Emulating Working in a Company in the Classroom: A Case for Hands-on Multiple Projects Oriented Course

Cristinel Ababei and Anca M. Miron
Marquette University / University of Wisconsin, Oshkosh

Abstract

We describe the design, implementation, and outcomes of an advanced engineering course emulating the working environment of a company. Shifting from a traditional teaching style to an approach where students must be completely involved in project-related research, implementation, preparation of deliverables, and presentation of results helps to: 1) foster self-learning, 2) engage students more and enable them to be pro-active and competition-aware, and 3) enable a smoother transition from full-time student to full-time employee. We used anonymous questionnaires as the primary methodology of data collection along with ratings of the projects in terms of extent of challenge/complexity and type of work (individual vs. team-work). The questionnaires assessed the following dimensions satisfaction, fairness, knowledge acquired, challenge, feedback, and validation. Students are more satisfied with their learning experience when they work in teams on more complex projects split into smaller subprojects rather than working individually on projects, irrespective of their complexity.

Keywords

Emulate corporate environment; Project-based teaching.

Introduction

The traditional approach to teaching has been a somewhat passive approach: assign students to read textbooks and work on problem sets outside school, while listening to lectures and taking tests in class. Because this approach has become too passive, recently new teaching styles have started to be experimented. Two promising such approaches include *flipped class room* and *project-based learning*[1,2].

While the project-based learning idea is not new, in this course, we implemented and extended this idea by placing a special emphasis on elements that transform the classroom into a corporate environment. We believe that this set-up benefits especially senior undergraduates and graduate students because this course represents the last "full-time student experience" for most of the enrolled students before their first workplace experience. Adopting the proposed teaching method can help and prepare students to transition from full-time students to full-time employees.

Description of the Course

In this section we present the structure of the course and discuss its objectives. While this discussion is within the context of a computer engineering course, titled "Advanced VHDL and

FPGAs", the generality and applicability of the presented ideas to other engineering disciplines should not be hindered by the course topic specifics.

All course activities are split into two main phases as described below.

Phase 1: Formal teaching of advanced concepts. The first phase of the course is allocated four weeks of the semester. During this first part of the semester, the instructor teaches advanced concepts on the topic of the course. In our case, these concepts are on VHDL (VHSIC hardware description language) and FPGA (field-programmable gate array) technologies. VHDL is a hardware description language used in electronic design automation to describe digital and mixed-signal circuits. VHDL is an essential skill for any computer engineering major because virtually any real digital circuit out there is designed using hardware description languages (HDLs) today. FPGAs are an increasingly pervasive technology and used as integral parts of complex designs ranging from consumer electronics to communications, military, and space systems. Today, FPGAs represent the hardware platform of choice to implement and test digital designs for a lot of circuit designers and educators. In this course, we worked with a Cyclone IV E FPGA chip, which is part of the popular DE2-115 FPGA development board[3] (shown in Fig.1) that we used for all projects.

Figure 1: DE2-115 FPGA development board used in this course.

We decided to run this first portion of the course using a more traditional teaching style, in order to convey some of the more complex and abstract concepts. One of the objectives here was to jump-start the students' preparation and readiness for the second portion of the course. Several individual homework assignments were used with the objective of refreshing some of the prerequisites.

Phase 2: Emulating working in a company. The second phase of the course was allocated the remaining twelve weeks of the semester. The goal in this second part of the course was to design and implement a challenging project – with the entire class operating as much as possible as in a corporate workplace environment. In our case, the project was to design and prototype a basic digital camera. The work required for achieving the stated goal was divided and formulated as three (however, this number could be different) separate projects, which are briefly described in Table 1.

The first two projects are individual projects, with the first one being more complex in order to serve as a "kick in the door" evaluation of each student. The third project has the highest complexity – however, students work on this project in groups of two or three students. Moreover, the third project was split into three sub-projects, as it will be discussed later. The successful completion of a project required a fully-working design and a written report describing design decisions and results.

Table: 1 Listing of the three main projects representing the main tasks in this course.

Project	Topic	Team Work?	Complexity
Project 1	Storing image in SDRAM memory	Individual	Medium
Project 2	Greyscale filter.	Individual	Low
Project 3	JPEG compression and decompression	Teams of two or three students	High

After the completion of each project, students filled anonymously in class a questionnaire designed to track their learning experience and satisfaction with the course. The questionnaire (which is included in the Appendix at the end of this presentation) represents our course assessment goals. The questionnaire assessed the following *evaluation dimensions*, which mapped closely onto our three major goals for this project: 1) satisfaction with own project work, 2) fairness of grade awarded, 3) amount of knowledge acquired, 4) perceived challenge, 5) direction/feedback received on the project, and 6) perceived validation.

In addition, the instructor (i.e., *manager* of the emulated company set-up) conducted closed-door individual student (i.e., *employee* engineer) interviews. These interviews play the role of performance reviews, similarly, to how such reviews are conducted in real world companies. Their objective is to privately provide each student feedback about their performance and recommendations on how to improve their performance. The individual performance reviews were conducted approximately in the middle of the semester, upon the completion of the first project.

When designing the idea of the *company-like teaching approach* presented in this paper, we focused on capitalizing on three behavioral and psychological processes: 1) fostering self-learning, 2) engaging students more and enabling them to be pro-active and competition-aware, and 3) enabling a smoother transition from full-time student to full-time employee.

1) Fostering self-learning: Project-based learning emphasizes learning activities that are long-term, interdisciplinary, and student-centered. It is known that project-based learning has numerous benefits[4,5] - including a greater depth of understanding of concepts, broader knowledge base, improved communication and interpersonal/social skills, enhanced leadership skills, increased creativity, and improved writing skills. Most importantly, project-based learning fosters a self-learning attitude, which is essential (and part of the mission statement of engineering colleges) to the students' success later in their careers in engineering fields, where advancements are made and technologies change at a very fast pace.

2) Engaging students more and enabling them to be pro-active and competition-aware: Because the deliverables of each project include demonstrations, students tend to engage earlier

the tasks and to take ownership of their projects in a competitive effort with respect to their peers.

3) Enabling a smoother transition from full-time student to full-time employee: One of the objectives of the proposed company-like teaching approach is to help students get used to working as a team member in a group that works on *product development* along a roadmap that includes a schedule with deadlines and action items, milestones, and deliverables. In such an environment, the successful implementation of the final product (in our case the digital camera) becomes the responsibility of the entire group/company. Therefore, in project 3, separate teams had to work on different tasks (in our case JPEG compression and JPEG decompression). Hence, the completion of the final product depended on the completion of each team's task.

Because the complexity of project 3 was higher, the project was split into three different steps in order to be more manageable (i.e., enable the manager to hold employees accountable for various phases of the project) and to help students have a better control of the deliverables as well as their grades.

Results and Discussion

In this section, we present course results and discuss the data that we collected via the questionnaire administered upon the completion of each project. This questionnaire is designed to capture the student's (i.e., employee) satisfaction[6,7], which refers to the student's sense of well-being within his or her work environment. The questionnaire - included in the Appendix at the end of this presentation - is comprised of eleven questions.

The top-level block diagram of the design that represented the topic of product development and prototyping by the emulated company is shown in Fig.2, which also highlights the tasks assigned to the individual projects.

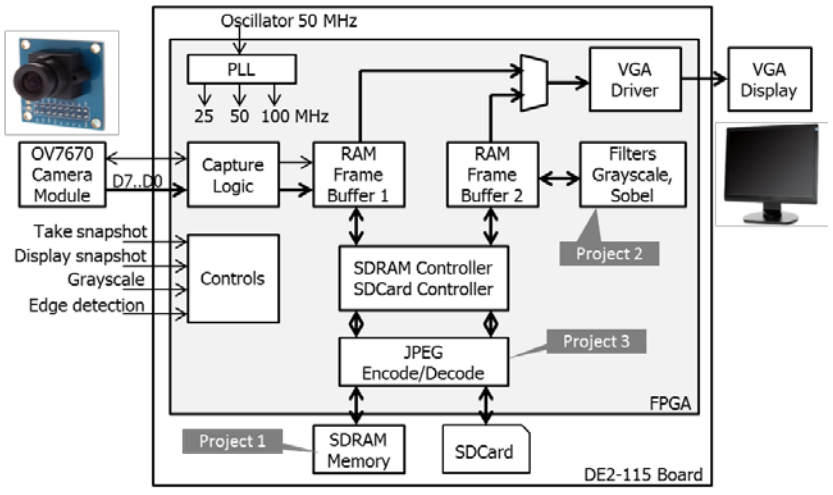

Figure 2: Top-level block diagram of the main product, a digital camera system, designed in this course.

By utilizing a scale from 1 to 5 (as explained in the Appendix), we plot the answers to five evaluation dimensions in Fig.3. For convenience, we also include in Table 2 a listing of all questions along with the evaluation dimensions assessed.

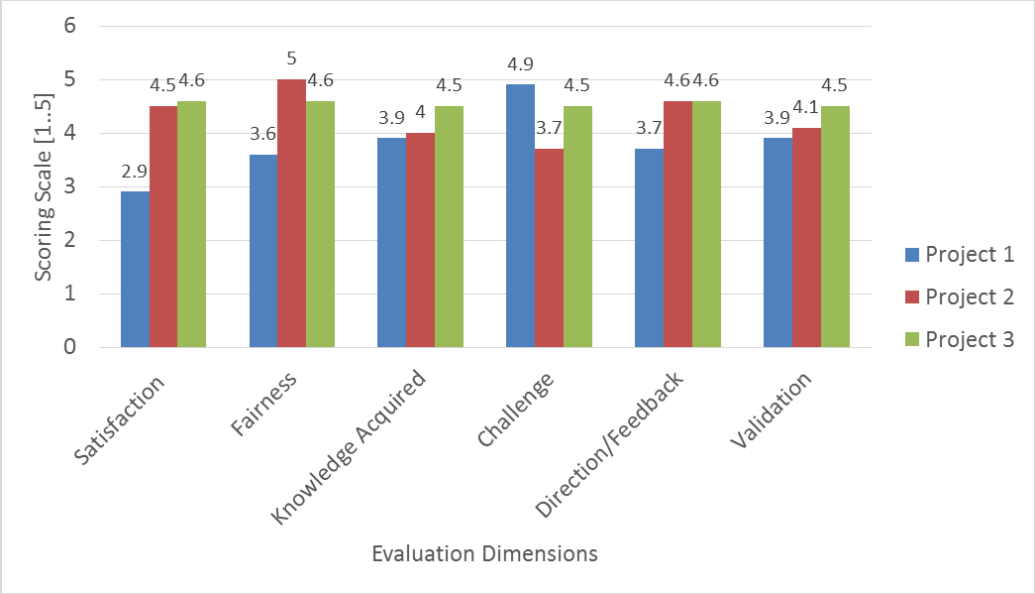

Figure 3: Students' average scores for all five evaluation dimensions (see Table 2) in the used questionnaire.

Table 2: Grouping of questions from questionnaire into five evaluation dimensions plotted in Fig.3.

Evaluation Dimensions	Question Code	Actual Question
Satisfaction	Q1	1. I am satisfied with my actual results I achieved in this project, irrespective of what the target was.
	Q11	11. Overall, I am happy about all outcomes of this project.
Fairness	Q2	2. The amount of work that I had to put in this project to successfully complete it was fair.
Knowledge Acquired	Q3	3. The amount of knowledge I gained by working on this project was satisfactory.
	Q6	6. I feel that the amount of information I learned by working on this project was more than in a traditional class.
Challenge	Q4	4. The difficulty of this project challenged my theoretical and skill abilities.
	Q5	5. This project offered a good number of problems that I had to think hard about and forced me to be creative in my attempts to solve them.
Direction/Feedback	Q7	7. The information and guidelines given to me in class helped to do my job.
	Q8	8. I get clear feedback from the instructor about how well I am performing in my job.
Validation	Q9	9. The instructor acknowledges and values my work.
	Q10	10. The instructor seeks my input when faced with a challenge or problem.

The analysis of these results allows us to make the following observations:

- Students are dissatisfied at the end of the project 1 as indicated primarily by the data points corresponding to the Satisfaction evaluation dimension in Fig.3. This can be explained in part by the fact that the project task was of medium complexity (as mentioned in Table 1) and the task was an individual effort.

- When the complexity of the task becomes low, which allows students to successfully complete the task, the students' satisfaction with the overall learning experience has improved. This is indicated by the higher scores to questions Q1 and Q11 (which represent the Satisfaction evaluation dimension) for Project 2.

- What is particularly interesting is that, while more satisfied, students acknowledged that they learned roughly the same amount of information in Project 2 (as indicated by the scores of Acquired Knowledge evaluation dimension) when compared to Project 1. Students also acknowledged that they were less challenged in Project 2 (as indicated by the scores of Challenge evaluation dimension).

- Finally, we note that students' were most satisfied with their learning experience in project 3 – which despite the fact that it was the most complex, received the highest scores, as seen in Fig.3. We credit this outcome to 1) the complex task of project 3 was split into sub-tasks (which had their own deadlines but became in this way more manageable) and 2) the work was a team effort, which, again, made the task more manageable because team members divided work among themselves and thus operated more efficiently and on time.

Therefore, our main take-away message from this course experiment is that students are more satisfied and have a better learning experience within a company-like working environment when 1) work is assigned in the form of more numerous individual projects but of lower complexity rather than as fewer individual projects but of higher complexity, and 2) higher complexity projects are assigned to teams of students and in addition are the project task is split into smaller sub-tasks. We also note that the idea of operating in a company-like environment helps to further motivate students because they share the responsibility of a successful completion of the overall course (i.e., the equivalent of product launch in a corporate environment).

Conclusion

We described the design, implementation, and outcomes of a new teaching approach as an enhanced project-based learning within a course set-up that emulates the working environment of a company. The objectives of the proposed teaching approach included: 1) foster self-learning, 2) engage students more and enable them to be pro-active and competition-aware, and 3) enable a smoother transition from full-time student to full-time employee. Utilizing multiple anonymous questionnaires, we found that students do better and are more satisfied with their learning experience when they work in teams on more complex projects split into smaller subprojects rather than working individually on projects, irrespective of their complexity.

Appendix

The questionnaire completed anonymously by each enrolled student immediately after the completion of each project is shown below. This research project was approved by the Marquette University Institutional Review Board.

QUESTIONNAIRE

Dear student,
This questionnaire is anonymous. The information you provide will help me to understand the effectiveness of the project-based teaching method in this course and your level of satisfaction with the last completed project. The results of this questionnaire may be analyzed for research purposes. The completion of this questionnaire should not take more than 10 minutes.
Thank you.

Directions: For each of the statements below, please circle the number that best represents your opinion.

	Disagree	**1**	**2**	**3**	**4**	**5**	**Agree**
1. I am satisfied with my actual results I achieved in this project, irrespective of what the target was.		1	2	3	4	5	
2. The amount of work that I had to put in this project to successfully complete it was fair.		1	2	3	4	5	
3. The amount of knowledge I gained by working on this project was satisfactory.		1	2	3	4	5	
4. The difficulty of this project challenged my theoretical and skill abilities.		1	2	3	4	5	
5. This project offered a good number of problems that I had to think hard about and forced me to be creative in my attempts to solve them.		1	2	3	4	5	
6. I feel that the amount of information I learned by working on this project was more than in a traditional class.		1	2	3	4	5	
7. The information and guidelines given to me in class helped to do my job.		1	2	3	4	5	
8. I get clear feedback from the instructor about how well I am performing in my job.		1	2	3	4	5	
9. The instructor acknowledges and values my work.		1	2	3	4	5	
10. The instructor seeks my input when faced with a challenge or problem.		1	2	3	4	5	
11. Overall, I am happy about all outcomes of this project.		1	2	3	4	5	

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Cristinel Ababei

Cristinel Ababei received the Ph.D. degree in electrical and computer engineering from the Univ. of Minnesota, Minneapolis, in 2004. He is an assistant professor in the Dept. of Electrical and Computer Engineering (ECE), Marquette Univ. Prior to that, from 2012 to 2013, he was an assistant professor in the Dept. of EE, SUNY at Buffalo. Between 2008 to 2012, he was an assistant professor in the Dept. of ECE, North Dakota State University. From 2004 to 2008, he worked for Magma Design Automation, Silicon Valley. His current research interests include design automation of systems-on-chip with emphasis on reliability, FPGAs, and parallel computing.

Anca M. Miron

Anca Miron received her MA and PhD degrees in Social Psychology from the University of Kansas. She is an associate professor in the Dept. of Psychology, University of Wisconsin Oshkosh. Dr. Miron is an emotion/motivation researcher interested in issues related to emotional intensity and emotion regulation. A second line of research explores the mechanisms underlying sensory interactions in close relationships. A third line of work investigates how people make justice judgments and whether group members shift their definitions of justice as a function of their current motivational goals.