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Teaching Multidisciplinary Design Optimization (MDO) in a Reconfigurable Interactive Classroom

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1. Abstract

Technology has so rapidly advanced in recent years that our present cadre of students has grown up using various personal communication devices, laptop computers, and tablets. Their expectation on content delivery within the classroom does not conform to the traditional approach of lecturing at a board. The students have access to an array of devices – in class – that provides to them instantaneous access to information, methods, and tools. Not only are the students more technological and computer literate, but the rapid computational advances have also resulted in a variety of applications being available that previously were not. The availability of new tools, as well as new hardware and networking capabilities, provides us with the ability to teach our students in new and exciting ways. In this paper, we review a new course being taught in the Aerospace Engineering Department at the Iowa State University – Introduction to Multidisciplinary Design Optimization (MDO). However, the emphasis is not on content of the course but rather the way in which delivery of the course content is enabled and supported through a new interactive reconfigurable classroom that supports fully integrated technology usage.

2. Keywords: Engineering Education,

3. Background: Technology in the Classrooms

It has become clear in recent years that delivery of educational content and student learning has become ever more reliant on technology – at least in K-12 education. Unfortunately, on the whole, K-12 teachers have more readily embraced technology in the classroom than university faculty. An article in *Education Week*[1] reviews the status of technology in education at the K-12 level in five key areas: technology infrastructure, research, E-learning, mobile computing, and social networking.

Technology Infrastructure: The article points out that as of 2010, 97% of all schools had Internet connectivity. However, connection speed remains an issue, and capabilities will likely not catch up with demand any time soon. Of particular challenge in this regard is the fact that newer digital tools require an ever-increasing amount of bandwidth. In this regard, university infrastructure, particularly in most engineering schools, is largely acceptable, with many universities offering state-of-the-art bandwidths.

Research: Unfortunately, while much research has been done pertaining to impact of new technologies on teaching and learning, the article points out that there has been minimal, if any, rigorous and objective large-scale studies on which to base decisions. The time lag associated with these large-scale studies, which require years of gathering data, make them obsolete quickly, given the emergent and rapidly evolving computational technologies on which they depend. In one meta-analysis of over a thousand studies, the U.S. Department of Education (2009) released a report (later revised in September 2010), that concluded that students in online-only courses performed slightly better than their in-class counterparts, while students in a blended (online/in-class) environment performed best of the three modes. This conclusion was based on students in higher education so, while possibly not as relevant for K-12, we can conclude that the data supports the university environment.

E-learning: The number of states offering full-time online K-12 schools has grown yearly with 2010 data demonstrating that 27 states in the U.S., as well as the District of Columbia, had such schools. In addition to full-time online schools are hybrid versions, in which some content is offered online, as well as traditional schools that offer supplemental online education. At the university level, there is a continuing growth of online offerings for individual classes and even entire online degrees. Quality and academic rigor remain question marks for many. A recent study by the Lumina Foundation[2] demonstrates that the American public still feels overwhelmingly that the quality of such degrees are inferior to degrees obtained in a traditional university environment.

Mobile Computing: In K-12 environments, the ubiquity of mobile devices across all demographics makes them an attractive means of incorporating game-based learning in the classroom and at home[3, 4]. The Horizon report[5] predicts that game-based learning will soon be prevalent across K-12 classrooms. The move towards game-based learning will have a tremendous impact on our university delivery of courses in the very near-term, when we understand that these students will be entering our classrooms in a matter of years. Embracing game-based learning in our engineering programs represents a critical need as well as opportunity.

Social Networking: In recent years, the debate on social networking has largely shifted from whether to make use of the technology to how to best use it. While security has been a major concern, particularly for K-12, tailored environments with enhanced security features have enabled cooperative and interactive learning online[6]. Wikis and blogs are becoming standard features in K-12 teaching and learning. Unfortunately, such environments are still not used to greatest affect in university classrooms.

The challenge as we move forward is to ensure that our traditional university programs adapt to the change already occurring within K-12 classrooms. These are the students who will be populating our university classrooms. They not only have a level of experience in interactive and technologically based education, but have an expectation of its use in their programs of study. It becomes incumbent upon us, therefore, to ensure we are not only meeting their needs, but are also at the forefront of using technology to enhance lifelong learning in all engineering disciplines.

4. Interactive Reconfigurable Classroom Environment

In the Iowa State University's aerospace engineering department, a new classroom has been developed and built, which is referred to internally as the "next generation interactive classroom." The classroom was originally conceived by Dr. Richard Wlezian, professor and chair of the aerospace engineering department and former NASA and DARPA program director. The classroom has been developed to embrace the latest technology available, as well as to enable incorporation of the technology aspects addressed above in active teaching.

The open-air classroom (Figure 1) is designed to enable interactive breakout groups, using rolling chairs, glass topped writing boards, and twelve video monitors lining both sides of the space. The rolling chairs provide for immediate reconfiguration of the classroom, enabling quick and effective breakouts. The glass boards line the entire space, with the monitors affixed directly to them, thereby allowing students to not only display their own work in real-time, but to also use the boards simultaneously.

Figure 1: Next generation interactive classroom (Howe 10)

The room easily holds as many as 120 students, providing them the ability to work in teams, with each team using individual monitors. Students can connect via AppleTV or through physical connections. In an alternate mode of operation, a master control allows for the instructor to display on all monitors and a drop-down screen simultaneously (Figure 2).

Figure 2: Team and lecture modes of operation

The room not only incorporates the latest technology infrastructure, but enables effective use of technology in other ways. The room has been used for the first offering of AerE 463X/563X: Introduction to Multidisciplinary Design Optimization (MDO), which was developed specifically to take advantage of the interactive reconfigurable classroom.

5. Teaming and Interaction in MDO: the Need for Rapid Teaming Environments

The new course, AerE 463X/563X: Introduction to Multidisciplinary Design Optimization (MDO), being taught by Drs. Christina L. Bloebaum and Bryan Mesmer, has been designed specifically with the new interactive learning classroom in mind. MDO is, by its nature, an endeavor requiring team interaction. The major topics in this class are identified in Table 1.

Table 1: AerE 463X/563X Outline

1 week	Motivation for MDO, Analysis versus Design, Multidisciplinary versus Interdisciplinary, Current Systems Engineering in perspective
1 week	Problem Formulation, Value Driven Design
2 weeks	Decision Analysis in MDO: Utility Theory, Game Theory, Mechanism Design
1 week	System Decomposition, Subsystem Couplings, Local versus Global Coupling Strengths, Design Structure Matrix
1 week	System Sensitivity, Global Sensitivity Equation Method
2 weeks	Search Methods in MDO: 1-D unconstrained, n-D unconstrained, n-D constrained (Sequentially Unconstrained Minimization Techniques)
2 weeks	Heuristic Search Methods in MDO: Particle Swarm Optimization (PSO), Ant Colony Optimization (ACO), Genetic Algorithms (GAs), Simulated Annealing (SAs)
2 weeks	MDO Frameworks: Multiple Discipline Feasible (MDF), Individual Discipline Feasible (IDF), All-at-Once (AAO)
2 weeks	Collaborative Optimization (CO), Concurrent Subspace Optimization (CSSO), Advantages/Disadvantages of Frameworks
1 week	Putting it all together: Decision Analysis, Value Driven Design, MDO

Each topic has been presented with the room in mind. As an example, during the discussion of system decomposition and the Design Structure Matrix (DSM) concept, students were challenged as teams to identify participating disciplines associated with a jet engine design, propose a decomposition strategy, list potential design variables and identify behavior variables (i.e. couplings) in the coupled analysis.

Figure 3 shows different teams working on the same challenge problem simultaneously. The room and supporting technology allowed students to rapidly form teams, start working on the problem quickly, communicate amongst themselves as well as other teams, and then report out using displays and glass boards. The entire exercise, supported by the technology and reconfigurability aspects of the room, occurred in a mere 15 minutes. Students were then reconvened in a traditional lecture environment, followed by a follow-up exercise where students again formed teams.

Figure 3: Teams explore decomposition using video displays, glass boards, and inter-team communication

Another example of the value provided from the reconfigurable capability can be seen in Figure 4, where the Particle Swarm Optimization (PSO) method has been taught using video displays concurrently with student participation. In this case, students were particles, randomly distributed around the cleared floor of the classroom. Chairs were easily pushed to the side, given the fact that they are all moveable (i.e. have wheels). The students were able to experience convergence of the method, even while seeing the equations and discussing the influence of the parameters associated with the method.

Figure 4: Particle Swarm Optimization (PSO) demonstration

The next generation room also enables the instructor to interact with the students in non-traditional manners. The instructor is able to flow freely from teaching mediums such as traditional projectors, stationary computers and white boards to non-traditional wireless tablets and circular student configurations. The ability for instructors to alter their teaching style seamlessly allows for the engagement of a variety of learning styles into the class[7, 8]. Properly planned lessons will enable each student with their individual learning style to connect to the material, enabling better learning and building interest for the material.

6. Concluding Remarks

It is clear that there are numerous opportunities available to incorporate leading edge technology, as well as facilities, into the teaching of MDO. Of particular benefit is the ability to rapidly redeploy students to enable in-class teaming exercises, together with the access to the internet, computers, tablets, and personal communication devices. This merger of technology with a reconfigurable classroom provides a state-of-the-art group learning environment, which can significantly enhance the student experience. Further, the ability to work effectively in teams having access to technology in the classroom will better prepare them for being MDO advocates in the future.

7. References

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