Appropriate Levels of Access: An Empirical Study on the Availability of Computers in Studio*

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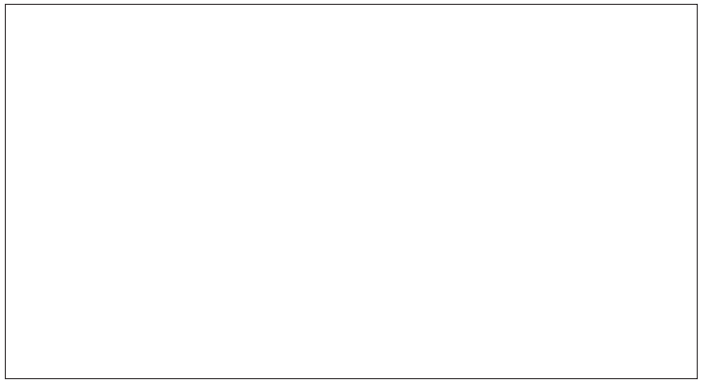
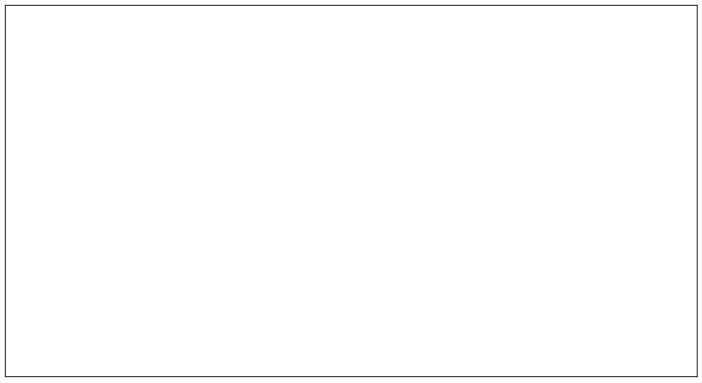
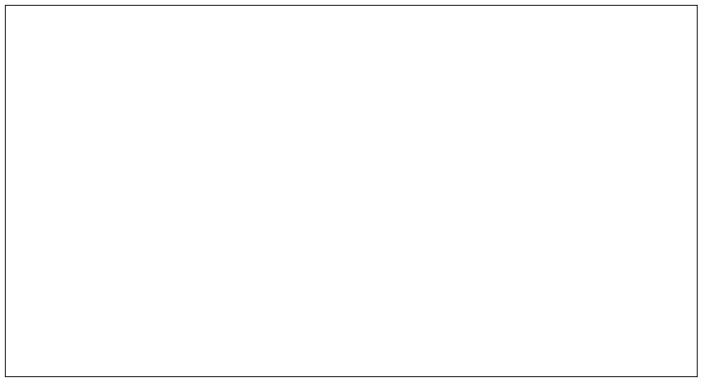
Abstract

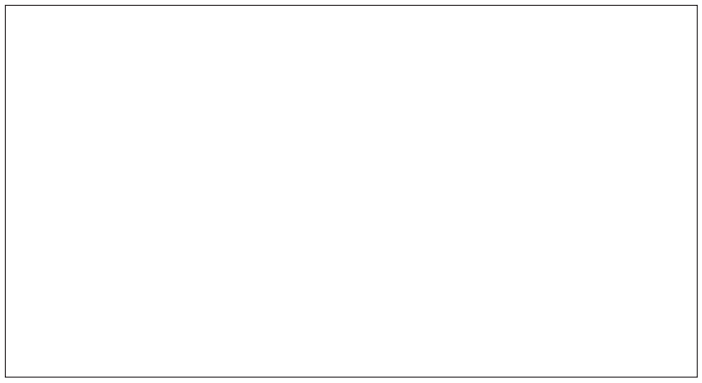
One of the most significant technological challenges facing architecture schools today is how to provide an appropriate level of access to computing resources. As the computer has become a significant tool in the study and practice of architecture, students need to have access to that tool in order to further their studies. But in facing this question of access, what is "appropriate"? Is there such a thing as too much access? Is 1:1 access—a computer for every student—the minimum level of access that schools and students should accept? Or is there a point beyond which more resources just means more waste; computers sitting idle and unused, or students using the computer for unproductive ends? These questions were the subject of an experimental series of studios in the spring of 2002, wherein three studios were given varying numbers of computers for a term. The use of these computers was then tracked, and compared with previous terms. In tandem, the quality of work produced by these three studios was compared. While additional experiments are most likely needed to draw firm conclusions, the results of this experiment seem to support defining "an appropriate level of access" at less than 1:1.

*A Digital *Work In Progress*









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1 Introduction

Over the past decades, the computer has assumed a position of increasing importance in architectural education. What was first considered a novelty with dubious relevance is now seen as an extremely useful, even necessary, tool for learning the theory and practice of architecture. Yet for all its usefulness, schools face considerable hurdles in their attempt to provide this resource to their students. The cost of purchasing and maintaining a reasonable amount of computer resources can be prohibitive. Naturally, schools want to ensure that those resources which they do purchase will be used effectively—rather than either sitting idle or being misused for non-productive ends. This paper describes one attempt to mediate these potentially conflicting desires, and help schools establish appropriate goals for student access to computing resources.

2 Background

Our school is comprised of roughly 500 students in 3 different sections. The architecture section is made up of graduate and undergraduate programs, and has approximately 270 enrolled students. All student activities are housed in one building, although faculty offices and school administration are in a separate location. In the next few years the school will be opening a brand new building that will house all aspects of the school. It has been determined that, as we move through this transition, the method we use to provide digital resources will change. We will move away from our current computer lab model toward a model where computers are integrated into the studio environment. The specifics of this integration and the method of providing computer resources are still under discussion.

Traditionally, computing resources have been provided via dedicated labs of desktop computers. While these labs have grown in number over the past decade, over the past 5 years there have consistently been 5 labs of approximately 100 computers. The resources in these labs are funded by a combination of student technology fees and matching funds provided by the college. The computers in these labs are from 1-3 years old at any given time, with computers distributed among the labs as evenly as possible.

In anticipation of our move into a new building, over the past 4 years we have begun placing desktop computers directly within design studios. These computers once resided in the labs; each computer is initially installed in one of the labs and then moved out to the studios after a year for the rest of the warranty period. The distribution of computers among the studios privileges higher-rank students, because these students tend to be best able to take advantage of them. However, each studio is given a mix of computers of varying ages, so even the sophomore and first-year graduate studios have some younger computers—if fewer of them. The distribution for the 2001/02 school year is listed in Table 1.

Year	Level	Students	Computers	Ratio
Second	UG	84	12	7.00 : 1
Third	UG	75	12	6.25 : 1
Fourth	UG	70	12	5.83 : 1
Three-Plus	G	12	2	6.00 : 1
Fifth	G	24	5	4.80 : 1
Sixth	G	22	8	2.75 : 1

Table 1. 2001/02 Computer distribution

Our philosophy when it comes to information technology has been to inconvenience the students as little as possible. Put into practice, this means that we maintain software licenses to meet the greatest conceivable demand—and when we encounter a shortage, we buy more licenses rather than accept that there will be times when students will have to wait to use a program. We maintain 17 printers and plotters for student use, realizing that at times some of these printers will sit idle. There are times, however, when every printer and plotter on the network is working simultaneously. During those periods of high demand, we do not want students to wait any more than absolutely necessary.

The other side of this philosophy, however, is when we encounter a resource that is barely used at all, or that duplicates one already available. Over the past several years we have faced several of these situations and removed the resource in question. In the case of software packages such as After Effects, or 2D CAD digitizing tablets, they were simply not used to any appreciable extent. On the other hand, we have eliminated Macintosh computers and programs such as Bryce or Minitab because they are duplicated by more popular resources (Form*Z, SYSTAT, and PCs respectively). In these scenarios, the money and time necessary to support these less necessary resources would be better spent addressing areas where students are encountering more serious shortages.

3 The Experiment

In light of the forthcoming building, coupled with the need to maximize student access with limited financial resources, during the 2001/02 school year we explored how student computer use patterns change in response to different levels of access to computers.

We selected 4 studios for participation in this study. All were vertical studios, comprised of students in their 3rd or 4th year of undergraduate education. Three of the studios had 10 students, while the fourth had 12. The details of the 4 studios are given in Table 2. The projects assigned to each studio were similar, although not identical.

3.1 The 1:1 Studio

Studio	Students	Computers	Studio in Separate Room?
1:1 Studio	10	10	Yes
2:1 Studio	12	6	No
Control A	10	5*	No
Control B	10	3	Yes

Table 2. Comparison of 4 experimental studios

The principal studio being studied was designated as the "1:1 Studio," and every student in the studio was provided with a desktop computer. These computers were the same as those provided to the other design studios—ranging from 2-4 years old, with identical operating systems and applications. These computers were arranged in the studio so that each student had two adjacent work desks—one for drafting and modeling, and one for computer use.

The project assigned to this studio was an "Institute for Food Engineering Research." This project was consistent in site and scale with the other studios in this study, although the specific program was different for each studio. While the studio instructor has an interest in digital technologies applied to architectural design, no device or tool was required to be utilized by the students in the production of their work.

The students in the studio completed a site analysis during the first week of the quarter. They then proceeded to design a full-scale cavity wall, accommodating needed water, air, chemicals, and heat/cooling to support a family of genetically modified corn. Digital fabrication tools were introduced at this point as well. Eight of the ten students worked in pairs, with the final two students working alone. Three of the pairs and one individual made use of this equipment, while the other students also used computer models to varying degrees. This phase of the studio concluded in the 4th week, and ended with a midterm review.

The remaining 6 weeks of the term were spent designing the Institute itself, and concluded with a final review. Progress meetings were conducted individually with the instructor, or as small group presentations. Each group determined the manner and media in which it worked independent of instructor feedback. One group and one individual student produced digital work almost entirely, while another group and two individuals split their work evenly between digital and manual production. The final group and one individual tended to eschew the computer in favor of manual production.

3.2 The 2:1 Studio

Another studio was designated as the "2:1 Studio," and the studio was given a computer for every two students. These computers were also identical to those given to all other studios. The computers were arranged in pairs, and distributed as evenly as possible in the studio in an attempt to provide all students equal access—but we did not specifically assign any computers to any students.

3.3 The Control Studios

The final two studios were designated as control studios, and were given computers using the same principles as every other studio in the school. The computers in these studios were placed in a single location within each studio, and no computers were specifically assigned to any students.

In this study we attempted to vary only the level of access that the students in each studio had. Students were also able to use any of the computers in the labs, and like all students in the school they were discouraged from using the machines assigned to any other studio.

3.4 Our Hypotheses

In conducting this experiment, we hoped to test the validity of two hypotheses. The first was that while use levels between the differing studios were expected to vary according to each studio's level of access to computers, those differences were not expected to be significant enough to justify the expense of providing 1:1 computing throughout the school. This hypothesis would be evaluated quantitatively, by using the use logs generated by a utility already in use in the school. The second hypothesis was that increased access to computers should result in a higher quality of work, because the tool would be readily available at all times—allowing the student to be simultaneously working on the computer as well as on a physical model or hand drawings. The second hypothesis would be evaluated qualitatively by the studio instructor in light of her experience leading previous studios.

It was necessary to test both of these hypotheses together because any attempt to verify either hypothesis alone could yield a misleading conclusion. Computer use is not an end in itself, so it is not enough to only induce students to use computers more often; the use must positively impact the process of studying architecture. On the other hand, increased computer use is certainly the goal of providing more computers; so there does need to be some form of quantitative element to verify that use is actually increasing.

3.5 Methods of Evaluation

In order to evaluate the first hypothesis, we utilized the computer use logs generated by Sassafras Software's KeyServer. This program is used by the school to ensure that the number of copies of a program running at any given point does not exceed the number of licenses which have been purchased. In performing this task, KeyServer logs who is using what software

packages, during what times, and on what computers. By analyzing these logs we would be able to determine how much use each studio was generating, and thus test the validity of our hypothesis. More information about KeyServer, including a list of programs under its control, can be found in the Appendix.
We used these logs to construct two general comparisons. The first comparison is between the 4 studios in this experiment, specifically during the quarter of the study. The second comparison focuses on the 1:1 Studio and one of the Control studios, and compares their use between the quarter of the study and the 5 previous quarters. For both comparisons, we look at the same set of 3 variables:

1) The average time that the students in the studio used a computer.
2) The average time that the students used 4 specific software packages.
3) The average session length as the students used those 4 specific software packages.

Similar qualitative comparisons were made by the 1:1 Studio instructor, based on her experience of leading design studios for several years.

4 The Results

Before discussing the results of this study, it is important to describe some complicating factors which arose during the course of the quarter. The first and most significant is the theft of 3 computers from the 2:1 Studio approximately halfway through the term. The stolen computers were replaced, but not until after several days had passed. The loss of half of the computers dedicated to this studio, even for several days, potentially changed the students' use habits significantly enough that any conclusions drawn from the 2:1 Studio data set must be viewed skeptically. It is for this reason that this paper talks primarily about the experience of the 1:1 Studio.

The second complicating factor stems from the physical layout of some of the studios in this study. While the 1:1 Studio and one Control Studio were taught in their own room, the 2:1 Studio, the other Control Studio, and 2 unrelated studios were all taught in one large room. The layout of this room for the term had two banks of computers—the computers given specifically to the 2:1 Studio, and a separate bank of 5 computers that were provided for the 3 other studios in the room—one of which had been designated as a Control Studio. Perhaps because of the aforementioned thefts, and also because of the ambiguous "ownership" relationship in that room to begin with, the students of the 2:1 Studio used all 11 computers in the room to fairly significant extents—while the students of the other 3 studios used only the 5 computers provided to them. It is for this reason that the results of the Control Studios are broken down into Control A and Control B. Control B is the studio that had the dedicated room with no outside competition for computers, while Control A faced such outside competition regularly. It is our position that this competition does not invalidate the results of the Control A studio, but that it is something to take into account when considering the results of this study.

With those caveats having been addressed, here are the results of the two different comparisons described above.

4.1 Latitudinal Comparison

This comparison looks at the differences in use between the 4 studios in this study for the quarter during which the experiment took place. The results of this comparison are displayed in Table 3.

Studio	General Use (days)	Core Use (days)	Average Duration (hours)
1:1 Studio	60.46	58.12	12.31
2:1 Studio	8.75	6.20	1.58
Control Average	5.15	4.54	1.76
Control A	(4.09)	(3.65)	(1.14)
Control B	(6.22)	(5.44)	(2.39)

Table 3. Latitudinal comparison results

The average student in the 1:1 Studio used a computer for just over 60 days and 11 hours during this quarter. That figure represents a 1,074% increase over the average student in one of the Control Studios, who used the computers for about 5 days and 3 and a half hours. This is also 591% more than the average student in the 2:1 Studio. The students of the 2:1 Studio, meanwhile, used computers 70% more than the students in the Control Studio. These relationships are illustrated in Figure 1.

Of the more than 30 software packages that students could use during this quarter, 4 programs accounted for 72% of the software used. Those four packages were Adobe Photoshop, Autodesk AutoCAD, Auto*des*sys Form*Z, and Macromedia FreeHand. This is in line with previous quarters, as these packages have accounted for 70-90% of software use for the past 2 years. These programs tend to be used more because the students are actively instructed in their use via a series of classes in the sophomore year. Other programs, such as Creative Labs Poser or Macromedia Dreamweaver, are taught only sporadically, or spread through word of mouth among the student body. In order to control for this haphazard method of instruction, we next compared the amount of use for only these 4 programs. Those results are illustrated in Figure 2, and fairly closely resemble the findings in Figure 1.

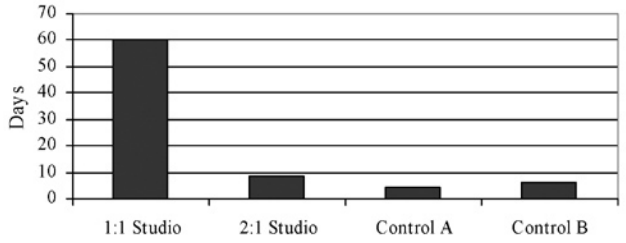

Figure 1. Average computer use per student

The students of the 1:1 Studio used the 4 core programs 1,179% more than the two Control Studios, and 837% more than the

students of the 2:1 Studio. Comparing the first two variables, it seems that the students of the 1:1 Studio emphasized the 4 core programs more heavily—spending 96% of their computing time in one of those 4 applications. By contrast, the 2:1 Studio generated 71% of their use in the core programs, while the Control Studios spent 89% of their time using the core programs.

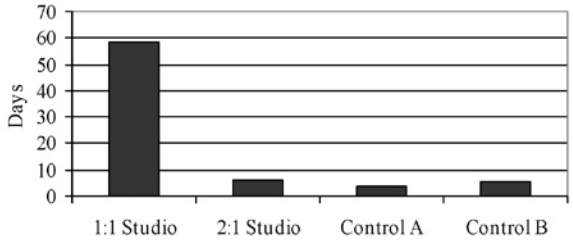

Figure 2. Average core software use per student

With this drastic difference in use one must ask whether the students of the 1:1 Studio were doing anything else differently, beyond just using computers more frequently. One answer can be found by examining the average length of time that each application was open. The average session duration is the final component of the latitudinal comparison, and is the subject of Figure 3.

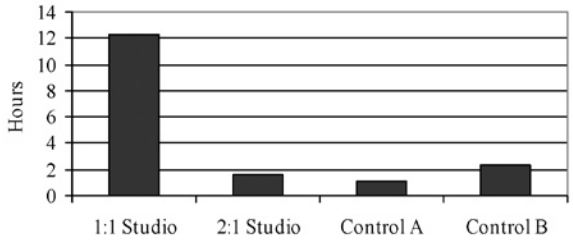

Figure 3. Average session duration

The average application session for the 1:1 Studio lasted almost 12 hours and 20 minutes— 599% longer than those for the Control Studios, which were just over 1 hour and 45 minutes long. They were also 679% longer than the average session length for the 2:1 Studio—which lasted about an hour and 35 minutes.

Looking at these results, it is highly doubtful that any group of students would be productive for an average of 12 hours at a time over the course of a quarter. The 12:20 average session duration leads us to suspect that the students of the 1:1 Studio were in the habit of leaving their computers running even when they were not working. This possibility is problematic; it suggests that for some portion of the quarter even though the computers were in use, they were not actively being used. The longer that an application session lasts, the greater the likelihood that it includes a portion of idle use. A session that lasts 2 hours is more likely to be entirely productive, while a session that lasts 24 hours probably contains a large amount of inactive time.

To explore this situation in more detail, we have regenerated the chart from Figure 1, focusing on sessions of specific lengths. Figure 4 shows these results. There are four series of data in this figure. The first includes all sessions and is identical to Figure 1. The second includes only those application sessions that were shorter than 24 hours in length. The third includes only those sessions under 16 hours in length. The last includes only those sessions under 8 hours in length.

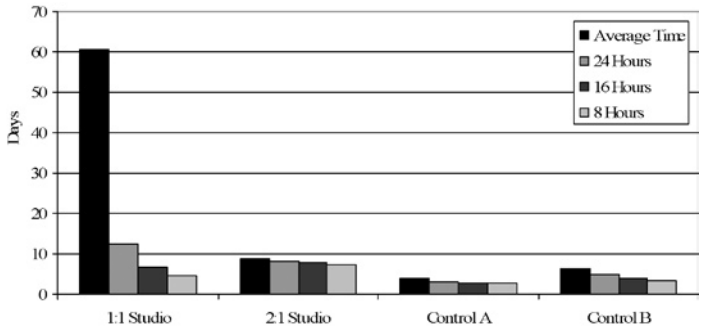

Figure 4. Average computer use per student, focusing on sessions of varying lengths

When sessions of extraordinary length are excluded from the sample, the use levels for the 1:1 Studio are reduced to a range similar to those produced by the other 3 studios. For sessions under 24 hours in length, the 1:1 Studio used computers 215% more than the control studios, and 50% more than the 2:1 Studio. When the data are restricted to sessions under 16 hours in length, the 1:1 Studio used computers 97% more than the control studios, and 16% less than the 2:1 Studio. Overall, 79% of the computer use observed from the 1:1 Studio came in sessions that lasted longer than 24 hours. This is in contrast to 5% of use by the 2:1 Studio and 23% for the Control Studios. It is risky to proceed too far down this path, however. While it is true that the great majority of use generated by the 1:1 Studio was from sessions over 24 hours in length, it is inaccurate to assume that none of that time was actually spent productively. It may be outside the capabilities of this analysis technique to accurately determine how much use was productive in nature as opposed to time the computers spent idly running the software. This is an area that should be investigated further, perhaps with a different set of monitoring tools.

In conclusion, the latitudinal comparison of these four studios indicates that our first hypothesis is accurate, to some extent. Students with greater access to computers will tend to use those computers more often. Conversely, our hypothesis was less accurate with regards to the extent to which those use levels increased. When students were given their own computers, they used those computers 1,000% more. By contrast, when students were given 2:1 access to the computers, they used those computers 70% more. While there are indications in the data that much of this increase is due to idle use, more analysis is necessary to evaluate that possibility.

4.2 Longitudinal Comparison

One possibility that must be examined is whether the students of the 1:1 Studio were predisposed to use computers more or less frequently than the average students. Such a condition would distort the results of this study, making evaluation of the first hypothesis more difficult. We have attempted to control for this effect in two ways. First, the students were not informed of the differing levels of computer access among the 4 studios before they signed up for their chosen studio. This prevented students from self-selecting into any particular study group. Second, we have conducted a time-based comparison—comparing how the students in the 1:1 Studio used computers in this quarter to how those same students had used computers in the previous 2 years. This longitudinal comparison looks at the same 3 variables as the first comparison. For the sake of contextualizing these results, we have also conducted this comparison for the students in the Control B studio. The results of these comparisons are displayed in Tables 4 and 5.

Quarter	General Use (days)	Core Use (days)	Average Duration (hours)
Spring 2002	60.46	58.12	12.31
Winter 2002	3.10	2.88	1.48
Autumn 2001	No reliable data available		
Spring 2001	4.34	3.97	0.80
Winter 2001	2.41	2.39	0.67
Autumn 2000	0.21	0.19	0.36

Table 4. Longitudinal comparison results for the 1:1 Studio

Quarter	General Use (days)	Core Use (days)	Average Duration (hours)
Spring 2002	7.37	5.44	2.39
Winter 2002	3.54	2.80	1.41
Autumn 2001	No reliable data available		
Spring 2001	5.76	5.40	0.93
Winter 2001	2.27	2.20	0.71
Autumn 2000	0.22	0.19	0.45

Table 5. Longitudinal comparison results for the Control B Studio

One difficulty that we had in completing this comparison is the fact that we have no reliable data for the autumn quarter of the 2001/2002 school year. During that quarter, it was discovered that a configuration error was preventing KeyServer from completely recording all network activity due to software on the computers being incorrectly configured. As a result of this error, much of the network was not reporting any use data whatsoever. The problem was fixed shortly after it was discovered, but the result is that there are no reliable data for the first half of the quarter. Rather than attempt to extrapolate from the data for the second half of the quarter, we have elected to omit this quarter's data entirely.

It should be noted that although this problem did occur, there is no reason to believe that the KeyServer system was incorrectly configured for any other quarter. We can say this with surety because the type of configuration problem observed in the autumn quarter will completely eliminate any use data being submitted for a specific computer and application. For the other 5 quarters examined in this study, no such far-reaching lack of data is evident. All programs submit at least some data from each computer at least once in the quarter, indicating that any lack of reported use stems from an actual lack of use, rather than the actual use not being reported.

The first variable in the comparison is the total amount of time that the average student in each studio used the computers. This relationship is expressed in Figure 5 for both the 1:1 Studio as well as the Control B Studio.

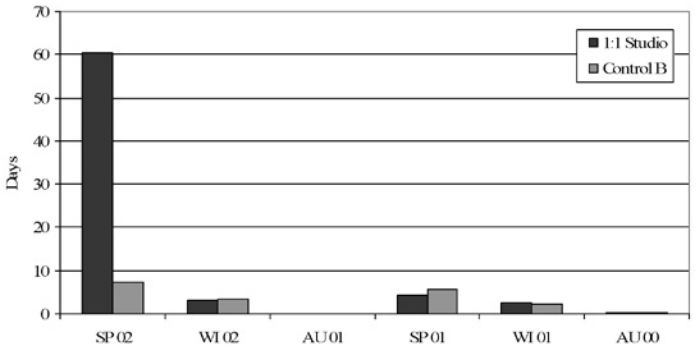

Figure 5. Average computer use per student, over 6 quarters

Before the beginning of this study, the students of the 1:1 Studio used computers roughly as much as the students of the Control B Studio. This similarity ended for the quarter of our study, as the use levels for the students of the 1:1 Studio increased by 1,852% over the previous quarter, and 1,294% over the previous spring quarter. The students of the Control B Studio, meanwhile, used computers 109% more than the previous quarter, and 28% more than the same quarter the previous year. Because of this, it seems that the increase in use is directly related to the level of access provided to the students, rather than any previously existing patterns of computer use.

The second step of this comparison is to focus only on the 4 core programs of the school. In addition to controlling for disorganized methods of software instruction, this step also controls for the changes in supported software that existed between the 2000/01 school year and the 2001/02 school year. This variable is expressed in Figure 6.

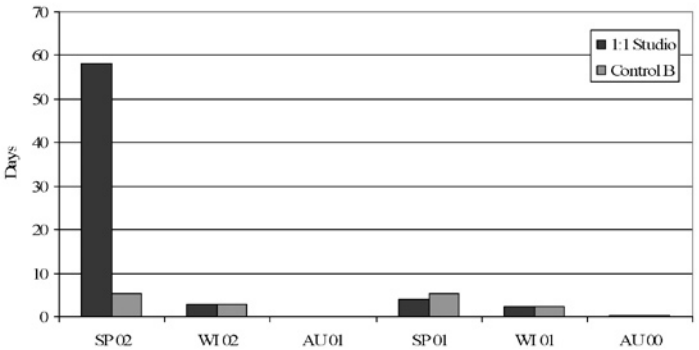

Figure 6. Average core software use per student, over 6 quarters

These results mirror those presented by the first variable in this comparison, which is that before this study the students in the 1:1 Studio did not use computers significantly more than their counterparts in the Control B studio. It is only when they were provided a dedicated computer that their patterns of use changed, even among the 4 core programs.

The final step in this comparison, then, is to examine how

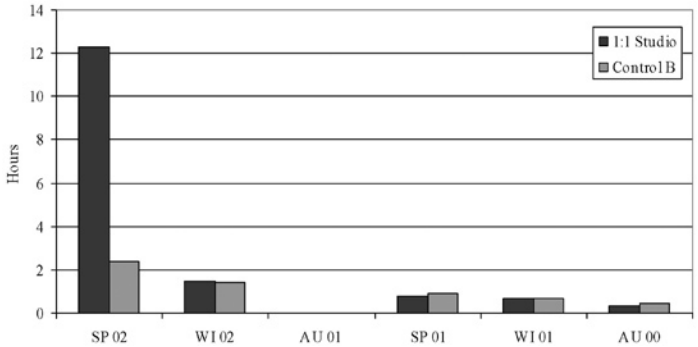

Figure 7. Average session duration, over 6 quarters

application session lengths changed over the past 6 quarters. This variable seems to confirm the same results that were previously hinted at—that the use patterns of the students of the 1:1 Studio were not initially different than the students in the other studios. In the quarters leading up to this study, the students of the 1:1 Studio and the Control B Studio tended to use the 4 core programs for approximately the same length of time per session—differing at most by 18%. Those session times increased drastically, however, when the 1:1 Studio was given greater access to computers. Session lengths for the 1:1 Studio were 317% longer than those for the Control B Studio, 737% longer than the quarter preceding this study, and 1,477% longer than the same quarter a year ago.

This comparison indicates that, before this study began, there were no significant differences between the use habits of the 1:1 Studio and the other studios. It is then reasonable to conclude that the differences observed during this study were caused by the differing levels of access between the studios, rather than any pre-existing differences in work habits.

4.3 Qualitative Comparison

Turning our attention to the second hypothesis, that increased access to computers should result in a higher quality of work, it is our observation that while the data indicates significant utilization of design software within the 1:1 Studio, there was incongruency between this use data and the observed data which warrants speculation. According to the instructor of the 1:1 Studio, the quantity of work (i.e. the number of drawings, images, etc.) actually presented during an average studio day was similar to that of other studios taught by the same instructor. This suggests that the increase in use resulted from activity other than the productive development of the project at hand. This could include the production of work the student deemed unsuccessful or inappropriate for presentation, or time spent grappling with software functionality. This brings to question whether or not students have the techniques and skills needed to effectively use the computer as a tool for architectural development. The quality of the work that was presented and level of architectural investigation was also not markedly different than other studios, as the grade spread for this quarter directly matched that of other studios taught by the same instructor (A- through B-).
It is also significant that even with individual “ownership” of a computer in the design studio, 8 of 10 projects heavily utilized hand production methods. This suggests that only in very rare circumstances would every computer within the studio be active. Thus, a 1:1 computer-to-student ratio would not be warranted.

5 The Conclusions

This study was undertaken to test two hypotheses. The first was that students with greater access to computers tend to use computers more heavily, but not heavily enough to justify providing a computer for every student. The second hypothesis was that increased access to computers should result in a higher quality of work. We believe that although a first reading of the results indicates that both hypotheses have been disproved, there are details in the results which strongly indicate otherwise.

After observing the use patterns of one studio of students who were each given a computer to use exclusively, it was initially observed that the students used the computers far more often than they had in the past, and far more often than other students in similar studios. However, there is reason to doubt these initial observations, as a large majority of the observed use came in continuous blocks that lasted for longer than 24 hours. This indicates that what appears as use was actually computers sitting idle, running software with no one at the keyboard.
When those extraordinarily long sessions are filtered out, use patterns fall back to levels comparable to the other studios of this experiment. If this alternate reading is valid, it would verify our first hypothesis—that levels of use do not increase significantly enough to justify the expense of providing 1:1 access.
If we accept the observed levels of use at face value, the second hypothesis was also refuted—despite such a drastic increase in use, the quality of work produced by the students did not increase. If we instead accept the alternate reading, that productive use did not increase significantly, it is difficult to evaluate this hypothesis at all as it was predicated on an increase of computer use.

It is our position that the alternative reading is correct, that productive use did not increase significantly enough to justify the effort of providing 1:1 computing, and that the second hypothesis cannot be fully evaluated. Although we believe that the results of this experiment are significant and valid, more study of this issue is clearly warranted. Repeating this experiment, perhaps

with changes to the technologies used to monitor computer use, will help indicate whether our alternate reading of the data is valid. Further study can also help explore issues that were not considered in this experiment, such as whether students use laptops differently than they use desktops, or how a studio might be structured to help students take advantage of the resources available to them. Continuing to explore these issues will become more important as schools continue to face the problem of allocating limited resources to providing appropriate levels of access to computers.

Appendix

Sassafras Software's KeyServer monitors only those programs which are placed under its control. Because of this, we do not monitor programs like Minesweeper, Internet Explorer, or any email programs. This setup keeps our records free of activity such as web browsing, email, or game playing.
Another aspect of how KeyServer works is that all use times are calculated based on *program* use, not *computer* use. If a student has two programs open simultaneously for an hour each, it shows up in the logs as 2 hours of use. Time that a student is logged in, but not using any controlled programs is not counted at all.

Software that was controlled during the spring 2002 quarter is listed below:

- Adaptec EasyCD Creator
- Adobe InDesign
- Adobe Photoshop
- Adobe Premiere
- Alias|Wavefront Maya
- Architectural Graphics Standards
- ArcInfo
- ArcView GIS
- Autodesk AutoCAD
- Auto*des*sys Form*Z
- Bentley MicroStation
- Curious Labs Poser
- Energy Scheming
- Extensis Portfolio
- GAMS
- GTK Build
- GTK Radiant
- IDRISI
- Limdep
- Macromedia Dreamweaver
- Macromedia Fireworks
- Macromedia Flash
- Macromedia Freehand
- MS Access
- MS Excel
- MS PowerPoint
- MS Word
- PCSWMM
- QTVR Authoring Studio
- Quake III Arena
- Rhinoceros
- SAS
- Stella
- SYSTAT