Incorporating Experiential Learning in Engineering Courses

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The author presents an example of an assignment given to students that incorporates experiential learning, and the results of students' feedback on this method of learning compared to conventional methods are summarized. A similar approach can be applied to other subjects in engineering, even without requiring a laboratory component in the course.

ABSTRACT

In recent years, "experiential learning" as a method of delivering course material has become more recognized in university education. This article is a report on a project conducted in the School of Engineering Science at Simon Fraser University that incorporates experiential learning in a lower division course. The course is a first-year, common core course in logic circuits. At the time that this project was implemented, the course did not have any lab components attached to it; therefore, incorporating experiential learning into the course was even more challenging. In this article, an example of an assignment given to students that incorporates experiential learning is presented, and the results of students' feedback on this method of learning compared to the conventional method are summarized. A similar approach can be applied to other subjects in engineering, even without requiring a laboratory component in the course. This article also provides example applications for analog and digital communication courses.

INTRODUCTION

"Experiential learning" as a method of delivering course material is becoming more recognized in university education in recent years. Many North American, as well as international, universities have formed research teams dedicated to incorporating experiential education in their curricula. Simon Fraser University (SFU) in Canada, with which the author is affiliated, is no exception. The Experiential Education Project at SFU began in late 2010 with a focus on documenting SFU's use of credit-bearing experiential education [1].

Experiential learning is the process of making meaning from direct experience, that is,"learning from experience" [2]. Aristotle once said, "For the things we have to learn before we can do them, we learn by doing them" [3]. A definition of experiential education by the Association of Experiential Education states, "Experiential Education is a process through which the learner constructs knowledge, skill, and value from direct experience" [4]. The idea of "Experiential Learning" was first reflected in the writings of John Dewey [5] and later popularized by many educational experts, such as David A. Kolb. Some researchers have distinguished between "experiential learning" and "experiential education" in that experiential learning relies solely on the individual and does not necessarily require a teacher, whereas many others have used the two terms interchangeably [2]. Obviously, it is the second school of thought (integration of experiential learning and education) that can potentially be applied to educational settings, such as degree programs at the university level.

The four critical steps associated with experiential learning are Action, Reflection, Abstraction, and Application (Fig. 1). This circular procedure is initiated with an experience and followed by reflective observation. Observations help people form general rules and modify their experience [2].

An enormous amount of our everyday knowledge is obtained through experiential learning. In other words, we experience various situations before understanding the rules governing them. For example, the process of language learning that a child experiences vividly expresses the steps necessary for experiential learning. The revolution in foreign language education, in which students experience various concepts before acquiring any sense of grammar, might have originated from experiential learning theory.

Research on experiential and community engagement learning shows that the concept of experiential learning has been mostly applied in the arts and humanities, has been applied to some extent in natural sciences, and has been applied minimally in engineering. This may, at first glance, seem rather intuitive considering the closeness of humanities subjects to human experiences. However, the role of engineering concepts in our modern lives should not be overlooked either.

Incorporating experiential learning in subjects such as electrical and computer engineering is more easily achieved in upper-division courses through course projects, internships, and capstone projects. In fact, many universities refer to their capstone projects as an example of providing experiential learning opportunity to their students. Examples are engineering programs at Purdue University, Oregon State University, and the University of British Columbia [6–8].

However, students need to understand the purpose and application of the theoretical knowledge they are gaining as early as possible, and this early integration of theory and practice can be achieved if they have experience with real-life examples related to what they learn.

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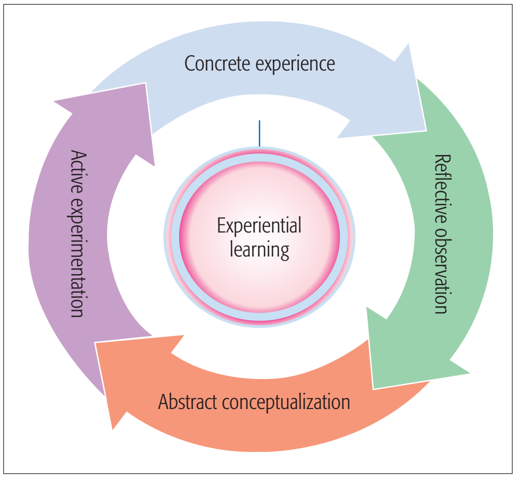

Figure 1. Experiential learning, circular diagram.

For lower-division courses, experimental work in the laboratory while learning theoretical background in conventional classes is often considered as experiential learning. While the importance of "experimental" work or hands-on experiments in education is undeniable, it should not be referred to as "experiential learning." As previously explained, experiential learning is a methodology where students experience different scientific experiments even before obtaining the theoretical concepts governing them.

A true implementation of experiential education is not single experiences in individual courses, but rather it is a task that must be organized at the program/school level that involves more effort of the trainers compared to conventional educational methods. In the engineering discipline, however, most courses are of a technical nature, and students require knowledge of the theoretical concepts, usually based in math and/or physics, to learn new and larger concepts in engineering. A complete overhaul of the education system from the traditional model to an experiential method may thus not be possible, or desired, at the program level or even for a single course in its entirety. The author, however, believes that it is possible to successfully deliver components of courses taught within the discipline of engineering in the form of experiential learning.

This article explains how experiential learning can be incorporated into parts of engineering courses, with or without hands-on laboratory components. The concept is explained by giving an example of an experiential learning assignment given to students in ENSC-150: *Introduction to Computer Design*. At the time of the implementation of this initiation, this course was part of the first-year curriculum of the Engineering Science program at SFU and did not include a laboratory component.

The rest of this article is organized as follows. In the following section, I present the experiential learning example used in ENSC-150. Then a summary of a survey conducted on students' experience is provided. Finally, I explain how a similar method to the example provided in this article can be applied to courses in the communication engineering discipline, and how further research can take the study of the effectiveness of this method to the next level.

Example of Experiential Learning in ENSC-150

This section provides an example of how experiential learning was incorporated in the form of an assignment as part of the course delivery for ENSC-150.

In this course, students are expected to learn about basic logic circuits and how logic blocks can be designed and employed to construct simple digital devices. Combinational and sequential logic designs are the main topics covered in this course. The course has large enrollments (above 100 students), and it includes lectures and tutorials but no laboratory component.

An example of a digital device that can be introduced to students in the advanced stages of this course is a digital clock. In the conventional method of teaching, the building blocks of this digital clock, that is, basic logic gates as well as flip flops, are first introduced to the student, followed by the design procedure for counters (which will count the seconds, minutes, and hours). The student is then taught the details of how each counter is controlled and is reset after going through one cycle. For example, the "seconds" counter is reset to zero after reaching the number 59, and this reset should trigger the "minutes" counter to increment by 1. In other words, in the conventional teaching method, the student is taught the individual components and the design procedure of a digital clock without being able to discover how this device works by first experimenting with it.

If, instead of following the conventional method, we were to use the concept of experiential learning by adhering to its true definition, each student would be asked to start by experiencing an actual digital clock, analyzing the circuit inside it, figuring out the building blocks of the clock, and understanding the interaction of the logic signals within the clock. Obviously, this approach would not be practical considering the scope and timeline of the course!

The challenges in ENSC 150 are the large enrollment in the class, the lack of a laboratory component in the syllabus of the course, and finally, the fact that it is not possible to see the circuit inside an integrated digital circuit! The approach we took here was to adopt a combination of theoretical (conventional) and experiential learning methods, as explained below.

Because the course did not have access to any hardware design lab, we used a logic simulation program, called DesignWorks, to enable the students to see the function of various digital circuits, and be able to make changes and modifications to circuits and see the results.

We presented this experiential learning example in the form of an assignment. The students were given a simplified block diagram of a digital clock. This clock consists of three parts, shown in Fig. 2. Part A receives a clock pulse of frequency 1 Hz and counts and displays the "seconds." Part B receives a clock pulse of frequency 1 pulse per minute from Part A and counts and displays the "minutes." Part C receives a clock pulse of 1 pulse per hour from Part B and displays the hours.

Students were also provided with the schematic of the circuits inside parts A and B. Figure 3

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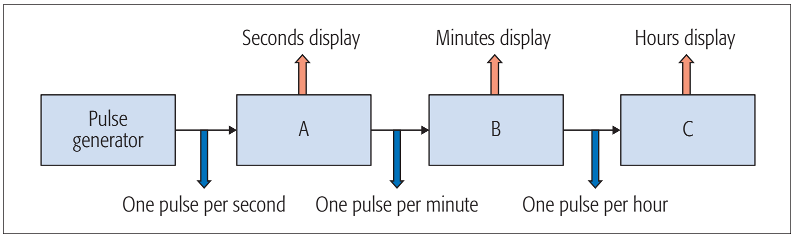

Figure 2. Simplified block diagram of a digital clock provided in the assignment.

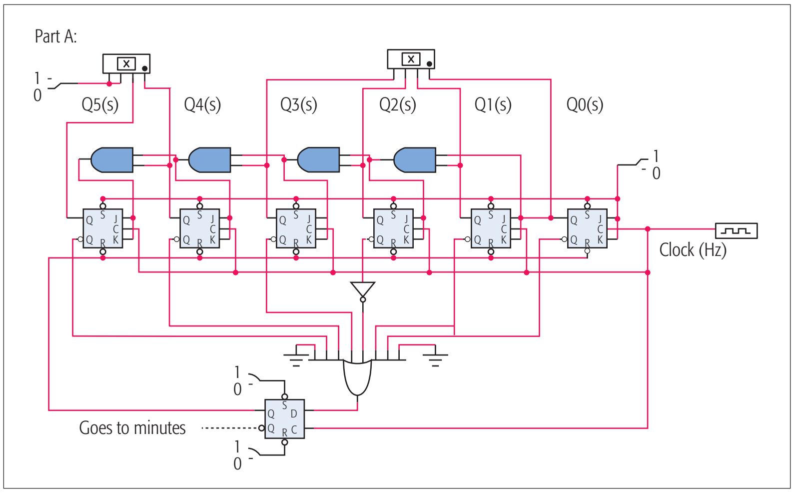

Figure 3. Digital circuit inside of part A; this circuit counts the seconds.

shows the circuit for part A (i.e., counter of the seconds). DesignWorks simulation files were also provided, so students could run the simulations and observe how parts A and B of the digital clock function, and how they interact with each other. Note that at this point in the course, the students had already learned about JK-flip flops, but they had not yet seen the structure of the counters used in this example.

For their assignment, the students were asked to run the simulations for parts A and B, to explain the function of these parts, and to demonstrate their understanding of how the counters for seconds and minutes work. Based on what they learned from the function of each of these parts and their interaction, the students were then asked to design part C of the clock and add it to the simulated circuit, thereby creating a complete clock that counts and displays hours, minutes, and seconds. They were also asked to design and include a seven-segment display showing the letters A and P representing a.m. and p.m., respectively.

As you can see, this assignment is quite different from the assignments engineering students are used to completing. Conventionally, students learn new concepts in a classroom setting during lectures or tutorials. Then they work on assignments where they are asked to apply the learned concepts to solve relevant problems. In the case of this assignment, students are first given access to an electronic device (in this case a partially functioning digital clock) in a lab environment (in this case a simulation program). By examining the components of this clock and observing the input and output signals to each component, they are expected to learn the operation of the counters used in a digital clock. They are then asked to demonstrate their learning, not only by explaining it in an article, but also by designing and adding the last counter to the clock, and, as a result, simulating a fully functioning digital clock.

After submitting their assignment, students were given a survey about their learning experience. The survey questions and results are explained in the next section.

Students' Feedback

A short anonymous survey was given to students at the end of this assignment. It was made clear to the students that participation in the survey was voluntary.The main questions on the survey were:

1. On a scale of 1 to 5, rate how you prefer the experiential method over the conventional method (1: not preferred, 2: less preferred, 3: equally preferred, 4: more preferred 5: strongly preferred)
2. Comment on the differences between the two methods.

Sixty-seven students (about 40 percent of the class) completed the questionnaire. Figure 4 shows the diagram corresponding to their answers to question 1. More than 37 percent of the students favored the experiential learning method compared to 28 percent who preferred the conventional method. The rest of the students did not favor one method over the other.

As for the students' comments in response to question 2, many found this experiment to be interesting, and they mentioned that they looked forward to more experiential learning approaches in future courses. The experiential method being more challenging and more time consuming was among the drawbacks of this method mentioned by some of the other students.

Other types of interesting and useful feedback received from students include students' rating of their level of understanding of subjects to which they were first exposed experientially compared to their understanding of subjects they learned with the traditional approach. However, it is important that topics at similar levels of difficulty be chosen for comparison. Questions can be posed independently for each topic, or can directly ask students to compare the experiential topics with traditional topics.

Possible Application to Communication Courses

This article uses an example to show how the concept of experiential learning can be applied to courses within the engineering discipline. The course considered here is a course in computer design. The course is a large enrollment course with no laboratory component.

The method explained in this article can be adopted and adjusted for various other courses in the field of electrical and communications engineering. In fact, in courses that include a hardware laboratory component, the opportunity to implement experiential learning is more readily available. A very simple example can be given for an analog circuit course. Here, students can be first introduced to a fundamental concept such as Kirchhoff's Voltage Law (KVL) through a laboratory experiment. Students can construct a simple resistive circuit including two or three loops to measure the voltage across each branch of each loop, and to find the relationship that exists among the measured voltage.

More sophisticated examples can be implemented in third- and fourth-year courses in communications engineering. For example, in a classic analog communication course, the students can first be introduced to the amplitude modulation (AM) system in the laboratory, where modulation and demodulation systems are available in modular format. Knowing that students have the pre-requisite background in signals and systems (i.e., concepts of the time and frequency domains), the instructor will ask students to experiment in the lab with the AM modulator and to observe the output signal on an oscilloscope and on a spectrum analyzer. Students will vary the frequency and amplitude of the input signals (message and carrier) and try to guess how the AM signal carries the information about the message signal. They can also change the DC offset of the message signal to observe the role of the modulation index and over modulation in AM. The instructor will then refer to students' observation in the lab, and provide them with the mathematical formulae that explain the observed results. If a hardware lab is not available, simulation programs such as Matlab can easily replace an experiment like this.

Another example for a digital communication course can be applied to teaching the concept of additive white Gaussian noise (AWGN) and its effect on the error rate of binary signaling. Students need to first learn about the nature of AWGN, that it can be modeled with a normal distribution, and that it is additive. In the lab, students can vary the level of the noise added to a baseband binary phase shift keying (BPSK) signal and measure the error rate at the output of the BPSK receiver (demodulator). They can then plot their measured error rate vs. noise level and try to make predictions about how changing the noise level or changing the modulation scheme would vary their results. The instructor will then guide students to reach the formulae for error calculations.

Finally, it should be noted that engineering educators who are interested in evaluating the effectiveness of these types of assignments may want to measure the learning outcome and level of understanding of students who have learned a concept through this method of experiential learning compared to a control group of students who have learned the same concept through the conventional educational method. This can be achieved if several experiential learning assignments are designed for a course so that students can have equal opportunity of being in a control group (conventional learning method) and a test group (experiential learning group).

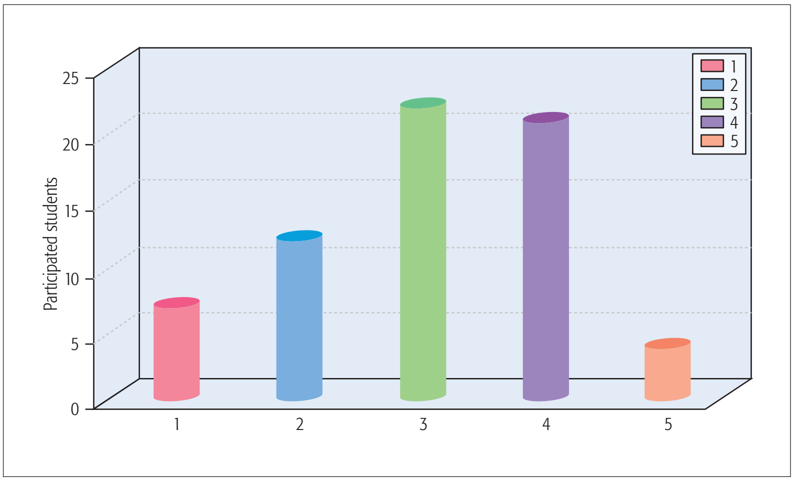

Figure 4. Students' feedback on experiential learning assignment.

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References

[1] http://www.sfu.ca/experiential/, accessed May 8, 2017.

[2] C. M. Itin "Reasserting the Philosophy of Experiential Education as a Vehicle for Change in the 21st Century," *J. Experiential Education*, Fall 1999, pp. 91–98.

[3] W. R. Bynum and R. Porter, *Oxford Dictionary of Scientific Quotations*, Oxford Univ. Press, 2005.

[4] C. Luckmann, "Defining Experiential Education," *J. Experiential Education*, vol. 19. no. 1, 1996, pp. 6–7.

[5] J. Dewey, "Democracy and Education by John Dewey 1916," *The University of Chicago Press Journals*, vol. 5, no. 1/2, 2008, pp. 87–95.

[6] "Experiential Learning & Research," Electrical and Computer Engineering, Purdue University; https://engineering.purdue.edu/ECE/Academics/Undergraduates/UGO/Enrichment_Opportunities/Experiential_Learning_Research, accessed May 8, 2017.

[7] "Experiential Learning," College of Engineering, Oregon State Univ., http://engineering.oregonstate.edu/experiential-learning, accessed May 8, 2017.

[8] "Experiential Learning and Research," Univ. British Columbia, Electrical Engineering at UBC's Okanagan Campus; http://you.ubc.ca/ubc_programs/electrical-engineering-okanagan/, accessed May 8, 2017.

Biography

Atousa Hajshirmohammadi (atousah@sfu.ca) is a senior lecturer in the School of Engineering Science at Simon Fraser University, British Columbia, Canada. Prior to that, she was a senior design engineer at LSI Logic Inc., California (2001–2004). She received her B.Sc. and M.Sc., in electrical and computer engineerin, from Isfahan University of Technology, Iran, and her Ph.D. in communications engineering from the University of Waterloo, Ontario, Canada. Her research interests are in multimedia communications, cognitive radio, and engineering pedagogy.