Early Project Based Learning Improvements via a "Star Trek Engineering Room" game framework, and competition

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Abstract - **In this work, we show how providing a constrained project framework for a second year digital design course improves the number of working student projects from 55% to 86%. Instead of an open-ended project as in previous years, we introduce an optional project framework, called "Redhawk Duels". Redhawk Duels is a game framework in which students design control algorithms and interfaces for a virtual ship. Once a competition begins, two opposing groups and their respective ships attempt to incapacitate the opposing ship by finding the opponent, shooting them, and budgeting their energy accordingly. Fifteen of the twenty-one groups in the 2010 class participated in Redhawk Duels for their final project, and 86% of these projects were working and demonstrated with sufficient complexity. The remaining six groups chose to implement open-ended projects and had a 66% success rate. This rate is similar to the 55% success rate of the 2009 class which were all open-ended projects. We surveyed the students involved to see how they felt the project helped them and how much they enjoyed the activity. The results show that the students strongly agree that participating in the framework motivated them and will help them in future engineering design projects.**

Index Terms – Digital Design, FPGA, Project Based Learning

INTRODUCTION

The engineering chief on the Enterprise, Scotty, could always come up with a quote such as, ``I'm giving her all she's got, Captain!" that would capture what most engineers feel during design and problem solving while building and testing large systems. This is especially true during the four years of undergraduate education where students take their first steps towards becoming an engineer. Not many people realize how hard it is to design even simple systems and to ask a young adult to build a system that doesn't inspire them can be mild form of torture. And yet Project Based Learning (PBL) is becoming more and more popular within Engineering as well as business and medicine [1] , [6], [7].

One way to motivate and inspire students to excel at their projects uses competition as an element of play that pushes students to spend significant time designing. In electrical and computer engineering, robotic competitions are the most popular type of competition where university teams compete against each other. For example, the robot world cup [2] is worldwide competition where more than 3000 competitors meet in a number of divisions. At Miami University, we compete in autonomous vehicle challenges to mow a lawn autonomously [3] with more than 20 teams from across the USA competing.

Though these competitions are great, the teams tend to include students from senior capstones or graduate projects and require a student to have at least three years of training. Newer students can still compete, but do not get the full benefit since the complexity of the systems is often beyond their understanding. Instead, these beginning students design simpler systems in programming courses and hardware design that either are toy projects such as processors and operating systems, or they build simple applications that don't necessarily capture their imagination.

In a digital system design course, the goal is to have students understand how transistors can be organized as logic gates, how logic gates can be organized to do calculation, communication, and control, and how calculation, communication, and control can be used to build systems that solve problems. In many cases, the last third of these courses involve a more complex design project as part of a PBL curriculum. These complex designs can include creating a simple computer processor, a vending machine, a traffic light, or an open project of the student's choice. At present, development boards using technology from companies such as Xilinx and Altera and their accompanying university programs [4],[5] allow students to build more and more complex designs that interface with a number of peripherals. For example, students at Miami University in 2009 built processors, encryption algorithms, hardware based maze games, and music tuners. Unfortunately, only 11 out of 20 open ended projects in 2009 were working at the end of the semester.

For this reason, we have created a game framework that will allow second year students to build their own ship interfaces in digital hardware. The idea is that adding constraints and example designs will help prepare students to build their first major project. The students have the option of participating in ``Redhawk Duels" as it is named, or generating an open ended project similar to how the course was run in 2009. In 2010, fifteen groups participated in Redhawk Duels and six groups chose to make their own open ended design. Fortunately, in 2010 all twenty-one projects were working demonstrations. However, four of these projects had poor evaluations due to their lack of complexity and are still considered to be failures. These failed attempts are distributed evenly between both the open projects and the Redhawk game framework meaning that the open projects had a 55% success rate in 2009 and a 66% success rate in 2010. Participants in the Redhawk Duels framework in 2010 had an 87% success rate in producing a working project with adequate complexity.

In the remainder of this paper we will describe the Redhawk Duel Framework, compare an open ended project to a Redhawk Duel project to illustrate that the two projects deal with similar design problems, and finally, we will show our results in terms of student's perception of Redhawk Duels with a survey.

BACKGROUND

PBL curricula are one of the norms for teaching engineering, business, and medicine [1], [6], [7]. Electrical and computer engineering is no different, and at Miami University, the senior capstone concludes this type of curricula with a number of projects over the four years. The capstone, itself, has been studied by scholars to help understand how to prepare students for this culminating experience [8], [9], and researchers have questioned what is project design teaching, learning, and thinking [1], [24].

The general approach in engineering schools is to prepare students as designers by including major projects throughout the curriculum. The accreditation agency, ABET, among other entities, influenced engineering programs into including a major capstone around 1995 to 1997 [7]. For computer engineering curriculum, lab courses have evolved to include both weekly labs with major term ending projects [10], [11]. In response to establishing project components to courses, a number of documented and undocumented efforts have been made with open projects [12], fixed projects [13], [14], and competitions [15].

Motivation for a student to do a project has been a topic of interest for engineering educators. In particular, robot competitions have been a popular approach to motivating and educating students [15], [16], [17]. Similarly, video game design has been a popular approach to motivating students to program [10]. Both of these approaches have been shown to be slightly male biased [18], [19], and are not necessarily the best approach to motivating females. Researchers at Miami have been looking into the best way to frame science, technology, engineering, and mathematics (STEM) for females, and their theories suggest that instead of competition as a motivator, many females prefer communal based goals [20].

Cliburn et. al. looked at student preferences on open ended versus set projects in a computer science courses [21]. Still PBL curriculum is the norm in engineering education, but there seems to be a large gap in how we design these projects to prepare and teach students for their capstones and beyond. This work attempts to address one aspect of this.

I. Course Context

For this work, we focus on the second year project in a particular course. This course, digital system design, is taught to 2nd year electrical and computer engineers, but is open to other students as there are no prerequisites. Normally, there will be some mechanical engineers, general engineers, physics, and computer science students in the class. The course at Miami, ECE 287, is similar to a student's first programming course where students are expected to learn design skills without any previous background on how to build a working system that solves a problem. The majority of these courses include a lab section, and by the end of the lab session, the students are expected to create a working project. The expectation in engineering is that students can design and create "working" projects in various courses, which is culminated in their final senior capstone.

For our course at Miami University, the last 4 weeks of the course is dedicated to the design of an open ended project (student's choice) where an oral proposal and written proposal need to be made so that the instructor can determine if the project scope is sufficient and possible to achieve within the timeframe. Then the students have the remainder of the term to produce a working project.

SECOND YEAR PROJECT - FRAMEWORK AND CONSTRAINTS

The goal of this work is improve the project success rate so that more than 90% of the ECE 287 class demonstrated a working project that includes both a finite-state machine with more than 10 states and interfaces with a peripheral (keyboard, mouse, VGA monitor, etc.) or includes a complex algorithm. We allow the students to choose from two options for their final project. One, the students can choose to implement an open ended project if they can demonstrate that they are motivated to build a particular thing. Second, we provide a framework that is a more constrained project which is framed as a class competition. Specifically, we want to create an infrastructure around the idea of a space ship battle where the students are charged with the task of improving their ships control system so that they can battle opponents. This is ``Star Trek" motivated where the image of Scotty is in the bowels of the ship trying to improve and repair the Enterprise in real-time.

To achieve this, we provide a game engine and a basic ship control prototype in digital hardware on a DE2 prototyping board (http://www.altera.com/education/univ/materials/boards/unv-de2-board.html). The students then have to improve the hardware that controls their ship so that it is easier to control and maneuver in battle against an opposing ship (another student group). These design improvements are part of the major design project and may involve interfacing with keyboards, PS2 mice, VGA, etc. (similar to the open ended

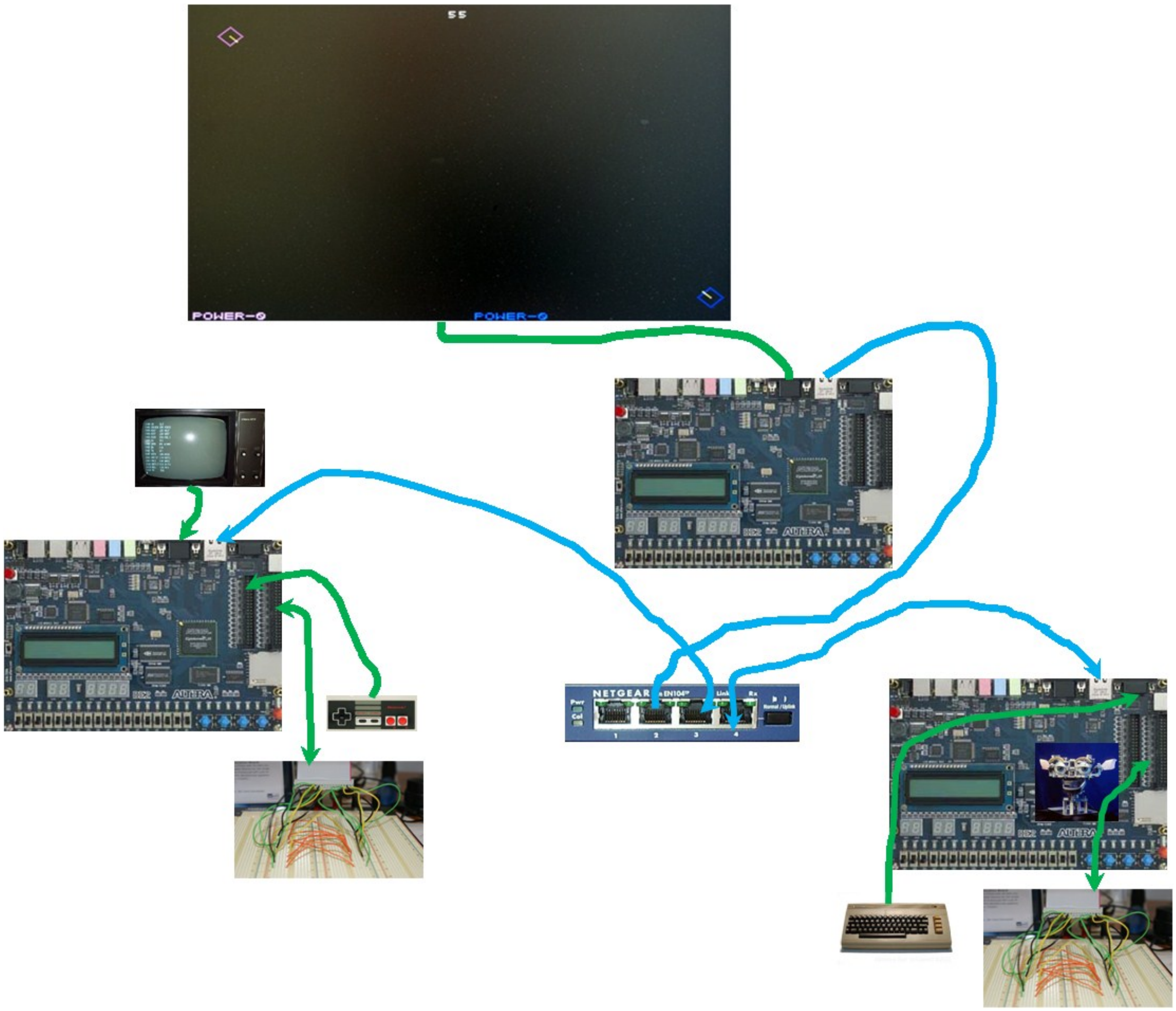

FIGURE 1
A BASIC ORGANIZATION OF THE GAME FRAMEWORK FOR REDHAWK DUELS.

projects) as well as the design of digital control algorithms. In reality, doing either an open ended project or participating in the competition will result in building similarly complex digital systems. The difference is that the created framework provides these early students with an example design that works with the system and the game provides constraints.

The game framework is called, ``Redhawk Duels'', and is similar in game mechanics to the first vector graphics game, ``Space Wars'' [21]. The basic goal of the game is to win by reducing the opposing team's ship power budget to zero. To do this, a ship can fly around a 2D rectangular map and shoot the opponent using a laser cannon. We have previously described the game mechanics of this framework in [22] and the source code for the games master and prototype of a basic ship are available at: http://code.google.com/p/redhawkduals/

Figure 1 shows the basic system organization for the game framework. The two DE2 boars in the bottom left and right hand corners represent the ship controls designed by two opposing student groups. Note how these boards are connected to various peripherals that the students choose to interface with (for example, in the lower right hand side of Figure 1 we can see the DE2 board interfacing with a keyboard). These two boards then interface with a DE2 board that runs the game. The view of the game world is not available to the players and they can only get their views of the world from the perspective of the information they gather and display locally (this display can be put on a VGA monitor as in the example setup on the lower left hand side of Figure 1). We have a video description of the project that can be viewed to help the reader understand the nature of the framework and how students built their various approaches (http://www.youtube.com/watch?v=GFkbvzrptSg&feature=player_embedded).

TABLE I
LIST OF PARAMETERS RELEVANT TO A PROJECT IN DIGITAL SYSTEM DESIGN

Criteria	Open Ended Project	Redhawk Duels
Group Work	X	X
Open Design Options	X	X
Framework		X
Detailed Constraints		X
High Workload	X	X

Table I shows the two project options and the criteria that can be associated with each type of project. Column 1 shows the parameter of the project, and column 2 and 3 indicate whether the open ended project or Redhawk duels satisfy these criteria, respectively. As we've described earlier, we believe that constraining the project and providing a working framework to start from will have a significant impact in guiding a second year student to building a successful project. Our results, in the next section suggest that this is true.

EVALUATION AND ASSESSMENT

As described above, we have created a game framework that will allow second year students to build their own ship interfaces in digital hardware. The students have the option of participating in Redhawk Duels, or generating an open ended project similar to how we ran the course projects in 2009. In 2010, fifteen groups participated in Redhawk Duels and six groups chose to make their own specific design. Fortunately, in 2010 all twenty-one projects were demonstrated in a working state (this means that the HDL they had written worked on the DE2 board, which was not the case in 2009). This improvement is a combination of more emphasis from me on the effort needed to create a working project and less people doing open-ended projects.
Looking deeper at the results, however, four of these projects had poor evaluations due to their lack of complexity and are still considered to be failed attempts (though much better than non-working designs). The projects that were considered failures did not have two of the following complexity requirements:

- A finite state machine with 10 or more states
- An interface with a peripheral device including such devices as keyboard, VGA monitor, sound, etc.
- A complex algorithm implemented in hardware

These failed attempts, in 2010, are distributed evenly between both the open projects (two) and the Redhawk game framework (two) meaning that the open projects had a 55% success rate in 2009 and a 66% success rate in 2010. Participants in the Redhawk Duels framework had an 87% success rate in producing a working project with adequate complexity. The best project reports are available to for the general public to view at our website: http://www.users.muohio.edu/jamiespa/teaching.html.

Table II shows the results from 8 survey questions given to the 2010 participants in the Redhawk Duel project. Of the 31 participants, 20 filled out the survey anonymously after the competition was complete. The survey consisted of 6 choices (Not applicable being the sixth) with the following weights:

- Strongly Agree = +2
- Weakly Agree = +1
- Neutral = 0
- Weakly Disagree = -1
- Strongly Disagree = -2

Therefore, a question mean greater than zero means that on average the students are agreeing with the survey question.

TABLE II
RESULTS FROM THE STUDENT SURVEY ABOUT VARIOUS ASPECTS OF PARTICIPATING IN REDHAWK DUELS COMPETITION

Survey Question	Mean	Standard Deviation
A. I enjoyed designing my ship control and competing in the Redhawk Dual class competition	0.55	1.19
B. Participating in Redhawk duals motivated me to work more on the project	1.20	1.06
C. The game framework provided me with good examples of digital design	0.50	1.06
D. Designing our own ship provided me with a significant experience on creating a user interface	1.37	0.83
E. The project helped me realize the importance of physics and math for simulation and games	0.48	1.10
F. The idea of competing motivated me to build a more complex design	0.95	0.94
G. This experience will help me in my future design projects in engineering	1.43	0.51
H. I would like to see this type of competition happen between Universities	1.45	0.69

From Table II, we can see that all the averaged survey results are in the positive agreement domain, but the magnitude and the size of the standard deviation suggest that only in a few cases we have significant agreement in the results. In particular, questions B, D, G, and H are the elements that the students strongly reported agreement to. Within this set of questions, the project motivated the students and is suspected to have a positive benefit in future projects. Also, from these survey results there is not a clear enjoyment of the project nor are the students finding the prototype ship useful as a sample design.

CONCLUSION

The Redhawk Duel framework has been created to help early computer and electrical engineers build successful digital hardware design projects. In this paper, we show results that suggest this framework is pushing us in the right direction. Our results comparing the ECE 287 class in 2009 to 2010 shows that participating in project with an existing framework and constraints improved the project success rate from 55% to 87%. The students, when surveyed, provided feedback that the project would help them in the future and motivated them to put more effort into their projects.

The question remains on how to push the 87% success rate to 100%. Analyzing the results shows that the 2 groups that did not succeed had both partners in the lower 10th percentile of the class. Qualitatively, these students did not put significant effort or time into their project. It is possible that analyzing the grades at some point in the course might show indicators of who might be in trouble before the projects begin. However, we are not certain if it is a good idea to organize groups based on identified concerns. Also, in the past groups for engineering projects have been organized based on using the Myers-Briggs Temperament Indicator [25], and this potential solution will be left for future work.

Also in the future, we plan to continue our approach for providing both constraints and a framework for second year students in digital system design. The reviewers noted that open-ended projects do have some advantages, and we believe this is true and our curriculum still has open-ended projects in the third and fourth years.

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