Learner Centered Games: A Pathway to Student Motivation and Engagement

Abstract

The internet has brought many new resources to students that have the possibility of improving the learning environment. However, with this has come an increasing expectation among students that learning should be easy and that the primary responsibility for student learning falls on the instructor rather than on the student. The challenge is determining how to redesign the educational process so that these new resources are used appropriately and do not encourage the student to become a passive learner. The key to addressing this challenge may be found in student motivation and engagement. According to the authors, student engagement is an essential element in the design and implementation of an effective learning environment that must be deliberately stimulated and measured. An engaged student is one who has a realistic plan for learning and implements that plan at their full potential. According to the authors, reconnecting or integrating the educational process with the student's values, interests, goals, and aspirations (who the student is) will significantly strengthen the motivational basis for their education and lead to a higher level of engagement, learning, and academic success. Although the most effective means of impacting student motivation and success is to address all aspects of who the student is, the focus of this paper is on the use of games delivered in a learner-centered environment that focuses on student interest and integrates the educational setting. The authors have designed and implemented several motivational and engaging games where engineering students go beyond their own expectations, and the expectations of faculty, and willingly spend three or four times more than that envisioned by the instructor for the projects. This significant increase in engagement and motivation provides evidence that games are an effective pathway to academic success. The particular connections between game activities and key aspects of student motivation are explored. An understanding of these connections is a powerful design tool for the development of new games that can focus on particular student needs.

Introduction

The engineering education environment has seen many changes in the past twenty years. Advances in computers, networks, and technology have made a wealth of information and computational tools accessible to students like never before. Course web sites give students access to supplemental learning materials[1], an ability to dialog with other students and faculty on forums[2], and even tutorial movies ranging from working through homework problems to using modeling or computational programs related to the course[3]. In addition, there has been a flood of interest in and funding of engineering education research. One would assume that with all of these advances and focused attention that student academic success would be growing exponentially. In fact, many advances have been made in the tasks that students can accomplish through the use of new technology, however one must question whether today's engineering students are making full use of their abilities and available resources. As many of the obstacles for learning are being removed, through recent advances in technology, students may take a more passive role in the learning process than they have in the past. An appropriate analogy may be

the shift in culture from reading novels to watching movies and the repeated criticism that children are not as imaginative as a result. Typically with any change there are positive and negative effects. The challenge in engineering education is to take advantage of the positive effects and understand and deal with the negative effects.

The authors have been actively using technology to enhance engineering education and have observed that students often develop an expectation that learning should be easy and primarily the responsibility of the teacher. Students, however, that make use of the new teaching tools (on-line lecture notes, simulation and modeling programs, etc.) achieve greater academic success than would otherwise have been attainable. It is clear that students who achieve academic success are the students who really learned. But who are the students that are learning in this new technically advanced learning environment? The authors suggest that it is the students that are engaged in the learning process. An engaged student is one who works at their full potential and makes proper use of the resources available to them. If they are provided with a tool that makes accomplishing a task easier they don't give less of themselves but rather press forward to accomplish greater tasks. They have a plan for learning that is realistic but that involves significant effort and challenge. Although a few engaged students may enter engineering programs it is possible to develop and nurture this characteristic in students through a deliberate plan and focus on student motivation[4,5,6].

Student Motivation and Engagement

The pathway that leads to academic success begins with motivation. A motivated student given the correct environment and direction will become an engaged student. An engaged student will take advantage of available resources and become an active participant in the learning process. For an engaged student, learning often extends beyond the teaching offered in lectures and provided teaching resources. This higher level of learning translates to academic success as measured by higher grades, greater depth of knowledge, and an increase in peer to peer mentoring, and overall improved retention. The authors have discovered that if students are guided along this pathway, they typically enjoy documenting and sharing their learning experience. This documented learning that extends beyond the provided resources can easily be added to supplemental course materials on the course web site. This public and lasting presentation of their learning has become an additional source of motivation for students.

It is important to provide engaged students with significant resources outside of required course content so that they are able to take their learning to whatever level their abilities allow. There is a danger however to providing a wealth of supplemental materials to students that have not been motivated and who are not engaged. Such students may lose sight of what is the essential course content and often become dependent on the teaching resources and are reluctant to think on their own. They become passive learners and look for the least challenging route through the course. The classroom can be an effective place to gauge and develop student motivation. Motivating students who will become engaged in the learning process requires deliberate and careful intervention, planning, and monitoring but can yield tremendous dividends in terms of academic success.

The key that has been used to unlock student motivation is simply reconnecting course content and the learning process with students' values, interests, goals, and aspirations. This approach is based on the National Academy of Science's principles for the design of learning environments (DLE principles) and the concept of selective integrative (SI) learning. According to a National Academy of Science report[7], effective learning environments are a complementary mix of learner-centered, knowledge-centered, assessment-centered, and community-centered environments[8]. *Learner-centered environments* help students make connections between their previous knowledge and their current academic tasks[7]. *Knowledge-centered environments* help students to develop organized knowledge that is accessible, applied appropriately, and that enables learning with understanding[7]. *Assessment-centered environments* provide students with opportunities to revise and improve the quality of their thinking and understanding[7]. Finally, *community-centered environments* promote a sense of community[7]. *Selective integrative learning* is enhanced learning obtained from integrating elements of the learning environment where it yields optimal results considering learning, costs, and complexity[9,10,11]. An SI environment seeks to integrate course content and the learning process with *content from other courses, the educational setting, accessible assessment/feedback, and family and student involvement*. Integration of the educational setting takes advantage of the many opportunities for guided learning in settings outside of the classroom and laboratory and allows for making stronger connections by instructing students in different mental and/or emotional states.

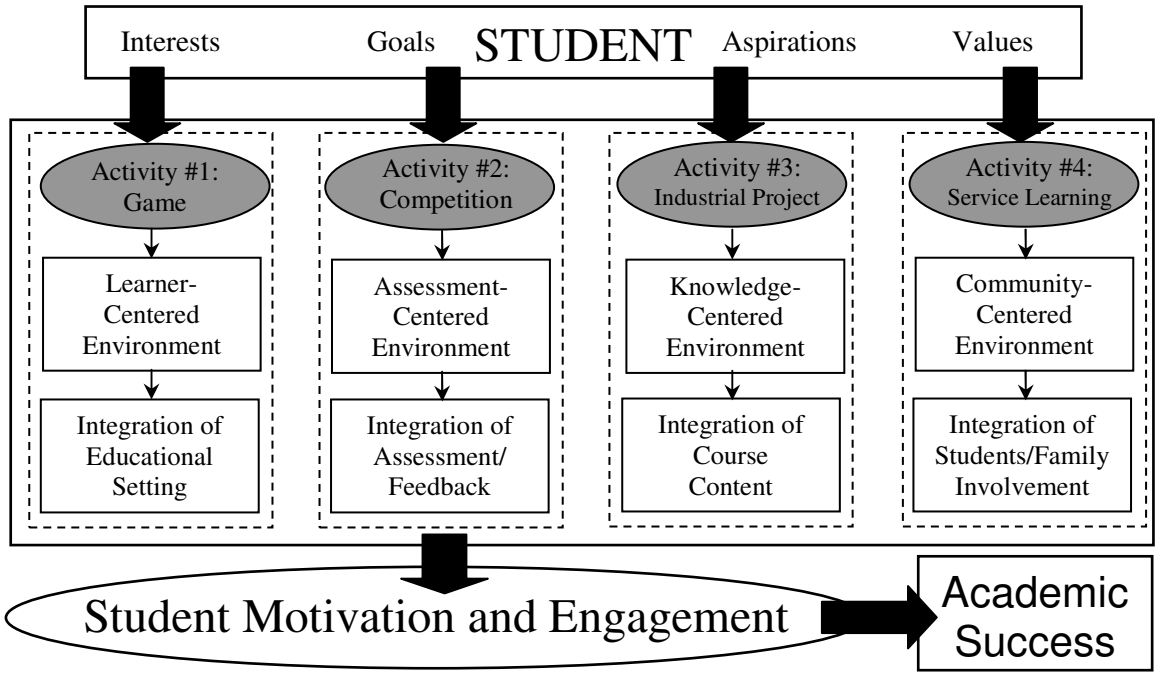

Figure 1: Pathways to student motivation and engagement

It is difficult to design an activity that supports every aspect of a well designed learning environment. A more expedient approach is to design activities that create pathways from individual student needs (interest goals, aspirations, and values) to motivation and engagement. Figure 1 shows an approach that uses four distinct pathways. Designing at least one activity for each pathway in a course helps to build a connection that will be effective for a variety of

students. Many proposed activities may actually span several pathways, however offering students a variety of focused pathways will target individual students and may be more likely to engage the student. The particular focus of this paper is on the development of one pathway to motivation; learner centered games that address the student's interests by integrating the learning process with entertainment, an atypical educational setting.

There are many possible approaches to designing an activity that will create a pathway to student motivation. One method is to randomly experiment with different activities and record student responses and outcomes. Although much can be learned from this process it is time consuming and students may not always benefit. A more systematic approach has been used by the authors that implements an engineering design method. The approach is based on the concept of Quality Function Deployment (QFD) to define, design for, and assess student motivation. The QFD approach quantifies the perceptions of and impact on stakeholders to determine effective and optimal activities that measurably increase student motivation and engagement. QFD is heavily used in industry to design commercial products and has been previously used to prioritize both courses and course content based on the degree of impact on program objectives[12]. The objective of the QFD is to provide a systematic method for using information collected from the different constituents (faculty, students, families, and employers) to identify, design, and evaluate which activities will best connect with students' values, interests, goals, and aspirations and result in motivation and engagement.

The QFD process begins by identifying the different expressions of student motivation (functional performance parameters or objectives) and how those expressions will be measured (measurable design targets or outcomes). Based on preliminary surveys of faculty and students it was discovered that student enthusiasm for course content would likely impact academic success. One measure of student enthusiasm for course content would likely be student retention and attraction. The list of functional performance parameters (objectives) identified that support the learner centered pathway include those shown in Table 1. The final step of the process is to design activities that focus on each functional performance parameter and assess measureable design targets (outcomes). The rating of the level to which the functional performance parameters are currently being satisfied in a particular course provides an indication as to what motivation activity needs to be added to raise the level to an acceptable value. This is an iterative process that may be repeated over several years to yield optimal results.

Table 1. Summary of QFD results for design of learner centered games

Functional Performance Parameters	**Measureable Design Targets**
Promotes Students' Perseverance	Increase Graduation Rates
Increases Students' Enthusiasm	Increase Retention/Attraction
Develops Students' Initiative	Increase Student Class Engagement
Increases students' Self-Motivation	Increase Student Employment Opportunities
Encourage Students to Take Ownership	Increase Student Class Engagement
Promotes Inquisitive Attitude	Increase Student Participation In Research
Develops Students' Willingness to Learn and Work	Increase GPA

In a freshman engineering graphics course, data on learned student visualization skills were collected for seven semesters to measure the impact of providing motivation activities that address historical low performance in this area (an average competency of 40%). Proposed

activities were evaluated on the basis of how they addressed the functional performance parameters as measured by the design target to which they have the strongest links. Through this approach several appropriate motivational games were identified and designed for students that ultimately led to greater motivation and engagement. The games created a pathway to student motivation using learner centered games that integrate the educational setting based on student interests.

Fourteen games were developed for the engineering graphics course that focused on identified problem areas including visualization skills. After implementation of the games, appropriate design targets were monitored for five semesters to measure the effect. The average competency level in visualization skills rose 29% following implementation of the games as shown in Table 2. In a student survey given in a semester when the games were an optional activity, 60% of students indicated that the games helped in the development of their visualization skills and 72% identified the games as a "helpful interactive approach to teaching key concepts in the course". Activities developed for the other pathways included: an assessment-centered engineering knowledge competition that integrates the assessment/feedback based on student goals; a knowledge-centered industry project that integrates the course content based on student aspirations; and a community-centered service learning project that integrates students/family involvement based on student values.

Table 2: Effect of games on measured competency in learned visualization skills

Semester	Fall 00	Spring 00	Fall 99	Sum. 99	Spring 99	Spring 98	Spring 97
Interactive Games	Optional	Required	Required	Required	Optional	Not Available	Not Available
Average Competency	62%	74%	77%	73%	61%	42%	39%

Following the development of learner centered games, the implementation must be studied and feedback given to the QFD design process to ensure that the activity is producing the desired effect. Although individual student response to activities that focus on different pathways will be unique, there should be a measureable effect on the total student population if the activity is to be added to the course. Such has been the case with learner centered games. These activities have been implemented in a number of mechanical engineering courses and have had a significant positive impact on a majority of students in each course. The positive results of the implementation of 14 simple web-based games was the impetus for the development of a game like framework for the entire course, an interactive 3-D virtual world chat community, that has also produced measurable positive results on motivation and engagement.

The Use of Learner Centered Games

The development of games needs to be learner centered in that it accounts for both the student's current level of learning and their interests. Some of the most effective games developed by the authors centered on course topics that students typically found to be challenging and that were significant to the understanding of other course content. Students need to know that there is a benefit to their learning attained through playing the game. To better understand student interest, students were surveyed and asked to select game like activities that they would be interested in.

A short summary of the game was all that was developed for the survey. A sample game summary that was presented to students is shown in Figure 2. Finally, simple prototypes of games have been tested with students to measure their interest in a particular game style or theme. Once a simple prototype game has been identified it can be formally developed to include significant course content. One discovery that simplifies the process is that a popular game theme or style that works well one course can often be effectively modified to be used in another course with similar success. Notable exceptions are games that are overused or that are age dependent. An example is the 3-D virtual world chat environment that continues to be successfully used in a freshman level engineering graphics course. A prototype of the same game like environment was developed for a junior level engineering course and was not well received by students. The difference was that the juniors felt they had too many time constraints to spend significant time in an environment that was game focused with learning mixed in. The upper division students prefer activities that are content focused but that are also game like.

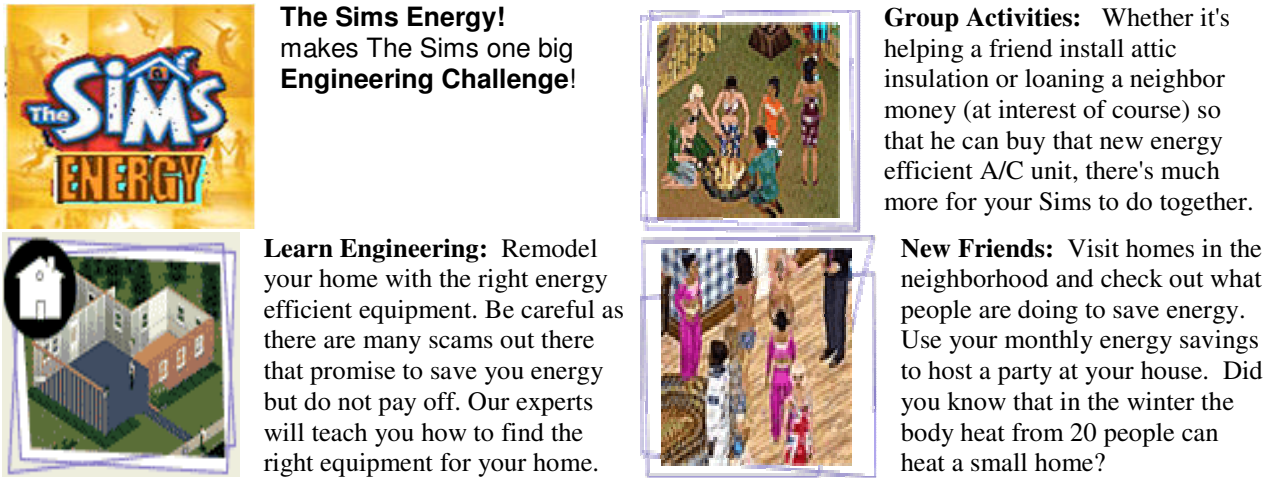

Figure 2: Game idea presented to students in activity survey.

Effective learner centered games can range from a simple online activity that takes less than a day for a faculty member to create and a few minutes for students to play to an elaborate environment that takes years of development and that serves as a framework of course content for the entire semester. Both have been used effectively by the authors with measureable success in student academic success. The simple games are a rational starting place for testing the impact of games. Once the connection between games and student motivation has been established the development and use of more significant activities can be explored. In either case a simple prototype should be tested as student response has generally been consistent between an early prototype and the final working game environment. Although in theory any game environment that interests students would be effective, the authors have solely worked with web-based games that are linked to course web sites.

An example of a game environment that has been successful in several courses spanning from freshman to seniors is a simple drag and drop game that has been implemented as a web page. The basic game design is built around the concept that objects on the screen have correct placement and it is the student's task to rearrange the objects until they have found their correct position. The game format includes the ability to provide feedback based on the student's

actions and congratulates the student when they successfully complete the game. The advantage of making this game a web page is that it is easily linked to other course content on the course web site. The most effective implementation of this game format has been in games that only take three to five minutes to complete. Longer games that cover more content are possible in this format by including several game levels that the student advances through.

One advantage to using game levels is that students can start at a level that is appropriate to skills and knowledge of course content (learner centered), although it has been observed that students enjoy the reward of completing levels below their abilities for the boost in their self-confidence. Figure 3 shows an implementation of this game format. The Java applet shows the prototype board that students will use in the upcoming lab and a schematic of the circuit that they will be building. The objective of the "game" is to drag the appropriate electrical components to the correct position to complete the circuit shown in the schematic. Students use the exercise before and during lab as they are more comfortable building the circuit after seeing the finished circuit with the physical components in place. This content focused game has a connection to a course learning objective that is obvious to students. This type of content focused game has worked most effectively with upper division students.

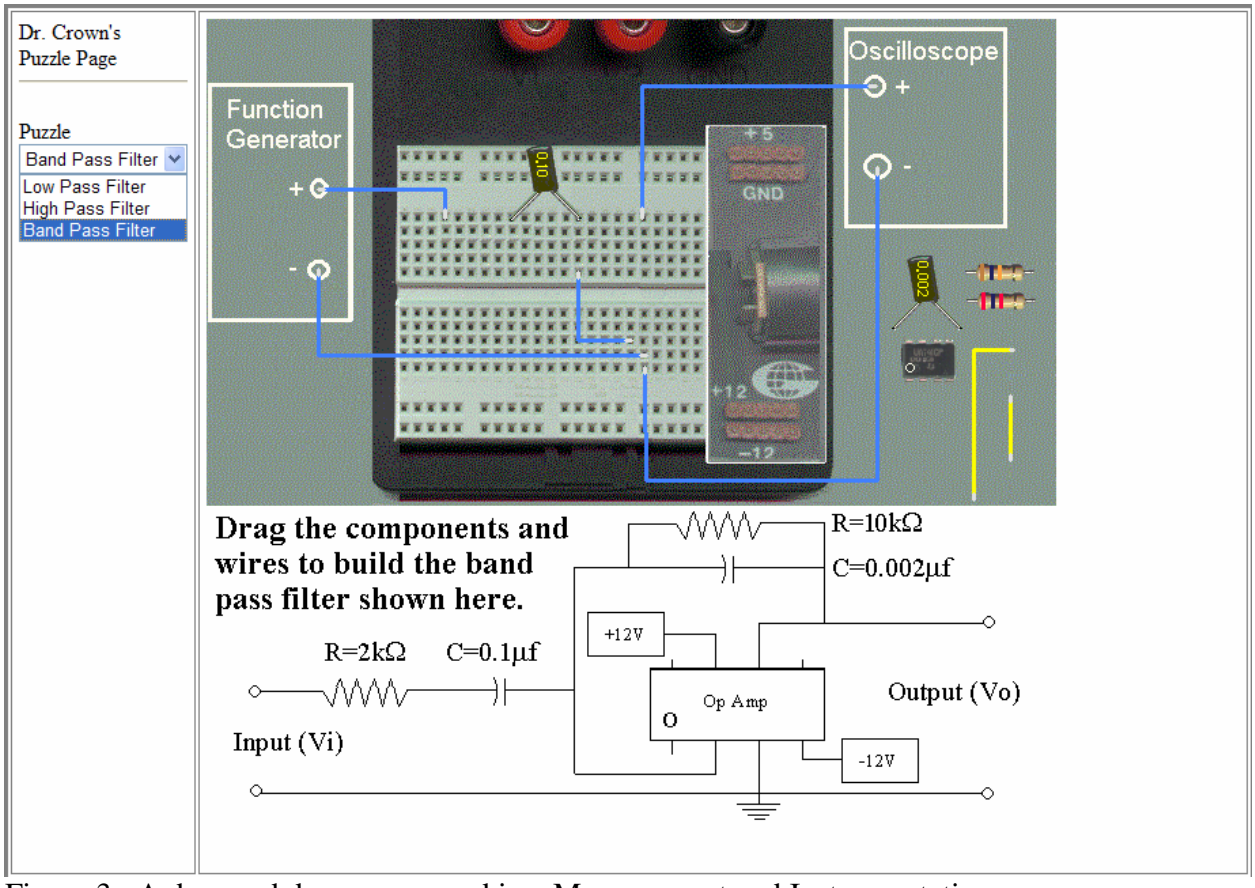

Figure 3: A drag and drop game used in a Measurement and Instrumentation course

Another game using the same game format was developed in the spring of 2007 by students as part of a class assignment. The objective of the game is to determine the appropriate forces and couples from a menu and place them in the correct location on a beam given the shear and

moments diagrams as shown in Figure 4. Since there is an infinite number of arrangement possibilities the game is open ended and challenging. Over 20 levels of the game provide an increasing order of complexity that provides students with immediate feedback as they move on to the more challenging levels of the game. The game was developed in response to the identification of a weakness in the students' fundamental understanding of shear and moment diagrams. The observed engagement of students in both creating and using the game as a study aid was unusually high as compared to other class assigned projects. The measured design target that was measured in this case was the performance on a midterm exam covering the concepts of Shear Force (V) and Bending Moment (M) diagrams and the corresponding equations. The average student grade on these concepts was an 83.5% as compared to an average of 76% on the remaining exam content that was not reinforced with a game activity. Students also strongly indicated on a course survey that they believed the games benefited their learning in the course. Specifically, 96% indicated that they agree or strongly agree that "the games helped them to understand the solid mechanics topics", 75% that "they will remember what they have learned for a long period of time", and 92% that "they would like to see these teaching methods (games) used in other classes."

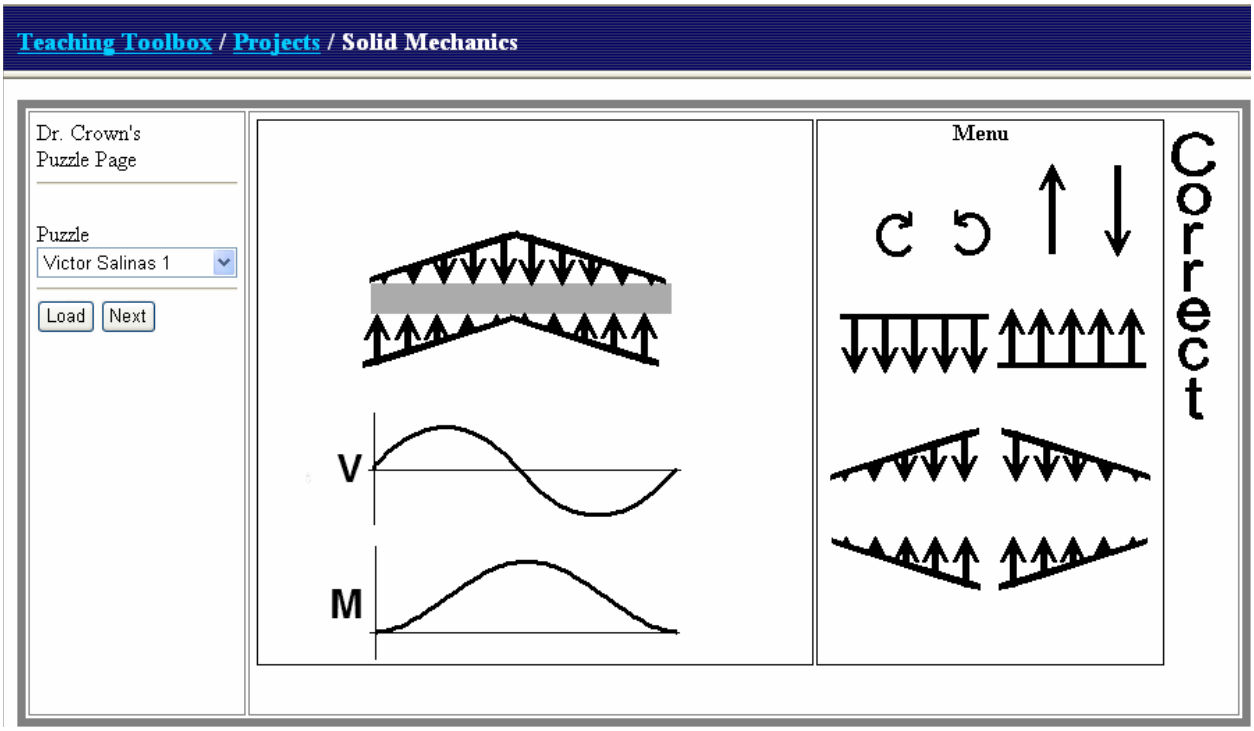

Figure 4: Sample of game designed by students

An example of a complex game environment that has worked well with freshman is the virtual world. The virtual world has been used effectively in the engineering graphics course as an interactive chat environment where students can engage in dialog about the course or simply to meet and interact with others in the course. The freshmen are best motivated by game focused activities that subtly mix in course content. The virtual world environment is used to deliver all of the laboratory content for the entire semester. Students also post their homework to the virtual world by creating objects for their virtual homes. Figure 5 shows the interaction possible in the engineering graphics virtual world.

The ability to leave a legacy in the virtual world environment has been the interactive game like feature that had the greatest impact on student motivation and engagement. This legacy is three fold in the graphics virtual world. Students regularly interact via a chat window to give real time assistance to other students in the class giving students the opportunity to pass on what they have just learned. Students' virtual homes are populated with furniture that they make with computer aided design software that they are learning how to use in the course. This outlet for the expression of their creativity in a game like environment has motivated students to the point that specific graded homework assignments are not necessary by the middle of the course. Finally, finished semester projects and exam work is incorporated into the site so that greater teaching resources are available to future students. In the fall semester of 2006 the average grade on the third exam was 91%. The exam assignment was to build a computer aided design (CAD) of a mechanism that would go in their virtual home. The majority of students went well beyond the assignment expectations and students spent 3 to 4 times the effort as on similar projects assigned before implementation of the virtual world. Examples of CAD models made by students motivated by the virtual world homes are shown in Figure 6. The models and student instructional content is posted on the course web site to give students a standard by which to measure their work and as a record of their accomplishments much like a high score on a machine in a video arcade.

Figure 5: Engineering Graphics Virtual World

Figure 6: Examples of student work following introduction of virtual homes.

Conclusions

Student motivation and engagement are critical variables in controlling academic success. It is possible to design and implement course learning activities that focus on motivation and engagement. A systematic approach for defining, designing for, and planning for assessment of student motivation is the QFD. This method has been effectively used to design learning activities that motivate students and ultimately produce positive measureable results in academic success. Learner centered games that focus on student interests provide an effective pathway to student motivation and academic success. Successful games include simple web based games that may take only a few hours to create to complex gaming environments that form a framework for an entire course. Students that are motivated through specifically designed course activities can not only provide opportunities to create environments that motivate and engage students to think reflectively about engineering content and to invest energy and time in mastering its concepts, but also provide opportunities to involve students in the development process to promote greater engagement and learning.

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