

Integration of Experiential Learning Modules in Sophomore and Junior Courses: A Pilot Study

Abstract

Evidence from past literature suggests that experiential learning activities can be highly beneficial to undergraduate engineering students when introduced early in their undergraduate studies. Learning modules based on experiential learning model have been developed and integrated into two core undergraduate courses (one sophomore and one junior) of mechanical engineering. Using the experiential learning model of Kolb, each learning module contains concrete engineering experience, theory, computer-based modeling and simulations, and hands-on laboratory exercises. The main goal is to provide experiential learning experiences based on real-world engineering problem solving, engineering design process, and engineering design skills. The first module was tested in the sophomore course, engineering dynamics, in the summer 2014 semester as a pilot study. The second module for a junior course, engineering analysis, was tested in the fall 2014 semester. Some of the results from these pilot studies are presented in this paper.

Background

Merriam-Webster dictionary gives one of the definitions of engineering as “the design and manufacture of complex products”. Engineers design and develop products based on design process that utilizes knowledge and application of science, engineering, mathematics, critical thinking, and decision making skills. An engineering design process will require many iterative steps requiring applications of higher order skills in the cognitive domain of Bloom’s Taxonomy¹, *application, analysis, synthesis, and evaluation*, or in revised form of Bloom’s taxonomy², *apply, analyze, evaluate, and create*. The revised form replaces noun in each skill level to the corresponding verb form and exchanges the places of top two levels. Both original and revised taxonomy are shown in Figure 1.

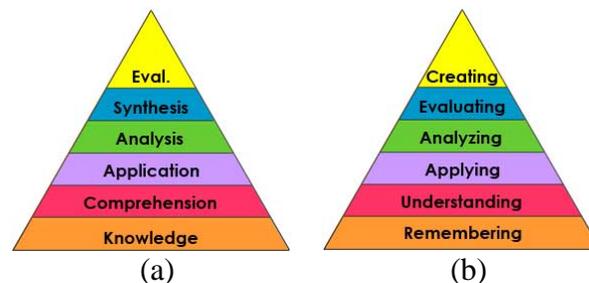


Figure 1 Original (a) and revised (b) Bloom's taxonomy³

A capstone design course, a culminating course designed to showcase students’ ability to apply engineering design process, is a required course in every engineering discipline to meet graduation requirement⁴. ABET, the accreditation agency for engineering, has placed great emphasis on the capstone design course as a vehicle to assess and evaluate students’ outcomes and education objectives of the program. In a capstone design course, students work in teams to

design, build, and test prototypes with real world applications. The capstone design course provides the students an opportunity to work with real-world, open-ended, interdisciplinary challenges typically sponsored by engineering societies, industry, and research companies. During the course, the students apply engineering design process: defining the problem, identifying specifications and constraints, developing conceptual solutions, evaluation of conceptual solutions, selection of a final design, and actual building and testing of the final design⁵.

A typical engineering curriculum is based on the structure of Bloom's taxonomy, emphasizing basic knowledge and comprehension in lower level courses (freshman and sophomore) and requiring application, analysis, synthesis, and evaluation in upper level courses (junior and senior). It is expected that a senior engineering student will be able to apply and synthesize engineering principles, analyze engineering problems, and evaluate solutions of these problems. However, many senior students in mechanical engineering are found lacking in these higher level skills based on over 20 years of combined teaching experience between the authors. One solution to address deficiencies in higher level learning skills of engineering students is through experiential learning.

Experiential learning

Kolb⁶ stated that experiential learning is the process of making meaning from direct experience, i.e., "learning from experience". As early as 1976, American Society for Engineering Education (ASEE) published a report on experiential learning where Harrisberger et al.⁷ evaluated six different experiential learning programs in engineering with the intent to determine the learning outcomes and learning potential of experiential project activities. The report identified the following skills and attributes that can be reinforced by a well-designed experiential learning program: *problem-solving skills, interpersonal awareness, creative expression, communication skills, technical skills, self-confidence building, computation skills, engineering fundamentals, organizational skills, leadership skills, planning skills, professional ethics, and engineering judgment*. Even though the main intent of a Capstone design course is to provide the skills and attributes mentioned above to senior engineering students, majority of the students do not demonstrate these skills in their Capstone design courses. It is the authors' strong beliefs that experiential learning model should be incorporated much earlier in an engineering curriculum in order for the students to experience engineering design process and design skills, supported by the recent findings by Conger et al.⁸.

According to Kolb⁶, "Learning is the process whereby knowledge is created through the transformation of experience" and he states that certain abilities are required in order to gain genuine knowledge from an experience:

- The learner must be willing to be actively involved in the experience;
- The learner must be able to reflect on the experience;
- The learner must possess and use analytical skills to conceptualize the experience; and
- The learner must possess decision making and problem solving skills in order to use the new ideas gained from the experience.

Kolb⁶ refers to these four stages as concrete experience (CE), reflective observation (RO), abstract conceptualization (AC), and active experimentation (AE).

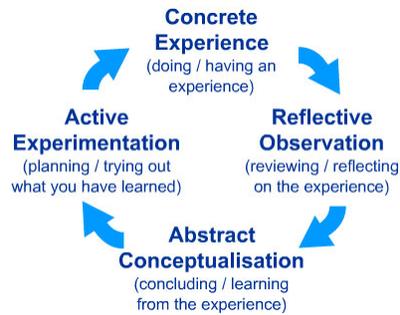


Figure 2 David Kolb's Experiential Learning Model⁹

Experiential learning model has been used in different disciplines such as soil science¹⁰, geography¹¹, mathematics¹², economics¹³, construction engineering¹⁴, chemical engineering laboratory education¹⁵, and computer science¹⁶.

Goals

The major goals of the paper are

- to develop learning modules based on experiential learning model to be used in sophomore and junior level courses, and
- to assess and evaluate effectiveness of these modules in improving engineering design skills of junior and senior engineering students.

Methodology

In an engineering design process, a group of engineers will use mathematical modeling, experimentations, and computer simulations to come up with a design solution to the problem. Thus, every engineering student needs theoretical knowledge, hands-on experience, and computer simulations during their undergraduate studies. In order to integrate experiential learning activities in mechanical engineering courses, the authors have developed learning modules that integrate theory, laboratory experiences, mathematical modeling, and computer-based simulations. These learning modules will be used in two undergraduate core courses of mechanical engineering, namely, MEEN 2302 Dynamics, and MEEN 3340 Engineering Analysis.

The development of modules follows experiential learning model of concrete experience (CE), reflective observation (RO), abstract conceptualization (AC), and active experimentation (AE) stages. In view of these four stages, each module introduces the students to an engineering experience or an engineered object that they can easily relate to and can readily apply the engineering design or analysis process. For example, every sophomore student is assumed to drive a car (concrete experience). A series of questions related to speed, acceleration, and engine power of a car will be posed to the students (reflective observation). Then, how theoretical principles from MENN 2302 Dynamics course can be used to analyze kinematics (motion) and kinetics (motion/force interactions) aspects of an automobile will be demonstrated (abstract conceptualization). Then, the students perform laboratory exercises and computer simulations to provide the last stage, active experimentation.

Current and future learning modules

- MEEN 2302 (Summer 2014 and Spring 2015)
 - ✓ Engineering dynamics in sports and transportation (Summer 2014)
 - ✓ Kinematics and kinetics of an automobile (Spring 2015)
- MEEN 3340 (Fall 2014)
 - ✓ Design and analysis of a suspension system (spring/mass system) in an automobile

Computer simulations utilizing Matlab and MathCAD packages have been developed and used as part of the learning module. In future implementations of these modules, engineering design and analysis software ANSYS/Mechanical Design, and Working Model will be used for analysis and design of engineering problems.

Pilot Studies

MEEN 2302 Engineering Dynamics

A pilot testing was done in the offering of MEEN 2302 in the summer 2014 semester. No quantitative evaluation was conducted because the summer course lasted only 5 weeks and the number of students enrolled in the course was quite limited (~ 20 students). The module as it was offered contains two parts: kinematics and kinematics. The first part involved investigating the role of kinematics in sport such as baseball, basketball, softball, football, and golf. The emphasis was on the topic of projectile motion as applied to these different sport situations. An example problem and MathCAD solution was provided to facilitate the students. The example problem was on the topic of football:

Problem

Determine the range of velocities and angles that the kicker uses to make the field goal or extra point. In analyzing the problem, you must research the dimensions and location of the goal post. Using these data, you must investigate, for example, the velocity and angle of the ball needed to make the field goal from 30, 40 or 50 yards.

The example was chosen as there was an interesting video series, science of NFL football, hosted on NSF Science 360 video website¹⁷. The students were formed into groups and each group was assigned one of the sports mentioned above to identify, analyze, and submit a report on a kinematic problem in their assigned sport. The second part involved investigating the role of kinetics in transportation as related to automobiles, airplanes, trains, and ships/boats. An example problem and MathCAD solution was provided to facilitate the students.

Problem

Choose a drag car and find out technical specifications such as weight, engine power, torque, rated speed, and acceleration. Using these data, you must investigate, for example, whether the engine power given by the manufacturer is sufficient to provide the rated acceleration given by the manufacturer such as the car can go from 0 – 60 mph in 6 seconds.

The evaluation of students' work and their comments on course evaluations showed that these problems improved students' appreciation of learning dynamics and how the principles of dynamics were actually utilized in real world situations.

MEEN 3340 Engineering Analysis

A pilot module for junior students was tested in fall 2014 semester. The module consisted of an experiment (a spring/mass system), emulating a simple suspension system of an automobile, and Matlab module to simulate the experiment. The experiment module consists of three parts: determining a spring constant of a single spring, determining a spring constant of two springs in series and parallel configurations, studying dynamic responses of 2nd order spring-mass systems (a single spring and a mass, two springs in series and a mass, and two springs in parallel and a mass). A photograph of the dynamic response test is shown in Figure 3.



Figure 3 Photograph of the dynamic response of a 2nd order system experiment

Students are required to capture the response of the system and plot them in order to compare with the simulation results. A sample experimental response is depicted in Figure 4.

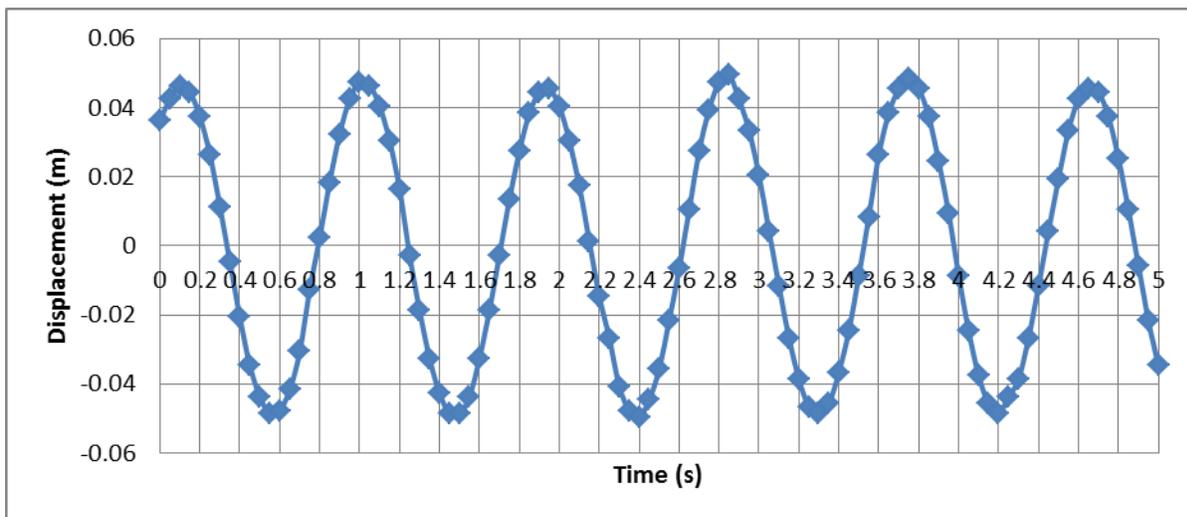


Figure 4 An experimental response of the 2nd order spring-mass system

Experiential results of dynamic response of spring combination and mass systems are required to compare with analytical results simulated with both Matlab and Simulink. The Simulink model used is given in Figure 5 below.

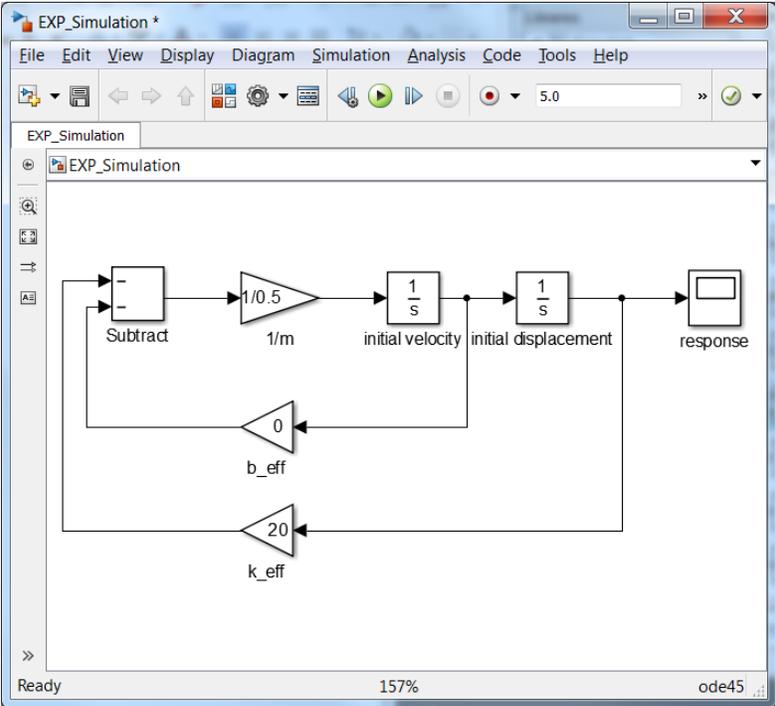


Figure 5 A schematic of Simulink module

An example output of the Matlab/Simulink module is given in Figure 6.

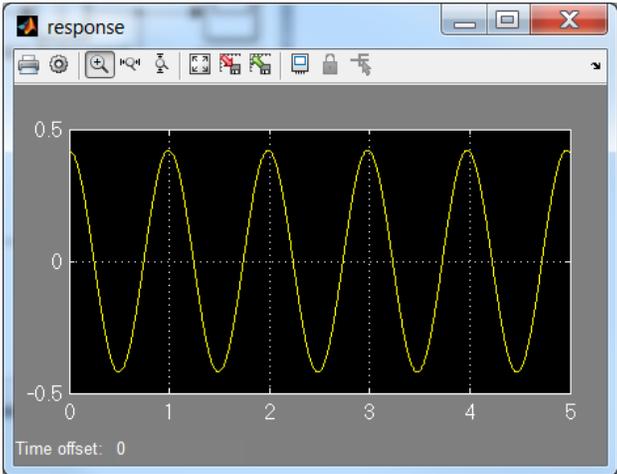


Figure 6 A typical output of Matlab/Simulink module

Assessment

Two forms of assessment; student survey and a pre- and post-quiz, were used in the course MEEN 3340. The class was divided into two groups and one group conducted the experiments described above. However, all students were required to conduct a project involving computation using Matlab and Simulink and submit a project report. The purpose of the survey was to evaluate the effectiveness of experiments and numerical computations in understanding the concepts and improving learning process of students. The survey results were summarized below.

All students who conducted the experiments agreed that experiments did help them develop critical thinking skills. On a scale of 1 to 5 with 5 being the highest, among the students who conducted the experiment the average rating of 4.25 on the question of whether experiments help improve their understanding of the course materials. On the other hand, the same group gave an average rating of 4.125 on the question of whether numerical simulations help improve their understanding of the course materials. On both questions, the lowest rating was 3 and highest rating was 5. For the same questions, students who did not perform experiment gave the ratings of 3.5 and 3.5 for both questions with the lowest rating of 2 and the highest rating of 5.

A quiz was given before and after experiment to all students to evaluate the effectiveness of the module in improving student's learning process. The quiz was provided in the appendix section of the paper. The results of the quiz show promising as the average scores of the students who conducted the experiments improve by about 80% after the experiment (an average score of 16 in the pre-quiz and an average score of 28 in the post-quiz).

Conclusions

Past literature shows that experiential learning activities can be highly beneficial to undergraduate engineering students when introduced early in their undergraduate studies. A pilot study was conducted in MEEN 2302 Dynamics in the summer of 2014 and MEEN 3340 Engineering Analysis in fall 2014 on using learning modules based on experiential learning model. Based on the preliminary results from MEEN 3340, students who conducted experiments (experiencing the theory through hands-on experimentation) believed that their understandings of course materials were significantly improved. The results of the pre- and post-quiz supported their opinion when average score of the students who conducted experiments improved by about 80%.

Future Work

The present study is a pilot study to explore the possibilities of integrating learning modules based on experiential learning model of Kolb. The preliminary results have shown that experiential learning model may significantly improve the learning process of students. The second iteration of using learning modules in MEEN 2302 Dynamics is ongoing in the spring 2015 semester and the third iteration is expected to continue in the summer 2015 semester. Further improvements are being made in the development of learning modules in next offering of MEEN 3340 in the fall 2015 semester.

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Appendix 1: Student Survey Form

Student Survey

MEEN 3340 Engineering Analysis

Fall 2014

Name:

Did you perform experiment during the course?

- Yes
- No

Doing the hands-on experiment in this course help you develop critical thinking skills such as conceptualization, problem solving skills, etc.?

- Yes
- No

Preparing the engineering report on the project in this course help you improve engineering skills such as solving ODEs?

- Yes
- No

Rate on the scale of 1 to 5 how useful doing the experiment in understanding the course material. (5 being highest)

- 1
- 2
- 3
- 4
- 5

Rate on the scale of 1 to 5 how useful doing the numerical simulations (Matlab and Simulink) in understanding the course material. (5 being highest)

- 1
- 2
- 3
- 4
- 5

Appendix 2: Pre and Post Quiz

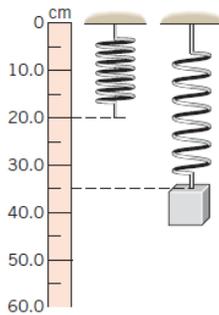
MEEN 3340 Quiz

October 23, 2014

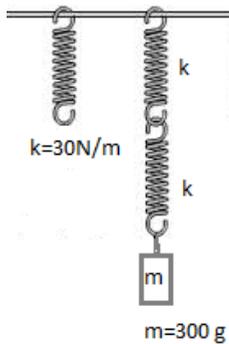
Name: _____

Note: Assume gravitational acceleration is 10 m/s^2 .

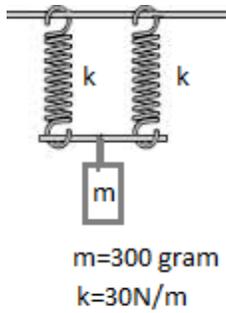
1. The mass of the hanging weight is 300 gram in the figure below. What is the value of the spring constant?



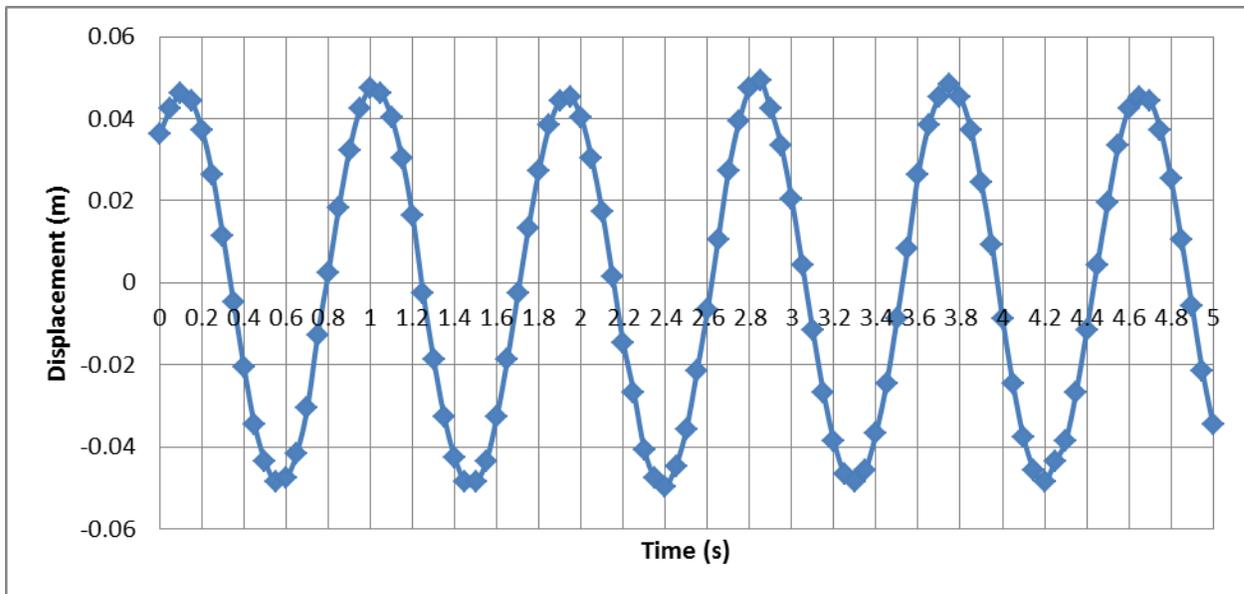
2. What is the static spring elongation x when two springs ($k = 30\text{N/m}$) in series with the hanging mass of 300 gram?



3. What is the static spring elongation x when two springs ($k = 30\text{N/m}$) in parallel with the hanging mass of 300 gram?



Experimental result of displacement response of a dynamic system is shown in the figure below. Problems 4 and 5 are based on the figure.



4. What is the system frequency in rad/s based on the plot?

5. The experimental result is obtained from the setup of the following system in the figure below.
 - a. Write the equation of motion.
 - b. The mass of the hanging weight is 500 gram. Using the frequency obtained from experimental result in problem 4, calculate the spring constant k .

