,250 Digital Images	
Selection of images	1st Year	6-Year Total	1st Year	6-Year Total
Full-time library staff for photo collection	797	2,392	6,200	7,440
Library student staff	10	30		
Selection & creation of digital images			6,200	7,440
Digitization of images			2,800	3,360
Web site design			1,500	1,500
Preparation of images for class use				
Library student staff (mounting photos, etc.)	310	930		
Teaching Fellows (selecting photos)	980	2,940		
Teaching Fellows (selecting slides, 56 hrs)	1,120	3,360	1,120	3,360
Preservation of images				
Library student staff	45	271		
Collection shelving space (capital)	70	417		
Collection shelving space (maintenance)	19	113		
Digital storage and access			470	2,049
Study space				
Photo study gallery (capital)	2,986	8,959		
Photo study gallery (maintenance)	812	2,436		
Totals	$7,149	$21,849	$18,290	$25,149
Film/photo less digital			($11,141)	($3,300)
Productive (unproductive) use of resources				-13%
Funding source				
Library budget	1,163	3,624	17,170	21,789
Art history department	2,100	6,300	1,120	3,360
University space costs	3,887	11,925	0	0
Totals	$7,149	$21,849	$18,290	$25,149

Before the Scully Project, the university incurred about $7,000 in academic support costs for Professor Scully's course in the year it was taught. These costs over a six year period, during which the course would be taught three times, are estimated at $22,000. As deployed in the Fall of 1996, Web-site support for Professor Scully's course cost an estimated $18,000, or $25,000 over a six-year period. The result is a $3,000 balance arguing against digital provision of images in Professor Scully's course, or a 13% productivity loss in the use of university resources. However, a longer amortization period clearly works in favor of digital provision. The cost model suggests that the break even point on the productive use of university resources comes in eight rather than six years.[19] This happens because:

- The higher absolute cost of the digital images results from one-time staff and vendor cost of converting analog images to digital format. While there is little incremental growth in these costs over six years, staff costs for providing analog images grows linearly. The long-term structure of these costs favors digital provision.
- The cost of the "real" space of bricks and mortar needed to house the photo collection is substantial and grows every year. Similarly, the operation and maintenance of physical space carries the relative high increases of costs for staff and energy. By contrast, the "virtual" space of digital media is relatively inexpensive to begin with, and its unit cost is falling rapidly. Again, the long-term

structure of costs favors digital provision.

- To secure the cost benefits of digital provision, an institution would need to increase the operating budget of its library while it reduced spending on Teaching Fellows and space (see the summary display of Funding Sources). More generally, an institution would need to manage its operating and capital budgets as, in significant measure, fungible. The commonplace failure to do this in higher education deprives us of important opportunities to increase institutional productivity.

Along with the amortization period, the number of images digitized is a another major variable that can be used to lower the total cost of digital provision and so move toward a productive use of resources. For years, it has been possible to mount no more than 400 photos in the study gallery. As Table 2 shows, if the Scully Web site had contained 400 digital images, rather than 1,250, conversion costs (italicized to isolate the changes from Table 1) would drop significantly and the six year cost of digital provision ($11,500) would be significantly under the cost of analog provision ($22,000). There is a $10,000 balance in just six years favoring digital provision, or a 88% increase in the productive use of resources.

TABLE 2, "WHAT IF" CONDITION #1: 400 images used primarily for memory training

1st Year and Cumulative 6-Yr Expenses	400 Photos		400 Digital Images	
Selection of images	1st Year	6-Year Total	1st Year	6-Year Total
Full-time library staff for photo collection	797	2,392	*2,067*	*2,480*
Library student staff	10	30		
Selection & creation of digital images			*2,067*	*2,480*
Digitization of images			*933*	*1,120*
Web site design			1,500	1,500
Preparation of images for class use				
Library student staff (mounting photos, etc.)	310	930		
Teaching Fellows (selecting photos)	980	2,940		
Teaching Fellows (selecting slides, 56 hrs)	1,120	3,360	1,120	3,360
Preservation of images				
Library student staff	45	271		
Collection shelving space (capital)	70	417		
Collection shelving space (maintenance)	19	113		
Digital storage and access			157	682
Study space				
Photo study gallery (capital)	2,986	8,959		
Photo study gallery (maintenance)	812	2,436		
Totals	$7,149	$21,849	$7,843	$11,622
Film/photo less digital			($694)	$10,227
Productive (unproductive) use of resources				88%
Funding source				
Library budget	1,163	3,624	6,723	8,262
Art history department	2,100	6,300	1,120	3,360
University space costs	3,887	11,925	0	0
Totals	$7,149	$21,849	$7,843	$11,622

The choice between 400 and 1,250 images has a dramatic impact on costs and productivity. That being so, one must ask what motivates the choice and what impact it has on student learning. Further consideration of this "what if" case is best deferred to the discussion of student productivity .

Speculation about another "what if" case is worthwhile. Professor Scully and his Teaching

Fellows made no use of the Web site in the lecture hall or discussion sessions.[20] What if they had been able to depend on it, instead of traditional slides, for their face-to-face teaching? There is of course a warm debate on whether digital images can match film images in quality or ease of classroom use. The question posed here speculatively assumes no technological reason to favor either analog or digital media, and focuses solely on what happens to costs when classroom teaching is factored in.

Two changes are identified (in italics) in Table 3. They are the cost saving when Teaching Fellows no longer need to assemble slides for the three classroom discussion sessions each conducts during the term and the added cost of equipping a classroom for digital instruction.

TABLE 3, "WHAT IF" CONDITION #2: 1,250 images used for memorization and instruction

1st Year and Cumulative 6-Yr Expenses	400 Photos		1,250 Digital Images	
	1st Year	6-Year Total	1st Year	6-Year Total
Selection of images				
Full-time library staff for photo collection	797	2,392	6,200	7,440
Library student staff	10	30		
Selection & creation of digital images			6,200	7,440
Digitization of images			2,800	3,360
Web site design			1,500	1,500
Preparation of images for class use				
Library student staff (mounting photos, etc.)	310	930		
Teaching Fellows (selecting photos)	980	2,940		
Teaching Fellows (selecting slides, 56 hrs)	1,120	3,360	*0*	*0*
Preservation of images				
Library student staff	45	271		
Collection shelving space (capital)	70	417		
Collection shelving space (maintenance)	19	113		
Digital storage and access			470	2,049
Study space				
Photo study gallery (capital)	2,986	8,959		
Photo study gallery (maintenance)	812	2,436		
Digitally equipped classroom (capital)			*692*	*2,075*
Digitally equipped classroom (maintenance)			*69*	*208*
Totals	$7,149	$21,849	$17,931	$24,071
Film/photo less digital			($10,782)	($2,222)
Productive (unproductive) use of resources				-9%
Funding source				
Library budget	1,163	3,624	17,170	21,789
Art history department	2,100	6,300	0	0
University space costs	3,887	11,925	761	2,283
Totals	$7,149	$21,849	$17,931	$24,071

This "what if" modeling of the Scully Project shows a $2,000 negative balance, or a 9% loss in productivity. While digital provision in this scenario is not productive within six years, the significant comparison is with the 13% loss in productivity without using digital images in the classroom (Table 1). The conclusion is that substituting digital technology for the labor of selecting slides is itself productive and moves the overall results of digital provision toward a productive use of university resources. This conclusion is strongly reinforced if one considers a variant "what if" condition, in which the Teaching Fellows teach not just three of these discussion sessions in a classroom but all fourteen of them, and where each Fellow selects his or her own slides instead of depending in considerable measure on slides selected by the head Teaching Fellow. This scenario is modeled in Table 4.

TABLE 4, "WHAT IF" CONDITION #3: 1,250 images used for memorization and instruction

1st Year and Cumulative 6-Yr Expenses	400 Photos		1,250 Digital Images	
	1st Year	6-Year Total	1st Year	6-Year Total
Selection of images				
Full-time library staff for photo collection	797	2,392	6,200	7,440
Library student staff	10	30		
Selection & creation of digital images			6,200	7,440
Digitization of images			2,800	3,360
Web site design			1,500	1,500
Preparation of images for class use				
Library student staff (mounting photos, etc.)	310	930		
Teaching Fellows (selecting photos)	980	2,940		
Teaching Fellows (selecting slides, 700 hrs)	14,000	42,000	*0*	*0*
Preservation of images				
Library student staff	45	271		
Collection shelving space (capital)	70	417		
Collection shelving space (maintenance)	19	113		
Digital storage and access			470	2,049
Study space				
Photo study gallery (capital)	2,986	8,959		
Photo study gallery (maintenance)	812	2,436		
Digitally equipped classroom (capital)			*3,358*	*10,075*
Digitally equipped classroom (maintenance)			*336*	*1,008*
Totals	$20,029	$60,489	$20,864	$32,871
Film/photo less digital			($835)	$27,618
Productive (unproductive) use of resources				84%
Funding source				
Library budget	1,163	3,624	17,170	21,789
Art history department	14,980	44,940	0	0
University space costs	3,887	11,925	3,694	11,083
Totals	$20,029	$60,489	$20,864	$32,871

As a comparison of Tables 3 and 4 indicates, the weekly cost of selecting slides in this new scenario increases twelve-fold, while the use of the electronic classroom increases five-fold. That the classroom costs are absolutely the lower number to begin with also helps drive this scenario to the highly favorable result of an 84% increase in productivity.

In considering these scenarios, it is important to emphasize they all assume funds for Teaching Fellows are fungible in the same way that the library's operating and capital budgets are assumed to be fungible. Faculty and graduate students are most unlikely to make that assumption. Graduate education is one of the core products of a research university. The funds that support it will not be traded about in the way one imagines trades between the operating and capital funds being made for a unit, like the library, that supports education but does not constitute its core product.

Productivity gains subject to reader control

Having accounted for the costs and potential productivity gains that are substantially under the university's administrative control, I will look briefly at potential productivity gains that lie beyond such control--the productivity of readers. In doing this we must consider the value of the qualitative differences between film and digital technologies for supporting Professor Scully's course. The availability of the images throughout the semester at all times of day and night, rather than just before exams, and the large increase in the number of images available for

study constitute improvements in quality that make any discussion of increased productivity difficult--but interesting and important as well.

Students were enthusiastic about the convenience of the Web site. They could examine the images more closely, without competing for limited viewing space, at any time they wished. Without question this made their study time more efficient and possibly--though the evidence is inconclusive--more effective.

Let us focus first on the possibility that, as one of the Teaching Fellows observed, students learned more easily but did not learn more. Let us imagine, arbitrarily, that on average students were able to spend two hours less on memory training over the course of the semester because of easy and effective access to digital images. What is the value of this productivity gain for each of Professor Scully's 500 students? It would probably be possible to develop a dollar value for it, related to the direct cost and the short-term opportunity cost of attending Yale. Otherwise, there is no obvious way to answer the question, because each student will appropriately treat the time as a trivial consideration and use it with no regard for the resources needed to provide it. Whether the time is used for having coffee with friends, for sleeping, for volunteer community work, for additional study and a better term paper, or in some other way, the student alone will decide about the productive use of this time. And because there is no administrative means to cumulate the time saved or bring the student's increased productivity to bear on the creation of the information systems that enable the increase, there is no way to use the values created for the student in the calculation of how productive it was to spend library resources on creating the Scully Project.

The possibility that students would use the time they gain to prepare better for tests or to write a better paper raises the issue of quality improvements. How are we to think about the possibility that the teaching and learning libraries support with digital information might become not only more efficient and productive, but also just better? What are the measures of better, and how were better educational results actually achieved? Was it, for instance, better to have 1,250 images for study rather than 400? The head Teaching Fellow answered with an unequivocal yes, affirming that she saw richer, more thoughtful comparisons among objects being made in student papers. But some student responses suggested they wanted to have on the Web site only those images they were directly responsible for memorizing--many fewer than 1,250. Do more images create new burdens or new opportunities for learning? Which objectives and what standards should guide decisions about enhancing instructional support? In the absence of some economically viable way to support additional costs, how does one decide on quality enhancements?

Such questions about quality traditionally mark the boundary of productivity studies. Considerations of quality drive us to acknowledge that, for education, we generally do not have the two essential features needed to measure productivity: clear measures of outputs and a well-understood production technology that allows one to convert inputs into outputs.[21] In such an environment, we have generally avoided talking about productivity for fear that doing so would distort goals--as when competency-based evaluation produces students who only take tests well.[22] Moreover, the rhetoric of productivity can undermine socially rather than empirically validated beliefs among students, parents, and the public about how higher education achieves its purposes. All institutions of higher education depend fundamentally on the maintenance of such socially-validated beliefs.

So I end this account of the Scully Project by observing that what we actually did was

marginally not productive, but could readily be made so by extending the amortization period for the Project, or by reducing the number of images provided to students.[23] It also appears that the Project made study much more convenient for students and may well have enhanced their learning. Such quality improvement, even without measurable productivity gain, is one of the fundamental objectives of the library.

These are conditionally positive findings about the economic productivity and educational value of a shift from photographs to digital images to support instruction in the history of art. Such findings should be tested in other courses and, if confirmed, should guide further investment in digital imaging. The soft finding that the use of digital images in the classroom may be productive is heartening, given that digital images may support improvements in the quality of teaching by simplifying the probing of image details and by enabling much more spontaneity in classroom instruction.[24]

All of my arguments about the Scully Project posit that new investment in digital technology would be supported by reduced spending elsewhere. However, doing this would be difficult, forcing us to regard capital and operating budgets--especially the funds that support both "real" and "virtual" space--as fungible. Other possible cost shifts might involve even more fundamental difficulties. It is, for instance, a degree requirement at Yale that graduate students in the History of Art participate in undergraduate instruction. Teaching discussion sections in Professor Scully's course is often the first opportunity graduate students take for meeting this academic requirement. For this reason and others, none of the shifts imagined in the scenarios described above would be easily achieved, and some would challenge us to revisit strongly embedded administrative practices and academic values. Funds rarely flow across such organizational boundaries. Failing to make at least some of these shifts would, however, imperil our ability to improve the quality and productivity of higher education.

PRODUCTIVITY AS AN URGENT CONCERN OF HIGHER EDUCATION

For a long time, higher education has behaved as if compelling opportunities for improving student learning should be pursued without much attention to productivity issues. Our community has focused on desirable results, on the outputs of the productivity formula, without disciplined attention to the inputs part of the equation.[25] One result has been that expenditures per student at public universities in the United States grew between 1979 and 1989 at an average annual rate of 1.82% above inflation. The annual growth rate for private universities was a much higher 3.36%.[26]

It is hard to believe such patterns of cost increase can be sustained much longer or that we can continue simply to increase the price of higher education as the principal means for improving it, and especially for meeting apparently insatiable demands for information technology. We must seriously engage with issues of productivity. Otherwise, there will be little to determine the pace of technology innovation except the squeaky wheel of student or faculty demand or, less commonly, an institutional vision for technology-enhanced education. In neither case is there economically cogent guidance for the right level of investment in information technology. We are left to invest as much as we can, with nothing but socially-validated political and educational ideas about what the phrase "as much as we can" actually means. Because we so rarely close the economic loop between the productivity value we create for users and our investment in technology, the language for decision making almost never reaches beyond that of improving convenience and enhancing quality. I believe it is vitally important for managers of

services must become much more productive.[30] Arguments about the incompatibility of higher productivity and the maintenance of quality care resonate strongly with parallel arguments about the impossibility of making higher education more productive without compromising quality. What makes the health care debate so instructive is that we already know which side will prevail. Everywhere we turn, medical institutions and the practitioners who lead them are scrambling to find ways to survive within a managed care environment. Survival means the preservation of quality care, to be sure, but the ineluctable reality is that quality will now be defined within terms set by managed care. We will find ways to talk about increased productivity and quality as complementary rather than as antithetical ideas.

Given the current state of public opinion about higher education, it is impossible for me to believe that we will not soon follow health care. We will almost certainly find ourselves embroiled in divisive, rancorous debates about higher education reform. I hope we will avail ourselves in these debates of a language about information technology that continues to embrace ideas of convenience but reaches strongly beyond them. We will need to talk meaningfully about productivity and link our ability to create productivity gains with investment in information technology. And I hope we will follow the medical community in working to make productivity and quality regularly cognate rather than always antagonistic ideas.

For the last 150 years or so, libraries have been the guardians in the Western world of socially equitable access to information. That is what it has meant for libraries to become public institutions, instead of institutions serving powerful elites, as they once were. This is a noble heritage and a worthy ongoing mission for our profession. And information technology will play a key role in advancing it. As Richard Lanham argues in a landmark essay, "if our business is general literacy, as some of us think, then electronic instructional systems offer the only hope for the radically leveraged mass instruction the problems of general literacy pose."[31] But unless information technologies are employed productively, they will not offer the leverage on information access and literacy that Lanham and others of us hope for. Indeed, unless those of us who manage libraries and other instruments of scholarly discourse are prepared to embrace the language of productivity, we will find our ability to provide socially equitable access to information weakened as decisions are made about where investments for democratic education will be directed. I look at managed health care and the Western Governors' University and fear that traditional universities and their libraries will lose ground, not because we have failed to embrace information technology, but because we have failed to embrace it productively. I fear that outcome most because it imperils the wonderful accomplishment of libraries and because it could significantly weaken the public good that free libraries have been creating for the last 150 years.

Scott Bennett
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information technology to understand the fundamental economic disconnect in the language of convenience and service we primarily use and to add the language of productivity to our deliberations about investing in information technology.

In connecting productivity gains with technology investment, we may find--as analysis of the Scully Project suggests--that some improvements can be justified while others cannot. Productivity measures should not be the sole guide to investment in information technology. But by insisting on securing productivity gains where we can, we will at least identify appropriate if sometimes only partial sources for funding new investments and thereby lower the rate at which overall costs rise in higher education above those in the rest of the economy.[27]

The stakes for higher education in acting on the productivity problems confronting it are immense. Today, it is regularly asserted that administrative activities are wasteful and should be made more productive. But turning to core academic activities, especially teaching, we feel that no productivity gains can be made without compromising quality. Teaching is rather like playing a string quartet. It required four musicians in Mozart's day, and it still does. To talk about making the performance of a string quartet more productive is to talk patent nonsense. To talk about making classroom teaching more productive seems to many almost as objectionable. The observable result is that higher education has had to live off the productivity gains of other sectors of the economy. The extreme pressure on all of higher education's income sources suggests we are coming to the end of the time when people are willing uncritically to transfer wealth to higher education. Socially validated beliefs about the effectiveness of higher education are in serious jeopardy.[28] If our community continues to stare blindly at these facts, if we refuse to engage seriously with productivity issues on an institutional and community-wide basis, we will bring disaster upon the enterprise of teaching and learning to which we have devoted our professional lives.

If this seems alarmist, consider the work of ten governors in the western United States intent on creating a high-tech, virtual university, the Western Governors' University.[29] Faced with growing populations and burgeoning demand for higher education, but strong taxpayer resistance to meeting that demand through the traditional cost structures of higher education, state officials are determined to create a much more productive regional system of higher education. That productivity is the key issue is evident in the statement of Alvin Meiklejohn, the chairman of the State Senate Education Committee in Colorado. "Many students in Colorado," he said, "are now taking six years to get an A.B. degree. If we could reduce that by just one year . . . it would reduce the cost to the student by one-sixth and also free up some seats in the classrooms for the tidal wave we see coming our way" (*New York Times*, 25 Sept. 1996, p. B9). Senator Meiklejohn is looking for a 17% increase in productivity. I think library and information technology managers know where some of that gain may be found. If however we scoff at the idea of increasing student productivity through the use of information technologies, if we insist that the job of measuring and redirecting the productivity gains we create with information technology is impossible, if we trap ourselves in the language of convenience and fail to engage with issues of productivity, then the consequences--at least in the West--are clear. Major new investment in higher education will be directed not to established institutions but to new organizations that can meet the productivity standards insisted on by Senator Meiklejohn and the taxpayers he represents.

A second and larger ground swell in American life is also instructive on the question of productivity. Health care reform and managed care are both driven by the idea that the high cost and poor delivery of health care must change, that costs must be controlled--that health care

APPENDIX: COST MODEL FOR THE SCULLY PROJECT

The cost model uses the following facts, estimates, and assumptions:

Introduction to the History of Art, 112a
- Course offered once every two years; three times in six years
- Number of students enrolled in Scully course = 500/term
- Number of weeks Scully photos available in study space = 9 weeks per term
- Length of term = 14 weeks
- Number of Teaching Fellows for Scully course = 25
- Approximate value/hour of Teaching Fellow time = $20
- Hourly wage for library student staff = $6.46

Staff costs for selection, maintenance, and display of slide & photo images
- 1 FTE permanent staff devoted to photo collection = $xx,xxx for salary and benefits
- % of permanent library staff effort devoted to Scully course = x%
- Library student staff devoted to photo collection = 40% of $11,500 = $4,600 at $6.46/hr = 712 hrs
- Library student staff devoted to exhibiting Scully photos = 48 hrs/year
- Time spent by Teaching Fellows assembling photo study =3.5hr/wk*14 wks = 49hrs
- Time spent by Teaching Fellows assembling slides for review classes = 56hrs

Cost to prepare digital images for instructional use
- Number of images in Scully Project = 1,250
- Digitization of images (outsourced) = $2,800
- Change in Scully Project Web site content over 6 years = 20%
- Selection and creation of images (by 2 Teaching Fellows) = $6,200
- Web site design = $1,500

Preservation and access costs for slide, photo, and digital images
- Library student staff hours spent on mending & maintenance of photos = 7 hrs/year
- Disk space required for Scully Project = .855 GB
- Disk space required per volume for Project Open Book = .015 GB
- Scully Project images = 57 Open Book vols
- Digital Storage costs = $2.58/year/Open Book vol.
- Digital access costs = $5.67/year/Open Book vol.
- Storage and access cost inflation = -13%/year

Study and other space costs
- Number of items in photo collection = 182,432
- Number of Scully photos mounted in study space = 200 for mid-term; 400 for final
- NSF of photo collection in Street Hall = 1,733
- NSF collection shelving for Scully photos =400/182,432 * (1,733-500)= 2.7
- NSF of photo study space = 2019 + .25*1500=2,394
- % of photo study space devoted to Scully photos per term = 20%
- NSF of photo study space available for Scully photos = 2,394 * .2 * (9/28) = 154
- NSF of photo study space utilized during term = 154 * 75% = 116
- Annual cost of space maintenance = $7 NSF
- Cost of new construction = $300 NSF
- Amortization of capital costs at 8% over 35 yrs = $85.81 per $1,000
- Capital cost of converting existing classroom for digital display = $50,000 depreciated over 6 years
- Maintenance of digital classroom hardware and software = 10% of capital cost/year = $5,000/year
- Availability of digital classroom = 8 class hours*5 days/wk*28wks*.8 efficiency factor = 896 sessions/yr
- Need by Scully grad. assistants for digital classroom sessions = 25*3= 75 sessions/yr = 8.3% of avail. sessions

ENDNOTES

For additional information about the conference, or The Andrew W. Mellon Foundation's scholarly communication initiatives, please contact Richard Ekman. For additional information about ARL or this

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