Enhancing Learning Techniques in Undergraduate Mechanical Design Classes

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Abstract

The paper discusses two different challenges, presented in the form of two projects, as a part of the Introduction to Mechanical Design class at California State University, Fullerton, using inquiry and project based learning approaches, respectively. The students take the theoretical ideas of mechanical design and implement them with moderate guidance for the first project and limited faculty involvement in the second project. In order to asses the approach, we use techniques to uncover what the students are asking themselves as they try to solve each challenge. Based on these questions, the main project objectives such as critical thinking, responsibility for students' own learning and intellectual growth, are discussed.

Introduction

An instructional strategy that comes close to emulating the constantly changing demands of our society is inductive teaching [1]. In this approach, the students are first presented with a challenge and they attempt to solve it. Learning takes place while students are trying to understand what they need to know to address that challenge. Students tackling these challenges quickly recognize the need for facts, skills, and a conceptual understanding of the task at hand. At that point, the faculty provides minimal instruction to help students learn on their own. Bransford, Brown, and Cocking [2] survey extensive neurological and psychological research that provides strong support for inductive teaching methods. Ramsden [3], Norman and Schmidt [4] and Coles [5] also demonstrate that inductive methods encourage students to adopt a deep approach to learning. Felder and Brent [6] show that the challenges provided by inductive methods serve as precursors to intellectual development. Prince and Felder [7] review applications of inductive methods in engineering education, and state the roles of other student-centered approaches, such as active and cooperative learning, in inductive teaching. Inquiry learning is one form of inductive methods and begins when students are presented with questions to be answered, problems to be solved, or a set of observations to be explained [8]. The same statements could also be made about problem-based learning, project-based learning, discovery learning, certain forms of case based instruction, and student research, so that inquiry learning may be considered an umbrella category that encompasses several other inductive teaching methods. Lee makes this point, observing that inquiry is also consistent with interactive lecture, discussion, simulation, service learning, and independent study, and in fact "probably the only strategy that is not consistent with inquiry-guided learning is the exclusive use of traditional lecturing [9]."

The sections that follow provide an overview of our efforts to improve the learning environment for undergraduate engineering students by presenting two activities in the form of challenges, which incorporate inductive teaching methods in small team environment.

Course Objectives

Education must prepare learners to cope with changes that will increase in complexity throughout their lives. Education cannot give learners all the information that they need to know, but rather it must provide the tools for continuing to learn. Keeping that in mind, the main objectives of the Introduction to Mechanical Design course were the following:

1. Ability to apply knowledge of mathematics, statistics, science and engineering
2. Ability to design a system, component or process to meet desired needs within realistic constraints
3. Ability to identify, formulate and solve engineering problems
4. Ability to use the techniques, skills and modern engineering tools necessary to engineering practice.

The process for integrating inquiry techniques into the course, contained designing activities, assignments, and assessments that are congruent with the four desired student outcomes: (a) improved critical thinking skills, (b) greater capacity for independent work, (c) taking more responsibility for one's own learning, (d) intellectual growth, congruent with the above mentioned goals and objectives.

In what follows, we discuss the two projects, Device Analysis and Design Challenge, both presented in the 'Fall 2012 as a part of the Introduction to Mechanical Design class at California State University.

Device Analysis: Project Scope

In the 'Fall 2012 a project activity was presented to the students, *using guided inquiry learning architecture*.

Students were given a hands-on problem to find a real-world mechanical device, disassemble it and analyze a mechanism of their choice, as a part of the device. The activity was designed such that students work either individually or in a group of two for two weeks in order to solve the problem.

In the end of the two-week period, the students were asked to presented their device analysis projects in front of the class, following seven main topics:

1. Description of the device and its operation.
2. Description of the science and engineering fundamentals.
3. Photographs of the device assembled and disassembled.
4. Photographs of the mechanism and its components.
5. Calculations and summary of the analysis.
6. Conclusions.
7. Possible ideas for improvements.

While the strategy was meant to be highly student-focused, the extent of teacher-directed vs. student-directed learning was varying depending on the level of the different students and their understanding of the inquiry process. On average, the amount of faculty involvement in the project was moderate. For this project the students mainly had to use the theoretical knowledge they had gained from the first part of the class.

Design Challenge: Project Scope

About a month later, after the completion of the first project, the students were presented with a second challenge, using *project based learning approach*. The overall goal of the open-ended challenge was to propose a design for a passive suspension for wheeled robotic platform suited for operation on rough terrain. The beauty of the open-ended problem was that the students become emotionally involved, as the available information is insufficient to solve the problem and the students must generate the missing information, which makes the answer unique to the student. The answer that the student gets to the open-ended problem is not as important as the student's logic and rationale for his/her design.

The students had to be able to develop selection criteria considering all relevant issues, develop and evaluate alternative solutions and chose a solution. The goal of the project was to give the engineering undergraduates understand and apply design tools and skills such as:

- sketching and drawing, in order to communicate design ideas in the team environment;
- kinematics, in order to understand what will work and what not and evaluate alternative solutions;
- statistics, to be able to analyze data;
- communication skills to learn how to work in an engineering environment and understand relationships between different concepts;
- ability to take decisions and defend them.

As a part of the learning process, the students had to work in teams of two and were notified that the faculty involvement in the project will be minimal.

Effectiveness of the Two Learning Environments

Anonymous survey questions (see Appendix A and Appendix B) were performed, based on the main course objectives, regarding the effectiveness of the two approaches based on students' perspective. Forty-eight students completed the survey. Table 1 shows the average learning outcomes from the two projects, based on student perception on a scale from 1 (poor) to 5 (excellent). Despite the fact that the Design Challenge was more complicated and the students worked without direct faculty assistance, the student learning outcomes were higher at 4.38 out of 5 versus 4.1 out of five.

Table 1 also shows the top and bottom three scored questions, based on student perception. The first project revealed areas that the students did not feel comfortable with, such as ability to take decisions and defend them, as well as ability to analyze a real-world mechanism. These issues were taken into account by the faculty and were substantially improved in the second project. This implies the faculty's efforts in emphasizing critical thinking and intellectual growth throughout the semester.

Table 1. Learning Outcomes, Based on Students' Perception.

Project	Top Two Scored Questions (see Appendix)	Lowest Two Scored Questions (see Appendix)	Average Learning Outcomes (from 1 to 5)
Device Analysis	1, 2	7, 8	4.1
Design Challenge	7, 8	1, 6	4.38

In an effort to get some ideas on enhancing the inductive teaching methods used, as a part of each survey, the students were asked to identify three questions that they were asking themselves, while solving each project. Later, the students' questions were classified into three major groups, according to the desired outcome goals: critical thinking, responsibility for one's own learning and intellectual growth. The results from the two projects are shown in Table 2.

The critical thinking, was assessed by the number of students' questions with regard to their interest in analyzing data, evaluating alternative solutions, taking critical decisions, and communicating design ideas.

The comparison in students' responsibility of their own learning was assessed by the number of student's questions regarding their desire to learn more, be successful and look for additional sources, out of the class.

The comparison in intellectual growth, between the two projects, was assessed by the number of student's questions regarding their ability/desire to propose improvements to a design, to find out the relationships between different concepts and to defend their design decisions.

Table 2. Comparison in Critical Thinking, Responsibility for One's Own Learning and Intellectual Growth between the two Challenges, Based on Student's Questions.

	Number of Questions, related to Critical thinking	Number of Questions, related to Responsibility to one's own learning	Number of Questions related to Intellectual growth
Inquiry/Discovery Learning (Device Analysis)	29	7	21
Project-Based Learning (Design Challenge)	41	26	35

Given the difficulty (if not impossibility) of carrying out a clean and conclusive comparative study, the best we could do is to look at the results to see if any robust generalizations can be inferred.

Fourty-eight students participated in the Survey. From the 144 students' questions, 57 questions from the Device Analysis and 102 questions from the Design Challenge projects seemed to comply with the three desired outcomes. Most of the students' questions (70) were related to critical thinking, fifty-six to intellectual growth and only thirty to responsibility to one's own learning. However, a simple comparison between the two projects shows that responsibility to one's own learning was the category that improved the most.

Lessons Learned

It is not quite easy to make a comparison in order to get any conclusion as to which of the two methods revealed more positive qualities from students', as well as from faculty perspective. However it can be seen that presenting two different projects using two different inductive approaches, which complement each other in one semester, brings successful results. For the limited time of a month and a half between the two challenges, the results show students' improved critical thinking, taking more responsibility for their own learning, as well as intellectual maturity. Our preliminary results show that guided inquiry seems to be efficient not only for learning new tasks, but also for transferring learned skills to tasks of a greater difficulty.

References

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Appendix A: Survey Questions

a result from the Device Analysis in what extent did you make gains in:
Hands-on activity in analyzing a real world mechanism
Ability to clearly describe the device and its operation
Ability to describe the science and engineering principles
Ability to present data, calculations and results from the analysis
Ability to asses the design and propose possible ideas for improvements
Ability to identify additional work that is needed to refine the results
Ability to take decisions and defend them
Ability to analyze a real world mechanism
Please, share at least three questions that you were asking yourself while worki the Device Analysis
. Additional Comments

Appendix B: Survey Questions

a result from the Design Challenge to what extent did you make gains in:
Solving real world problems without direct assistance
Working efficiently with others
Ability to think through a problem with specific constraints
Ability to develop models which help you to communicate and better understa ur design ideas
Ability to asses the performance of your design, based on task objectives
Ability to identify additional work that is needed to refine your results
Ability to take decisions and defend them
Ability to analyze a real world mechanism
Please, share at least three questions that you were asking yourself while worki the Device Analysis
. Additional Comments