An Application Overview of Project-Based Learning in Freshman and Senior Level Courses with 12-step Design Process

Akin Tatoglu[1], Gonca Altuger-Genc[2]

1 University of Hartford
2 Farmingdale State College

Abstract

Project based learning is an effective pedagogical strategy that can be implemented to various engineering courses from freshman to senior level. Flexible nature of the project-based learning allows instructors to custom design their projects to complement their courses' learning objectives while providing a more effective learning environment for students to practice mathematical tools and skills. Project-based learning approach may have different goals and expectations for freshman students than senior students. In this paper, we review two project-based learning approaches following 12-step design process for freshman level mechanical engineering technology course and senior level mechanical engineering course. Design steps, implementation and timeline of assigned tasks, expected deliverables, and assessment of the projects will be discussed. Finally, execution of 12-step design process with a timeline is presented and discussed.

Keywords: Project Based Learning, 12-step Design Process, Mechanical Engineering, Technology

Introduction

Engineering and engineering technology departments offer various technical topics and aim to increase students' analytical skills. Graduates of these majors are expected to fuse their knowledges and have hands-on experiences[1]. Project-Based Learning (PBL) is a flexible teaching method that student can improve his/her technical skills with a challenging real world problem[2-3]. Advantages include not only continuous feedback from instructor, but also students' reflection on learning that results with an efficient, two way communication channel[4]. In addition, students have an opportunity to learn from their peers and improve their leadership skills once they work in teams[5].

One of the most important characteristics of PBL approach is to encourage students to ask questions and forecast outcomes while collaborating with peers to produce a final product. During that process, instructor is a technical advisor and allows students to gather knowledge by interacting with the environment[6].

In this paper two undergraduate courses are examined. One of the courses is a freshman level engineering design course offered as a part of 4-year BS degree in Mechanical Engineering Technology Department. The other course is a senior level mechatronics system design course offered as a part of 4-year BS degree in Mechanical Engineering Department. Both courses follow the 12-step design process[7]. This methodology starts with problem identification and scope of project deliverables. Students are not expected to have all technical knowledge in the beginning of the process as one of the steps includes a research task. Once all background work is studied, system constraints could be used to tailor final product definition that aligns with team's skill level. Once goals are set, students are encouraged to discuss solution options in depth and explore alternate methodologies that they could utilize. Finally, one of the approach is selected and a proposal is drafted by the team. After this point, hands-on section of project-based learning begins with prototype design, development and testing steps. Based on test results and instructor feedback, necessary updates are applied to design itself. Final design and manufacturing options are discussed and presented.

This paper will provide an overview of how project-based learning component is incorporated in a freshman level mechanical engineering technology and a senior level mechanical engineering course following 12-step design process. Project requirements, expectations, goal and objectives will be discussed and project assessment techniques will be reviewed. Finally, design process steps studied at both courses are identified and differences and commonalities are observed.

Freshman Level Computer Aided Drafting and Design Course

Freshman level Computer Aided Drafting and Design (CADD) course is offered in the Mechanical Engineering Technology Department at Farmingdale State College. CADD is a 3-credit core course that meets weekly for 2 hours of lecture and 2 hours of laboratory. In this course, students learn basics of technical drafting, how to use AutoCAD in their designs as well as how to develop 3D models using the Inventor software. During the lectures, the course instructor provides an overview of the theoretical material along with hands-on in-class examples. During the laboratory portion of the course, instructor presents in-class design exercises along with exercises covered in the course textbooks. CADD course uses two textbooks: first textbook focuses on principles of drafting, drawing and using AutoCAD for 2D designs[8] and the second textbook focuses on 3D modeling principles with Autodesk Inventor[9]. The laboratory portion of the course is designed in two parts: in the first part, an in-class design exercise is completed through a step-by-step instruction, in the second part, students are provided with a design question/project that needs to be completed individually. In the first part of the laboratory, students learn different design approaches and different commands to complete their drawings and models. In the second part of the laboratory, students complete laboratory assignment on their own under the supervision of their professor. The professor is available in the classroom to answer any questions and to help with troubleshooting.

In an effort to support student learning and to provide students a platform where they can demonstrate and implement what they learnt in the course, a project-based learning approach is incorporated. The goals of the semester project are: (i) to provide students a hands-on project-based learning experience, (ii) to provide students an opportunity to implement skills and tools they learnt in the class in a project, (iii) to provide students experience in working with deadlines and schedules in an engineering design project. For the semester project, students are given the flexibility to work individually or as a team of two. The semester project is designed to follow a semester long schedule. A sample schedule of tasks is shown in Table 1. As shown in Table 1, throughout the semester, students continuously work on their projects. Certain weeks through the semester students have deliverables they need to submit for review. Course instructor reviews the progress through these deliverables as well as through weekly laboratory reviews. With the continuous feedback students receive from the course instructor, they can review and revise their drawings and make necessary corrections and updates before submitting their project portfolio at the end of the semester. At the end of the semester students are expected to deliver: hand-drafted designs, AutoCAD design (orthographic views), Inventor 3D part files, Inventor 2D Drawing files, and project report.

The assessment of the semester project has two components: formative assessment and summative assessment. In the formative assessment students receive weekly feedback in class, in addition, the course professor reviews students' deliverables on weeks 6, 7 and 10-13 and students receive feedback on these deliverables. The second assessment component is summative assessment. At the end of the semester, students submit their project portfolio for final review and grading, the semester project carries 15% weight grade towards their final semester grade. The summative assessment grades are provided to the students prior to the course's final exam.

Table 1: Project-based learning semester schedule with Design Process Steps.

		Senior Level Course			**Freshman Level Course**
DPS	**Week**	**Tasks**	**DPS**	**Week**	**Tasks**
	1 - 4	Introduction	1	1-3	Introduction, Form your team
1		Students form a team and project ideas are proposed by students.	2	4-5	Pick the product you are interested in designing.
2,3,4		Instructor gives feedback and helps student define the final deliverable	3		Research your product to see what are most common features, functions, and constraints.
5		Teams and project definitions are finalized, and students submit initial project report.	4,5		Review different designs for your product.
5		Students submit Bill of Materials.	2,6,7	6	Identify criteria, constraints, requirements and needs for your product. Brainstorm on design ideas.
6	5-7	Students get familiar with data acquisition systems they will use for their projects.	8	7-9	Pick one of the design ideas and use AutoCAD program to develop a 2D drawing of the design.
7		Teams submit their project progress report and get feedback.	9		Receive feedback on the designs and project status.
8,9,10,11	8-14	Teams work on their project while continuously getting feedback.	10	10-13	Update the AutoCAD 2D drawings based on Prof. feedback, redesign if needed.
12	15	Teams demonstrate their projects and submit their final report.	11		Work as a team to complete the 3D solid model design using Inventor software. Assign materials, add dimensions to Inventor 2D drawing files.
			12	14	Present the project

Design Process Steps (DPS) items: 1. Define a Problem, 2.Brainstorm, 3.Research and Generate Ideas, 4. Identify Criteria and Specify Constraints, 5. Explore Possibilities, 6. Select an Approach, 7. Develop a Design Proposal, 8. Make a Model or Prototype, 9. Test and Evaluate the Design using Specifications, 10. Refine the Design, 11. Create or Make Solution, 12. Communicate Processes and Results

Senior Level Mechatronics System Design Course

Mechatronics System Design is a three credits senior level course offered in the Mechanical Engineering Department at University of Hartford[10]. Other majors within the same college might take the course as part of their professional elective as well. Course offers one lecture hour and one lab hour weekly for first ten weeks. Final four weeks focus on the semester project.

Lecture component of the course helps student learn practical and hands on solutions for the topics they have learned during dynamics, electrical components, mechanisms and automatic control systems courses. Topics delivered include types and principles of transducers, sensors and how to interface them with a process in a computer environment. Course also offers in depth knowledge about sensors including operating principles, modeling, design considerations, and applications.

Course has a computer interfacing module that delivers topics about signal conversation, interface components, and real time application of microcomputer systems to problems in manufacturing and robotics. This component uses NI DAQ cards, LabView software and Arduino single board controllers. A mass-spring-damper experiment is delivered to study a typical second order dynamical system which utilizes real time data acquisition and post-processing techniques.

Design projects involve problems from industry that require computer interfacing and experimental techniques. Example of project titles include robotics based "Maze Solving Autonomous Mobile Robot", "Underwater Robot Design and Development", "Object Tracking with 3-DOF Turret" as well as automation focused titles such as "Elevator Automation Project", "Automated Filling Station". Deliverables of the semester project includes a detailed technical report.

When the students have completed this course, they will be able to understand use of modeling, analysis, and control dynamics of physical systems, have the ability to select and interface sensors, actuators, and controllers for industrial applications, carry out experiments on actual systems involving monitoring and control. Students will be exposed to modeling using software such as LabVIEW and Arduino, carry out a real life mechatronics project, will have more experience in writing a technical report scientifically explaining steps and project outcomes.

During first half of semester, a lab work is assigned weekly. The following three weeks, lab component includes specific topics for students' projects specifically on sensors. Finally, last four weeks include lab section where the instructor continuously gives feedback. Students are graded for each lab report including a feedback. Students are expected to submit an initial project report before week#5, a project progress report before week#10. Once semester is completed, students are expected to demonstrate their project in front of an audience and submit their final report. For the technical writing component of the course, instructor supplies a generic template and recommends detailed description of the sections specific for each project. During the semester, instructor gives continuous feedback. Grade distribution of the final project including technical report is as following: Initial project report, project progress report and presentations are 20% and while final project report has 40% weight, presentation and demonstration have 40% weight. Table 1 lists project related tasks with respect to 12-step design process.

Comparison of Project Design Processes

Both courses discussed above had used 12-step design process. The major differences between two student bodies are technical skill level followed by experience in design approach. This results with different amount of time spent as well as different level of instructor engagement. For the freshman level course, more time spent not only in the beginning of the semester but also at the end, while the senior level course spent equal amount of time for the first 5 steps and double the amount for steps 6-11. It can also be observed from Table 1 that freshman level course spent three weeks to deliver and study the concepts of a design process, to explain terminology and discuss philosophical approach itself, where as the time spent in the senior level course for conceptual design process is much shorter. This is expected, as freshman students are learning how to use design software AutoCAD and Inventor as they are working on their projects whereas senior level students are proficient in using design and modeling software.

Although both courses focus on different subject matters and have different student levels (freshman vs. senior), there are many commonalities between the project-based learning approaches. The commonalities are: (i) Both instructors provide weekly feedback and use formative assessment throughout the project. This provides students a great learning experience and because they receive continuous feedback students are always engaged in their projects. (ii) Both instructors employ a semester-long schedule for the projects, which helps students keep track of their milestones and goals. (iii) Both instructors encourage team-work, as it is a great way for students to learn to share responsibilities of a project.

Conclusions

In this paper two different project-based learning applications following 12-step design process for two different level of students have been reviewed and compared with respect to time spent on each individual design process step. For the freshman level, the project-based learning component was incorporated to a Computer Aided Drafting and Design course where the project is designed to support students' learning experience and strengthen their design skills. Project is designed to provide students a hands-on applied learning experience in product design, part design using the tools and skills they gained in this course. Hands-on project-based learning complemented the computer aided drafting and design learning process while fulfilling course objectives. For the senior level Mechatronics System Design course, students are challenged with a real world manufacturing and/or robotics related real world problem consists of sensors, actuators, data acquisition, monitoring and post-processing as well as a technical report. While senior level course has a more challenging writing component and requires a completed product, both courses follow typical design steps and expect students to improve their knowledge in a progressive way. Although the two projects are implemented to two different courses, in two different schools, and in two different student levels, it is also observed that there are many commonalities regards to assessment methods of the instructors, semester-long scheduling of the projects and gaining project experience.

Acknowledgment

The authors would like to thank Center for Teaching Excellence and Innovation of University of Hartford and First In the World – Research Aligned Mentorship (RAM) Program of Farmingdale

State College for supporting the development of the hands-on applied project learning experience for the Mechatronics System Design course and the Computer Aided Drafting and Design course, respectively.

References

1 Blumenfeld, Phyllis C., Elliot Soloway, Ronald W. Marx, Joseph S. Krajcik, Mark Guzdial, and Annemarie Palincsar. "Motivating project-based learning: Sustaining the doing, supporting the learning." Educational psychologist 26, no. 3-4 (1991): 369-398.
2 Mills, Julie E., and David F. Treagust. "Engineering education—Is problem-based or project-based learning the answer." Australasian journal of engineering education 3, no. 2 (2003): 2-16.
3 Gann, David M., and Ammon J. Salter. "Innovation in project-based, service-enhanced firms: the construction of complex products and systems." Research policy 29, no. 7 (2000): 955-972.
4 Krajcik, Joseph, Katherine L. McNeill, and Brian J. Reiser. "Learning-goals-driven design model: Developing curriculum materials that align with national standards and incorporate project-based pedagogy." Science Education 92, no. 1 (2008): 1-32.
5 Sarin, Shikhar, and Christopher McDermott. "The effect of team leader characteristics on learning, knowledge application, and performance of cross-functional new product development teams." Decision sciences 34, no. 4 (2003): 707-739.
6 Frank, Moti, Ilana Lavy, and David Elata. "Implementing the project-based learning approach in an academic engineering course." International Journal of Technology and Design Education 13, no. 3 (2003): 273-288.
7 Karsnitz, John R., Stephen O'Brien, and John P. Hutchinson. Engineering design: An introduction. Cengage Learning, 2012.
8 Hung, Jeff, "Technical Drawing with AutoCAD", Linus Learning, 2014, ISBN: 1-60797-434-7
9 Hung, Jeff, "101 Autodesk Inventor 2017", Linus Learning, 2016, ISBN: 1-60797-663-3
10 Tatoglu, Akin, and Ingrid Russell, "Implementing Self Learning Skills with Multidisciplinary Robotics Courses", ASEE Mid-Atlantic Conference (2016).

Akin Tatoglu, Ph.D.

Akin Tatoglu is an Assistant Professor at Mechanical Engineering, University of Hartford, CT. He focuses on mobile robot navigation and 3D reconstruction of objects and environments. Dr. Tatoglu is driven by the fundamental challenges that various autonomous mobile robots have in common: localization and traversing through unstructured environments. In particular, he is interested in identifying surrounding objects and interacting with them, as well as obstacle avoidance techniques. He has contributed to the development of various mobile robots and implemented their control system and sensor fusion algorithms. As a roboticist, his interests include mechatronics, energy efficient hybrid robotics design, cyber-physical systems, machine learning, adaptive systems and artificial intelligence. Dr. Tatoglu is a member of ASEE and Journal Technical Editor Board member of the ASEE CoED Division.

Gonca Altuger-Genc, Ph.D.

Dr. Gonca Altuger-Genc is an Assistant Professor in the Mechanical Engineering Technology Department at Farmingdale State College located in Farmingdale, NY. Dr. Altuger-Genc holds Master's in Engineering and Ph.D. degrees in Mechanical Engineering from Stevens Institute of Technology and currently serves as the Graduate Program Coordinator for the School of Engineering Technology at Farmingdale State College. Her research is focused on lifelong learning, simulation-based learning, and project-based learning. Dr. Altuger-Genc is a member of ASEE and Journal Technical Editor Board member of the ASEE CoED Division.