AC 2008-257: A DUAL-MODE/DUAL-WORKSPACE CLASSROOM ENVIRONMENT

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A Dual-Mode/Dual-Workspace Classroom Environment

Abstract

As "hand-written notes" and "personal narrations" are the most natural tools to record, review, integrate and develop our own learning process, this article describes a collaborative learning and teaching environment integrating the use of Pen Tablets and multimedia technologies at the student/teacher level with the goal of achieving active learning for students in the classroom. An innovative hardware and software integration of the PCI NetSupport Manager Suite, TechSmith Camtasia Studio and Wacom Pen Tablets was implemented to provide both "teacher-centric" and "student-student collaborative" modes in this classroom. Students were also provided with dual graphics displays allowing the student to use one display for his or her personal workspace, while the second display could be used to view/share information with the instructor's desktop, or to share into other students work during collaborative sessions. This project was started in mid-August 2007 and assessment results are presented in this article for Fall 07 and the early part of Spring 08.

Introduction

One of the thrusts for our Biological and Agricultural Engineering Department curriculum is to promote the active learning aspects for our engineering students during classroom lectures as well as during laboratory experiments needed for the course[1]. Based on student technology fees, departmental and collegial funds, two collaborative classrooms were created. Classroom A currently has 35 workstations for students and a teacher station connected to an isolated 1.0 Gbps LAN, while Classroom B is similarly equipped but with only 12 student workstations. In both classrooms, the desktop PCs are equipped with specialized software to allow synchronous collaborative interactions between teacher-students and student-student for in-class projects, as well as for receiving classroom instructions from experts located outside the campus via videoconferencing technologies. Starting in Fall 2005[2], we incorporated the use of a Tablet PC by the teacher in developing hand-written materials that are best created during class time, such as deriving computer algorithms interactively with student inputs, going over solutions to quizzes, tests or review sessions. This Tablet PC was also used to directly control remote lab equipment and to send its "apparent" desktop, along with hand-written annotations, to the student PCs thus allowing the students to "see" the operation of the remote lab equipment as well to operate the remote equipment by proxy via the Teacher Desktop Station (see Fig. 1). From this experience, it was apparent that the student PCs were "closed boxes from which information can be published or into which information can be drawn, but they are not able to interact spontaneously with other closed boxes"[3]. Furthermore, for more active on-line learning, Boettcher[4] noted the rise of "performance content that is generated spontaneously in the process of student learning", and applying this trend for face-to-face instruction results in a need to provide students more opportunities to develop course materials in concert with the instructor during class time, such as solving an optics problem or building a simulation model, and also to participate in other students work or just simply to take one's own class notes. Thus as personal "hand-written notes" and "narrations" are the most natural tools to record, review, integrate and develop our own learning process, we are continuing the existing project to include the use of Tablet PCs (or Pen Tablets with Desktop PCs on Windows Vista) and multimedia technologies at the student level with the goal of achieving more active and hopefully deeper learning for students in the lecture hall as well as in the laboratory. Barkley et al.[5] listed that "learning to

listen carefully, think critically, participate constructively, and collaborate productively to solve common problems are vital components of an education for citizenship in the twenty-first century". Thus to provide such a classroom environment for interactive and collaborative education and from our previous experiences in designing and teaching in such a classroom, it was concluded that we needed both a "teacher-centric" architecture to deliver materials from teacher to students, and also a "collaborative e-chalkboard" where students could post individual works to be contrasted side by side by the teacher and/or to be collaborating with other class mates, because while "collaboration" is to be fostered to yield better subject matter comprehension and retention, student discipline and interest still need to be supervised in any real classroom.

Project Description

A. IT Architectures Chosen

De Souza[6] described three conceptual metaphors for computer-mediated multi-user communication:

1)   As a communication center, i.e. a central service provider attending to independent users' requests for various services (i.e. standard server and thin clients).

2)   As a virtual environment for more immersive or semi-immersive interactions among users (i.e. on line games).

3)   As a telecommunications device for one-to-one or one-to-many users applications.

Of course most multi-user applications do not adhere to a single metaphor, and currently there are several interactive instruction software that emphasize one or the other of the two aspects, "teacher-centric" such as "DyKnow-Vision" and "NetOp-School" while "GroupScribbles" and "TeamSpot" offer elegant collaborative solutions (this list is by no means exhaustive):

a)   DyKnow-Vision (UUhttp://www.dyknow.com/products/vision/).

b)   NetOp-School (http://www.netop.com/netop-8.htm).

c)   GroupScribbles (http://groupscribbles.sri.com/).

d)   TeamSpot (http://www.tidebreak.com/).

We believe that the architecture offered by GroupScribbles is the most elegant one, however right now it can only support the sharing of small Post-It type of notes and for real classroom teaching we need to be able to share regular windowed applications. TeamSpot is more oriented towards professional work environments so it does not yet have "student management" tools like in Dyknow Vision or NetOp School. For many years, our department had used the NetSupport Manager Suite ("Tutor" and "Control" in the company-recommended "teacher-centric" mode until we got introduced to "GroupScribbles" thanks to a webminar offered by the Hewlett-Packard Company at (http://h20325.www2.hp.com/blogs/highered/archive/2006/11/17/1948.html). This webminar made us realize that the 2 NSM tools "Tutor" and "Control" can be combined "innovatively" to provide both "teacher-centric" and "collaborative e-chalkboard" modes in an "undocumented" way with pen and audio technologies. Why "undocumented"? It was because the software

maker (NetSupport Limited) did not themselves envision for the software suite to be used in this manner.

Figure 1 described the IT architecture used for the BAE Interactive/Collaborative Classroom (Room 310) starting Fall 07 in its "teacher-centric" mode. The NSM Tutor (also commercially known as NetSupport School) deployment from the Teacher Tablet PC and Teacher Desktop PC to Student PCs was a "standard procedure" for interacting with students[7]. In the "teacher-centric" mode of our instructional system, the main task for the Teacher Desktop PC was to deliver lecture materials (i.e. the Teacher's Desktop view) to each student PC in their own application windows, thus allowing students to create their own personal notes using their Pen Tablets and the Windows Snipping Tool. The Teacher Desktop PC secondary task was to use TechSmith Camtasia Studio to record the Lecture materials along with the teacher narrations and other verbal interactions within the classroom. These Camtasia recordings could be processed into Flash movies and published on the UGA prototype BlackBoard Vista CMS system within 1.5 to 2 hours after classes for students to access 24/7.
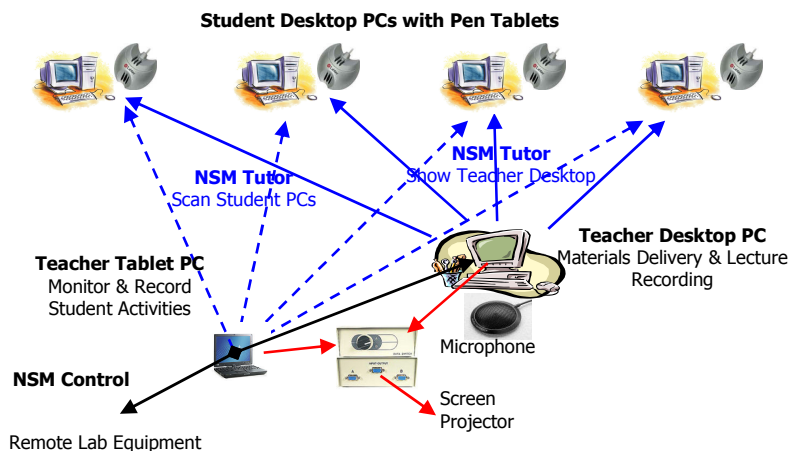

Figure 1. IT architecture for Interactive/Collaborative Classroom ("Teacher Centric" mode).

As its primary task, the Teacher Tablet PC also used NSM Tutor and Camtasia Studio but to monitor and record student activities by "scanning" their desktops sequentially for a given time period during each scanning cycle. These recordings were reviewed by the instructor at a later time to document the time spent "on-task" by the students and also to observe the problem-solving approaches used by students during planned independent problem-solving activities. The Teacher Tablet PC secondary task is to "activate" the NSM Control tools on selected student PCs as part of the sequence to get our instructional system into the two "collaborative" modes to be described in details below.

For the first mode, called "collaborative community work", Figure 2 described the IT architecture to deploy the NSM Control tools on the student PCs in order to let them access the Teacher Desktop PC, essentially serving as an E-chalkboard, where the community work would be realized. There were several steps needed to establish this mode of operation:

1. The instructor started the process on the Teacher Desktop PC by opening the needed application software where the community work would be performed from then on.
2. Via the Teacher Tablet PC, the instructor remotely executed the start of the NSM Control tools, on selected or all student PCs, which would appear on each student PC as a new windowed application.
3. On each student PC, this NSM Control application window was configured to contain a single icon corresponding to the Teacher Desktop PC and it would be entirely up to the student to want to connect to the Teacher Desktop PC in order to contribute to the community work or just to watch the community work unfolding on a large projector screen in front of the class (see Fig. 2).
4. Then, if the "contributing" student double-clicked on the Teacher Desktop icon, a new application window would pop up, showing the contents of the Teacher PC Desktop. At this point, the "contributing" student would be sharing into the Teacher PC desktop via his or her local keyboard and mouse/pen, and he or she could also resize this window as needed in order to contribute efficiently to the community work in progress.
5. However there is a limit of 10 simultaneous student connections imposed by the Windows Vista Operating System, thus when some students had finished with their contributions, they would need to disconnect so as to allow other students to have their turns to contribute.
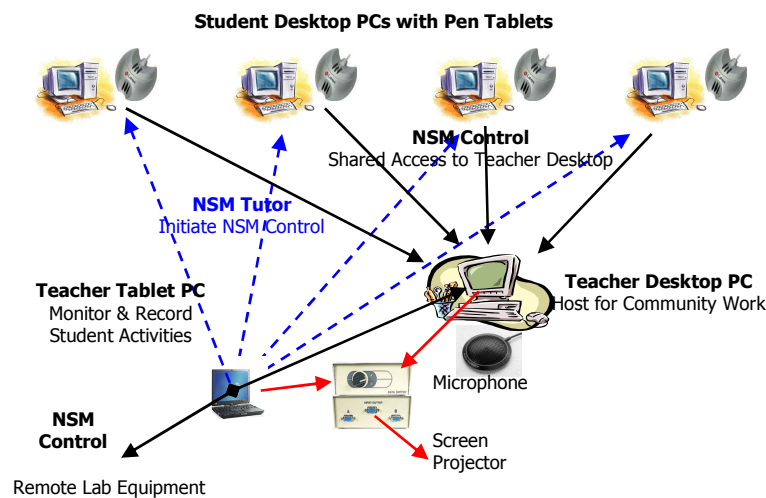

Figure 2. IT architecture for Interactive/Collaborative Classroom ("Collaborative Community Work" mode).

The second "collaborative" mode allowed "student initiated works" to be modified by the rest of the class in the following manner (see Fig. 3):
1. Let's say that the class was divided into Demo Students who were willing to showcase their current works and Contributing Students who were willing to offer constructive features to the works being shared. The instructor would start the process on the Teacher Desktop PC by using NetSupport Tutor to "View in Share Mode" each of the Demo

Students PCs.   This action would result in the creation of several application windows on the Teacher Desktop PC, each window corresponding to the Desktop of each "Demo Student" PC.   .

2. Next, via the Teacher Tablet PC, the instructor remotely executed the start of the NSM Control tools, on all Contributing Student PCs, which would appear on each Contributing Student PC as a new NSM Control application window.

3. Similarly as for the first "collaborative" mode, this NSM Control application window was configured to contain a single icon corresponding to the Teacher Desktop PC and as before, it would be entirely up to the student to decide to connect to the Teacher Desktop PC in order to contribute to the Demo Students' works.

4. Then, if the Contributing Student double-clicked on the Teacher Desktop icon, a new application window would pop up, showing the contents of the Teacher PC Desktop. At this point, the Contributing Student would choose which Demo Student's desktop, i.e. which application window already created by the Teacher in Step 1, to work with. He or she can then contribute to the chosen Demo Student's work via his or her local keyboard and mouse/pen. Of course, the same limit of 10 simultaneous student connections imposed by the Windows Vista Operating System still applied as before.
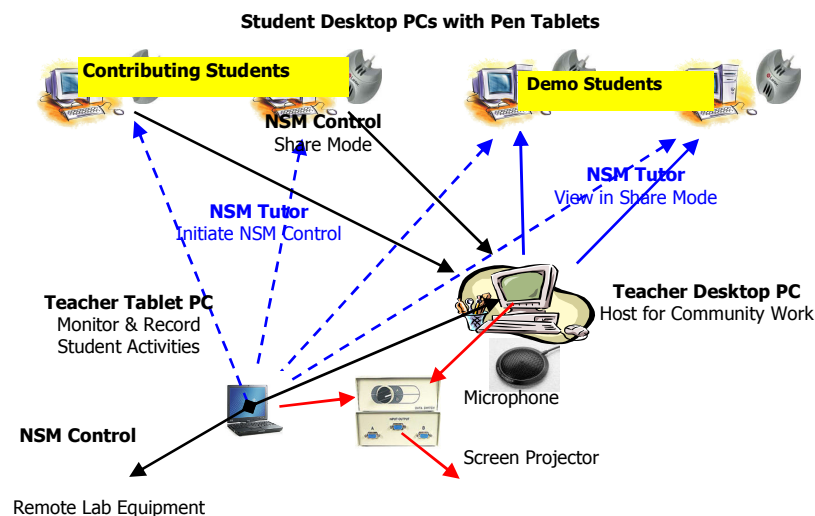

Figure 3. IT architecture for Interactive/Collaborative Classroom ("Student Initiated Work with Class Contribution" mode).

In this second "collaborative" mode, the Teacher Desktop PC acted more like a "switch-board" switching in and out the Demo Students' desktops while maintaining its "host" capability for Contributing Students' PCs as in the first "collaborative" mode.

The reader can access narrated recordings of a demo session from 3 points of view: Teacher Desktop PC, Teacher Tablet PC, and Student PC at the following web site: http://www.engr.uga.edu/people/thai/BAE310-F07.htm.

This new instructional system was designed to make the Teacher Desktop PC become a "common learning space" where any student can put up (or withdraw) their works there, when

and if they want to do it, allowing much more natural behaviors. One benefit was that the Teacher could compare several student works "side-by-side", although up to the 10-connections limit imposed by the Windows Operating System and as much as the resolution of the Teacher PC Desktop allowed. Here the desktop's resolution used was limited by the multimedia recorder tool Camtasia Studio to 1024x768 to keep the 75-minute lecture recordings at reasonable file sizes. The truth is that 10 concurrent students were really more than any single instructor could handle at any one time. Another benefit was that each student could annotate the other student's work being "shown", resulting in a more flexible "collaborative" tool than the standard (and more lengthy) procedure of using the "Show Leader" or "Exhibit" tools as originally recommended by the software manufacturer NetSupport Limited. Each student could also create their own notes using the Pen Tablet and the Windows Snipping Tool from Vista and save them in a variety of file formats (HTML, JPG, etc…).

B. Other Implementation Details

We preferred to use USB-Port Pen Tablets over Tablet PCs because they were cheaper to buy and maintain and allowed us to use our existing desktop PCs while the mobility features of Tablet PCs were not needed in our case as we were bound to the classroom space. We also had to upgrade to Windows Vista as it is the only OS that would allow full digital ink capabilities for Pen Tablets on desktop PCs.

At first, we planned to use personal microphones on all student PCs for audio communications as an "undocumented" feature was uncovered during our experimentations with NSM V.9 whereas we could achieve voice conferencing capability for "free" at the Teacher Desktop PC. However V.9 did not work with Windows Vista and when we updated to V.10 for Vista compatibility, we had found that the Audio tool no longer worked properly (NetSupport Limited acknowledged this problem but they had not provided any solution up to now). Thus our next plan is to drop omni-directional microphones from the classroom ceiling and use analog mixers to bring all audio inputs into the Teacher Desktop PC audio input for Camtasia recordings. Currently, the instructor has to repeat the students' questions in order to have them recorded in Camtasia Studio audibly.

Assessments for Fall 07

This classroom was used in the Fall 07 semester to teach Simulation with Discrete-Events and Continuous-Time models with 10 students and all hardware and software functioned as designed.

0n 8/16/07, students used the Learning Style Assessment tool available at the University of Arizona Learning Center (http://www.ulc.arizona.edu/learning_style.php) to determine each student learning style, i.e. whether he or she was a Visual, Auditory or Kinesthetic learner and the results are shown in Table 1 whereas the highest score would indicate the main tendency for how that particular student would rather learn.

Table 1. Student Scores in Visual, Auditory or Kinesthetic Learning Styles (Fall 07).

Student	1	2	3	4	5	6	7	8	9	10
Visual	31	**35**	35	**31**	**41**	**35**	25	31	**39**	**35**
Auditory	33	27	25	25	27	33	**31**	**35**	21	**35**
Kinesthetic	**35**	29	**39**	29	37	33	**31**	32	25	33

There were 5 Visual learners, 2 Kinesthetic learners, 1 Auditory learner, 1 mixed Visual-Auditory and 1 mixed Kinesthetic-Auditory, and thus the majority of the students in Fall 07 were Visual learners.

A.   Surveys Results

Also during this semester, we had done 2 surveys (in September and November) and had used the student tracking tool in our course management system (Blackboard Vista) to understand student usage of the published class contents.

Survey 1 was given on 9/25/07 and 7 out 10 students answered this survey having the following 8 questions and using a 6-point Likert scale where "StD" meant "Strongly Disagree", "D" meant "Disagree", "SlD" meant slightly disagree, "SlA" meant "Slightly Agree", "A" meant "Agree" and "StA" meant "Strongly Agree":
1. In-class course materials delivery methods were effective.
2. I understood the materials presented during in-class lectures.
3. Materials presented via PowerPoint slides were effective.
4. The Pen Tablet was an effective tool to take notes in class.
5. Sample models presented via Arena software were effective.
6. Recorded lectures were easily accessible.
7. I felt comfortable going through recorded lectures.
8. I understood the materials presented in recorded lectures.

Student responses to Survey 1 are shown in Table 2. Although results from Question 1 showed that in-class delivery methods were mostly effective, results for Questions 2 and 8 clearly showed the benefit of the availability of the recorded lectures with Question 8 scoring higher than Question 2. The author has seen this pattern repeated in his other courses on Introductory Java Programming. The interesting fact to point out was that the recorded lectures were just straight unedited recordings of the classroom activities, but somehow the students felt that they understood the materials in the recorded versions better, perhaps because it would be the 2nd time that they would see and hear the materials, and perhaps the "timing" of the review was more conducive to their learning processes as they were "ready" to deal with the materials, and also they could pick out only the needed information as many times as needed, all of which not possible to achieve during the actual lectures.

Table 2. In-class & Off-Line materials effectiveness (Survey 1 results).

Question #	"StD"	"SlD"	"D"	"SlA"	"A"	"StA"
1				3	3	1
2		1		1	4	1
3		1	2	2	2	
4	3	3	1			
5				1	1	5
6				1	3	3
7				2	3	2
8				1	3	3

The PowerPoint slides were derived from a set provided by the Arena book publisher and the effectiveness of the PowerPoint slides used was mixed (Question 3). Students definitely did not like to use the Pen Tablets (Question 4) - perhaps this was linked to the fact that most students were "Visual" rather than "Kinesthetic" (see Table 1). One student actually declared that the Pen Tablet was "alien" technology. This resistance may be due to the fact that all students were using the Pen Tablets and the Windows Vista Snipping Tool for the very first time. Other students also expressed unfamiliarity with the operation of Windows Vista which may contribute to this resistance. Reviewing the Tablet PC recordings of the in-class "scanning" of students desktops showed that some were looking at the PDF version of the PowerPoint slides as posted on the UGA Course Management System web site, while others were going through the sample Arena models themselves, or just were doing other tasks unrelated to the course. It also must be recognized that the software needed in our course was not designed to exploit the full capabilities of the Pen Tablet as they were created with keyboard and mouse in mind.

Results for Question 5 clearly showed that it was an effective pedagogical approach to teach Discrete-Event modeling concepts by using worked-out sample models facilitated by our computerized instructional system. Results for Questions 6 through 8 showed that our UGA Course Management System was also quite useful and effective.

Survey 2 was given on 11/29/07 and again 7 out 10 students answered this survey having the following 8 questions and using the same 6-point Likert scale as before:
1. In-class course materials delivery methods were effective.
2. I understood the materials presented during in-class lectures.
3. Materials presented via PDF/Word documents were effective.
4. The Pen Tablet was an effective tool to deliver materials in class.
5. Sample models presented via Stella software were effective.
6. Recorded lectures were easily accessible.
7. I felt comfortable going through recorded lectures.
8. I understood the materials presented in recorded lectures.

Please notice that questions 3, 4 and 5 were modified from Survey 1 as students already indicated that they did not care to use Pen Tablets in taking notes, and also the second part of the semester covered a different topic (Continuous Systems) using Stella software and the class

materials were then provided as PDF and Word documents created by the instructor. Student responses to Survey 2 are shown in Table 3.

Table 3. In-class & Off-Line materials effectiveness (Survey 2 results).

Question #	"StD"	"SlD"	"D"	"SlA"	"A"	"StA"
1				1	5	1
2			1	3	2	1
3		1	2	2	1	1
4	1	2	1	1	1	1
5		1			3	3
6	1			2	2	2
7	1			2	3	1
8			1	1	3	2

Responses to Questions 1, 2 and 8 were about the same, perhaps "gaining" by 2 responses for Question 1 and "loosing" by two for Questions 2 and 8. Responses to Question 3 were also about the same as in Survey 1 although the Stella "Notes" format were definitely less "professional" as compared to the PowerPoint slides used in the first part of the course. Nonetheless these results indicated that the course notes needed to be improved in the future. Regarding the Pen Tablet usage in delivering class materials (Question 4), at least 3 out 7 students now thought that it was an effective tool and perhaps because it just turned out that the Stella materials needed more ad-hoc hand-written notes (graphics and words) to convey Continuous Systems concepts (i.e. Stella) than when the Discrete-Event Systems concepts (i.e. Arena) were discussed at an earlier part of the course. Results for Questions 5 through 8 showed a reduction in perceived effectiveness of the Stella class materials, perhaps because more mathematical skills were now required of students than for the previous Arena part. Essentially a Continuous System model required the students to start from a given system behavior and work back towards a mathematical solution that would yield such a behavior, while a Discrete-Event System model was usually "cranked" forward and students just had to make sense out of whatever results were obtained. i.e. more "intellectual" feedback was required in creating Stella models than for Arena models.

Survey 2 also asked students about their frequency in using the 3 types of class materials provided: PDF/WORD files, Recorded Lectures and Example Models. These results are shown in Table 4.

Table 4. Off-Line materials usage frequencies (Survey 2 results).

Frequency	Regularly	Occasionally	Not At All
PDF/Word files	3	2	2
Recorded Lectures	2	5	
Example Models	5	2	

The results for "Recorded Lectures" were rather surprising, perhaps they were partially or wholly due to the fact that the prototype Blackboard Vista CMS tool (server in New York) did not

"stream" the recorded lectures as fast and as well as the current UGA CMS tool (WebCT 4.1 and local server at UGA), meaning that students could not just go back and forth to any section of the recorded lectures as they wished with Vista while they could with WebCT 4.1. The results for "Example Models" were very encouraging as it meant that most students did re-examine the behaviors of sample models **after** they had been explained in class.

Some of these "survey" results were also found in analyzing student tracking data as shown in the next section.

B.　　*Student Tracking Results*

On 9/20/07, the first test was given with the following results based on 10: 6, 6.8, 7.5, 7.5, 8.3, 8.5, 9, 9, 9.3, and 10 for an overall average of 8.19 and an obvious bi-modal distribution. On 10/11/07, the second test was given with the following results based on 10: 3, 4.5, 5, 5, 6.5, 7, 7, 7, 8.3, and 9 for an overall average of 6.23 (a drop of 2 points) and still showing an obvious bi-modal distribution. The final course grades were 2 A's, 1 A-, 1 B, 2 B-'s, 1 C+ and 3 C-'s.

Using the Tracking tool from the Blackboard Vista CMS, we computed the amounts of time spent by students perusing different types of files posted there and compared these values with the corresponding student test grades and other observations in class so as to detect any correlations and perhaps to discern possible learning styles for each student. There were 3 types of files available to students: Type 1 was PDFs containing PowerPoint slides and other instructor-prepared class notes, Type 2 was narrated classroom lectures or specially-made tutorials for specific purposes, and Type 3 was actual Arena or Stella model files. These time results (in minutes) are shown in Table 5 for the top half of the class and Table 6 for the second half.

Table 5. Time periods (minutes) spent on various file types for class TOP half and corresponding test grades.

Time Period	File Type	Student 1	Student 2	Student 3	Student 4	Student 5
8-16 to 9-21	**All**	543	82	27	75	30
	1	108	54	8	41	27
	2	3	2	*17*	*34*	0
	3	432	26	2	0	3
Test 1		**10**	**9.3**	**7.5**	**9**	**9**
9-22 to 10-11	**All**	88	28	362	23	90
	1	0	4	187	2	1
	2	0	0	*115*	0	*45*
	3	88	24	60	21	44
Test 2		**9**	**8.3**	**7**	**7**	**7**
10-12 to 11-16	**All**	80	90	75	36	41
	1	79	40	12	30	35
	2	1	0	*63*	0	1
	3	0	50	0	6	5

Table 6. Time periods (minutes) spent on various file types for class SECOND half and corresponding test grades.

Time Period	File Type	Student 6	Student 7	Student 8	Student 9	Student 10
8-16 to 9-21	All	95	158	41	160	10
	1	144	139	12	52	4
	2	*51*	*11*	1	*16*	6
	3	0	8	28	92	0
Test 1		**6**	**6.8**	**8.5**	**8.3**	**7.5**
9-22 to 10-11	All	49	41	45	75	20
	1	20	0	0	0	0
	2	11	*10*	0	*17*	1
	3	18	31	45	58	19
Test 2		**6.5**	**5**	**5**	**4.5**	**3**
10-12 to 11-16	All	33	99	43	78	90
	1	32	71	33	38	58
	2	1	*27*	9	*37*	*11*
	3	0	1	1	3	21

Tables 5 & 6 showed only Students 3, 7 and 9 reviewed the recorded class lectures regularly, while the rest were occasional reviewers only. It is interesting to contrast these results to the ones from Tables 2 and 3 where the students mostly agreed that the recorded classroom lectures constituted a useful resource, however they did not use it regularly. The top student (1) practically did not use the recorded lectures at all, but preferred to use the PDFs and model files, however this student was active in class, but did not take much class notes, so it seemed that this student must have very good visual and auditory memories, and seemed to learn more by reviewing text notes and practicing with actual simulation models. Overall there seemed to be no trends between the two halves of the class regarding total times spent reviewing materials posted on Blackboard Vista. However individually, students 2, 7, 9 and 10 definitely switched gear after Test 2.

Conclusions and Current Work

Recent multimedia and computer technologies allowed the design of a classroom that exhibited both "teacher-centric" and "E-collaboration" characteristics by using the NetSupport Manager (NSM) suite. Although NSM was a "teacher-centric" design, it's "Tutor" and "Control" tools were creatively recombined to provide both aspects. A more affordable access to pen technologies was possible by using existing desktop PCs equipped with Pen Tablets instead of the more expensive Tablet PCs. However so far students had shown resistance to using this technology, thus in the future we plan to spend more time at the beginning of the course for student training in using Pen Tablets and related note-taking software in Windows Vista. Another explanation could be that so far we dealt with mostly "Visual" learners who preferred to "watch" the "shows" being performed by the instructor rather than taking personal notes (actually one student mentioned that he just could not listen to the lecture and took notes at the same time). However, the instructor had found the use of the Pen Tablet indispensable for

delivering flexible and targeted course materials during and after class lectures. Also as a point of introspection, the current class materials were created by the instructor during a time when the "teacher-centric" mode was the only one available in the classroom, thus these course materials will need to be revised to include more collaborative opportunities.

During the break between Fall 07 and Spring 08 semesters, we had performed a limited experiment whereas one student PC was equipped with Dual Graphics displays so that the student could use ONE display for his or her "PERSONAL WORKSPACE" while the SECOND display was used for the teacher to send over the materials shown on the Teacher Desktop in the Teacher-Centric Mode, or to be used by the student to remotely share into the Teacher Desktop when the class was in Collaborative Mode (see Figures 4 and 5). This approach received good acceptance from the testing student, thus equipment had been installed so that Dual Graphics displays can be deployed for all student PCs this Spring 08 semester when a course on Applied Machine Vision is currently being taught.
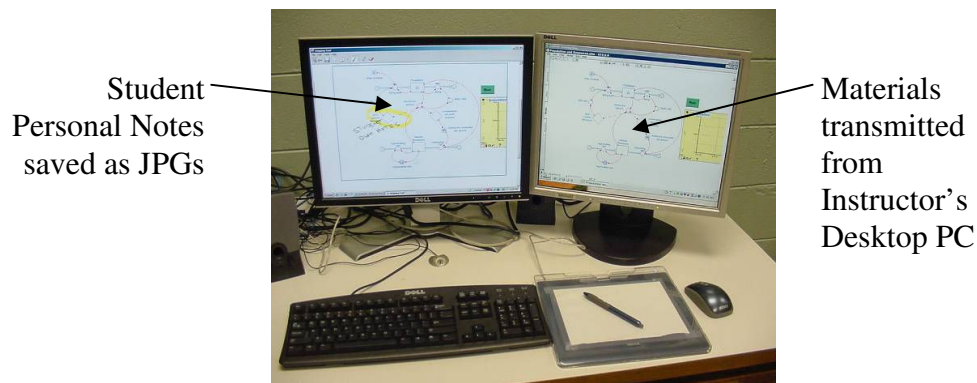

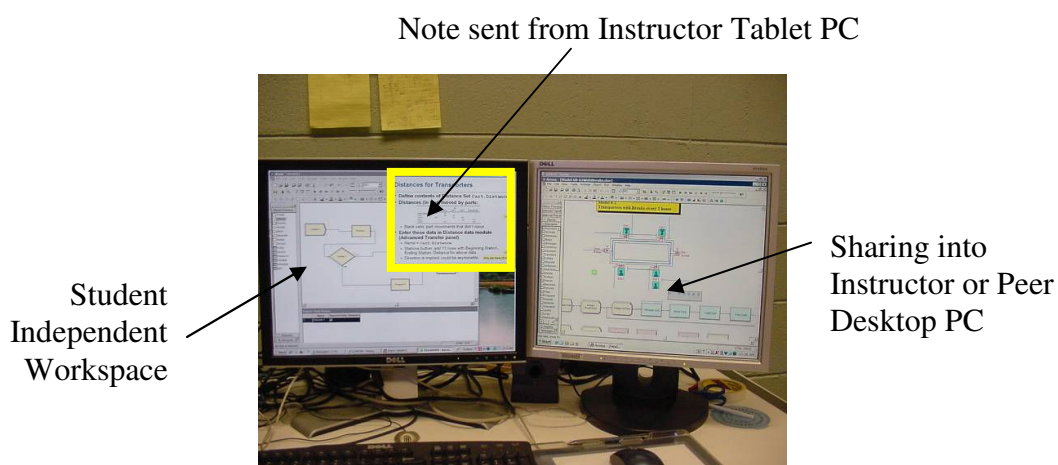**Figure 4. Student creating personal notes within Dual-Workspace environment.**

Figure 5. Student own workspace (left display), instructor or peer student workspace (right display) and instructor note (upper right corner of left display).

Potential beneficiaries of this type of facility are teachers and students in courses where instructor and students can access their own computers allowing the following features:

1. Courses needing network access to remotely located lab equipment during lectures or emphasizing the development of problem-solving skills in students that can represented with graphics and hand-written annotations.
2. Increased student interests and interactions in classroom lectures are expected and students are empowered in generating richer and personalized multimedia notes and sharing their solutions with peers as lectures and labs are merged seamlessly.
3. 24/7 access to recorded classroom activities via the web is enabled for students to do reviews at their convenience.
4. Teachers and administrators can also use classroom recordings to evaluate instructor's effectiveness as well as to understand student behavioral and learning patterns during class.

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