Creating a Participatory Learning Environment in Large Lecture Classes Using Pen-Based Computing

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Abstract: Although large lectures are a reality of formal learning organizations, particularly in nation's research universities, limited research looks at how we can improve learning within them. Most learning sciences research focuses on small or medium classes or informal learning leaving a gap in our understanding of learning related issues in large lectures. In this paper we present a theoretical investigation of the use of pen-based computing in large lectures (>150 students). In particular, through this case study we examined how the combined use of Tablet PCs and the interactive software DyKnow creates a learning environment that is conducive to student participation and learning. We argue that these technologies enable participation by facilitating *creation*, *sharing*, *recording*, and *reflecting* of representations. Although the ideas presented in this paper are primarily theoretical, we do find supporting evidence through in-class (N=100 to 250) and online surveys (N = 525) of engineering freshmen at Virginia Tech.

Introduction

In spite of decades of research and theoretical ideas around situated learning (Lave & Wenger, 1990) and the benefits of apprenticeship based practices (Collins, Brown & Newman, 1989), the reality of education is still one of efficiency based on Taylorism. Students enter classrooms for a mandated time period and are taught specific topics 'efficiently.' Most of us are a part of this reality at our institutions. Large lecture classes with several hundred students are especially popular in the introductory freshman year. For example, a freshman year engineering course "Engineering Exploration EngE1024" at Virginia Tech was taught in a 32-seat classroom until fall 2004 and beginning in spring 2005, the course format was changed to include a large lecture (150+ students) followed by a hands-on workshop section (32 students) (Lo, et al., 2006). Given the large extent to which these classes are prevalent, there is surprising little research on learning in these classes. Furthermore, given the recent increase in the use of in-class technologies (Lohani, et al., 2007), we need to examine if current or future technologies can support learning in large lecture classes (for exceptions, see Dufresen et al. 1996; Kashy et al. 1999). In this paper, we present a theoretical foundation for understanding the role of pen-based technologies within large classes. Pen-based computing, which allows for digital inking and annotations, are increasingly being used in higher education (Roschelle, et al. 2007; WIPTE 2007). The conceptual ideas developed in the paper are supported by data from in-class (N=100 to 250) and online survey data collected by the authors from their students (N=525) in EngE1024, instructor notes, and digital artifacts collected from the students. The in-class survey data was collected during different lectures and therefore the sample size varies across items.

The Context for the Study

The case study presented in this paper comes from an implementation of pen-based computing in a 2-credit freshman year engineering course – Engineering Exploration EngE1024 – at Virginia Tech. The course, offered by the Department of Engineering Education (EngE), includes general problem solving, engineering ethics, sketching, early design (including realization), graphing and simple analysis of graphs, flowcharting and introduction to programming concepts using LabVIEW. EngE 1024 is a required course of all engineering freshmen (~1300 each year). For our freshmen this is their first foray in college education. Course activities are targeted at generating excitement about engineering profession and cultivating awareness of engineering practices among them In recent years, a number of hands-on activities have been designed and implemented in EngE1024 as a result of a NSF supported project (Lo, et al., 2006, Lohani et al., 2006, Mullin, et al., 2007). Current course delivery format includes a 50-min lecture led by an EngE faculty in a large classroom followed by a 90- min. hands-on workshop led by a graduate teaching assistant (GTA) every week. Authors co-taught two large lectures (300 & 150 students) of EngE 1024 and supervised all GTAs in Fall 2007. As a result of a new computing initiative, all incoming freshmen were required to purchase a Tablet PC and we used the device and the software DyKnow extensively in the lecture sections. This was the second year of Tablet PC implementation in engineering instruction at Virginia Tech (Lohani et al., 2007, 2008).

Participatory Learning and Representations

We conceive of participation as becoming engaged with a community of practice. Participation, meaningful and guided (Cobb et al., 2001; Rogoff, 1990), is critical for learning. We believe that large classes can be used to facilitate learning process that can be engaging and can help build learning communities for long term gains. Therefore, in our conception of large lectures we focus our attention on how the use of pen-based computing can help achieve that goal by acting as a critical "node" in a distributed activity system of large lecture classes. The state of the research on the use of pen-based computing in large classes is limited to studies of student assessment, grading, and successful implementations (see Besque, 2006). In short, most studies report short-term gains without a careful understanding of how classes are actually transformed as a cognitive or activity system as a result of these technologies. The primary idea underlying our conception of enabling participation in large lectures is that "ability is part of the individual–environment transaction (Barab & Plucker, 2002)." Therefore, we realized that we need to put effort in the design of the environment, especially the role of technology in the environment, since technology transforms the system. We see students engage with the lectures as they participate by co-constructing and co-interpreting representations. One critical element of a distributed participatory system is the use of representations within the system. Representations can range from any visual, textual and/or audio symbol that can be socially interpreted. In the context of our paper, we largely conceive of representations as semiotic means employed in science and mathematics, and particularly in engineering, such as equations, sketches, flowcharts, and graphs. Representations have been a strong focus of research within the learning sciences and have played an especially strong role in our understanding of science and mathematics practices (Danish & Enyedy, 2006; Greeno & Hall, 1997; Hall, 1996; Lee & Sherin, 2006; Suthers & Hundhausen, 2001; Zhang, 1997). Empirically, most of the studies have looked interactional account with a few participants – in this paper we try to look at them from the viewpoint of a large class. Norman (1993) talks about cognitive artifacts and how representations make us intelligent; cognition and learning are primarily the use of representations and thinking is with and through representations. Digital representations in software such as DyKnow can reorganize learning by providing the affordance to co-create representations. They also make it easier for people to share representations. One of the ways is to look at technology more holistically as a part of the "sociomaterial" fabric (Orlikowski, 2007) that makes up an organization. In this sense, technology is seen as being intrinsically tied to the practices of the organization. Yet, not all technological artifacts are knowledge artifacts or are part of knowing. They may indirectly facilitate knowing (Barab & Roth, 2006) but they become part of the cognitive system, we argue, by performing a critical role in the action by producing *representations* that are engaged with knowing. They become part of an activity system or a cognitive system. In figure 1 we provide a conceptual diagram of the process by which representations enable participation in large lecture through the use of Tablet PCs and DyKnow. This figure serves as frame that forms the basis of the discussion that follows. It is not meant to be exhaustive or represent a strict cyclical process. For instance, we recognize that sharing might occur before creating, the basic idea is that the four activities of creating, sharing, recording, and reflecting, are critical for learning within the activity system.

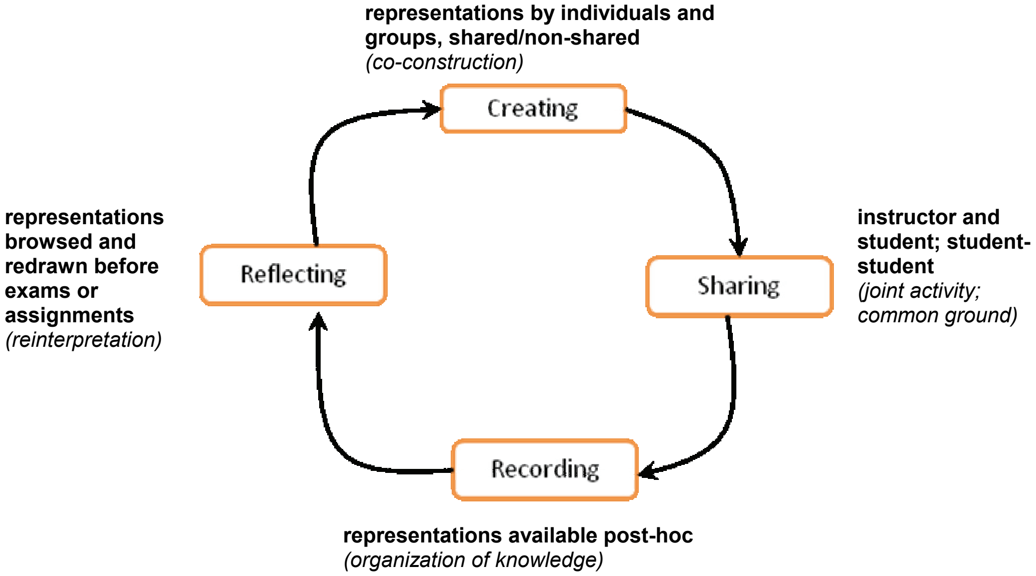

Figure 1. Enabling Participation in Large Classes through Pen-Based Computing.

The Technologies: Tablet PC and DyKnow

The case study presented here relies on two primary technologies. The hardware required is a Tablet PC and the software is DyKnow. In addition, the classroom environment should be able to support Internet connection for all students and the instructor(s) which is used to connect to the server that hosts the DyKnow application.

Tablet PCs

Tablets have a long history in the computing field. Alan Kay first conceived of the idea of "Dynabooks" and proposed that they will be the first "metamedium" for use by humans. One of the first commercially available devices based on this concept was Apple's Newton which was introduced in 1993. And even though the Newton finally took the form of a PDA, and was not a commercial success, it proved that pen-based computing devices were feasible in terms of design. In the last 5 years there has been a surge in the availability of Tablet PCs and their use in educational settings (WIPTE, 2007), with a number of factors, not the least of which is a stable operating system, playing a part. Tablet PCs are unique since they combine high computing power with direct pen-based input and unlike smaller devices, such as PDAs, they provide larger screen space as well. This combination provides users with the affordance (Norman, 1990) to engage in several design activities such as sketching and ideation directly in digital medium, allowing them to easily store, manipulate, and share their creations. The ability to be able to manipulate and share creations digitally takes Tablets beyond what could be done with paper and pen, and people sitting around a table. In this study we will focus on one particular affordance of Tablets – the ability to create and share external representations.

DyKnow Software

DyKnow (www.dyknow.com) is an interactive software that supports collaborative note-taking and interaction among different stakeholders such as students and instructors. DyKnow uses a client-server architecture where different computers are connected to a central server that 'serves' the software to the subscribers. Once a user logs into the software they have different options based on the privileges associated with the account. Instructors have the permission to start and stop a session and can control most options such as looking at the list of participants, taking attendance, and being able to initiate chat. Student participants, on the other hand, have limited privileges to initiate interaction within DyKnow but can participate by observing dynamic representations made by the instructor and making representations of their own. Overall, the primary control of the interaction rests with the instructor. Figure 2 gives a quick glance at the DyKnow interface. There are other software applications such as Microsoft OneNote, Classroom Presenter (Anderson et al., 2007), and GroupScribbles (Dimitriadis et al., 2007), available for the Tablet related applications, but DyKnow software met our needs and resources of supporting hundreds of users at the same time.

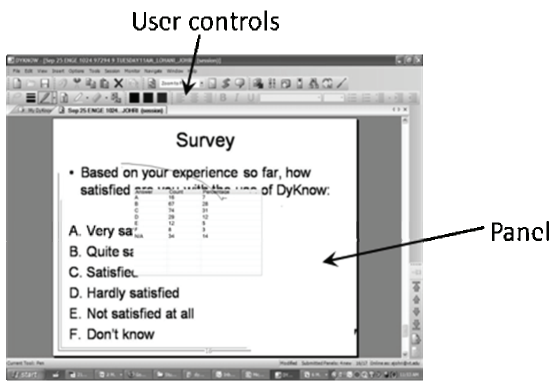

Figure 2. The DyKnow Interface.

Enabling Participation by Supporting Representational Practices

As discussed previously, we conceptualize the use of Tablets and DyKnow as a way to enable participation by the creation, exchange, and use of representations within the class. These representations are crucial for any socio-cognitive system and for learning. In this section we look in-depth at how participation is supported.

Creating Representations

One of the biggest advantages of using DyKnow on Tablet PCs is the ability to be able to create representations of different kinds on the panels (panels are slides or pages within DyKnow). The ability to create representation that can be viewed dynamically by students helps eliminate the need of a whiteboard in the class and makes it easier to reach and interact with hundreds of students. Through this technology, students can get the representations directly on their computer. In addition, DyKnow allows students to add to the representation presented by the instructor by creating their own representations. Students can add text or graphics to comments made by their instructor on a particular panel. They can also take notes on a separate area about a panel. In this way the students become participants and co-creators in process, creating a common foundation (Alterman, 2007). The ability for self-expression and co-creation of a representation is critical for student participation and learning (Suthers & Hundhausen, 2001). "As individuals or groups work on problems, they may make drawings, write notes, or construct tables or equations. These representations help them keep track of ideas and inferences they have made and also serve to organize their continuing work (Greeno & Hall, 1997; pages not numbered)." Figure 3 shows an example of a representation of a "human hand system and its interacting components" created by a student after students were instructed about use of a systems approach in engineering.

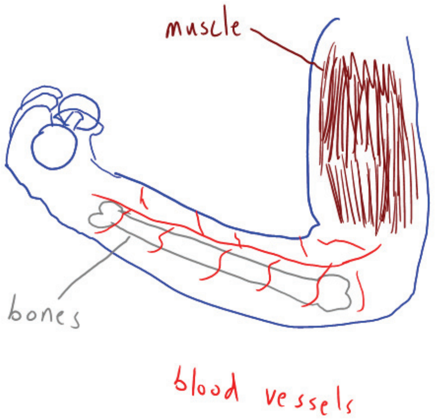

Figure 3. Representation of a "human hand system" shared by a student in EngE1024

The functionality to create representations is also supported in other ways through multiple kinds of annotation and pen tools. For instance, the instructors can prepare panels in advance by writing on them with a purple ink which is only visible to the instructor even when the panel is shared. By doing this the instructor can create elaborations on the panels but ask students to participate, by creating their representations and writing, rather than doing all the work for the students. Participants can use different colored inks for differentiating among the representations they are making. Instructors can use a flicker tool to highlight certain area within the panels and draw the attention of the students. Of course, there is a functionality to highlight and erase the writing. Free hand annotation which allows for free hand sketching makes the creation of representations easier, flexible, similar to what students are used to using pen and paper. Our in-class survey results show that the majority of students (70%, N=163) either "agree" or "strongly agree" with the statement that they like the ability to write on the panels. The students also like that the instructors can write on the panels (57%, N=75).

Sharing Representations

In addition to creation, one of the primary participatory processes is the exchange or sharing of representations among the members of a group or community. Within DyKnow the representations made by the instructor are of course shared with the students. But more than that, the representations made by the students can be shared with the instructor and with other students as well. Through the "Panel Management" function, DyKnow allows the instructor to pull panels from students. The instructor can pull the panels for a particular student (using their user-id as identification) or anonymously. In addition, the panels can be pulled randomly from among the class. These can be previewed and the instructor can then share them with the rest of the class. This function creates visibility among the participants. In our class we used this functionality in several ways. We provided different kinds of panels – blank, partially filled – to the students and asked them to draw some representation on the panel. We then used the panel management functionality and shared the panels with the class. As an example, a student's representation of a "hand system" and its components, as shown in figure 6, was shared by authors with the entire class to further emphasize the importance of systems approach in engineering. The answers or ideas provided by students ranged from nothing to very substantial representations. Initially we were hesitant to share panels that did not have anything on them or had very little but a comment during office hours from a student convinced us that this was the right thing. The student said that seeing such panels made him realize that he was not the only one that did not get it, there were others as well and made him feel like there were other participants like him and that he could do it. Therefore, we realized that just showing selected panels that were 'really good' might have adverse effect in that students might feel threatened. The students were engaged and we tried to do this as often as possible – every 10 minutes or so – to keep the students engaged.

In addition to the panels and representations on panels, DyKnow also supports additional representations that can be shared. DyKnow has a polling functionality where students can be polled and these results can be shared back with the students. In our class we used this in several different ways. One was to gauge the opinion of students, to get feedback about the class and the software, and to quiz them on multiple choice questions. Another representation allows the students to display to the instructor their status – how well they do or do not understand what is being taught. This shows up on the instructors screen as a pie chart with different colors and different colors for each student as well. This increases awareness and visibility within the activity system making it easier for the instructor to repeat a certain idea or example. One of the advantages of in-class exchanges is the number of responses, signifying interactions, which we can get from students. When we asked students to submit panels we got responses from all of them and then we could share back some of the panels with them. The ability to provide a public forum for individual effort (Wolfam, 2002) is one of the advantages of large classes and we are able to do that. This was also true for features such as "polling" and "voting." In our in-class survey, 50% (N=110) of the students either "agreed" or "strongly agreed" with the statement that they "like the sharing of panels in class." Figure 4 below shows DyKnow in use for previewing student panels and collecting them for sharing with the class. On the left is the list of student from whom the panels have been selected for previewing. Figure 5 shows a panel where one of authors is teaching linear regression concepts by drawing representations on the panel. On the right is the status panel where the red color represents the students who selected "I do not understand" on the status indicator. In this example, it can be seen that a good number of students indicated their inability to understand linear regression concepts which was addressed by reviewing the key concepts again. Therefore, sharing representations aided in developing a formative assessment based instruction.

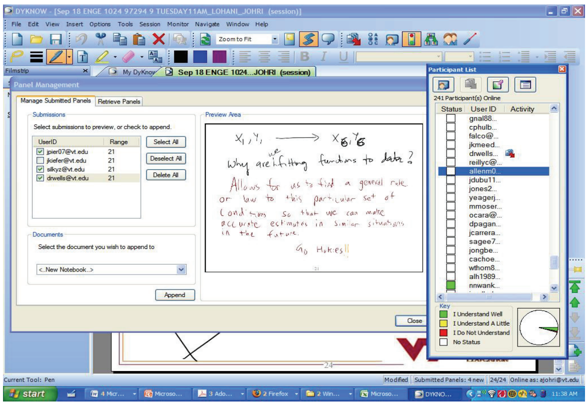

Figure 4. Previewing and Collecting Student Panels and Looking at Participants

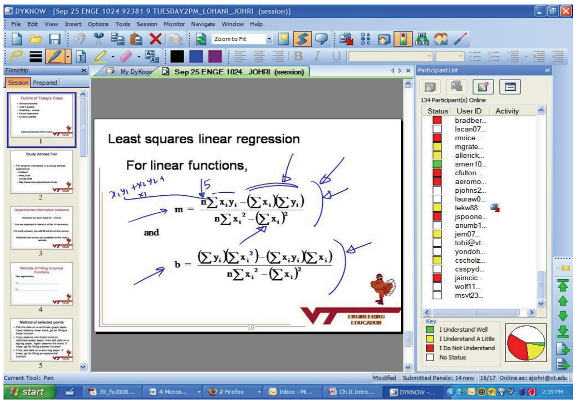

Figure 5. Lecture Slides (Left), Explaining a Formula (Center) & Student Feedback (Right)

Recording Representations

Another affordance of DyKnow is the ability to create a permanent record of the panels and representations. This works both statically and dynamically. As panels are passed from the instructor to the students they have the record of representations drawn by the instructor as well as what they drew themselves. They can later return to these panels and even 'play' them in the manner in which they were passed and drawn upon in the class. Recordings serve as organizational memory as well as provide a basis for building something on top of it. Unlike the process where something was written on the white board and then erased there are records here. Also, there is a transformation where rather than students copying what was on the board they get most of it and then can build on top of it. The presence of representations makes it possible for observational learning but also to be able to participate later on, more like a lurker. Representations can be used later to write upon and re-interpret. The recording of representations allows us to extend the learning environment beyond the lecture, as is usually the case. We forget that students' lives do not stop after the lecture and they participate in a number of networks of events and these representations often become a part of their conversation and interaction. Therefore, they are essential for organizing their knowledge and in the long term for building an organizational memory. In our survey students reported that they used the recordings of the lectures and the representations created therein to review for exams and for homework. Although some students reported that they used the recordings frequently (11%, N=12), most of the students said that they used them on a "need to know" basis (41%, N=43).

Reflecting on Representations

The recorded representations provide the opportunity to be able to reflect on the artifact, reinterpret, and review it. Therefore, the participatory environment created by the technology enables and supports reflection which leads to understanding, "People use representations to aid understanding when they are reflecting on an activity or working on a problem (Greeno & Hall, 1997)." This process sometimes occurs in the classroom when a previously produced artifact is reviewed in class in the following lecture. There is more writing and discussion around it and reflection on what it is. But the reflecting occurs primarily outside of classroom. Students bring up the panels and review them before exams. Of course, the process of reflection is indirectly, or directly, present in the creation of artifacts that follow. Whether in exam, as part of an assignment, or as a design product, the understanding that students derive is reflected later on. In practice, as students take the follow-up courses that build on this course they use many of the concepts that they learn here. Therefore the process of reflection is the key to learning. An an example, below is an email received by one of the authors from a student during final exam period in fall 2007 that illustrates use of sharing and reflection on representations by a group students in authors' class for EngE1024 final exam preparation.

> *Hi Dr Lohani,*
> *This is the study guide that my friends and I built. We called each other then I sent out an email. We all logged in. We picked topics. Then we started filling it all in. Taking turns helping each other and chatting with our writing function at the same time as we were typing. As promised I'm attaching a copy of this file. Thanks!*

Another aspect of reflection is formative assessment in the class. According to Angelo & Cross (1993), classroom assessment is an ongoing process and by employing short and simple assessment techniques instructors can get feedback and in turn provide students with feedback on the results of the assessment and suggestions for improving learning. DyKnow proved to be an efficient tool to incorporate formative assessment into instruction. An example is presented below from a lesson on flowcharting. Traditionally, the instructors used to describe the flowcharting process by developing an incomplete flowchart. This year due to incorporation of DyKnow, we decided to share a blank panel with all students and asked them to draw the flowchart on their own for a given problem. This problem was discussed before giving this in-class assignment and involved use of sequential and decision control structures. It may be noted that students were assigned to read a flowcharting document before coming to this lesson. We collected some panels randomly after about 5 minutes and started projecting collected panels on a large screen through a projector. The first panel shared with the class, work submitted by one of the students, is shown in figure 6. Since the panel did not show any significant amount of work, the author, feeling that it would embarrass the student, although unknown to class, who submitted the work, quickly changed to another panel that showed a reasonable effort (see figure 7) and discussed various elements of the flowchart that were right or wrong or missing. This was the first day the author experienced the instant advantage of collecting students' work through panels and has implemented this strategy since then to cover a number of other aspects of the course. Students were thoroughly assured that the work is being collected anonymously and their submissions would in no way affect their course grade. Since students did not have the option to prevent their panel from collection, they were encouraged to participate in the class activity which was found very helpful in a large class. After one of the lectures on flowcharting a student stopped by the second author's office and admitted feeling very good after seeing the first panel, see figure 6 again, and thinking that he's not the only one who's lost in the class. Ever since that discussion, we have started using all panels for discussing students' work or prior knowledge.

Figure 6. Student panel showing flowchart work

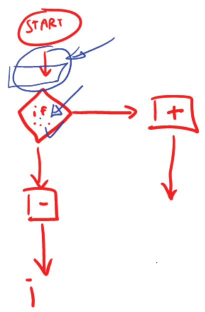

Figure 7. Student panel showing flowchart work

Conclusion

Recent technological advances are making it possible to transform experiences within classrooms through the use of devices with new affordances as well as replication of prior affordances in digital forms. These technologies and their application bring to light many learning sciences theories and how they can be conceived. As can be seen from this preliminary account of the use of pen-based computing hardware and software there is a possibility and an opportunity to transform large lecture classes to make them more inclusive and participatory. Our account of the use of Tablets and DyKnow is different than previous accounts of using technology in large classes. We're uniquely qualified to examine role of technology in developing feedback instruction system to enhance learning experiences of students in large classes. To our knowledge ours is the largest engineering program in the country that requires its students to own a Tablet PC. Together, Tablets and DyKnow have the ability to create, share, record, and reflect on different kinds of representations and give students a chance to express themselves and engage in the lectures. If we consider the class as a cognitive system, then the tools available for use within the class re-arrange cognition and learning. Large lecture classes have their limitations in terms of engaging students and the individual attention. One major limitation is the use of gestures and facial expressions to advance communication and encourage joint activity. Common ground and mutual knowledge are hard to ascertain and establish. The use of these technologies helps us overcome some of these disadvantages. When asked in an exit survey (N=525) if the use of technologies in the class "effectively contributed" to their learning, 148 (28%) students responded "Strongly agree" and 242 (45%) students said "Agree." 69 (13%) students were "Neutral", 58 (11%) "Disagree," and 19 (4%) marked "Strongly disagree." Therefore, the overall response to the use of technology was quite positive. The results were similar to a question about DyKnow, "The DyKnow software has been successful in making the classroom environment interactive and conducive to learning:" Strongly Agree 70 (13%), Agree 251 (47%), Neutral 124 (23%), Disagree 62 (12%), and Strongly Disagree 28 (5%). In the same survey the student were asked for open-ended responses to "usefulness of Tablet PCs for in-class activities)," several responses pointed out the usefulness of DyKnow, especially the ability to work with representations:

- "I liked that we could make our own notes on the Dyknow program during lecture."
- "Being interactive and allowing us to draw things that needed to be drawn and just give a different feel to the ordinary class lecture"
- "DyKnow, being able to add my own input/notes to the slides, having all my notes in one place, drawing designs"
- "DyKnow was especially useful on the tablets because we could interact by writing or ideas and thoughts out on the tablet. It was easy organize notes in class using OneNote, it helped to be able to write directly on the slides used in the lecture."
- "DyKnow made it easier to follow a professor's lecture, draw right onto the program using your notes without all the paper mess"
- "The questions that we were to answer or illustrate an answer for & then were shown to the class-- keeps people engaged during class"
- "I thought the tablet was very useful when the instructor was trying to draw what his point was. The good part about having a tablet and DyKnow was that we got to keep a copy and go back to it if we were confused."

The theoretical and conceptual understanding we have built in this paper will guide future design iterations of the class and the data collection. In future studies we will focus on two different affordances of the Tablet PC: 1) Digital inking and annotations – being able to sketch, manipulate the sketch, take notes, activities typically performed by an individual, and 2) the affordance to be able to share the representations with others either via the digital means such as DyKnow. In particular, we want to assess students' use of Tablet PCs for sharing and interacting. Anecdotal evidence from informal observations suggests that although students highly appreciate the digital-ink feature and being able to annotate, the use of Tablet's collaboration features among students is limited. Previous studies show that even within large lectures small group exercises can be used successfully (McKinney & Graham-Buxton, 1993). We also plan to collect focus group data to learn the "reflection" process and the use of representations beyond their creation and sharing in the classroom.

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