AC 2009-2009: SERIOUS GAMING FOR AEROSPACE ENGINEERING DESIGN: EXPLORING LEARNING POTENTIAL AND STUDENTS' READINESS

Yogesh Velankar, Purdue University

Yogesh Velankar is a graduate student in Purdue University School of Engineering Education. His research interests are in the area of corporate learning and designing effective learning environments.

Sean Brophy, Purdue University

Dr. Sean Brophy, is an assistant professor in Purdue University School of Engineering Education. His research interests are in using technology for learning and assessment. He brings experience in designing effective learning experiences based on theories of knowing and how people learn.

Masataka Okutsu, Purdue University

Dr. Masatak Okutsu is a postdoctoral researcher in Purdue University School of Aeronautics and Astronautics. He provides expertise in Space Mission Design and is a co-instructor in the Introduction to Aerospace Design during past semester. Dr. Okutsu is leading the project development of AeroQuest Serious Game.

Daniel Delaurentis, Purdue University

Dr. Daniel DeLaurentis is an assistant professor in Purdue University School of Aeronautics and Astronautics. His research interests and specializations are in the area of Aeronautical and Systems of Systems expertise. He is lead instructor of the Introduction to Aerospace Design course.

Serious Gaming for Aerospace Engineering Design: Exploring Learning Potential and Students' Readiness

Introduction

Engineering design involves generating original ideas and transforming them into innovations. This process of formulating ideas and expanding them is not done in a vacuum. The ideas come from careful listening to customers' needs and awareness of current technologies and understanding governing principles to identifying appropriate conceptual design alternatives. Developing this talent in engineering students involves engaging them in various design challenges that are solved through collaboration with team members. Project-based and challenge-based instruction are excellent instructional methods for organizing these kinds of learning experiences. An Aerospace Engineering Design course has blended project-based learning experiences into the traditional sequence of lectures and homework instructional design. Prior evaluations of this course demonstrate that students find this approach compelling and vital to their learning because it replicates experiences they anticipate having in their career. However, the experiences are still too artificial. Students report frustration when they know they need information, but the source of this information does not come until lectures scheduled much later in the course. Also, the instructor would like more detail of the quantity and quality of a team's interactions. The advancement of technology and what is known about principles of serious games suggest a course like this could be enhanced if it were implemented as a serious game.[1]

Our research team is transforming an introductory aerospace design course into a multiplayer on-line serious game in an effort to target learning goals beyond our current course implementation. This paper explores the rationale and potential for this conjecture. In addition, we recognize the success of this project depends on learners' willingness to use technology and learn with technology. In particular, what is their readiness to participate in a serious gaming environment? We begin with a brief description of the current course and how we are transforming it into the game play in the serious game. Next, we provide a brief description of learning theory guiding our design decision for the gaming experience. Finally, we share results from an initial study to evaluate students' use of technology and their willingness to use various technologies for learning. We end with future directions for using serious games for engineering design courses.

Current Course

The current course introduces second year undergraduate engineering students to principles of design and analysis of aeronautic vehicles. The course presents the fundamentals of Aeronautics & Astronautics Engineering (AAE) through a course project presented as a Request for Proposal (RFP) for a client. These fundamentals include aircraft and spacecraft anatomy, propulsion, aerodynamics, stability and control, orbital mechanics, vehicle sizing and cost estimate / analysis. The course culminates in a design project, which gives students the opportunity to apply their new aerospace design

knowledge to develop a conceptual design of an aerospace vehicle system. *Students work in teams* to perform analysis and design to fulfill an RFP, and deliver a technical presentation of the design along with a report that describes the approach followed to arrive at the final design configuration. The course is a required for a B.S. AAE and offered every semester. It can also be taken as a technical elective for other majors. The enrollment for this course is ~120 students per semester (Fall and Spring for 16 weeks).

This introductory aeronautical design course is ideal for an engineering serious game since teaching the fundamental task of engineering, which is to develop technical solutions by applying established scientific principles, is already embedded within the course. Also, this course is available to students early in the academic curriculum. Open enrollment to pre-college students with good academic background may also be a possibility, allowing prospective college students to explore engineering as their possible academic career. Most importantly, experience in this game can simulate the real-life of a working engineer. The established sense of *"presence"* in a corporate culture may increase students' awareness of common procedures and protocols for successful design activities.

Learning with Serious Games

Serious games are growing in popularity as a possible venue for current generation of learners. Over 97% of children ages twelve to seventeen play video games and engage in video based activities as part of their everyday life.[2] The popularity, complexity and engagement of these environments could have high potential for engaging learners in the richest learning experience for formal learning. Squire[3] argues that recent developments in gaming, particularly interactive stories, digital authoring tools, and collaborative worlds, have great potential for engaging learners in generative learning experiences. That is, learning experiences involve the acquisition and application of knowledge that often leads to synthesizing new knowledge.

Video games have the potential to change the landscape of education as we know it. Some learning scientists suggest that video games matter because they present players with simulated worlds: worlds which, if well constructed, are not just about facts or isolated skills, but embody particular social practices. Further it is argued that video games thus make it possible for players to participate in valued communities of practice and as a result develop the ways of thinking that organize the knowledge of that practices to accomplish common activities by the practice.[4]

Game Play for AeroQuest

Our serious game, called AeroQuests, is a corporate simulation of an aerospace design firm with an innovative work environment designed to foster the generation of new ideas for advanced aircrafts. Students take on the role of an intern working in the Research and Development portion of a company called AeroQuest. The major goal of the game is to design a competitively priced aircraft and/or rocket that a client needs delivered in a very short time. Each student is part of a design team who has their own room where they can

solve problems and develop their conceptual design for the RFP. Students collaborate with each other in various rooms in the 3D virtual world. Figure 1 illustrates these various spaces. For example, students can meet in a large courtyard that can host events like an interactive poster fair, or meet in an airplane hangar where they can experiment with various airplane configurations and test the performance of their design to meet specific missions. Or they can call up interactive simulations and models to conduct analysis on various aircraft components like an airfoil. Also, the design room contains a rich set of information resources in the form of videos, charts and text documents.

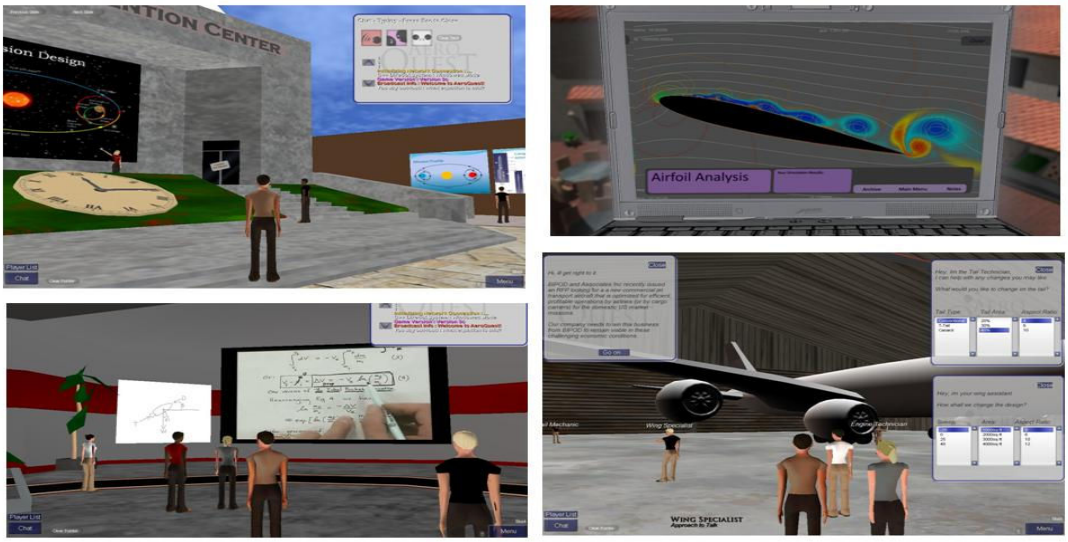

Figure 1. AeroQuest 3D virtual world with design tools and public forums

The game is in MPO (multi-player online) format. The process of design engages learners in a series of quests involving collaborative design team interactions, focused research and design activities on specific components and systems integration activities to bring the entire design together. We are combining current theories of learning and instruction with the principles of game design to provide a powerful new learning experience that prepares learners for future self regulated learning outside of academia.[1,5,6]

Our intent is to create a sense of presence in a corporate environment that will lead to a higher level of engagement and motivation for the students. Further it will provide an opportunity for students from multiple institutions to team with each other to pursue various design activities. We are currently developing a set of design tools contained in the design room to support a team's design decisions. For example, we are providing general tools such as shared white boards for generating ideas and refining these ideas. However, we also want students to perform analysis on their conceptual design. We are currently generating interactive design tools (e.g. house of quality, and morphological charts) to support students justification of design decisions. Further, we are working on methods for team members to share synchronously and interact with computational models to analyze potential design options. We see this suite of tools as central and the emersion in the virtual world as a method to introduce learners to a community of practice through a game like experience.[7]

Our overarching goals are to foster in students: experience and skills that develop adaptability and flexibility, a venue for innovation, and ability to combine technical knowledge with knowledge of management, business, and team dynamics. These goals will be achieved while the student is also entertained and engaged by the game's sensory features and interfaces combined with the intrinsic motivation from the intellectual puzzle associated with designing a quality product.

Linking Theories of Instruction with Gaming Principles

The principles guiding the design of scenario-based games are very similar to those guiding the design of effective problem-based learning environments. Both engage individuals in generative activities where they are challenged by the activities but to a level that leads to success as they progress. In addition, players obtain continuous feedback on their progress toward ever increasing levels of complexity that require them to refine their mastery of various tools and strategies. We see an opportunity to leverage effective instructional models based on theories of learning and knowing (e.g. as summarized in How People Learn Framework[8]) to guide the structure and interaction in a serious game.

The current course design already leverages ideas for effective learning environments associated with anchored inquiry approaches to instruction. The course engages learners in a process of guided inquiry around an interesting and complex challenge presented in a Request-For-Proposal (a common industry practice). Then through lectures and assignments learners develop the competencies necessary to respond to the RFP. Students engage in the process because the context is both interesting and valued by them, and because the activity of thinking through the problems successfully is intrinsically rewarding. Transforming the course from the academic setting to a serious game requires a framework, or model, for representing the instructional design and opportunities for assessment.

We believe participating in a 3D virtual world as part of learning the fundamentals of flight could provide learners with a stronger connection with the practice of engineering and a stronger ability to manage their design process. [1,2,6,9] Part of managing the process is coordinating meeting with team members, working together to make design decision and constructing design documents. This could involve using web-based tools such as simulations/models, wiki's for project management, video or voice-over-IP (VOIP) to communicate with teams. In addition it requires learners to be familiar with and interested in engaging in virtual worlds and game metaphors. The combination of all these tools and games need to be familiar and approachable to learners. If they are not accessible to the learners, then they may not be willing to participate in the gaming experience. One of our underlying assumptions is that students enrolled in our course fit the national/international demographics of students with a strong background and interested in technology based communication, entertaining and learning environments.[2] We need to explore several research questions to test our conjecture that serious gaming will be an acceptable learning venue for all students. These questions include:

- What are students' perceptions of technologies for leisure, communication with others and learning?
- How consistent are students perceptions across cohorts each semester and how do they align with the national/international demographics of young adults?[2]

The computer game technology provides a unique opportunity to monitor teams' actions and behaviors. This information can help an instructor track a team's progress and provide the instruction with multiple methods to provide suggestion and strategies for keeping teams and individuals on track. An additional goal for our research project is to explore the potential of using the 3D world to monitor team's decision making process, but this is outside the scope of this paper.

Methods

Students' use of games and their perception of technologies for learning were measured with a short survey developed across two semesters. In the Spring of 2008, a long survey of experimental questions was defined based on surveys used for evaluating game use and educational technologies.[2,10] The design of the instruments consisted of 54 items. We were interested in knowing what technologies are most commonly used by our students. Next, we targeted four basic categories of items targeting students' background with 1) games, 2) technology tools for communicating with others, 3) media production tools for internet, and 4) internet information sources (wikis, blocks and podcasts). The survey questions were developed to gain an understanding of students' current use of technology and games, and their use for academic learning purposes. Initially, some demographic information was collected, and most of the questions were close ended. The questions aimed at capturing what kinds of technologies do students own, how often they used different technologies and engaged in gaming. Additionally, students were asked to respond to how they liked to learn using technology and which technologies they would be willing to use for personal and teamwork activities in the aerospace engineering course. Finally, questions were posed to gain an understanding of how students played video games and what were their favorite online games. Many of the items targeted similar data using different formats of the questions. Therefore, we divided the questions into two separate surveys. These items were combined with specific course evaluation questions related to specific instructional methods used throughout the semester. The two versions were collated together, one after the other and passed out to students. Therefore, we were able to randomly assign an instrument to students and managed a balanced distribution between the two groups.

In the Summer of 2008, a third survey instrument was constructed based on the results of two surveys used earlier in the Spring semester. The research team decided to combine all the technology and gaming questions into a single survey and administered the same towards the middle of the Fall 2008 semester.

Participants

A total of 63 students responded to the survey in Spring 2008 and 100 students responded in Fall 2008. Table 1 below shows the distribution of participants across the two semesters.

Table 1. Participants

	Spring 2008		Fall 2008
	Form 1	Form 2	Combined Form 1& 2
Male	24	25	69
Female	3	5	14
Did not indicate	4	2	17
Total	31	32	100

Procedures

The survey was paper based and administered to students by members of the research team. It was made clear to the students that their participation in this survey was completely voluntary and had no implications on their course performance. The resulting data was manually entered into a spreadsheet and was subsequently analyzed to identify emerging trends and patterns.

Analysis and Results

The research questions for this study focus on profiling students' use of technology on a daily basis and what they are willing to use to support their learning during the design course. The survey was organized around three major categories related to the research questions. The first category focused on what technology students own and how often do they use various technologies. The second cluster of questions asked students to rate their experience using various technologies for their learning. The last cluster of survey items targeted students' willingness to use various technologies to support their learning. We attempt to line up the results of each section to provide a quick analysis for how repeatable the results are from semester to semester.

Technology Ownership

Figure 2 illustrates the students' reports on technologies they own. The figure indicates that standard cell phones are an integral part of every student's experience. As technology changes there may be a trend toward smart phones (internet ready and multi-purpose). Also, almost all students own either a laptop or desktop computer. Music players are common and owned by the majority of students. Like previous studies[2] a majority of students own game consoles of some sort.

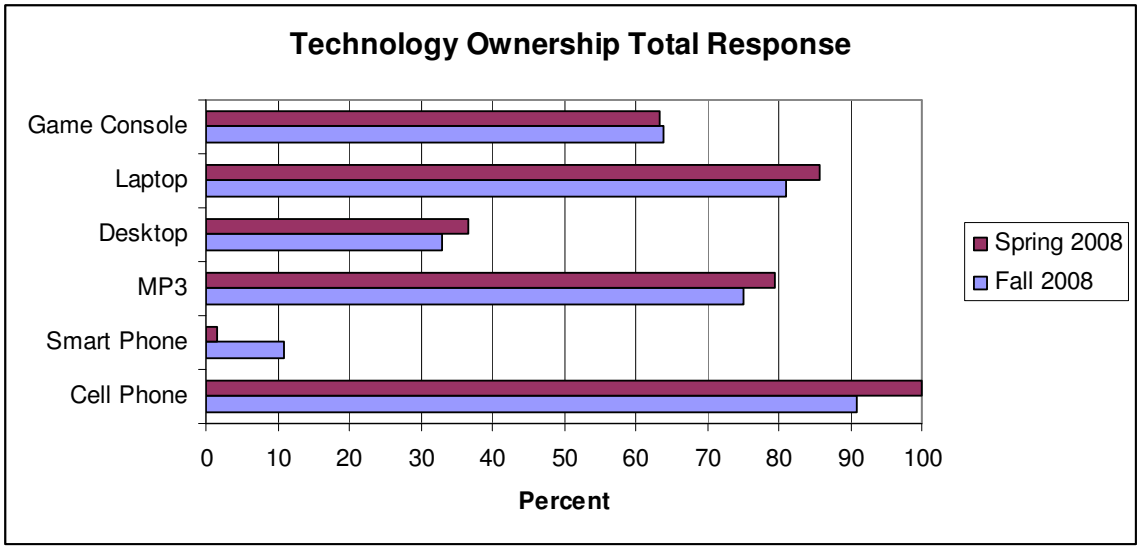

Figure 2. Technology Ownership, Spring 2008 (n = 63) and Fall 2008 (n = 100)

Figure 3 summaries students self report on how often they use various technologies. The items are grouped into four categories of questions that students answered shown in Table 2. Second year students indicate they play various games on a monthly basis. Also, as seen by other studies[2,11], these students are very social and interact with others on a weekly basis through a number of internet mediated methods.

Table 2. Categories of students' response on how often they use various technologies

Category	Survey Items
Playing games	Play online games Play consol games Play computer games
Communication methods with others	Participate in online social networks Use web based video conferencing Create, read and send text messages Create, read and send instant messages
Constructing multimedia information tools	Create web pages Create audio/video files to share with others
Get information from various internet 2 resources (beyond web searching)	Use podcasts Use Blogs Access or use wikis

However, students do not develop their own video or web based resources. Nor do they make use of various information resources such as blogs, podcasts or wikis. This could stem from the lack of use of these resources in their courses. Or they do not have personal interest in generating these kinds of resources as part of their regular activities (hobbies or sharing video on youtube.com).

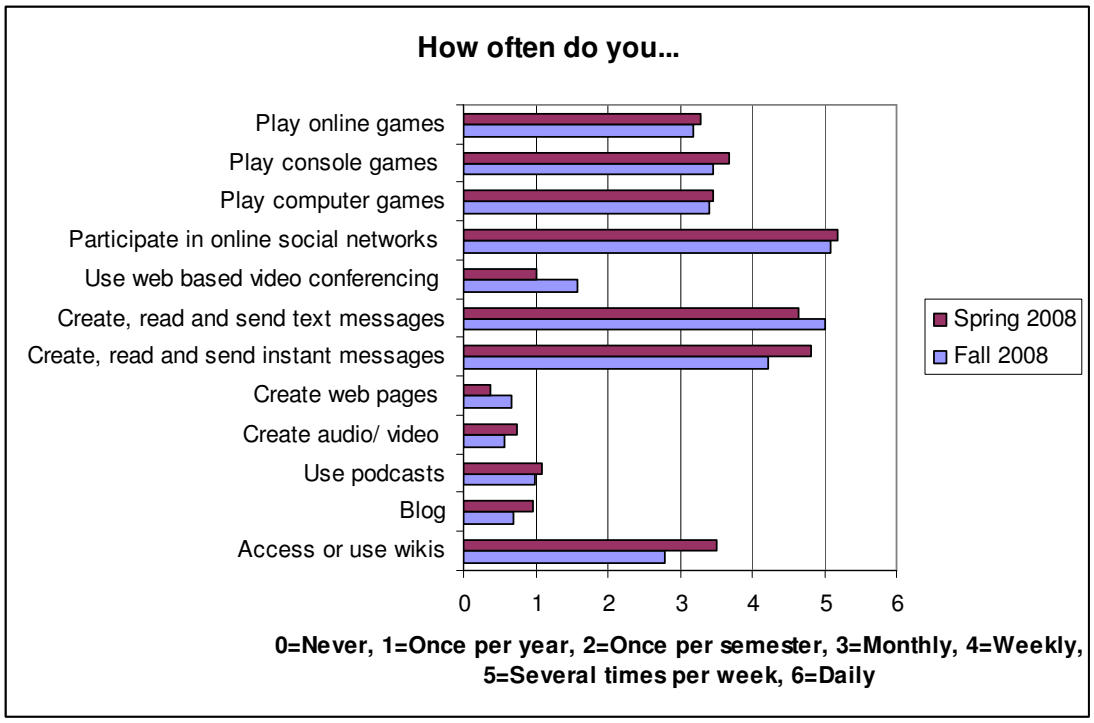

Figure 3. How often do you… Spring 2008 (n = 31) and Fall 2008 (n = 100)

Game Play Activity

Many second year students in aeronautical engineering experience game play, but this is not a central part of their activities. Interestingly, when they are playing games they are more likely to extend the social behavior indicated in the prior set of questions. That is, students' report engaging in game plays with others more frequently than alone (Figure 4). Game play is not the single player activity that might be associated with older style games. This is consistent with the Pew Report on teens and games.[2]

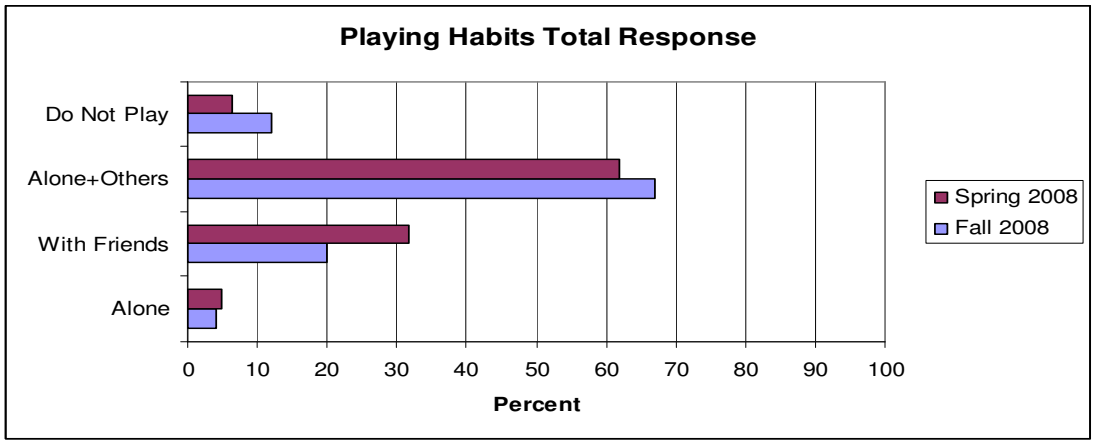

Figure 4. Playing Habits Total Response, Spring 2008 (n = 63) and Fall 2008 (n = 100)

Learning with Technology

The last two clusters of items on the survey asked students to rate their using technologies for learning. Figures 5 and 6 illustrate the results from two semesters. A majority of engineering students have used various technologies for their learning and agree that they like to use technology to support their learning. For example, they want programs they can control, like simulations and computational models. However, they do not indicate using much text based conversations (e.g. chat, blogs and wiki's) as a method for learning in their courses. This may not be an issue of willingness, but rather what is used in their current course as we look at the next cluster of items.

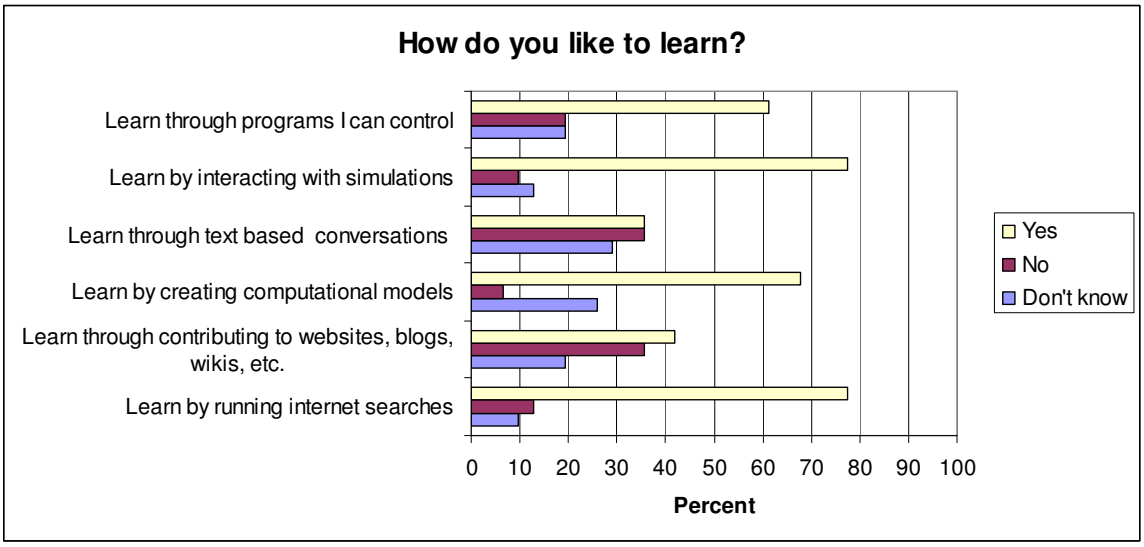

Figure 5. How do you like to learn? Spring 2008 Form 1 (n = 31)

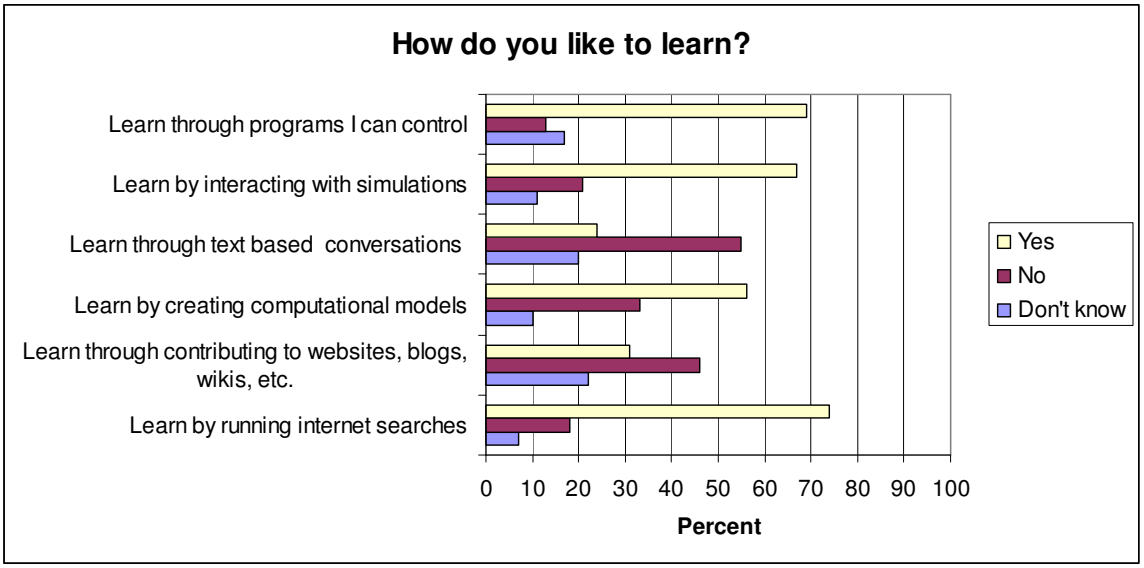

Figure 6. How do you like to learn? Fall 2008 (n = 100)

Students report mixed results over the two semesters regarding their willingness to use various learning technologies. Table 3 outlines a grouping of items used to capture various uses of technology related to general use and specific to engineering activities. Results for each of these items are shown in Figures 7 and 8.

Table 3. Categories of students' responses use technologies for peer interactions

Category	Items
Games	Multi-user online games
Simulations/models	Discipline specific technologies MATLAB Simulations
Communicating with friends	Online social networks Instant messaging Email
Getting information	Wikis, Blocks, Podcasts, webcasts, video-based tutorials, video conferencing
Online learning module delivery	Online-learning module with simulation BlackBoard

Several important observations can be identified for this cluster of data results. Many students report a willingness to use computational models and tools as part of their learning and some text based methods for communication. Unlike the other survey items, there is a larger variance between the two implementations of these studies across semesters. Also, a large percentage of students selected "don't know" for a large number of items. Additional analysis is being done on this data set to determine if specific profiles of students' responses to these questions compared with similar items on the survey.

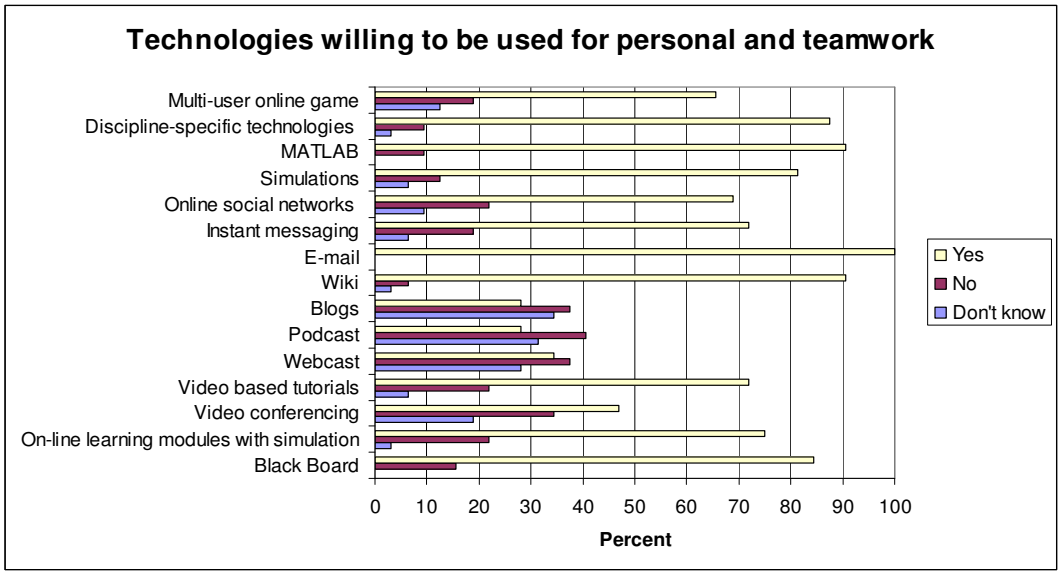

Figure 7. Technologies willing to be used for personal and teamwork Spring 2008 Form 2 (n = 32)

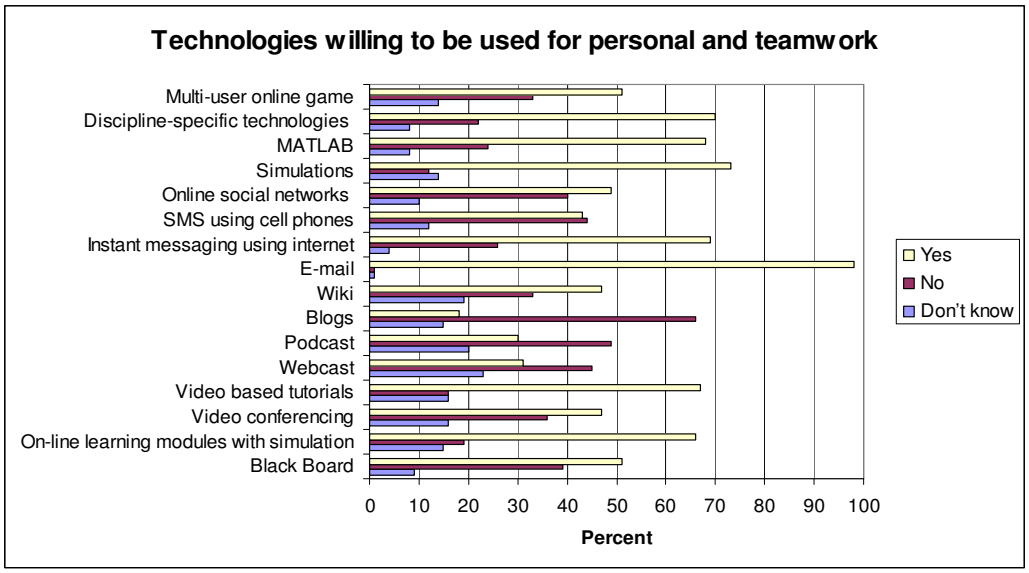

Figure 8. Technologies willing to be used for personal and teamwork Fall 2008 (n = 100)

The Fall 2008 survey also included questions about the advantages and disadvantages of multiplayer online games for learning. The following representative quotes from students summarize the advantages:

- "You get some social interaction with the mental stimulation of video games."
- "Talk instantly with each other, gain experience faster, easier making everything more fun."
- "Interactions with others, ability to ask questions."
- "Varied perspectives & the medium to express them."

Major disadvantages are evident from the following representative student comments:

- "When online, sometimes people forget you know who they are because of the anonymity typically offered by the internet, leading to random disruptions."
- "May not work properly on some computers, easy to lose the point of learning & just aim on winning."
- "The equipment required for every person to have is a major disadvantage, if one person's equipment isn't fast or isn't working properly, that person's experience becomes a poor one."
- "Miscommunication with others because of communication barrier of not being face to face."

Discussion

The surveys were designed to profile students' ownership and use of technology as part of their lives and their willingness to use technology for learning. The second year engineering students are high tech users of computer technologies and cell phones. They are very active in their social behaviors using facebook and text chat to keep in contact with others. Even in their game play they indicate playing more with others than alone. Many of the students have participated in interactive role playing games like AeroQuest. Also, many of the advantages students identified highlight the social interaction benefits of collaborating through the electronic medium. However, they also highlight the disadvantage of potential miscommunication. Many students indicate a willingness to use a number of technologies for working with their team including emails, simulations, and MATLAB. They are also willing to use distance education methods for their team based design activities.

We are encouraged that students are willing to consider using games as part of their learning experiences. Further students indicate a willingness to use many of the kinds of tools we are integrating into the learning experience like computational models, wikis and on-line tutorials. A small portions of students indicate they "don't know" about using these tools, but we hope they will be willing once they become more familiar with the tools. One concern we have is that a portion of the students mention not wanting to use games and other learning resources as part of their learning experience. We do not have enough information at this time to identify potential reasons for why they think this way other than the qualitative analysis of the open ended questions at the end of the survey for Fall 2008. As part of a future study, we would like to add additional measures to have a stronger indicator for why students might be reluctant to use the technology. Is it merely an issue of easy accesses and stability of the system, or is it more the uncertainty of the experience as a learning environment?

Final Remarks

The development of AeroQuest is ongoing and will be tested in the Fall of 2009. We are conducting a number of baseline and preliminary studies to anticipate the potential impact of our game. We observed many positive indications that students will be interested in using a serious game for learning about aircraft conceptual design. However, informal conversations during a pilot test we conducted during the previous semester indicated potential anxieties of students. Students will be anxious to try something new when a high stakes event like course grades is involved. Also, they would like to have visible contact with their instructors. Additionally, several students indicated that if they have the opportunity to meet face-to-face with their team or their instructor, then they would prefer this mode of collaboration. These are valid concerns that we are addressing as we design the game. For example, the gaming environment will be designed to give students various feedback opportunities through automated methods. In addition many learning experiences will involve direct contact with the instructor, but in the virtual world. We anticipate that the combination of automated feedback and more direct feedback from the instructor will ease students' anxiety.

Further we want students to be engaging in more self regulated learning experiences; therefore, we feel the level of direct contact with the instructional team should be monitored and regulated similar to what would be expected on the job. Students will have a much better indication of their progress in the course than through traditional methods. In addition, instructors can use this same data to monitor students' progress and offer assistance when needed. We are currently building a number of collaboration tools in the virtual design room to permit students to work together to generate ideas and develop possible solutions for their conceptual design. In addition we are working on methods for students to use computational tools as a team to analyze and justify their design decisions. We anticipate that these virtual tools could be more productive than tools used for face-to-face meetings. Therefore, students may find these tools more productive resulting in a stronger willingness to use these tools. We also believe the role playing in the corporate environment will add to their interest in the game and more importantly give them a stronger concept of what it means to work in the profession.

The virtual world provides a unique space for a class to meet and interact with their peers, instructors, TA's and artifacts in a way that cannot be simulated in the same way in traditional classrooms. Teams can now access information as they need it rather than waiting for the appropriate lecture to be delivered at a specific time in the semester. Learners have more control of regulating their own pace for learning new content. In this way, we can provide students with more meaningful engineering design experiences.

Acknowledgements

Funding for this research and AeroQuest was made possible by Purdue University's Discovery Learning Center, and the support of the School of Engineering Education, and the School of Aeronautics and Astronautics.

References

1. Gee, J. P. (2007). *Good video games and good learning: collected essays on video games, learning, and literacy (New literacies and digital epistemologies).* New York. Peter Lang Publishers.
2. Lenhart, A., Kahne, J., Middaugh, E., Macgill, A., Evans, C. and Vitak, J. (2008). Teens, Video Games, and Civics. *Pew Internet and American Life Report*. New York:Pew Research.
3. Squire, K. (2003). Video games in education. *International Journal of Intelligent Simulations and Gaming*, 2(1), 49-62.
4. Shaffer, D. W., Squire, K., Halverson, R., & Gee J. P. (2005). Video games and the future of learning. *Phi Delta Kappan*, *87*(2), 104-111.
5. Amory, A., Naicker, K., Vincent, J., & Adams, C. (1999). The use of computer games as an educational tool: identification of appropriate game types and game elements. *British Journal of Educational Technology, 30*(4), 311-321.
6. Munz, U., Schumm, P., Wiesebrock, A., & Allgower, F. (2007). Motivation and Learning Progress Through Educational Games. *IEEE Transactions on Industrial Electronics, 54*(6), 3141-3144.
7. Barab, S., Thomas, M., et al. (2005). Making learning fun: Quest Atlantis, a game without guns. *Educational Technology Research and Development,* 53(1): 86-107.

8. Bransford, J. D., Brown, A. L., Cocking, R. R., & Donovan, M. S. (2000). *How people learn: Brain, mind, experience, and school (Expanded ed.)*. Washington, DC: National Academy of Sciences.
9. Westera, W., Nadolski, R. J., Hummel, H. G. K., & Wopereis, I. G. J. H. (2008). Serious games for higher education: a framework for reducing design complexity. *Journal of Computer Assisted Learning*, 24, 420-432.
10. Nordstrom, P. A. (n.d.) *FACAC student survey report, Fall 2006*. Retrieved March 2008, from http://tlt.its.psu.edu/about/reports/2006
11. Caruso, J. B. & Kvavik, R. (2005). *ECAR study of students and information technology 2005: Convenience, connection, control, and learning*. Educause. Retrieved March 2008, from http://connect.educause.edu/Library/ECAR/ECARStudyofStudentsandInf/41159