# ECOLOGY OF THE COMPUTER LABORATORY

By

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*ABSTRACT*

*Global communication, international workflow, and connected learning are converging to realign power, wealth, and work. As Friedman (2006) explained, many forces are coming together to cause a flattening or leveling effect of the world's workforce. This has allowed many skilled workers from emerging nations to enter into the workplace and compete for jobs that were traditionally held by only a few wealthy industrial nations. Although the playing field is being leveled for some occupations, Florida (2005) convincingly argues that the international economic landscape is becoming spiky with innovations being concentrated in a few urban centers.*

*These urban centers provide the new creative class with ecosystems that enable their prosperity. Innovations are improved and brought to market more quickly in settings where talented people collocate (Florida 2005). It is vital that graduates enter the workforce prepared to orchestrate globally distributed work using computer-based communication systems and know how to engage creatively in collocated activities. Despite these demands on our graduates, many university computer laboratories are sociofugal environments (environments that discourage social interaction), fostering the individual consumption of information versus collaboration. This paper examines the college computer lab as an ecological system that may impede transference of critical 21st century sociocutural norms and workplace skills.*

*Keywords: Computer Laboratory, Classroom, Ecosystem, Sociofugal, Sociopetal, 21st Century*

## INTRODUCTION

We are living in extraordinary times. Significant forces in global communication, workflow, and education are converging to realign power, wealth, and work. As Friedman (2006) explained, many forces are converging to cause a flattening or leveling effect of the world's workforce, allowing many skilled workers from India, China, and numerous other nations to enter into the workplace and compete for jobs that were traditionally held by few wealthy industrial nations. These significant changes are disruptive, causing workers around the globe to retool their skills in an effort to find employment.

Friedman (2006) and Pink (2006) explained that a new middle class has emerged due to these changes. This is a new influential class of workers whom have found areas of work that are difficult for others to replicate at lower cost and from a distance. Restated, workers in the new global-influential class protect their careers by working in areas that are difficult to outsource or automate. These areas of work are what Pink (2006) calls *high concept* and *high touch* occupations. "New forms of work rely increasingly on high levels of specialist knowledge and on creativity and innovation particularly in the uses of new technologies. These require wholly different capacities from those required by the industrial economy" (Robinson, 2001 p. 5).

The impact of these global changes are being reflected in university program enrollments. For example, following the dot-com bubble burst in the 1990s, computer science program enrollments dropped significantly. In 2004, the enrollment at MIT's electrical engineering and computer science department was down to 200 undergraduates from 385 in 2001. Stanford University's undergraduate computer science majors declined from 171 to 118 from the year 2001 to 2004 (Frauenheim, 2004). Similarly CSU computer science majors dropped from 600 to 260 between the same years (James Peterson, personal communication, April 25, 2008). Understanding the significance of the workforce changes Georgia Tech's President was quoted as saying, "how can we prepare our graduates not only to thrive in the innovation economy, but also to be sensitive to the human and environmental impacts of innovation and to manage the disruption it causes? How can we prepare them to be lifelong learners, comfortable with the notion that their careers will likely change course several times along the way? How can we prepare them to be citizens of the world who understand the global dynamics of our economy?" (Furst & DeMillo, 2006, p. 11).

Responding to these changes and global pressures, educational institutions at all levels have worked to redesign curriculum in an effort to retain students and to maintain relevancy. Faculty at Georgia Tech realized that it was not sufficient to educate computer science graduates to be extremely good at one analytical skill. Although these specialized skills are necessary, to compete graduates need to be able to bring together many aptitudes and skills synthesizing their technical competence with relationship building, bringing together seemingly unrelated fields to create unique and ongoing value. Today, organizational scholars recognize that creativity is a vital component for success in an environment marked by rapid change (Ford & Gioia, 1995).

In an effort to bolster sagging enrollments and to increase employability of its graduates, Georgia Tech has spent considerable efforts to change its curriculum. The curriculum redesign effort focused on producing undergraduate computer science graduates that are:

1) Extremely adaptable
2) Apt at forging new and dynamic relationships, tackling novel challenges, and synthesizing the "big picture;" and
3) More competent at utilizing creativity and tacit knowledge (Furst & DeMillo, 2006, p. 8).

Facing similar enrollment patterns, faculty at Colorado State University designed a new major in Applied Computer Technology. This new program was designed to allow each student the option and flexibility to consider combining their computing technology program with other major or minor courses of study. Furthermore, students are encouraged to participate in independent research projects, engaging them in novel challenges to develop their creative problem solving skills, a necessity for future employability.

There has been concerted effort to improve curriculum that promotes 21st Century skills, requiring students to synthesize ideas, collaborate, and work toward creative solutions to problems. However, less effort has been spent discussing how the physical environment of the university enables or inhibits these types of activities. The hidden curriculum of the university manifests itself in the physical environment in which the students are engaged.

The hidden curriculum includes the norms, values, and expectations that are communicated to students outside the planned or "official" curriculum (Henson, 2006). For example, Armstrong, Henson, and Savage (2001) describe the hidden curriculum as "…all those things in the school setting that send our learners messages regarding what they should be doing and even how they should be thinking" (p.410). The physical environment is a powerful contributor to the hidden curriculum, for example, an instructor may announce that the course values small group discussions, but the chairs have been bolted to the flow arranged in tight rows that face the front of the classroom. The hidden message of the room is that the instructor is probably not very serious about implementing the particular course value of small group discussion.

This paper examines the physical environment within Colorado State University's College of Applied Human Science College computer labs and discusses how the setting can be designed to promote creative behavior. This investigation takes an American perspective and therefore pertains most directly to educators in the United States. The authors' intention was to provoke additional thought and research relating to ecosystems and the learning process. The authors envision to conduct future researches across social boundaries and cultures as insights from different ecosystems would be insightful.

### Creative class: Innovation and Creativity

How information and knowledge is produced and exchanged is central to the way in which we understand what we can accomplish and achieve. Over the past 150 years, modern complex democracies have depended on an industrial information economy where information has been scarce, created by an elite few, and controlled through an industrial-based educational system (Benkler, 2006). This information-scarcity model has isolated many, placing them outside the industrial information economic system. However, enabled by technology, we are witnessing a shift in information production, ownership, and control. We are seeing new social and cultural adaptations where more-and-more autonomous individuals, working in collaborative groups, are creating new innovative forms based on existing information.

In an era where information is increasingly becoming a commodity, those that succeed will be individuals who can combine information in creative and innovative ways. Fundamentally, we are seeing the rise of a new global "creative class" a prosperous group that gains recognition and acceptance through creativity and innovation (Florida, 2002). Runco (2004) reinforces the importance of creativity stating, "because of its role in innovation and entrepreneurship, creativity has become one of the key concerns of organizations and businesses" (p. 659). The business sector has identified creativity as the engine of technological and economic development (Plucker, 2004). Employers want people who can think intuitively, who are imaginative and innovative, and who are flexible, adaptive and self-sufficient (Robinson, 2001).

The importance of innovation and creativity to the success of individuals is well supported within the research literature. After reviewing the literature on creativity, Runco (2004) concluded that the majority of research findings suggest that creativity is beneficial. Furthermore, Plucker (2004) stated that, "Creativity appears to be an important component of problem-solving and other cognitive abilities, healthy social and emotional well-being, and scholastic and adult success" (p. 83). Learning how to be innovative and creative has become necessary for individual success in the information rich global economy.

Misunderstanding of creativity and common myths of innovation have acted to retard skill development. The myth of the "lone inventor" is a falsehood that history often teaches for its convenience and brevity to explain the historical heroes of discovery. However, reality is that most innovation is a process of collaboration and joint discovery and is not based on a sole individual's epiphany (Berkun, 2007). Robinson (2001) states, "creativity is not purely an individual performance. It arises out of our interactions with ideas and achievements of other people. It is a cultural process" (p. 12). Research evidence suggests a need for a balanced role between individuals and groups during the creative process. Educators need to balance the strengths and abilities that individuals bring to the creative process with those of the group (Plucker 2004). The widely held myth of the "lone inventor" continues to bolster the old industrial-based education system that focuses on individual achievement over collaborative discovery.

### Organizational Ecology

According to Becker (1995) organizational ecology is the transformation of the physical workplace to support business processes. It is how organizational leaders… "choose to convene their employees in space and time in pursuit of a long-term competitive edge" (p. 12). The key elements of organizational ecology include:

1. Decisions about the physical setting in which work is carried out.
2. Decisions about the processes used for planning and designing the workplace system.
3. Decisions about how space, equipment, and furnishing are allocated and used over time (Becker, 1995, p. 12).

As mentioned above, one of the great myths of creativity and innovation is that creative people work in isolation. However, most innovations are highly connected and dependent on predecessor ideas and inventions (Burke, 2007 & Berkun, 2007). In the majority of cases innovation is as much a social process as it is technical (Hargadon, 2003). Florida (2005) found that innovators and thus innovations are highly concentrated in a few global innovation centers. These innovation centers, such as San Francisco, Los Angeles and New York are dominating cutting-edge innovation. Furthermore, he found that creative innovators needed to physically move to and be absorbed by these growing innovation ecosystems in order for their ideas to be fully accepted. The social nature of creativity has led organizational leaders to examine and redesign organizational ecosystems.

Over the past two decades, corporations have been working to redesign business operations to respond to the demands of creativity and innovation. Many organizations introduced new business processes in the 1990s that flattened organizational hierarchy, reduced operating expenses, increased productivity through teamwork, and increased creativity and problem solving. Disruption continues today as corporations continue to distribute their workforce throughout the world taking advantage of efficiencies afforded by low wage workers.

These pressures required that they focus on cost reduction and innovation in order to compete globally. Prior to these pressures companies spared no expense offering employees what was considered to be high-quality work environments. These environments often came with large closed door offices and workspaces (Becker, 1995). However, as competition grew, companies were forced to evaluate not just the nature of the space allocated to each employee but to investigate how workplace ecology impacted productivity. Over the past several decades innovative leaders have focused on building ecosystems that encourage their employees to cooperate, to engage across artificial company boundaries, in an effort to increase creativity.

Research Design Connections (http://researchdesignconnections.com) in their Winter 2008 newsletter reports on a multidisciplinary design firm that took on the task of designing a workplace for creativity. Their focus was on people, activity, and conversation. They discovered that to promote creativity they needed spaces that meet individual and team needs, conversational needs among employees, flexible spaces to support teams with multi-functional tasks, spaces that allowed for the expression of organizational identity, spaces that supported greater transparency between and among spaces, and circulation options that allowed for greater communications and collegiality.

Another example of the role of the workplace physical environment is seen in the work of Fong (2006). She believes that when employees are in an unusual environment that will increase their creative thinking abilities. Many companies have taken this position and have designed unusual physical environments to promote creativity, for example, hanging bicycles from ceilings and other innovative ways to make the work environment unusual and to promote creativity.

## Classroom Ecology

Educational environments, building spaces and associated artifacts have been shown to nonverbally provide students with social and cultural information through informal learning. The buildings and classrooms that students inhabit are part of a hidden curriculum that communicates expected roles and positions of learners in that social environment (Johnson, 1982; Sommer, 1966). The learning environment has been shown to be a powerful teaching instrument; however, a majority of effort goes to lesson preparation while little emphasis is placed on space planning (Martin, 2002). Sommer (1966) found that sociopetal (bringing people together) furniture arrangements increased conversations between people in classrooms, cafeterias, bus stations, and libraries. Research evidence strongly suggests that there is a relationship between the designed school space and learning.

Built in the twentieth century, most school buildings reflect the dominant educational approach of that time, which was to help students build stocks of knowledge and information. In an era where information was considered scarce, this approach was practical. Classrooms were designed in sociofugal (keeping people apart) arrangements to isolate students and identify those who excelled at retaining information, a highly sought out skill (Brown, 2008; Sommer, 1966). However, the 21$^{st}$ century is different; the half-life of information is shortening. In this century the information and knowledge is evolving at an exponential rate and subsequently less emphasis is placed on knowledge retention. Students will no longer have the opportunity to build an inventory of knowledge in their heads and then apply it after graduation. A demand-pull model (just-in-time learning) of education and work will dominate this century, where those individuals who succeed will connect with rich learning communities built around current and rapid experimentation and application (Brown, 2008). Again, those that successfully move into the 21st Century creative class will be those who can convert newly acquired knowledge and information into practical solutions and innovations.

Acquiring the skills necessary to create and innovate can be difficult in the current industrial-based educational ecosystem. Dudek (1993) in his work studied nearly 1,500 children in 11 schools between the ages of 10 to 12. Results provided evidence to further support the hypothesis that the environment of a particular school and the immediate atmosphere of the classroom are powerful stimuli for the creativity processes that he measured using the Torrance creativity test battery. Plucker (2004) states that, "classrooms generally do not appear to be creativity-fostering places, primarily due to the biases of teacher and traditional classroom organization" (p. 84).

## Ecology of Computer laboratories

Information and computer technology hold great potential for supporting learning and enhancing creativity. "Connecting individuals, peers, and social groups as part of their own feedback loops with diverse technologies, at times more perceptive than they themselves, holds great potential for learning, personal growth, motivation, creativity, and life enhancement" (Burleson, 2005 p. 449).

During the 1990s the first version of the World Wide Web (Web 1.0) experienced tremendous growth with a rapid expansion of information. This information was typically static in nature and required advanced programming and technical skills to produce and publish. Over the last several years, a quiet revolution has been underway, with Web 2.0. Today, Web 2.0 tools continue to emerge and proliferated at an unprecedented rate, with new easy-to-use author tools emerging daily. Web 2.0 tools such as social bookmarking, tagging systems, and various content sharing sites are designed to encourage sharing and collaboration. Although many of these sites are still maturing, their design enables the exchange of tacit knowledge via conversation (not technical publication). These informal, peer-to-peer networks, will have far-reaching implications on how people learn, create, and innovate (Brown, 2008).

Web 2.0 advancements have been so rapid that they have far outpaced the computer laboratory ecosystems in which they reside. There is a mismatch between the need to foster interaction and collaboration between students and the physical space within the computer laboratory that often is designed to promote individual task activity. If instructional goals include the use of Web 2.0 tools to connect, share, and create, then we need to seriously think about how design features can support or hinder these goals (Weinstein, 1992).

## Methodology

The multiple case study strategy (Stake, 2005) guided the empirical approach to the purpose of this project - how a university college has created computer laboratory spaces in which students can engage various computer-based learning and discovery. This study was conducted in two parts. The first involved documenting the physical space of each computer laboratory while the second involved observations conducted in a cross-disciplinary project-based course that was being taught in one of the College of Applied Human Sciences (CAHS) computer laboratories.

*Descriptions of the cases:*

The College of Applied Human Sciences (CAHS) at Colorado State University consists of six academic departments: Construction Management, Design Merchandising, Food Science and Human Nutrition, Health and Exercise Science, Human Development and Family Studies, and Occupational Therapy. The College is also a home to the School of Education and the School of Social Work. Over 3900 undergraduate students are currently served by the College which graduates approximately 600 students each year (Office of Budgets and Institutional Analysis, 2007). The goal of the College is to "help students learn to apply creative, interdisciplinary research to solve social problems" (http://tinyurl.com/47lfdk).

The college supports all nine academic units by maintaining six computer laboratories that are located across the campus. These laboratories are funded through a student technology fee that is assessed each semester. These fees are administered by the CAHS Dean's office and used to update and maintain email services, file storage, web hosting and computer laboratory equipment and connectivity to the Web. Fees also support software licensing fees for a variety of software including Adobe Acrobat, Illustrator, Photoshop, AutoCAD, VIZ, Revit, MerchMath, and SolidWorks.

*Procedures:*

First, field observations on the material culture were collected from each of the six CAHS computer laboratories. Detailed measurements were made of each of the laboratories' computer workstations and the overall layout of each computer laboratory was sketched. In addition, photographs were taken of each laboratory to document the overall layout.

Second, field observations were collected within the undergraduate education course titled Educational Technology and Assessment (EDUC331). This case-example was selected for convenience purposes (the lead author of this article is the instructor) and due to the fact that the course was taught within a typical CAHS computer laboratory. Furthermore, the course curriculum and content requires the students to work on several group projects (groups of 5-6 students) and to engage in the use of online collaboration tools such as wikis, social networking sites, and social bookmarking. The summary of these findings are discussed in the following section.

## Findings

The findings are reported in two parts. In part one the researchers present the field observations of physical spaces and classroom observations are presented in part two.

*Findings (Part One): Documentation of Physical spaces*

The authors visited each of the six CAHS computer laboratories to observe and collect detailed information on commonalities and differences. All six of the laboratories were built around common desktop PC workstations. In total, the college has approximately 269 workstations operating within these laboratories. All of the workstations are operating on Windows XP Pro and have the full Microsoft Office 2007 suite of applications. Additionally all of the computers are connected to the Web via a 100Mb connection. Each machine was capable of accessing the Web unrestricted using Internet Explorer 7.0. In addition, specialized software was included on computers in laboratories that were co-located with particular programs. For example, the CAHS computer lab that is located in the Industrial Science Building (a building located adjacent to the Construction Management Department) included specialized software for estimating construction projects (Timberline Office 9.1) and software for producing construction drawings (Revit Architecture 2008).

In addition to computer workstations, each laboratory included a laser-jet printer, a scanner, a mounted projector, and a large screen for instructor-led demonstrations. Several of the computer laboratories were equipped with color desk-jet printers, large format plotters, and recordable CD/DVD technology. All CAHS laboratories were overseen by a student lab operator that controlled access and maintained operating hours. Students had access to these facilities during operating hours except while formal instruction was being held.

It was found during the study that the majority of the computer laboratories were set in sociofugal furniture arrangements. Of the 269 workstations college wide, 228 (85%) were arranged in tight rows as is shown in Figure 1. The workstations were arranged in rows either facing inward toward, each other or against the wall. In all of the CAHS laboratories the instructor was the focus of control having a lectern and computer screen for presentation. The majority of the workstations allocated space for the computer and monitor and limited space for books or notebooks. The typical workstation measured 30 inches (76 cm) by 36 inches (91 cm).

There were two CAHS laboratories with L-shaped workstations. These expanded desktop workstations provided additional workspace for each individual student. They were designed to accommodate large drawing documents and artwork. For example, students in Construction Management work with large format construction documents to conduct quantity take-offs to derive cost and time estimates for their projects. Figure 2 provides an illustration of this L-shaped configuration. Although these L-shaped workstations provide more workspace, their arrangement within the laboratory was very similar to the workstations discussed above. The L-shaped stations were either arranged in tight rows facing forward as shown in Figure 2, or arranged back-to-back similar to those in Figure 1. Furthermore, in both laboratories that contained the L-shaped configuration

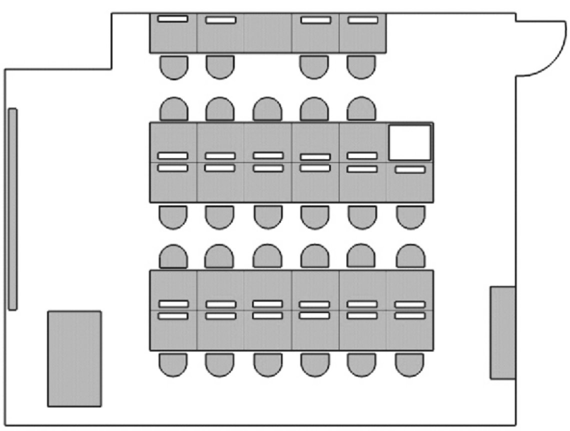

Figure 1. Typical sociofugal CAHS computer laboratory (image to scale)

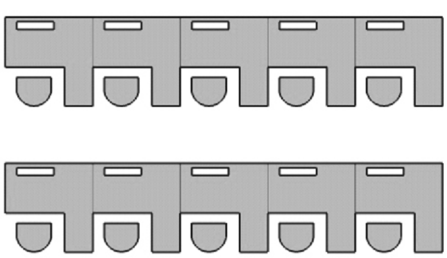

Figure 2. L-shaped workstation with additional space for large format documents

the instructor maintained the lectern and large projector screen for instructor-led presentations.

*Findings (Part two): Classroom observations*

While teaching class (Educational Technology and Assessment) within the CAHS Education Building computer laboratory the first author of this paper made several field observations. These observations are illustrated and noted here. The course was designed to instruct pre-service teachers on how technology can be used to support learning. Two philosophical beliefs informed the strategies for developing and delivering the instructional content of this course. The first was that computers in combination with Web 2.0 tools are powerful collaborative tools that can connect learners to communities of experts and therefore should be central to learning. The second was that technologies, such as Web 2.0 tools, are emerging and rapidly expanding and therefore the only realistic way to remain current and knowledgeable with these technologies is through a process of continual learning.

Based on these educational philosophies the course focused on collaboration and its significance to learning. An emphasis was placed on constructivist learning approaches that leveraged Web 2.0 online collaborative learning environments to enhance classroom-based education. Overall the first author of this paper observed that students understood the significance of online collaboration to education, however, the sociofugal configuration of the classroom worked to counter the idea of collaborative learning. Although the students began to embrace the power of online collaborative learning, when they were asked to engage in team-based projects in the classroom, the traditional sociofugal arrangements (the hidden curriculum) communicated to them that collaboration was not the focus of the course. Furthermore, the constrained configuration of the computer workstations prevented the online resources (technology) from becoming an integral component of the learning.

*Team Collaboration:* Observing students within the class, it became apparent that most were uncomfortable while working in teams to complete collaborative projects. Introducing a team-based project to the students was typically met with less than enthusiastic approval. Furthermore, student evaluations of projects appeared to drop when diversity (instructor selected teams to promote cross-disciplinary diversity) was used to make team assignments.

Group size for projects was typically between five and six. As team members worked to complete the project it was evident that the sociofugal ecosystem had a significant impact on the group dynamic. Figure 3 provides an illustration of how students arranged their chairs to engage in group activity and discussion. This illustration is drawn to scale providing a clear picture of the crowded nature of the workspace when arranged in teams.

Furthermore, it was observed that this crowded arrangement completely removed the computer from the center of the discussion and activity. Despite the fact that the students were being asked to work on projects that integrated technology, the sociofugal configuration of the room prevented them from gathering with the computer (technology) at the center of the team discussion. In this atmosphere it appeared as though the technology was quickly removed from the focal point of conversation.

Additionally the sociofugal arrangement of the furniture reduced the peer-to-peer leaning in the classroom. Figure 4 provides an illustration of how direct observations of each others' computer monitors and subsequent peer-

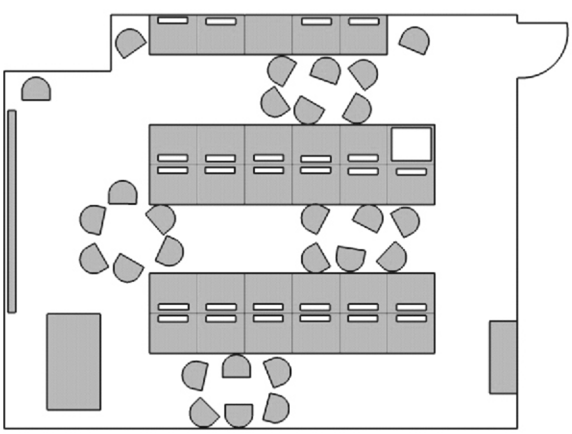

Figure 3. Observations of group activity in sociofugal CAHS computer laboratory (image to scale)

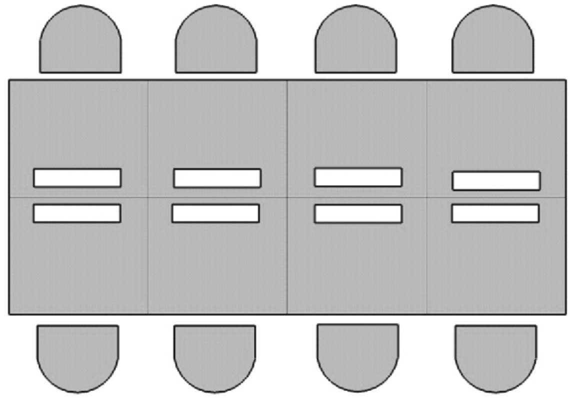

Figure 4. Typical workstation arrangement and impact on peer-to-peer learning

to-peer learning was limited to adjacent classmates. The back-to-back arrangement of the desk and the height of the computer monitors on the desks eliminated cross-desk communication. A frequent observation was that students typically worked in pairs to assist and learn from each other. This led to the isolation of some students who could have benefited from more peer-to-peer learning.

*Findings: Outside the College of Applied Human Sciences*

After conducting observations on the College of Applied Human Sciences computer laboratories, and reflecting on the Sociofugal nature of these learning spaces, the researchers investigated the other computer laboratories on the Colorado State University (Fort Collins) campus. There were 40 teaching and learning computer laboratories, but only two were arranged in a sociopetal arrangement. Both of these laboratories were located within the Center for Science Mathematics and Technology Education (CSMATE). The two CSMATE laboratories were deliberately called experiential learning studios to reflect the idea of a shared collaborative learning space. Figure 5 provides an illustration of the CSMATE workstation configuration. Four desktop computers were clustered together allowing for ease of communication and collaboration. The computer monitor was recessed within the desktop and was viewed through a glass tabletop panel. The recessed monitor allowed the student to communicate directly with one another from the seated position.

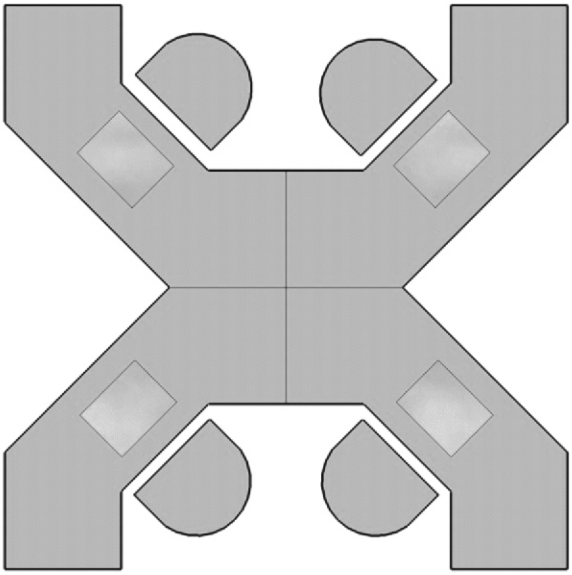

Figure 5. CSMATE sociopetal computer workstation arrangement

## Discussion and Conclusion

In the twenty first century information is no longer scarce. It is no longer sufficient that we teach students to build stockpiles of knowledge and information. We need to find ways to engage them with information acting quickly to solve problems. With the reduction in information half-life and ubiquitous access to information through knowledge communities, those that enter the creative class (new global middle class) will be those that can convert newly acquired knowledge into practical solutions and innovations. These new skills will require students to build both virtual (online) and local communities in an effort to succeed.

Making this shift will require us to look at all aspects of our outmoded industrial-based education system, including the impact that traditional sociofugal classrooms have on student learning. The authors feel that the hidden curriculum of computer laboratories communicates extremely strong counterproductive messages to students. It is also believed that placing students in rows and the instructor at the front of the room with a lectern and large screen communicates that the information and knowledge resides within the instructor. This clearly communicates to students that passive listening is the most valued activity. Furthermore, arranging the furniture in sociofugal arrangements and forcing them to meet in less than optimal group configurations, clearly tells students that collaboration is not important and not valued within the classroom. The authors have observed that these non-verbal elements of the curriculum make it extremely difficult on instructors who are attempting to encourage these important 21st century learning skills.

The authors suggest that those who are considering the design of a computer laboratory, to look for Sociopetal furniture layouts that allow students to engage in group activity. Suggestions may include circular layouts that would allow five to six students with laptops to meet and discuss project work. These round tables should provide connectivity to the Internet allowing the computer to remain at the center of the discussion. This configuration may include a projector that allows each student to project their computer screen image onto the center of the table. Furthermore, the instructor lectern and large format computer screen should be minimized or eliminated. This type of ecosystem would more clearly communicate to students that collaboration and peer-to-peer leaning is vital to them in the class and provide them with a glimpse of how they can succeed in a world dominated by those that collaborate to create.

It is outside the scope of this paper to discuss or examine in detail the suggestions for sociopetal arrangements for computer labs. It is suggested that additional research needs to be conducted on different types of arrangements and the effectiveness of each to assist in student engagement and learning.

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