AC 2009-1745: USING DISTANCE LEARNING FOR CAD-BASED TRAINING AND PLM EDUCATION OF INCUMBENT ENGINEERS

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Aerospace Systems Design. He also has been responsible for the establishment of most of the Aerospace System Design laboratories in the School of Aerospace Engineering, such as the Aerospace Systems Design Laboratory (ASDL) in 1992, Space Systems Design Laboratory (SSDL) in 1996, and the Integrated Product Lifecycle Engineering (IPLE) Laboratory in 2007.

Prior to coming to Georgia Tech in 1984, Dr. Schrage served as an engineer, manager and senior executive with the Army Aviation Systems Command (AVSCOM) from 1974 to 1984. In these capacities he was involved in the design, development and production of all of the current Army Aviation systems, including the UH-60 Black Hawk, the AH-64 Apache, the CH-47D Chinook, the OH-58D Kiowa Warrior, and the RAH-66 Comanche Development. Dr. Schrage also served as the Associate Technical Director for Science and Technology, AVSCOM and the acting Chief Scientist for the Army Combined Arms Center.

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Past work in Aerospace School involved working within the NASA URETI Center to enhance the education outreach of this center both at the industry, academic and K-12 perspective. For twelve years he worked to keep the College of Engineering at the forefront in the area of continuing education by working with the schools within the college of Engineering. He also worked with The Logistics Institute within the ISyE school to increase their presence within the industrial community with new continuing education courses in the areas of logistics, material handling, warehousing, manufacturing. Mr. Atkins has been co-director of Material Handling Short Course at Georgia Tech since 1984. He established outreach group within Georgia Tech Research Institute that provided marketing support for the Trade Adjustment Assistance Center, assisting small to medium sized firms across the Southeast and helped found the Material Handling research Center (NSF IUCR) at Georgia Tech.

Using Distance Learning for CAD-Based Training and PLM Education of Incumbent Engineers

Abstract

Product Lifecycle Management (PLM) -- the process of managing a product from its conception through retirement -- is being applied to programs across Boeing to improve performance and lower costs. Engineers involved in every stage of a product's design, development and manufacture need to have an in-depth understanding of PLM and its challenges. At the same time, continual advances in engineering design and simulation tools and methodologies require engineers to refresh their knowledge of the fundamentals and to keep up with new developments.

To address these immediate and growing needs, Georgia Tech's School of Aerospace Engineering joined with Boeing's Learning, Training and Development (LTD) organization to offer three courses within a continuing education certificate program that blends academics with the practical information that engineers need to be successful. The courses are taught off-hours with virtual lectures delivered by Georgia Tech professors and virtual labs delivered by both Georgia Tech faculty and Boeing Subject Matter Experts (SMEs). Similar programs have been offered in the past, but this is the first time industry and academia have partnered to offer a PLM program involving CAD-based training in an entirely distance learning format. The virtual labs will utilize distance learning technologies to give students the ability to access and learn CATIA V5, ENOVIA LCA and DELMIA remotely.

The benefits of this type of distance-based training program are numerous, especially to a large global corporation. The ability to train engineers in multiple geographic locations at the same time on how to use complex, 3D engineering software is extremely valuable. It eliminates the need for either subject matter experts or potential students to travel to a common location in order for the training to take place, saving a company significant amounts of money. Online training is not new, but online training of robust CAD and 3D simulation software such as CATIA, Pro-Engineer, Unigraphics or DELMIA is not easy to do or well documented.

This paper will describe the technical architecture of the distance-based lab environment, challenges of using instructors from both academia and industry to co-teach the lab simultaneously, steps taken and testing that was done prior to implementation, student reactions to the learning environment, shortcomings of this approach compared to a traditional classroom, lessons learned, and ideas for future improvements to the distance-based lab approach.

Introduction

There are many engineers in industry who lack the knowledge of current PLM concepts and tools. This can be detrimental to both them and their company in today's highly competitive manufacturing markets. Companies who do not constantly look for new ways to adapt and improve in order to give them a competitive advantage may be surpassed by competitors. The development of this Integrated Design and Manufacturing through Product Lifecycle Management (IDM-PLM) Certificate Program in a completely online environment to educate engineers and technologists at The Boeing Company in PLM theories and applications can provide employees across the country the continuing education they need in order to maintain a competitive edge. Previously these types of technical training courses were only offered in person in specific geographic locations where a very large number of engineers were located. Thus, a large percentage of engineers outside those areas are unable to receive this type of training without enduring steep travel costs. Furthermore, these training courses are on-hours, meaning the employee would have to put current work on hold to attend the classes. Lastly, these on-hours training classes are just that, training classes. They only teach people how to use the software, without explaining why the processes used are important in a more educational fashion. One solution to this problem is to provide employees with continuing education from academic experts in an online learning format. The success of this online IDM-PLM continuing education program could improve these employees' understanding and application of PLM, and thus improve their performance within their job roles, increase their satisfaction of their jobs, and ultimately create a positive impact within their company in the future.

Web-based learning and training has been shown to be just as effective as traditional face-to-face learning.[1,2,3] In fact, a study by Zhang found that students in a fully interactive multimedia-based E-learning environment achieved better performance and higher levels of satisfaction than those in a traditional classroom.[4] The question that arises is "Why is this?" There are several factors that can influence the learning outcomes and student satisfaction of a distance learning course. These include student self-motivation, student-learning style, instructor knowledge and facilitation, instructor feedback, interaction, and course structure.[5] Although, questionnaires used in this study touch on most of these aspects, the description of the infrastructure used to support the lab portion of the class will be the main focus of this paper. This includes describing the technical architecture of the distance-based lab environment, challenges of using instructors from both academia and industry to co-teach the lab simultaneously, steps taken and testing that was done prior to implementation, student reactions to the learning environment, shortcomings of this approach compared to a traditional classroom, lessons learned, and ideas for future improvements to the distance-based lab approach.

Although a great deal of literature has supported the success of online learning, literature has not shown that online learning has been used extensively for technical CAD training and education that involves highly graphical 3D imagery and normally requires hands on training. A study by Jenson and Raisor did investigate the effectiveness of a course teaching Pro/Engineer, a high-end constraint and parametric-based 3D solid modeling package.[6] The distance-based course was derived from an existing face-to-face course that contained both theory and a hands-on laboratory component; similar to the present study. Jenson and Raisor linked their classroom on the main campus of the university to a classroom at a remote location. A 50 minute connection was made three times a week for 15 weeks, resulting in interactive web-based lectures for the remote location. Students from both locations were required to complete 19 laboratory exercises using Pro/Engineer, however, the software was only resident at the main campus. Students at the remote campus accessed the software from a distance via the Internet. Live demonstrations were done similar to the lecture sessions, although instead of PowerPoint slides being displayed, Pro/Engineer was shared over the Internet between the two classrooms. The primary objective was to help quantify the effectiveness of using the Internet for technical course instruction and delivery. The study found that students at the remote location performed at the same level as students at the main campus on a Pro/Engineer skills assessment at the end of the course. On average, participants reported being satisfied with the course delivery. However, the results of the study were somewhat limited by its pure quantitative methodology which couldn't provide in-depth responses regarding students' experiences of the course.

A question that arose in the present study was the appropriateness of an online learning format for teaching technical content, such as the use of a sophisticated 3D solid modeling package like CATIA, in a corporate/university program. Additionally, what were students' and instructors' opinions of offering a course on technical content in an online environment?

Distance Learning

The evolution of distance education occurred through four generations: (a) printed instruction, (b) early technology in broadcasting systems, (c) online instruction, and (d) web-based teleconferencing.[7] Online instruction is defined as any form of learning and/or teaching that takes place via a computer network.[8] Recently, the advancement of online instruction contributed to the expansion of educational opportunities by reaching people in various geographical locations; thereby allowing learners global access to education.[9]

Traditionally, educators have valued face-to-face interaction with students as the most effective learning method to engage learners and generate critical thinking. However, many higher education professionals now agree that, given the advances in teaching technology, the online mode of learning may be an effective alternative, especially if face-to-face teaching is not an option. Current literature suggests that online learning mode of instruction is as effective as face-to- face classroom instruction and at times may surpass face-to-face in academic quality, rigor and outcomes.[2,3] This idea, now commonly referred to as the "No Significant Differences" (NSD) phenomenon, was also the focal point of a book written by Thomas Russell. Russell examined 355 research reports, summaries, and papers that document NSD in student outcomes between alternate modes of education delivery.[2]

In spite of the many promising features of distance learning, there are some potential drawbacks associated with it. First, it has a limited capability to engage learners in learning events unless the learners are self-motivated and active learners.[10] Additionally, it is suggested that successful learning in a distance-based environment is dependent on a student possessing strong organizational skills in their learning habits.[11] Engler reported that quality of dialogue in distance learning is impacted by issues such as a lack of physical cues, for instance body language and facial expressions.[12] A lack of community or belonging, preventing the development of shared emotions and feelings between instructors and learners, is often reported in online learning experiences and are some of the most important factors influencing learning satisfaction and transfer effectiveness.[13,14] Creating a sense of presence to make learners feel very alive, has also been suggested as another issue to overcome in delivering vivid learning experiences to online learners.[13,15] Newby, Stepich, Lehman, & Russell also noted that distance technology can be both costly and difficult to implement, can involve more complex instructional methods, and frequently requires more planning and preparation of materials than traditional classroom-based courses.[16] It is advisable to assess whether or not the advantages of new distance learning programs or courses outweigh these type of drawbacks before committing to such programs.

Architecture of Distance-Based Lab Environment

The Introduction to IDM through PLM course was a 10-week online learning course. The first objective of this course, which deals with the theory of PLM and its importance, was to educate engineers on how their decisions immediately affect other engineers' activities. The second objective was that participants should gain entry level knowledge and application of CATIA, ENOVIA and DELMIA engineering software for 3D part design, change management and 3D virtual manufacturing in a PLM environment. The 10 week course utilized an online learning approach for the delivery of the instructional content. Figure 1 is a diagram depicting the networking architecture of how the personnel and technologies within this online learning environment were connected. Each week consisted of a two-hour remote lab, which this paper focuses on, and a two-hour remote lab. The classes were conducted by faculty at the Atlanta, Georgia campus of Georgia Tech and transmitted over high-speed internet to students attending the sessions from either their home or work location all across the country. WebEx Meeting Center and WebEx Training Center were the software used to enable online instruction and interaction. A teleconference line was used for audio interaction among the students and instructors, but students were asked to keep their phone line muted. If they had a question they were instructed to click on the "raise hand" icon inside of WebEx Meeting Center which would prompt the instructor to call on the student, who could then un-mute their line and ask a question or make a comment regarding the current discussion. Students were also free to use the chat area inside WebEx to type in questions or comments. A teaching assistant monitored the chat area and alerted the instructor if question or comment needed to be discussed as a group.

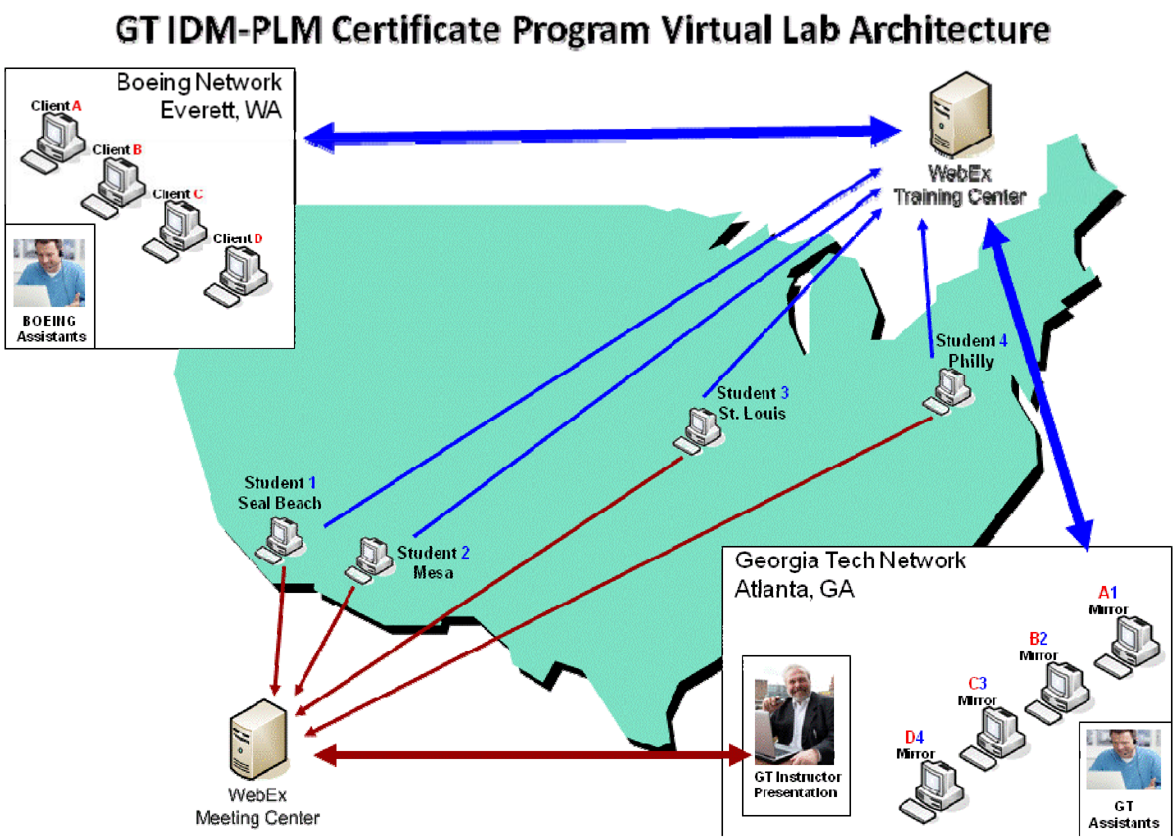

Figure 1. Networking architecture for online IDM-PLM Course.

Testing and steps taken prior to implementation

Prior to implementation of this class, several steps were taken to test the new distance learning environment. The Boeing computer lab contained 12 desktop PC's and 10 laptop computers, all loaded with CATIA, ENOVIA and DELMIA software to be used for the applied tutorials. The Georgia Tech lab had 24 desktop PC's that would be used to link to the computers at Boeing being remotely accessed by students across the country. One of the main obstacles to teaching a class such as this in an online fashion is the amount of bandwidth and computing power required to have a number of students simultaneously access the network and remotely connect to the computers in the Boeing lab, while at the same time also connecting another group of computers in a lab at another location.

An alpha test was first conducted with five to six individuals in order to simply test the connectivity issues. Two people were located in the Boeing lab playing the role of Boeing instructors, two people were located at the Georgia Tech lab playing the role of Georgia Tech instructors, and two people were located at other locations playing the role of students. All individuals were dialed into a teleconference number to enable verbal communication. Then, all people were given login information to a WebEx training center session. Once in the WebEx session, the Boeing instructors created "breakout" sessions for each student that allowed them to individually connect each student to one of the computers in the Boeing lab. The students were then given access to remotely control that computer and the applications on it. The Boeing personnel then added a Georgia Tech computer to each of the breakout sessions. This enabled the Georgia Tech instructors to visually see the desktop of the Boeing computer that students were also connected to and operating remotely.

Once connections had been established, the students were instructed to start CATIA on the remote computer and open up a part file that had been stored on the desktop. Once the students had the parts open the latency of the graphics was tested. Instructors verbally told the students to pan, rotate and zoom the part. Each time one of these actions was performed, the students would verbally say when they perform the task and the Boeing and Georgia Tech personnel watching the students work, responded with how long it took for the operation to happen. For example, the student would say, "I am going to pan the part to the left, now". The Boeing and Georgia Tech personnel would then wait to see how long it took for the part to move and respond "I see it now". It was determined that a latency of one second or less would be satisfactory for the course. The alpha test with two students produced results of approximately 0.25-0.5 seconds.

After a successful alpha test, a beta test was then conducted to increase the amount of students, connections and bandwidth required. For this test, eight students connected to eight Boeing computers remotely, and eight computers at Georgia Tech were also connected to those Boeing computers. The same procedures as described for the alpha test were conducted and this time response times for the remote connections ranged from 0.5-1.0 seconds. These results were deemed satisfactory for the course, but it was noted that with a few more students in a live class that the speed of the remote connectivity could be an issue.

Student reactions to the learning environment

Course evaluations were given to students following the last class in the form of an online survey. All twelve students who were enrolled in the course completed the survey which included 20 multiple choice Likert-style questions as well as an open-ended response. This allowed both quantitative and qualitative data to be collected. Table 1 shows a portion of the results from the multiple choice questions that specifically reference the remote lab portion of the course that is being discussed in this paper.

Table 1. Student responses to Likert questions on the remote lab sessions.

Question	**n = 12**	**Mean**
The audio technology used in the course worked well for verbal interaction		4
The text-chat functionality in the course worked well when one-on-one assistance was needed		3.5
The remote tool used to run the classroom computers worked well		3.16
The V5 software performed well		3.5
Overall, the instructors were effective teachers		4.16
The laboratory sessions contributed significantly to your learning of course material		4.08
The optional extra practice sessions were important to understand and/or complete some class objectives		4.16
I learned a great deal in this course		4.08
Scale		

1 = Strongly Disagree	2 = Disagree	3 = Neutral	4 = Agree	5 = Strongly Agree

As indicated in the results of the survey questions above, students' biggest concern with the lab was the performance of the remote computers used to access the PLM software. Also important to note is that overall the students rated the effectiveness of the online instructors high and agreed that they learned a great deal in this course. The students' comments included in the open-ended portion of the survey supported this quantitative data.

The qualitative data were coded using NVivo statistical software to examine emerging themes in participants' responses. The theme that occurred most frequently was that the instructors in course did a fantastic job answering questions and helping students learn the materials. One student noted, "…the instructors and support staff were all awesome. You all have so much patience and are definitely well versed in the subject matter that we were exposed to over the last 10 weeks, many thanks".

Student comments included references to some of the technical issues in the class. One student commented that, "There were technical issues that prohibited learning on occasion. The expertise of everyone involved overcame these issues on most occasions". Also, multiple students made reference to the slow response time of the remote computers being used to allow students access to the PLM software. One comment on this was "The biggest problem from my perspective was the sluggish response time of the remote computers. The DELMIA lab was ineffective for me because of the time delay between my button click and the screen response." This is something that will have to be addressed for future online courses of this nature. The bandwidth required for transmitting such large amounts of graphical information in real-time back and forth between two locations is very intensive. Figure 2 depicts all the themes that emerged from the qualitative student responses and the frequency at which they occurred.

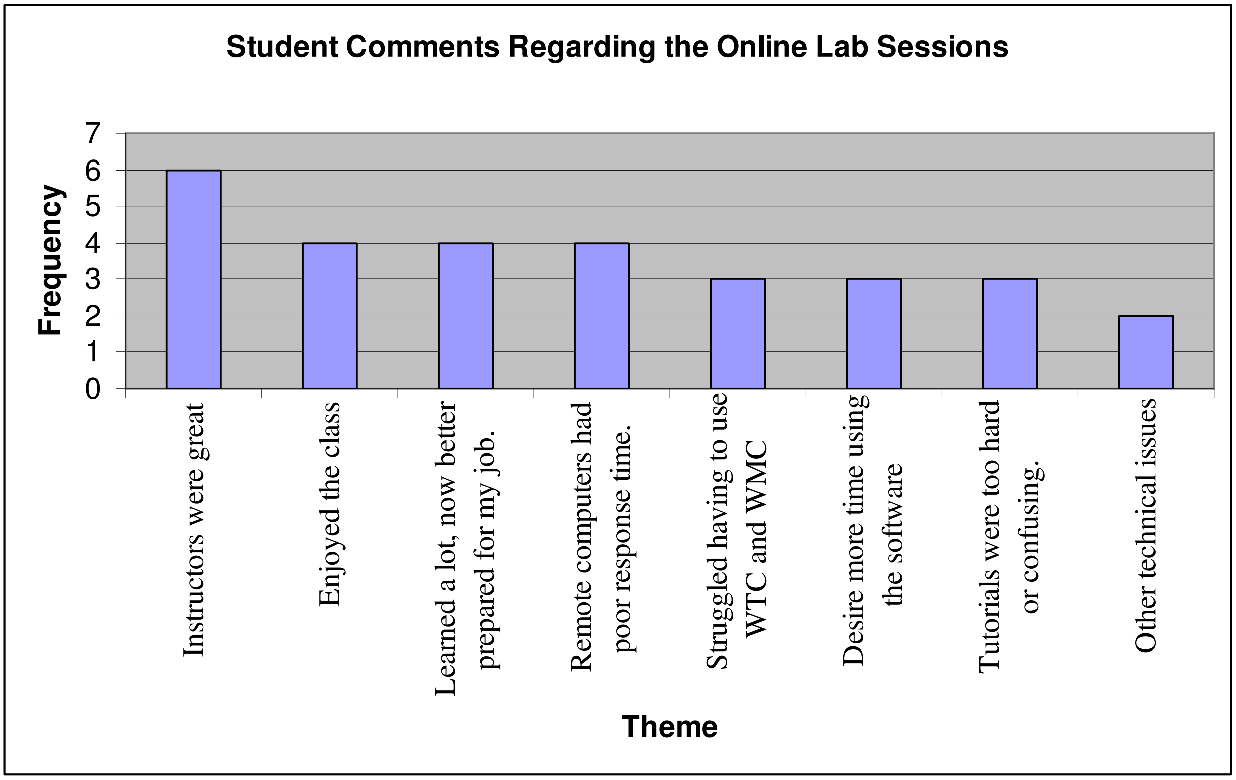

Figure 2. Student comments regarding the remote lab sessions.

Lessons learned and recommendations

Two weeks after the conclusion of the course, a focus group consisting of lab instructors, subject matters experts (SMEs) on the WebEx software used for distance learning and content SMEs was formed to discuss lessons learned throughout the course. Many of the issues discussed also align with the responses given by the students in the post-course survey, as detailed above. The following are the main challenges that were encountered during the online lab portion and recommendations for actions to take, as expressed by course instructors and staff during the focus group discussion.

1. Store all files needed by students for each class period in a folder on a network drive that has a shortcut to it located on the desktop of the remote computers students are accessing the CAD software from. This requires pre-class communication and confirmation between University SME and Industry SME (short meeting). Video tutorial files should provided online on WebCT and downloaded by students to their local computer prior to the beginning of each class, or provide all video files on a CD to students prior to the start

of the course. Too much time in each class was spent on students gathering needed files or downloading them through a remote computer.

2. Compress the file size for any videos or PowerPoint files that are needed. Too many of the files were 10MB or greater which can take a long time to download over a remote computer connection.
3. Boeing instructors need to verify with Georgia Tech Instructors which workbenches in CATIA and DELMIA will be used for each class sessions. Prior to class Boeing instructors then needed to ensure that the proper licenses that enable the needed workbenches are selected on each remote computer being used by students.
4. Audio just through the one telephone conference line can be challenging to manage. One solution is for a TA to contact one-on-one with students having issues on a separate phone call. Also need the Host of audio phone line to mute all inbound lines to prevent cross-talk while students are working or while the instructor is giving directions.
5. Consider utilizing a teleconference service that includes an operator to control the phone lines. The operator can create "breakout" audio sessions that would allow an instructor to have a one on one conversation with a student while the rest of the group is still able to communicate in the main audio session.
6. Many students expressed that having to run both a WebEx Meeting Center (for instructor demos and group chatting) and a WebEx Training Center (for student access to software on the remote computer). Two Webex sessions is challenging for some students. Look for a solution that is more efficient yet still allows proper communication between students and instructors.
7. Emphasize getting more feedback from students in class. Examples, ask students to select the green checkmark in WebEx if they can hear the instructor ok, and then don't move on until you here from everyone. Ask student to turn on the coffee mug icon when they go on break or away from computer so you know if someone is currently away. Ask students to turn on their "happy face" icon when they have a completed a task and then wait for everyone to finish before moving on.
8. To increase student participation and interaction, make use of the Polling function in WebEx Training Center. This is a quick way to check in with all the students and make sure they are following along and understand the materials.
9. Shorten the number of steps that are required in each task. Instead of a student going through 30 minutes of work before checking back in is too long. Shoot for five to 10 minute segments. This will help keep everyone on the same pace and prevent some students from getting too far behind.
10. Ensure the size and quality of the font in the tutorials is appropriate. The font on some tutorials was too small to be easily seen by some students, especially through a remote computer connection in which the video quality is slightly reduced.
11. Ensure screen size and resolution on students' computers is appropriate for working on the remote computers. What is the minimum for effective transmission - possible recommendation to use a minimum standard on the student's end (e.g. 1024 x 768). If students can use an external monitor, that might be recommended.
12. Make sure all tutorials and slides include page numbers to make it easier for students to go back to specific slides or ask questions about certain tasks.

13. Have instructors and teaching assistants walk around the lab looking at the students' screens to proactively offer help and suggestions rather than waiting for questions to come in via the chat.
14. Ensure all students and instructors activate the audio alerts inside WebEx Meeting Center and WebEx Training Center. This will sound an audible notification any time a student clicks on the "raise hand" icon or a comment or question is entered into the chat area.
15. Dedicate more time in the first class period to showing the student how to use the distance learning software (WebEx Training Center in this case). This is such an important part of the class and can lead to high levels of frustration for the students; it should not be overlooked. An extra hour of preparing the students to use it better up front can save numerous hours of helping students with it later on in the course.

Conclusion

This course taught both theoretical PLM concepts as well as giving hands-on training of 3D CAD and PLM software. This paper has focused on describing and assessing the infrastructure used for an online lab portion of the class. The main challenges associated with teaching a highly applicational engineering class in this fashion were the slow response times of the remote computers and the ability of the students to properly use the distance learning software. Additionally, having instructors from both academia and industry co-teach this course from two different geographic parts of the United States presented additional challenges in teaching this online course.

Recommendations have been made to improve future offerings of both this course and other related programs. Many of these recommendations have already been incorporated into the second course of the three-course Georgia Tech IDM-PLM Certificate Program. The second course focuses on knowledge-based systems development and virtual manufacturing, building upon the concepts taught in Course 1, as discussed in this paper. The results detailing the effects of implementing the recommendations mentioned above within Course 2 will be presented in future papers. Furthermore, future research will include pre- and post-test assessments in order add another method of measuring the success of the program.

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