Computing Labs Study
University of Colorado Boulder
Office of Information Technology
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Executive Summary
We propose to convert central computing labs into flexible-use spaces by the fall of 2012; and deliver lab software to students, faculty and staff over the campus network. Former central lab spaces will be outfitted with flexible furniture, sufficient power outlets, and enhanced printing solutions so that a variety of learning activities can happen there. By adding software site licenses, using software virtualization, and relying on students using personal laptops; we will meet the teaching and learning needs of more students for roughly the same cost.

Overview
In 2010 CU-Boulder had 54 student-funded computing labs with 1,466 computers. 33,321 students and faculty members used them and logged into them over 1.2 million times. In spite of this amount of use, the Office of Information Technology (OIT) has received requests from various campus administrators to repurpose lab spaces, and to find ways to deliver lab services at lower costs. These pressures led us to conduct a study of computing labs on the CU-Boulder and other campuses, and to make the following recommendations.

Recommendations
• We recommend increasing reliance on student-owned portable computers by providing licensed and virtual delivery of common lab software to student- and campus-owned computers.

• We recommend repurposing some central computing labs into flexible-use spaces with the furniture, sufficient power outlets, and printing solutions needed to entice students to bring their laptops to campus.

Rationale
Repurposing central and departmental labs will free up space for departments, reduce administrative and infrastructure costs, and at the same time enhance technology-assisted teaching and learning on campus. Key components of our recommendations reflect what we have learned in this study:
• At least 97% of CU-Boulder students own laptops and other mobile computing devices.
• Students want more flexible learning spaces that allow their mobile devices to be more functional while they are on campus.
• Some faculty are teaching in computer labs because of the rich technological environment provided by labs, not because they are teaching a specific software title that is provided in the lab.
• Peer institutions are transforming their labs into flexible-use spaces to allow for more active and interactive learning than is possible in traditional labs.
• New virtualization technologies and robust networks make it possible to create and sustain virtual computer labs and deliver software to student-owned devices.
We believe we can entice students to bring their mobile computers to campus because they will be able to access common lab software titles over our network from anywhere on campus (instead of in fixed labs). If they access this software in former lab spaces, they will enjoy flexible furniture arrangements, sufficient power and outlets, and printing to accommodate their individual and collaborative work. With these proposed changes any classroom can become a potential instructional computing lab.

Our recommendations can be funded by targeted cost reductions in our current lab environment, including:

- Reducing the number of computers devoted to physical labs.
- Improving staffing efficiencies.
- Increasing the lifecycle of hardware in labs.
- Reducing the number of currently deployed computers in Norlin Commons, while providing new capabilities to support student-owned devices.

**Introduction**

Computing labs have become an expected feature of the University of Colorado Boulder campus and of higher education institutions across the country. However, over the past decade, our university has been asked to do more with fewer financial resources in roughly the same space, even while enrollment has steadily risen.

At the same time, student ownership of personal laptops has steadily increased. In a 2010 survey of CU-Boulder students with 782 responses, just under 97% said they owned a laptop computer. This is corroborated by anecdotal evidence from Bug Buster walk-in consultations and student orientation sessions, and by CU Bookstore computer sales.

This has led administrators to ask whether computing labs are necessary in their current form. Some speculate that lab spaces could be changed or repurposed to accommodate budget and space pressures. Some also wonder if students should simply bring laptops with them to campus to use in classes and for other academic work. As a result, this study examines **how we can improve the quality of our computer-enhanced teaching and learning while addressing the financial and space issues associated with computing labs.**

This study consists of a review of literature on how other universities are providing and supporting computing spaces. It contains results of three surveys: one of peer institutions, one of CU-Boulder students, and one of the faculty. It contains a history of labs at CU, an inventory of computing labs, an analysis of the data produced from these methods, and a suggested direction for the campus.

**Current Environment**

Faculty at CU-Boulder use computer labs in two primary ways: one is to **enhance their teaching by integrating the use of computers** into their class time; and the other is to
teach computational skills, writing, or design skills through specialized software that is available in the lab.

Overview of Computing Labs at CU Boulder

Our current generation of computing labs at CU-Boulder began in 1983. Over time, the campus greatly increased the number of labs, including large facilities in Norlin Libraries and in the Engineering complex. Amidst this effort, little funding was available to OIT to create centrally-supported labs. To address the need for funding, the campus instituted a student-computing fee in the early 1990s. The initial $15 per-semester fee generated $650,000 annually. This amount has increased to a $135 annual fee, which generates approximately $4 million, with the funds managed by OIT. See Appendix 1 to see how student fee funds are currently allocated.

In the early 1990s, these funds supported general computing resources (such as the campus modem pool and central computing labs), departmental labs—many of which were managed by OIT—and ad hoc proposals for departmentally-managed spaces. Over time, to ensure long-term availability of all student-fee-funded spaces, the ad-hoc requests were no longer honored. Instead, half of the student fees were dedicated to general information technology services for students (networking, email, printing, and associated staffing), and half (labeled ICWG, or Instructional Computing Working Group funds) supported labs that were open to all students and managed by OIT.

Because computing labs were increasingly requested for instructional use, the ICWG advisory board began allowing these uses, provided that a certain number of open hours were maintained for general student use. Projectors and other classroom technologies have been added to many labs to facilitate instruction.

OIT manages two virtual UNIX/LINUX labs, and has managed four physical UNIX labs since the late 1980s. Since 1996, OIT has provided SCARPIE (Stationary Computing Apple Resource for Personal Internet and Email) computer stations, which now number 120 around the campus. They continue to be popular and are requested in most new and renovated buildings. OIT currently contracts with departments to provide lab management for seven departmental computing labs. Most recently, OIT has begun collaborating with the Libraries and other units to create commons computing spaces that feature more flexible lab arrangements with comfortable, movable furniture, laptops, and large LCD screens.

A Snapshot of the Current Computing Lab Environment

The annual computing fee of $135 per student supports 54 labs with 1,466 machines. Unique logins in 2010 totaled 33,321, and total logins totaled over 1.2 million. The most commonly used applications on lab computers are web browsers (I.E., Firefox, Safari, etc.), Microsoft Office, Mathematica and Matlab.

We have several kinds of computing lab environments at CU-Boulder.

• Instructional labs — computers in rooms with projectors and audiovisual support that are able to be reserved for teaching.
• Open labs — computers in rooms set up primarily for drop-in use by students. CU-Boulder has few open-only labs. Those comprise one lab in the University Memorial Center (UMC) and two in the Engineering Center.

• Commons areas — flexible, comfortable furniture arranged in configurations to allow for individual and collaborative work. Checkout items such as laptops are occasionally offered in these environments.

• UNIX Virtual labs — servers that can be accessed from any computer to run common applications, such as MatLab.

• Departmental labs — similar to instructional labs, but closed to the general public, with computers and software applications that are commonly used by students of the department for design, computation, and writing.

The numbers of computers in instructional labs, open labs, and commons areas are listed by platform in Table 1.

<table>
<thead>
<tr>
<th>Platform</th>
<th>Number of Labs</th>
<th>Number of Seats</th>
</tr>
</thead>
<tbody>
<tr>
<td>Macintosh</td>
<td>20</td>
<td>509</td>
</tr>
<tr>
<td>Windows</td>
<td>29</td>
<td>750</td>
</tr>
<tr>
<td>Dual Boot</td>
<td>4</td>
<td>195</td>
</tr>
<tr>
<td>Linux</td>
<td>1</td>
<td>12</td>
</tr>
</tbody>
</table>

Table 1: Lab, Computer, and Seat Breakdown

What do faculty members say about our current computing lab environment?
In the fall of 2010, CU-Boulder faculty were surveyed and asked about their uses of computing labs. This survey was announced in a Faculty/Staff Buff Bulletin as well as through email messages to faculty members who reserved computer labs in 2010. We received 49 responses to the survey. Respondents reported teaching on average one course per semester in computer labs. They described two general ways they used labs for instruction: either as a supplement or enhancement to their teaching; or as a way to teach students computational, writing, or design skills through specialized software during class time. Those faculty members who raised issues about the labs sought improvements in the processes used to request software, in the size of labs, and in the equipment installed in the labs. Further details about the faculty survey results can be seen in Appendix 2.

What do students say about the current computing lab environment?
A student survey was conducted in the fall of 2010. Students were asked about their computer habits and preferences, as well as how they used computing labs and informal computing spaces on campus. The survey was announced in two successive Buff Bulletin messages, which covered the two-week period the survey was available. Students were also invited to participate by clicking on a shortcut in the Macintosh computer desktops in Norlin Commons, UMC 138, and ECCR 225. In total, 782 surveys were completed.

Most students reported having difficulty finding suitable space on campus to use their personal computers. About half of the students said they used computer labs fewer than once per week. Half said they use university-provided open computing spaces (Norlin
Commons, UMC, and ECCR labs). When students used on-campus spaces for computing, they reported valuing ample quiet space, abundant electrical outlets, printing capacity, and wireless networking. They desired all this in facilities that are available in the evenings and even 24 hours per day. Further details about the student survey results can be seen in Appendix 2.

The Future of Lab Spaces

Literature Review

The term learning space is a buzzword in educational literature, and represents the rich intersection of teaching, learning, space, and technology (Oblinger, 2006). Learning spaces are a particularly pertinent topic on university and college campuses as faculty, staff and administrators explore how to best integrate learning with daily campus life and serve a variety of students. These explorations are reflected in the literature on learning spaces, which includes case studies, assessment reports, project overviews, lessons learned, and theoretical discussion about the concept of “space” in learning. A majority of the literature focuses on learning space design practice relating to libraries (Beard & Dale, 2010; Cohen, 2009; Crook, 2005; Fox & Stuart, 2009; Haug, 2008) and classrooms specifically (Hammons & Oswald, 2009; Long, 2005; Tom, Voss, & Scheetz, 2008; Whiteshead, et al, 2009) and to a lesser degree computing and learning labs (Burgstahler, n.d.; van den Blink, 2009). The following literature review highlights the primary themes of this work and identifies overarching trends and principles concerning learning space design. Active learning is mentioned in nearly all the literature addressing learning spaces and is referenced as a goal in learning space design.

A series of shifts in approaches to learning space design is identified in this literature. One societal shift is from the information age to the interaction age. This is a shift away from networks solely transporting data to networks facilitating interaction, and a movement away from individual users to group users (Milne, 2007). Another shift is from learning as a more passive and stationary activity to learning as active and interactive. Another shift is a movement from thinking of learning spaces to thinking of learning environments (Warger and Dobbin, 2009).

Space design in universities seems to be focused on “... connect[ing] students to knowledge-making activities and to one another” (Long & Holeton, 2009). It also focuses on considering the learning activities to be conducted in a space and how they may be supported and promoted (Nixon; Bennett, 2006). And finally, it seems to be focused on carefully assessing and articulating the vision of a learning environment, and not assuming that a space design will result in certain learning behaviors (Bennett, 2006).

Flexibility in adopting evolving technologies, catering to a wide variety of uses, and encouraging creativity and dynamism in user interaction with the space is important when designing learning spaces (Grummon, 2009: Hammons & Oswald, 2009; Kennedy, 2008; Tom, Voss, & Scheetz, 2008; van den Blink, 2009). Reconfigurable furniture ensures multiple uses for a space and empowers students and faculty in facilitating their learning.
Flexibility is evident in learning environments that include a spectrum of seating and technological options from which users may select. A sufficient supply of power outlets, accessible Wi-Fi, and a variety of work stations for multiple purposes including “on-the-go” stations for quick printing and emailing, individual longer-term stations with privacy, and larger tables with a number of chairs and computer monitors for group work allows users to seek out and use a space in a number of ways. (Tom, Voss, & Scheetz). See Appendix 3 for the complete literature review and list of references.

Peer investigation
An investigation of peer institutions’ web sites was conducted as a part of this study to learn more about their computer labs and learning environments. We examined web sites of the Universities of Utah, Virginia, and Michigan; Stanford, Yale, Pennsylvania State University, North Carolina State University, and Duke University. This evaluation found that computer labs are widely available in peer campuses such as the University of Utah, Stanford, Yale, Pennsylvania State University, the University of Michigan, and Duke. Departmental labs are less common at our peers’ campuses, but they are still prominent at the University of Utah, Stanford, Yale, Pennsylvania State University, and the University of Michigan. Commons environments were found at the University of Utah, Stanford, and Pennsylvania State University.

Several peer institutions report using virtual labs, which are being piloted at the University of Utah, the University of Virginia, and Duke. They are in production at the Pennsylvania State University’s Erie campus, North Carolina State University, the University of North Carolina at Chapel Hill, and the University of Michigan. Please see Appendix 4 for a full report of our investigation of peers’ web sites.

In addition to our investigation of web sites, we also sent a survey to eighteen members of the Association of American Universities Data Exchange (AAUDE). We received seven completed surveys. Most respondents said that in the past five years, their computing facilities have largely stayed the same, However, they appear to be anticipating a shift from university-supplied computers to student-supplied computers. In response, they appear to be investigating changing facilities, amenities, and technological infrastructure to accommodate students with personal laptops as the primary mode for computing on campus. They reported investigating software virtualization, streaming, and checkout, as well as the use of thin clients (computers that rely on a server or other computer to do most of the data processing for them) and virtual desktop infrastructure. Please see Appendix 2 for a full analysis of the peer survey.

What do faculty members say about the future of lab environments?
Faculty members we surveyed said they would use the computer labs more often if we could make it easier to schedule them, if they were more widely available, and if the process for requesting software was easier and timed better. Others pointed to a desire for better or more stable equipment in the labs. 58% of the faculty members surveyed said they would like to see OIT maintaining or increasing the current number of labs without requiring students to supply laptops. 40% would like to see the current number of (instructional) labs increased over the next five years.
What do students say about the future of lab environments?
Students said the aspects of lab environments that were most important to them were quiet spaces, comfortable furniture, sufficient power outlets and wireless connectivity, available printing, and access in the evenings and even twenty-four hours per day. For a full analysis of survey responses, please see Appendix 2.

CU-Boulder labs: already evolving
A significant aspect of CU-Boulder labs management includes piloting new solutions that meet the needs of faculty and students. Several possible future solutions are already being tested or are in production in labs on campus.

Common Engineering loadset
There is now a single loadset in use across all the Engineering labs, which helps meet demand for the high-end CAD software that used to be available in only one lab in Engineering.

Application streaming
Using Microsoft App-V, labs staff have been able to sequence some applications for streaming. This provides applications that were previously only deployed in specific departmental labs to all open and instructional labs. For example, labs staff are deploying the application Stata not just to the departmental labs where it is taught, but also to labs in Norlin and Engineering, allowing students to use the application outside of class time. Our recommendations call for an increase in such application streaming.

VDI (Virtual Desktop Infrastructure) proof-of-concept and prep for implementation
In 2010, CU-Boulder worked through a Proof of Concept (POC) with Dell to provide a VDI solution for some labs. While the results were promising, the POC indicated that networking issues needed to be resolved before a full deployment could be undertaken. Testing indicated that VDI worked well in an isolated network environment (server and clients on the same switch not connected to campus network). When the infrastructure was placed in the Computing Center with clients on main campus subnet, significant performance degradation occurred. The performance issues were significant enough to limit the value of VDI as a potential solution at this time. Should these networking issues be resolved a VDI solution would be appropriate for computing labs where Microsoft Office and web browsing were the main activities, and for SCARPIEs; however, it would not be a suitable solution for environments with high-performance graphics requirements. The benefits of VDI include centralized management, which could lower costs. New Dell machines for summer 2011 installations will support both local loadsets and VDI management. Also we can leverage the PC procurement process to get lower costs on Dell computers.

Like CU-Boulder, many schools are experimenting with virtual labs. A common refrain from administrators at those schools is that while the ability to provision software anywhere is great, it is unclear how much money a virtual solution will actually save. For example, the costs of servers and staff for the solution are anticipated to be equal to or greater than the savings realized from fewer desktop computers purchased. However, if
reliance on student computers is acceptable, a virtualized solution could afford the campus the opportunity to repurpose lab space as different types of learning (or other) environments. For more detail about virtualization, please refer to the “Virtual Labs” section of Appendix 4.

Recommendations
When pondering changes in computing labs, CU-Boulder needs to consider pedagogy first and to commit to providing environments for active and interactive learning. At the same time, the campus needs to be as efficient as it can with resources devoted to designing and supporting these spaces. Faculty and students want the campus to provide flexible lab spaces for instruction. They want the computers and software in them to be available as much as possible. With this in mind, we propose to move forward with significant changes in how we approach our computer classrooms, open labs, common spaces, and departmental labs.

CU-Boulder should leverage student-owned laptops, and provide students, staff, and faculty with licensed and virtual delivery of software, which will enable the campus to repurpose some of the spaces devoted to central computing labs into flexible-use spaces equipped with sufficient power and outlets and printing solutions. This solution also has the potential to lessen burdens on departmental labs. Repurposing central and departmental labs will free up space for departments, reduce administrative and infrastructure costs, and at the same time enhance technology-assisted teaching and learning on campus. Key components of our recommendations reflect what we have learned in this study:

- At least 97% of CU-Boulder students own laptops and other mobile computing devices.
- Students want more flexible learning spaces that allow their mobile devices to be more functional while they are on campus.
- A subset of faculty teaching in computer labs are doing so because of the rich technological environment provided by labs, not because they are teaching a specific software title that is provided in the lab.
- Peer institutions are transforming their labs into flexible-use spaces to allow for more active and interactive learning than is possible in traditional labs.
- New virtualization technologies and robust networks make it possible to create and sustain virtual computer labs and deliver software to student-owned devices.

We can entice students to bring their mobile devices to campus by providing them with common lab software titles over our network. They can then access this software in spaces with flexible furniture arrangements, sufficient power and outlets and printing to accommodate their individual and collaborative work. If students bring laptops to campus, and have access to software needed in courses, any classroom is a potential instructional computing lab.
Our plans to **create flexible-use spaces and provide licensed and virtual access to software** can be funded by **targeted cost reductions** in our current lab environment, including:

- Reducing the number of computers devoted to physical labs.
- Improve staffing efficiencies.
- Increasing the lifecycle of hardware in labs.
- Reducing the number of currently deployed computers in Norlin Commons, while providing new capabilities to support student-owned devices.
## Appendix 1: Student Computing Fee Allocation 2010-2011

<table>
<thead>
<tr>
<th>Description</th>
<th>Amount</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic Technology Spaces</td>
<td>$744,648</td>
<td>9.0 FTE Lab Support staff and support costs, student hourly workers (includes labs and Norlin)</td>
</tr>
<tr>
<td>Academic Technology Support</td>
<td>$81,531</td>
<td>Training (1.0 FTE and support costs)</td>
</tr>
<tr>
<td>IT Service Engineering</td>
<td>$90,902</td>
<td>1.0 FTE Project/Program staff</td>
</tr>
<tr>
<td>Common Good Licenses</td>
<td>$142,200</td>
<td>Campus Agreements with Microsoft and Apple, Skillsoft CBT</td>
</tr>
<tr>
<td>Identity Management</td>
<td>$195,900</td>
<td>Implementation and ongoing support, R&amp;R</td>
</tr>
<tr>
<td>IT Security</td>
<td>$78,748</td>
<td>1.0 FTE and support costs</td>
</tr>
<tr>
<td>Messaging/Calendaring</td>
<td>$248,152</td>
<td>Mirapoint, Ironport, R&amp;R funding</td>
</tr>
<tr>
<td>Network</td>
<td>$35,000</td>
<td>Wireless networking in student fee-based buildings (Wardenberg, Rec Center, UMC)</td>
</tr>
<tr>
<td>Technology Spaces</td>
<td>$2,027,731</td>
<td>Campus Printing Initiative (CPI, $300,000 total); IT equipment refresh and other upgrades (for making rooms &quot;smart&quot;, e.g., furniture, networking, FACMAN work, etc.) for labs; software licenses such as MS Vista Office, Mathematica, SAS, SPSS, STATA, Autodesk, Altiris, etc.; and PCs for Scarpies and Team Rooms</td>
</tr>
<tr>
<td>Technology Tools</td>
<td>$111,254</td>
<td>Xythos, CULearn Next Generation (NG)</td>
</tr>
<tr>
<td>Web Presentation</td>
<td>$16,055</td>
<td>Maintenance costs</td>
</tr>
<tr>
<td>IT Support</td>
<td>$167,223</td>
<td>1.0 FTE and support costs, Bugbusters (TCOM and Norlin)</td>
</tr>
<tr>
<td>Apps, DB, MW &amp; ISS</td>
<td>$153,922</td>
<td>2.25 FTE and support costs</td>
</tr>
<tr>
<td>Total Funding</td>
<td>$4,093,266</td>
<td>$4,093,266 continuing funding, $260,000 temporary funding, 15.25 total FTE</td>
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</table>
Appendix 2: Summary of CU-Boulder and AAUDE Surveys

Executive Summary

According to a survey of AAUDE (American Association of Universities Data Exchange) institutions, our peers appear to be anticipating a shift from university-supplied computers to student-supplied computers. In response, they appear to be investigating changing facilities, amenities, and technological infrastructure to accommodate students with personal laptops as the primary mode for computing on campus.

CU-Boulder faculty respondents report teaching an average of one course per semester in computer labs. Faculty tend to use computer labs as a supplement or enhancement to their teaching, or as a way to teach the technologies in the labs (for example software titles). When faculty members had issues with labs, they were in the areas of the process for requesting software, the size of labs, and the equipment in the labs.

Most students reported difficulty finding suitable space on campus to use their personal computers. About half of the students say they use computer labs fewer than once a week; and half say they use University-provided open computing spaces on campus (i.e. Norlin Commons, UMC, and ECCR labs). When students use on-campus spaces for computing (either with their personal laptops or university computers), they report valuing ample quiet spaces, electrical outlets, printing capability, and wireless networking that is available in the evenings and even 24 hours a day.

Background

Throughout the fall semester of 2010 CU-Boulder students and faculty were surveyed about their use of computer labs on campus. The student survey was announced in two Buff Bulletin messages and was made available in computer desktops in the Norlin Commons, UMC 138, and ECCR 225 labs. In all, 782 responses to the student survey were received.

The faculty survey was announced in a Buff Bulletin and through direct email messages to faculty members who had reserved computer labs in 2010. In all, 49 responses were received.

Another survey was conducted in spring of 2011 asking members of 18 Association of American Universities Data Exchange (AAUDE) institutions about trends in computer lab and learning spaces on their campuses. In all, seven responses were received.

Student Responses

The student survey represented a broad distribution of student classifications (first
year through doctoral students). The majority of respondents (60%) were from Arts and Sciences. This is slightly lower than the percent of Arts and Sciences undergraduate students out of the total of undergraduate students (67%). Nineteen percent were from Engineering and Applied Sciences, which is higher than the percentage of Engineering students (12%) of the total population of undergraduates. Eleven percent were from the Leeds School of Business (which is the same as the percentage of Leeds students as a portion of the total population. Other students were from Education, Journalism and Music. Forty percent of students responding reported receiving financial aid. This is slightly more than the 35% of students determined to have received financial aid by CU-Boulder’s office of Institutional Research and Analysis.

Computer Use Patterns
Half of the students report using computer labs on campus less than once a week. When they do use those labs, they report mostly using Microsoft Office, Adobe Acrobat Pro, and Mathematica or Matlab. Nearly all (91%) of the students rated themselves as intermediate computer users. Twenty-two percent of students reported owning a desktop computer, but 97% said they own a laptop computer. Thirty-seven percent said they bring their portable computer with them to campus always or most of the time.

Obstacles to Laptop Use on Campus
Most students say it is sometimes difficult for them to find convenient space to do their schoolwork in public campus spaces. Students cite key factors in their use of a public space to do work as finding a quiet area with comfortable furniture, sufficient electrical power, wireless access, and printing ability, concern about damage or theft to their computers, and the weight of their computers. Students desire access to public spaces in the evenings and even 24 hours a day.

Use of Open Computing Facilities
Fifty-nine percent of students said they regularly use open computing facilities on campus. Those open computing facilities include commons areas, like those in Norlin Library, and traditional labs like those in the UMC, and the Engineering Center. Students report mostly working alone (N = 522; 64%) in those open facilities, while a significant group reported working with others (N = 276; 34%). The most frequent computing activities done in an open facility were using Microsoft Office, using CULearn (CU-Boulder’s learning management system) or CUConnect (portal), printing, checking email, using Facebook, and browsing the web. Most students report using open computing facilities less than once a week.

Use of Norlin Libraries and UMC Lab Spaces
Most students reported not using the Norlin and UMC open computing spaces, but of those who did use those spaces, the majority of them did so less than once a week. Those students who used the open computing facilities found the location, wait times, printing capability and capacity of computers to be most important factors in their decision to use those facilities. Most students say it is sometimes difficult to
find an available computer in these facilities, but the majority of them are either satisfied or very satisfied with the facilities.

Use of Engineering Open Lab Spaces
The vast majority of students reported never using the ECCR computing labs. This is understandable given that fewer than 20% of the respondents were from the College of Engineering. Of those who use the ECCR open computing facilities, the most important factors in their decision to use those labs were the location, the proximity to the Engineering Center, the wait time, software titles available, ability to print, and the performance of the computers. Most students said it was usually easy to find an available computer there and that they are either satisfied or very satisfied with the labs there.

Faculty Responses
Fifty-four percent of the 49 faculty responding were from the College of Arts and Sciences. This college makes up 52% of the CU-Boulder faculty. Nineteen percent were from the College of Engineering and Applied Sciences. This college makes up 13% of the CU-Boulder faculty. Faculty members from Business, Education, Journalism, and Music also responded.

Seventy-nine percent of respondents said they teach two or fewer classes per semester in labs. The most common response was that faculty members teach one class per semester in a lab. Most faculty members responding said the reason computer labs are important to their teaching is that the technology supports or enhances their teaching (17 responses); or that the technology is the focus of their teaching (16 responses). For example classes in programming have technology as the object of their teaching.

A few faculty members cited difficulty scheduling labs for their courses as a barrier to them using labs in their teaching. Others reported not needing labs for their teaching. Of those who used labs, the most common challenges they reported are the small size of labs, and labs not having the software and hardware they would like. Others cited the room configuration (5 responses), failed equipment (3 responses), and interruptions from others in the lab while they are teaching (2 responses).

Just over half of the faculty members responding said they are familiar with the process OIT uses to solicit requests for software or changes. Sixty-seven percent said they know who their liaison is for OIT managed labs. Forty-four percent said they find it difficult to request new or updated software. Several of those faculty members (7 respondents) said the timing of making requests and getting responses from OIT was an issue. Eleven respondents would like to see the software request process improved. Other changes that were suggested for OIT included improving information about the labs (4), the availability of labs (2), the equipment in the labs (3), and the location of labs (1).
AAUDE Peer Responses
In spring 2011, a survey was sent to peers at 18 institutions who are members of the Association of American Universities Data Exchange. These institutions included:

Georgia Tech University
Iowa State University
Massachusetts Institute of Technology
Michigan State University
Ohio State University
Pennsylvania State University
Stanford University
Texas A&M University
University of Florida
University of Iowa
University of Kansas
University of Maryland
University of Nebraska
University of North Carolina
University of Rochester
University of Southern California
University of Virginia
University of Wisconsin

We received seven responses. The survey asked about the state of computing facilities on these campuses and what the future seemed to be for those facilities.

Most respondents said in the past five years, their computing facilities have largely stayed the same. The same number of computers and facilities have been made available to students. In the next five years, however, most respondents thought the number of computing facilities on their campuses would decrease.

The respondents’ institutions reported investigating software virtualization, software streaming, software checkout, thin clients (computers that rely on a server or other computer to do most of the data processing for them), and virtual desktop infrastructure.

Most respondents reported laptop adoption rates at their schools to be over 75%. They also expected a significant amount of student-owned laptops would replace university-supplied computers. As a result, most respondents thought in the next five years they would increase the number and size of facilities and amenities available to students to use their own computers.
Appendix 3: Literature Review and List of References

Learning Environments: A Review of the Literature

The term “learning space” is a current buzzword in educational literature, and represents the rich intersection of teaching, learning, space, and technology (Oblinger, 2006). Learning spaces are a particularly pertinent topic on university and college campuses as faculty, staff and administrators explore how to best integrate learning with daily campus life and serve a variety of students. These explorations are reflected in the literature on learning spaces including case studies, assessment reports, project overviews, lessons learned, and theoretical discussion about the concept of “space” in learning. A majority of the literature focuses on learning space design practices relating to libraries (Beard & Dale, 2010; Cohen, 2009; Crook, 2005; Fox & Stuart, 2009; Haug, 2008) and classrooms specifically (Hammons & Oswald, 2009; Long, 2005; Tom, Voss, & Scheetz, 2008; Whiteshead, et al, 2009) and to a lesser degree computing and learning labs (Burgstahler, n.d.; van den Blink, 2009). The following literature review highlights the primary themes of this work and identifies overarching trends and principles concerning learning space design.

Underlying Theory and Assumptions in Learning Space Design

Thinking about learning spaces rests on a number of principles and practices concerning the use of space and technology in pedagogy, as well as the mission of post-secondary institutions in the 21st century. Key among these is the implicit recognition of the value in active learning. Active learning is mentioned in nearly all the literature addressing learning spaces and is referenced as a goal in learning space design. Active learning moves beyond an understanding of learning as the transmission of information and content from source to receiver and instead views learning as a rich, active, and social process requiring interaction among learners and involvement in the learning processes through discovery, application, and exploration. It is further based on the assumptions that learning is an active endeavor and one pursued differently by various learners (Meyers and Jones, 1993).

Current and anticipated change in technology is also a relevant principle in learning space design. The Information Age—an era in which large amounts of information was highly accessible to users in an array of forms and from a spectrum of sources—is rapidly morphing to the Interaction Age. This shift is evidenced in technological evolutions such as a shift away from networks solely transporting data to networks facilitating interaction; and a movement away from individual to group users (Milne, 2007). The shift from the Information Age to the Interaction Age is reflected in an emphasis on active learning and becomes pertinent to learning spaces as campuses work to support and promote both human-to-human and human-to-information interaction in learning space design.
A parallel shift in pedagogical practice also underscores the move toward interaction and active learning in education. The past few decades have witnessed a distancing from the industrial model of education to the inquiry model. Whereas the former revolved around highly individualized and highly regulated learning, the latter rests on active, social, continual, contextual, and holistic learning and necessitates “learning designs that connect students to knowledge-making activities and to one another” (Long & Holeton, 2009). The principles of active learning, interaction, and inquiry unite within thinking about learning space design to promote spaces wherein learners may pursue a variety of rich and rewarding learning experiences.

It is important to note two additional principles when it comes to thinking about campus learning spaces. The first is an understanding of the richness and complexity of a particular space and what features constitute a space. Warger and Dobbin (2009) suggest a shift away from the term “learning space” to that of “learning environment” in recognition of the breadth of factors relevant to learning effectiveness. Far from the physical characteristics of a space alone, learning environments are comprised of the values placed on teaching and learning, the role of emotion in learning, and the cultural and social contexts relevant to learning practices. Recognition of these dimensions within learning environments allows for overt reflection about how a campus communicates its values surrounding learning and teaching and shares those values with its campus population (Warger & Dobbin).

Finally, it is necessary to articulate assumptions about the relationship between space and behavior when thinking about learning spaces/environments. Assuming design of a space will result in certain learning behaviors is a deterministic view resulting in potential missed goals and failed expectations (Bennett, 2006). Carefully assessing and articulating the vision of a learning environment, the goals for user behavior and how best to direct that behavior is an important step in environment design. “Architectural or environmental probabilism,” rather than determinism, helps guide this process and works under the assumption “well designed spaces afford their occupants the opportunity to act in certain ways but [does] not ensure that those activities will happen” (Bennett, p. 15).

Design Principles and Trends
Themes and trends in learning environment design reflect the theories and assumptions outlined above. Further, design themes are grounded in rigorous assessment concerning where and how students engage in learning processes. Such assessment found students frequently study from home (dorm rooms, apartments, houses); technology is a ubiquitous component of students’ study time (Whiteside et al); and students often seek out particular features of a study environment based on the learning task (Nixon, 2009; Whiteside et al, 2010). For example, students working on writing assignments reported a desire for more solitude, quiet spaces, and comfortable furniture; those working on exams, problem sets and lab assignments expressed a desire for collaborative workspaces (Nixon). Therefore,
planning for learning environment design should include consideration of the learning activities to be conducted in the space and how those activities may be supported and promoted (Nixon; Bennett, 2006).

Flexibility is a central design principle in thinking about learning environments and refers to flexibility in adopting evolving technologies, catering to a wide variety of uses, and encouraging creativity and dynamism in user interaction with the space (Grummon, 2009; Hammons & Oswald, 2009; Kennedy, 2008; Tom, Voss, & Scheetz, 2008; van den Blink, 2009). Flexibility is manifest in design through the use of reconfigurable furniture, including tables and chairs that may be shaped into a variety of configurations and suit individual as well as small and large group work. The possibility for reconfiguration ensures multiple uses for a space and allows users agency in creating a space suitable for their learning needs. Flexibility is also evident in learning environments that include a spectrum of seating and technological options from which users may select. A wide supply of power outlets, accessible Wi-Fi, and a variety of work stations for multiple purposes including “on-the-go” stations for quick printing and emailing, individual longer-term stations with privacy, and larger tables with a number of chairs and computer monitors for group work allows users to seek out and utilize a space in a number of ways. Figure 1 depicts an example of a learning environment including reconfigurable furniture and a variety of workstations (Tom, Voss, & Scheetz).

Figure 1: An active classroom learning space blueprint from the University of Missouri-St. Louis).
References


**Appendix 4: Peer Investigation**

In late fall 2011, CU-Boulder used information available on university websites to investigate computing lab offerings at institutions known to be either similar to CU-Boulder in size or funding, or implementing new computing lab solutions. Results of the investigation are categorized by lab type: open, instructional, and commons.

**Open Computing Labs**

Open student labs are labs that are made available to any student, regardless of discipline. While open student labs are sometimes scheduled, they are generally considered to be labs that are open for student drop-in usage most of the time. Because they cater to a wide variety of disciplines, the software installed is generally software that is used regularly across many disciplines (i.e., Office, web browsers, statistics software). Because the software installed is generally software we think all students probably have installed on their own computers or desktops, the value these types of labs provide is often called into question. We wanted to see what others schools were doing with these spaces, and how prevalent they are at other institutions. Here at CU, the two labs that we consider open student labs are UMC 138, and the 4 labs that make up the NAC in the Engineering building.

The **University of Utah** has many centrally-managed computer labs, but they also have many labs managed by other departments or colleges. There are 4 open labs, most of them located in Library locations. They contain about 130 PCs and 54 Macs total. The University of Utah College of Social and Behavioral Science has 5 open labs, and 4 of those are reservable for classes. They have 30-40 Windows machines in the reservable labs, and the smallest lab of 9 machines is split between PCs and Macs.

**Stanford** provides open computer clusters in library locations, the student community center, and student residence halls. All of these are dual-boot iMacs, and
there are about 500 of them spread around campus. There are 3 open multimedia labs that provide access to high-end software for multimedia production and editing. The residence hall locations consist of at least 2 dual-boot machines, a scanner, and a printer. Most also offer large-screen LCDs for use with personal laptops.

**Yale** has 4 computer classrooms designed to serve interdisciplinary needs. There are 60 computers total in these labs. They allow scheduling of these spaces as well, but they are not affiliated with any one department. There are also 6 general purpose labs that are not used as classrooms. There are 60 PCs and around 25 Macs in these labs. They also have 16 residential and graduate dormitory labs that each contain between 5-10 machines in each lab.

**Penn State** has about 23 open labs, containing about 500 machines total. 350 or so of these are PCs, and the rest are Macs. 4 of these labs can be used for instruction, but the rest are open to students when not used for classes. Penn State is deploying Linux in select labs as they feel they are giving students the opportunity to work with an OS that is gaining a foothold in many private sectors.

**Michigan** has 29 labs open to general use. It appears many of these labs are of the small variety, between 3 and 10 computers in each lab. While some are larger than others, many of them appear to provide both Macs and PCs, scanners and printers.

**Duke’s** Office of Information Technology supports 25 computer labs, including two multimedia project studios. Most of these labs are reservable.

**Departmental Labs**
Departmental labs are those that contain hardware and software that are very specific to a particular discipline. Because of this, departments regularly schedule classes in these labs in order to teach students how to use particular software. The software installed in these labs can be cost-prohibitive for a student to own, so labs are often open outside of normal class hours to allow students to do homework using the software.

The **University of Utah** has around 11 department computers labs. They vary in size, but generally each lab either has all Macs, or all PCs. There are around 400 PCs and 100 or so Macs.

**Stanford** doesn’t appear to manage many departmental labs centrally. They manage a digital language lab of about 20 machines, and an academic technology lab made up of high-end Macs that run graphics and multimedia software.

**Yale** has 18 departmental labs, but each of these labs usually only has between 2 and 7 computers apiece. The largest departmental lab is a 14-seat Music lab.
Penn State has a large number of labs dedicated to specific departments, which are considered private; or used primarily for instruction, which are not open. While their web pages indicate a large number of these labs, there are over 30 that have at least 20 machines. There are many more labs that contain between two and 10 machines.

Michigan's central IT organization manages a few special labs, that might not be considered department labs. There is a lab that provides high-end computers, other hardware, and software to students who need to work with multimedia class projects. They even manage a 24-seat computer gaming lab!

Commons
The University of Utah has a commons environment they call the Knowledge Commons. There are 150 PCs and 90 Macs in this environment.

Stanford has a commons-type environment in their Myer Library. It contains dual-boot iMacs, although it was hard to find an exact number. They provide equipment checkouts including camcorders, projectors, laptops, and other multimedia equipment to students with a school ID card. They sell blank DVDs, batteries, and other media. They also have a poster printing drop-off service for conference and presentation needs. The student consultants who work at the desk are trained in image, audio, and video editing applications.

Penn State has a commons in their Pollock 201 undergraduate library. It consists of around 26 Macs, and 131 Windows machines. They have collaboration spaces in this lab to fill a need for two- to six students to gather and spread out their materials.

Virtual Labs
Many schools are experimenting with virtual labs. A common refrain is that while the ability to provision software anywhere is great, it is unclear how much money a virtual solution will actually save. For example, at North Carolina State University, the school will stop buying about 500 new desktop computers a year, which will save $500k. However, the university will need to buy more servers to support the virtualization solution, which will eat up those savings.

There are two main types of virtual labs being used in other schools. Some are using a Terminal Services model, in which the server runs a single instance of the operating system, and unique sessions are spawned for each client connection. Clients use a Remote Desktop client to login to the remote server. "Screen scrapes" are sent back to the client from the server in this scenario. The other solution, using VDI and tools like VMWare and Citrix, is the newer and more costly technology. It allows clients to either run virtual machine images from a remote server, or run
those images on their own desktop. The processing can be done on the client if desired. Both solutions have pros and cons:

**Pros:**
- Patch management and software upgrades are easier
- Software and hardware is very stable
- New computers and users can be easily provisioned
- Provisioning of applications and VMs is much faster
- Cheaper hardware can be deployed in labs, and it lasts longer
- The client machines better utilize their resources (CPU, memory)
- The client machines consume less power
- Mobile or remote users can connect to the server from anywhere

**Cons:**
- Some software applications have problems running in a Terminal Services environment.
- USB drives and portable drives are not recognized by some VDI connection brokers
- Virtual machines may run slow depending on the speed of the network and number of concurrent users
- Data center servers for VDI have a large up-front cost
- There could be security concerns since mobile and remote users are connecting straight to the data center for virtual machine images
- If the servers are down, or network is down to the server, the lab is down

The University of Utah College of Social and Behavioral Science has a virtual lab that allows 70 concurrent connections. They consider the project in a beta state, and are evaluating their ability to deliver applications from a centralized server. They are using Citrix XenApp. The software they provide in the virtual lab is:

- ESRI GIS Desktop 9.1
- Firefox
- Wadsworth Microcase 2006.2007
- Microsoft Office 2003 and 2007
- SAS 9
- SPSS 15 and 16
- Stata 9
- SSH

We were unable to find evidence of a virtual lab environment at Stanford or Yale. Penn State Erie, the Behrend College, is another school in the Penn State system. They appear to offer a virtual lab environment, but it is only accessible from Internet Explorer on a PC or through a terminal services Client in Linux or the MacOS. They point out that all the software is running on the same hard drive on the server, and not to remove or change configurations or software. All this seems
to indicate this setup is simply a Terminal Services solution, and is not a virtualization solution that separates hardware and software into separate layers.

**North Carolina State University** is running a virtual computer lab on Apache's VCL project. NC State donated the source code for the project to Apache back in 2008. They can provide Linux, Solaris, and various versions of Windows to lab computers or to students and faculty on their own desktops. To access the software, one must run a remote desktop client application. This means processing is done on the server side, and the client receives "screen-scrapes" from the remote server for display on the clients. The system provides a web page that provisions remote access to a dedicated computer resource for the user. It is provisioning a computer that is usually housed in a data center, either a blade server, rack-mounted server, or virtual machines. It can also provision physical computers in labs. An important note is that while the school provides the base OS images, they provide a mechanism for an instructor to build an image that can then be either remotely provisioned or deployed to a lab. It’s also important to note that while NCSU says they have plans to close about half their labs in the coming years, they have not shut down any labs yet.

The **University of Virginia** is commonly cited as a school that has closed all its labs and moved to virtualized solutions. That's not entirely true, but it’s the direction their Information Technology & Communication group has decided to go. Their reasons are fairly simple:

- Almost all students arrive at campus with a mobile computer of their own. For those that cannot afford to provide their own laptop, the school has programs that either provide laptops or help with financial aid.
- Use statistics show that students likely have 95% of the software in public labs. This software is either free (Firefox, IE, Acrobat Reader) or is available at a low cost to students (Microsoft Office). 5% of their lab software is in specialized programs like Matlab, Eclipse, Mathcad, or SPSS.

UVA plans to move to a virtualized environment in the next few years. They are concentrating on making the wireless service more robust and secure in order to facilitate the growing number of wireless devices. They also make the Office suite more affordable to campus ($15).

The campus tested two different solutions: terminal services (remote desktop services) and virtualization using VMware. They concluded that terminal services did not meet stability, scalability, or compatibility needs, and therefore could not recommend it as a viable long-term solution. Virtualization, on the other hand, provided benefits in all areas, and was determined to be the long-term solution to meet the requirement of providing specialized software regardless of location. Since not all problems have been resolved, they are recommending keeping at least one lab open. This service came online in Fall 2010. As such, based on the schedule of current lab usage and hardware lease expirations, labs will be
reduced by about 375 seats over the next 3 years. Smaller labs are being phased out first.

The closed lab spaces are being repurposed as group collaboration and experimentation spaces. Student can bring their own laptops and mobile devices to conduct group work.

The CIO at UVA reported that the school spends around $300k a year maintaining labs, but that it's difficult to predict how much the school will save by phasing out labs. It isn’t yet dear how much the back-end will cost to implement.

**Duke University** is following NC State's lead and using their technology, the Apache VCL project, to do it. They are shutting down six labs in residence halls and those will be transitioned into group working spaces for students. Their virtual machines provide current versions of Matlab and Microsoft Office. They provide a web interface that allows students or classes to make reservations for the lab. The user can then access their image at a scheduled time through a remote desktop agent.

The **University of North Carolina at Chapel Hill** also is running trials on the Apache CVL project. They currently have no plans to close down any labs. They expect to save money by leaving hardware in labs longer, and by purchasing fewer software licenses.

The **University of Michigan** School of Business is providing remote desktop access to a virtual computer lab. So is their Engineering school, which says it provides the same applications and services that are in the normal computer labs through a Virtual Sites service.

**References**

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Duke

**Appendix 5: Action Plan**

The following steps need to be undertaken to achieve the recommendations listed in this report.

- Continue with and advance application streaming technology **Fall 2011**
  - Determine licensing costs for Microsoft App-V, and find out if it can be added to MS Campus Agreement
  - Figure out how to deliver streamed apps to student owned-machines
  - Identify applications that can be streamed in labs, and make them available from other labs.

- Identify applications that we could provide to student-owned machines **Fall 2011 (costs depends on licensing deals)**
  - Figure out licensing details that would allow streaming, virtualized use
Figure out licensing details that would allow students to install the software directly on their own machine.

• Realign Norlin Commons with the vision of a Information Commons Plan Fall 2011, implement Summer 2012 (~$200K [+ savings])
  o Reduce the amount and cost of deployed hardware
  o Provide gaming/entertainment areas
  o Provide devices that assist in collaborative projects
  o Provide comfortable furniture and peripherals that encourage students to bring their own computers
  o Provide knowledgeable student workers who can help students answer questions or get started with multimedia projects.

• Design and implement a centrally-managed VDI infrastructure that can be leveraged by student labs, department labs, individual machines and student mobile devices. Begin design in Fall 2011, with an implementation goal of Spring 2012 (front-loaded costs; ongoing cost neutral)
  o Replace appropriate lab hardware with thin clients
  o Provide a mechanism for instructors to make software requests and “reserve” a VDI lab
  o Provide a method for departments to leverage the VDI infrastructure that would allow them to provide their own VMs for their lab or student use
  o Provide a method for departments to partner with OIT to manage their own thin-client labs that leverage the central VDI infrastructure
  o Provide methods for mobile users to access VMs running departmental software via web browsers and RDP.

• Remove open student computing labs and unneeded departmental labs Ongoing (repurpose funds into renovations and furnishings; ongoing reductions and increased space opportunities)
  o Encourage departments to allow OIT to repurpose spaces into open collaborative areas with nice furniture and peripherals that encourage students to use their own devices
  o Decommission UMC 138 computer lab by the end of Summer 2012.