AC 2009-879: USE OF TABLET PCS TO GENERATE CLASS DISCUSSION AND FACILITATE DEEPER UNDERSTANDING

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He was Chairman, IFIP TC-6 (International Federation for Information Processing Technical Committee on Data Communications) 1985-91. He founded and from 1979-1985 he chaired WG 6.5, the Working Group on Electronic Messaging of IFIP TC-6, and is one of the “fathers” of email. He was President, International Council for Computer Communication (ICCC), 1992-96.

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With co-authors David J. Farber and James Bair, he was lead author of the first book on Office Automation, "The Office of the Future", North-Holland, Amsterdam, 1979 and he published the first popular paper on email (Datamation, 1977).

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Use of Tablet PCs to Generate Class Discussion and Facilitate Deeper Understanding

Abstract:

At ASEE 2008, we reported encouraging results from our use of Tablet PCs in teaching complex information structures in wireless engineering and network security classes. In recent years there have been a number of similar studies on the use of Tablet PCs in the higher education classroom and their impact on teaching and learning. Most, if not all, report that learning is enhanced when tablet PC's are employed to increase interaction between students and instructors and among students.

A common approach in keeping students engaged and interacting is by periodically broadcasting questions to students and having them send their responses anonymously to the instructor. All or selected answers are then shared with the class in order to generate discussion. In this paper we will specifically focus on this mode of utilizing Tablet PCs in an undergraduate Computer Science Data Structures course to study the impact and benefits of this facilitated discussion in terms of students' deeper understanding and improved learning of the lecture material. We will report both quantitative data that show improvements in scores on exams, and we will provide examples of specific exercises given in class, along with students' answers.

In addition, we will report on students' perceptions of the impact of this mode of teaching on their ability to learn. This will be based on analysis of questionnaires completed by the students, and comparisons of results for this undergraduate computer science class with results from graduate wireless communications classes. The graduate student surveys yielded an average score of 4.21 out of 5 points on the positive impact of the interactive use of Tablet PCs on improving learning. We also provide some comments made by graduate and undergraduate students.

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Introduction:

Microsoft PowerPoint slides are still considered to be among the standard tools in modern lectures; as stated by many authors presentation slides help instructors prepare well thought out and organized lectures that can be distributed to students in either electronic or hardcopy format prior to start of class. Students can then concentrate on understanding the concepts while adding clarifying notes and comments on their copy of the notes. The integration of pen support for digital ink in more recent versions of PowerPoint on a Tablet PC has clearly helped address some of the limiting features and inflexibilities of this system, among them the inability of the instructor to adjust the lecture materials in response to students' reactions, to further develop examples and explanations on-the-fly, and to clarify and explain hard to understand topics. However, PowerPoint slides still encourage passive learning; since students aren't fully engaged and participating, the system does not facilitate interaction among students and the instructor. There are many other electronic delivery systems such as Classroom Presenter, DyKnow, MS Windows Journal, MS OneNote, and Ubiquitous Presenter that have been used to combine handwriting and slides on the PC and Tablets. This next generation of presentation systems such as DyKnow and Ubiquitous Presenter are interactive teaching tools that address this inherent lack of interactivity by enabling students to electronically respond to and interact with instructor during class activities and even take control of the system.

Among useful features of Dyknow Vision are private chat with the instructor, panel submission, and status reporting. For example, a student could send a message to the instructor to go over a specific topic or work through a homework problem. An instructor can periodically send a request to students to update their status and indicate how well they understand the lecture; the system is capable of tabulating the aggregate data received and presenting it graphically to the instructor for possible dynamic adjustment of the lecture. Many educators have experimented with these interactive teaching tools and the unanimous agreement is that Tablet PCs combined with interactive teaching tools increase student participation and facilitate improved interaction. Koile and Singer[1] reported that interactive presentation tools increased student attentiveness rates and provided immediate feedback to both students and the instructor about student misunderstandings. This enabled the instructor to adjust the lecture dynamically to better respond to student learning needs. One commonly used mode of operation for engaging students with Tablet PCs is to ask students to solve a problem or respond to a question posted by the instructor during the class. Students can send their solution to the instructor wirelessly and have it examined and corrected immediately and possibly shared with the rest of the class for further discussion. This is a form of peer learning and the discussion facilitated by the instructor can further encourage students to probe deeper into the concepts to increase deeper understanding and to avoid misunderstanding.

System description:

Each student in a computer science Data Structures course is given an HP Tablet with the Windows XP operating system. The DyKnow client application for interactive teaching is installed on the machines. The classroom is equipped with wireless access points that provide network connectivity among the machines as well as Internet access to the DyKnow server. At the beginning of each session the instructor starts a new session and uploads prepared lessons along with classroom activities onto the server; students log on to the live session and remain synchronized with the instructor's machine. DyKnow provides features such as use of Microsoft digital ink, chat, anonymous polling, student annotation of screens with their own notes which they can save at the end of the session, and content broadcasting. DyKnow enables students to share their work with the class and collaborate with other classmates to solve problems.

Data structures class:

Our Data Structures class is among the foundational courses for baccalaureate level computer science majors. The course covers standard data structures routinely used in computing applications. Some focal points of the course include developing an understanding of the containers for organizing and storing information along with the algorithms that operate on them. The standard structures to be studied are Lists, Queues, Stacks, and Tree structures and the algorithms that work on them. Often students misunderstand an algorithm or don't quite understand the underlying structure's properties; this generally leads to incorrect solutions. National University was among the recipients of a 2007 HP Technology for Teaching – Higher Education grant. As a result of receiving this grant the Data Structures course was revised to incorporate the use of Tablet PCs in the classroom. In particular, integrating DyKnow enabled the instructor to broadcast activities from the instructor's display to students and anonymously collect their answers. This allowed the instructor to preview all submitted solutions and then show selected student work to the whole class for further discussion and clarification. This created a learning environment that allowed the instructor to dynamically generate a real-time facilitated discussion about the key points that led to peer learning.

In class activities and interactions:

Early in the term a set of problems was designed to help familiarize students with the DyKnow system; these problems were simple and very general; they focused on using DyKnow features such as the status report, panel submission, and display control. DyKnow was used in almost all classes. Standard PowerPoint slides along with class activities were uploaded to the DyKnow server prior to the start of the class. Each student was loaned a Tablet PC for the class period. At the beginning of the class students logged on to a DyKnow session to access the lecture notes. Although DyKnow allows students to scroll back through charts presented earlier during the lecture, students were asked to remain synchronized with the instructor's display throughout the class. A one-click DyKnow command takes care of this. Sample activities and a summary of the discussions generated as a result of the activity are described next.

Insertion into a list

In one class activity student were asked to describe how they insert an element into an array based implementation of a list structure. Here the instructor's objective was to make students think about the amount of "work" that is involved in inserting an element into an array. Almost all students' responses were similar to the one seen in Figure 1a. Most students presented a sketch of an insertion algorithm; although correct, no one really elaborated on details of what is involved in shifting the elements. This prompted a discussion on how we could go about shifting the elements in an array through a simple loop and the best way to define and quantify "work".

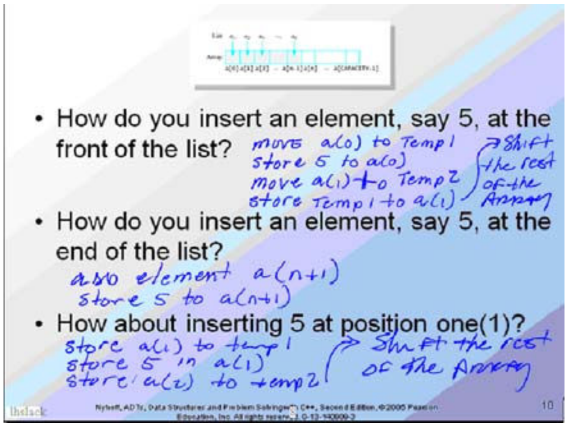

Fig.1a
Answers are correct but not elaborated. There is no hint of the work that's involved in the insertion

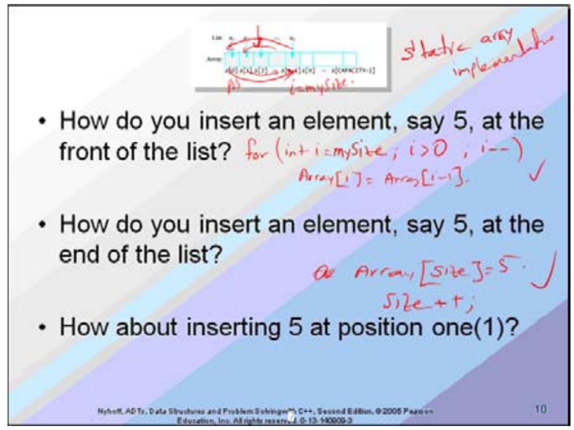

Fig. 1b
The code for shifting is presented. The code can be used to discuss the work done by the algorithm

Once students grasped the concept of work involved in shifting of array elements their focus immediately changed to how to reduce this effort. One student suggested placing the current value of the position at the far end of the array (after the last element) then putting the new element in its place. This would save a lot of time; however it would not be satisfactory if the array were to remain sorted. Student engagement and participation was very high during the discussions and the interactive nature of the presentation system allowed the instructor to dynamically steer students towards the objective of the activity and further refine and deepen student understanding of the material. The instructor was able to sketch diagrams, and provide solutions spontaneously in real time, thus engaging and promoting student directed learning through a creative, interactive and dynamic process.

Assignment operator

In another activity the instructor's objective was to assess students' understating of why the assignment operator should be overloaded in structures that use dynamically allocated memory. By looking at the students' submissions, the instructor received immediate feedback on actual understanding or misunderstanding of the students. Each of the slides in figure 2 prompted the instructor to pose more questions based on the student responses; the discussion expanded into shallow vs. deep copying. This activity was designed to be minimal with no elaboration; the graphics in figure 2b are the type of answers the instructor was looking for. Denning, Wilkerson el at[2] indicate that students tend to elaborate on minimally required answers, as demonstrated in figure 2. They continue to remark, that such elaborations are pedagogically desirable for further exploration of the problem and the follow up discussion points facilitated by the instructor.

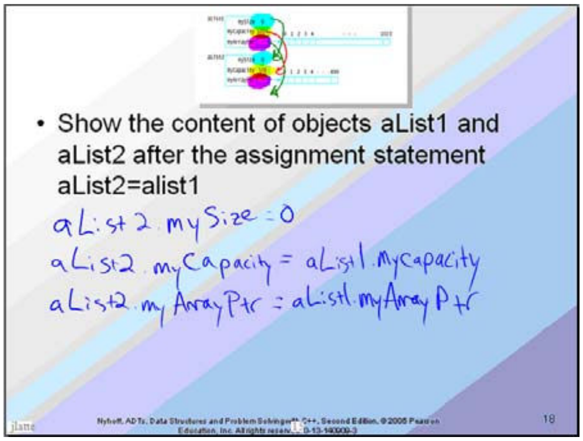

Fig. 2a
Students were asked about the implications of the last line of code in this slide. The instructor discussed the implications and consequences of shallow and deep copying

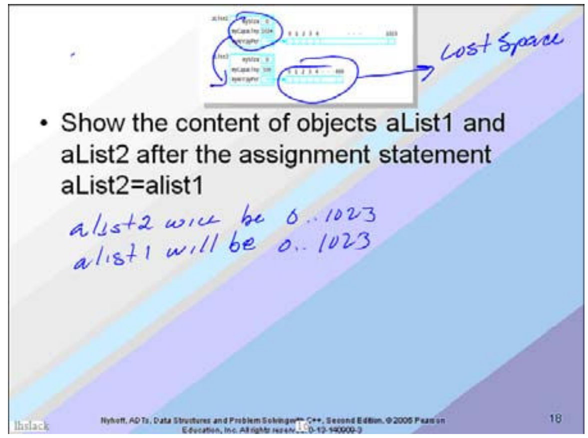

Fig. 2b
A brief, but correct response. This student used both graphics and text to summarize the impact of shallow copying.

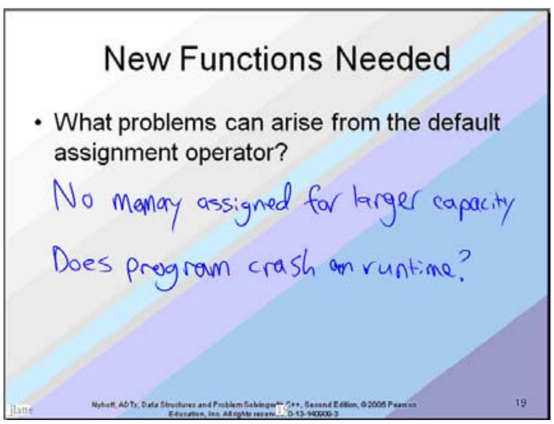

Fig. 2c
Student submitting this slide appears to be lost and needing directions. Nevertheless he is raising an interesting question about the system crashing.

Linked list

Most structures in a computer science course have a linked implementation, thus it is essential for students to have a good grasp of pointers. In one activity the instructor asked students to delete a node from a linked list. This requires some pointer reengagement; however the order in which the pointers are rearranged is the key to correct operation. The pointer *ptr* is pointing to the node preceding the node to be deleted. This is a routine process and should be well understood by the students. Fig 3a shows two submitted slides. In both cases the order in which the step are taken for deletion is incorrect. These and other slides generated many useful discussion points. In the case of figure 3a a few students immediately picked out the errors in the code. The instructor guided students through the code and demonstrated why the code would not work. Enabling students to make a connection between new concepts and their implementation in a programming language is an important task in computing education; this was clearly the case in the discussion that followed the slides in which the visual representation of the solution was tide to the code. This is routinely done in a class such as data structures.

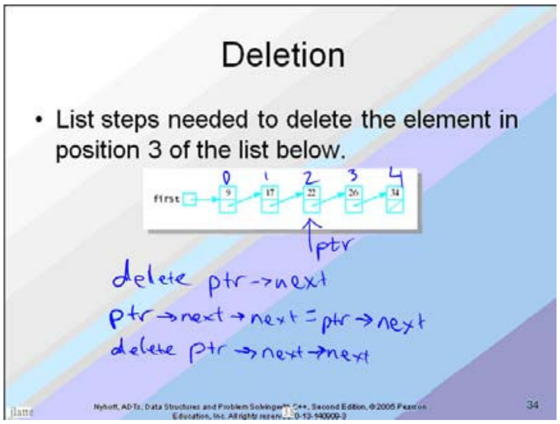

Fig. 3a
Student is rearranging the pointers out of sequence.

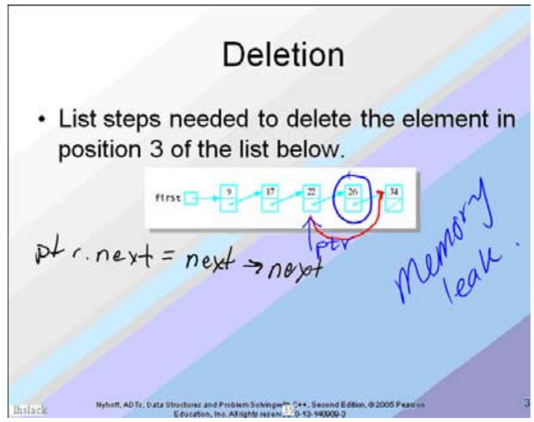

Fig. 3b
The list is updated, however the node is not returned to the system. Memory leakage.

Heap Structure

In the next activity students were asked to insert a key into a heap structure. The objective of the instructor here was to force students to think about the heap structure and work through a seemingly simple algorithm. Although all the students indicated that they understood the algorithm, a good portion of them failed to correctly demonstrate the insert algorithm (see the sample submission slides in figure 4). This is another good example of where the student response helped the instructor to spontaneously digress from the planned lesson to take advantage of the information received from the student submissions. An important part of lecturing is adjusting material in response to audience reactions and developing spontaneous examples and explanations to clarify and expand on topics. Surprisingly one student sent the slide shown in figure 4.1. Unlike other submissions the student had decided to use the array representation of the heap which was very interesting in itself, since the tree representation is more intuitive and more common for discussions. This prompted the instructor to ask students to recall the formulation for the left child, right child and the parent node in an array implementation of a heap. Furthermore, the heap constructed by the student turned out to be a minimum heap; however maximum heaps had been the focus of discussion in the class. This enabled the instructor to discuss the minimum heap property. In another activity students were asked to follow the insert algorithm to enter an element into a heap. One submission clearly indicated that the student had not followed the discussion of the insert algorithms and simply used a Binary Search tree insert algorithm. The interactive slides were highly useful in generating discussion around student misunderstanding, misinterpretation and mix-up of structures and algorithms.

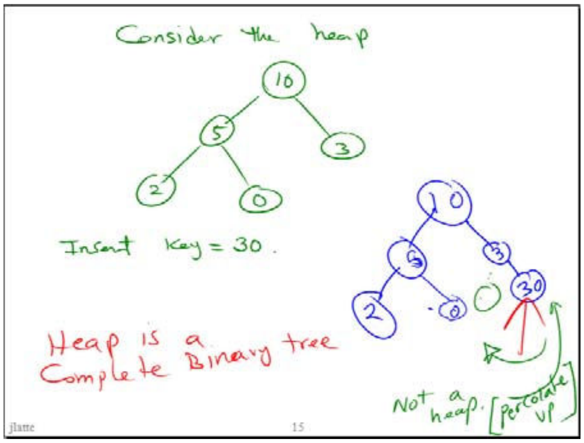

Fig. 4a
Student incorrectly used the binary search tree insert algorithm to add an element to a heap.

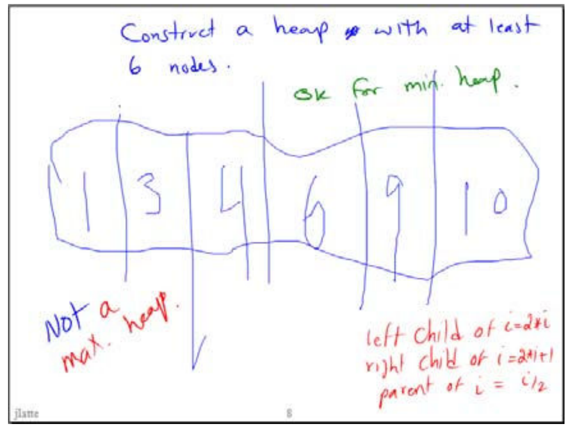

Fig. 4b
Student submitted the array implementation of the heap which raised a number of interesting discussion points

Impact:

Classes at National University follow a unique one month format; students take one course per month and have about 11 hours of class sessions each week. Naturally keeping students engaged for long hours requires well planned class activities and collaboration exercises. In the past, some instructors have used in-class open lab assignments to keep students involved and active, but this may not fully utilize the instructor since students work on their own on their assignments and periodically may ask the instructor individual questions. Although administering a class lab has some merit it may not be appropriate for every class session. The use of a Tablet PC with the DyKnow system is enabling the instructor to keep students engaged through panel submission during the entire class period. Furthermore, the system provides substantial opportunities for dynamic exchange of ideas and discussion among the students and the instructor.

We reported preliminary quantitative data at the ASEE 2008 Annual Conference[3] showing significant improvement in scores on specific examination questions concerned with complex information structures in a graduate course on Wireless Security in our Master of Science in Wireless Communications degree program. During the past year this measurement has been expanded to additional classes and more students. Identical question were used in the exams across all classes, but values were changed to ensure that students had not somehow gotten hold of an old exam and copied answers. Figure 5 shows our latest results. The figure shows that the number of students answering the specified questions correctly improved from an average of 18% correct answers on these five questions in October 2007 exams to a weighted average of 57% correct answers on the combined results of January 2008, July 2008, and January 2009 exams, when the students were first given real-time, in-class exercises to help them learn the concept to a greater depth. In addition, the overall weighted average of grades on the combined results of the January 2008, July 2008, and January 2009 exams improved by nearly 7.1% from 77.2% to 84.3%. Figure 5 uses October 2007 as a base with only nine students. Ideally, we would like to have had a larger number of students in the base. However, these results are so encouraging, that we have not been willing to penalize students by running a class without using the Tablet PCs, solely to increase the size of the base sample.

Impact of Exercises

Comparison of answers to five questions on mid-term exams – pre grant/post grant – Wireless Security Course – 4 classes

	% of Students Answering Correctly	% of Students Answering Correctly	% of Students Answering Correctly	% of Students Answering Correctly	Average Improve-ment
Description of Question	**Oct-07**	**Jan-08**	**Jul-08**	**Jan-09**	**Change**
Eselbrücke	22%	88%	95%	71%	63%
Use Vigenére Tableau	11%	81%	89%	72%	70%
Polynomial Representation	33%	75%	95%	94%	55%
Encrypt Short Message	11%	69%	88%	78%	68%
Cipher Block Chaining	11%	50%	40%	22%	27%
Average of the five Qs	18%	73%	81%	67%	57%
Number of Students	9	16	21	16	
Avg Grade overall	77.18%	84.10%	85.27%	83.06%	7.07%

Figure 5 – Quantitative Evidence for Impact of Exercises

All students in the sections of the undergraduate data structures class that utilized the Tablet PC and DyKnow were very impressed by the system and indicated that they would like to see it used again in other classes as well. The system promoted critical and innovative thinking and sharing with peers.

Student comments from both graduates and undergraduates were generally very positive; however a few comments pointed to areas where the way the Tablet PCs are used with DyKnow can be improved. For example, one graduate student complained that he did not have as much eye contact with the instructor, as in a more traditional class. Interestingly, some students appeared to have a hard time adapting to saving their class notes on the server. One undergraduate student indicated that the display was too small and he preferred an 8 x 11 page.

We conducted anonymous surveys in several classes in the Master of Science in Wireless Communications graduate degree program to evaluate students' assessment of their engagement in learning and improvement in the speed of learning when tablets PCs combined with DyKnow were used in the class. Two key questions to which they responded included:

1. Classes taught with a Tablet PC keep me more engaged in learning than classes taught with desktop or laptop computers for students
   Possible answers: 5 Strongly Agree, 4 Agree, 3 Neutral, 2 Disagree, 1 Strongly Disagree

2. Use of Tablet PCs by students enabled me to learn new concepts better/faster because I was able to understand the way other students reasoned about a problem
   Possible answers: 5 Strongly Agree, 4 Agree, 3 Neutral, 2 Disagree, 1 Strongly Disagree

The same survey was administered at the end of four different graduate classes taught using tablet PCs and DyKnow. Student responses have been collected for the first class in the program, two classes in the middle of the program and a class at the end of the program. Results are shown in Figure 6. Students clearly agree that use of the tablet PCs with DyKnow helps them remain more engaged. While the score is slightly lower for their perception of how much faster they are able to learn new concepts, it is still very high. The sample size was small in the last class. We are continuing to gather data to determine whether the student learning experience is not helped as much by the time they reach the end of their degree program, or whether this was an aberration, due to the small sample size for the last class.

Master of Science in Wireless Communications (MSWC) Program	**Initial Class**	**Middle Classes**	**Last Class**	**Weighted Average**
No. of Responses	10	26	7	42
Question 1 – More Engaged in Learning	4.50	4.42	4.57	4.47
Question 2 - Learned new concepts better/faster	4.20	4.27	4	4.21

Figure 6 – Survey Results

Conclusions:
The combined Tablet PC/DyKnow system promoted critical and innovative thinking in the classroom. Sharing and discussing submitted panels with the class was tremendously useful in exploring the problem at hand and clarifying misunderstandings. Explorations

helped students gain a better and a deeper understanding of the material. Our measurements have provided quantitative data to support these assertions and results of student surveys confirm that not only the instructor but also students perceive positive benefits from this approach to teaching complex engineering concepts.

Some have claimed that one could accomplish similar results with pencil and paper. However, this approach would lose the interactivity generated by use of the Tablet PC. The time to collect the papers, go through them, and then pick out some examples to share with the class is sufficiently great that the spontaneity would be lost. The instructor's time would be taken away from the class to doing the clerical activities of copying examples for sharing with the class. Another suggested approach has been to have students go to a whiteboard to do their exercises. However, the logistics of having every student in class go to a whiteboard simultaneously to work on a problem are such that the flow of the teaching is interrupted, and student learning is impeded. As a result, it is rarely, if ever, done. We conclude that use of the combined Tablet PC/DyKnow system has improved our ability to teach, and both our students' speed of learning, and engagement in what is being taught.

References

[1] **K. Koile and D. Singer,** *"Improving Learning in CS1 via Tablet-PC-based In-Class Assessment,"* Proceedings of ICER 2006 (Second International Computing Education Research Workshop), September 9-10, 2006, University of Kent, Canterbury, UK

[2] **Tamara Denning, William Griswold, Beth Simon and Michelle Wilkerson**. *"Multimodal Communication in the Classroom: What does it mean for us?"* In Proceedings of the Special Interest Group on Computer Science Education (SIGCSE) Technical Symposium

[3] **R. Uhlig, A. Farahani, A. Cruz, S. Viswanathan, H. Evans, and M. Sotelo**, *"Achieving Compelling Student Comprehension of Complex Information Structures for both On-Site and On-Line Courses",* Proceedings of the American Society for Engineering Education 2008 Annual Conference, Pittsburgh, PA