Improving Self-Efficacy in Engineering Students using PLC Based Traffic Light Experiments

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Abstract
In ABET EC2000, eight of the eleven attributes are defined as abilities of engineering program graduates. While educators have methods to measure these abilities, the students are often left with a somewhat vague idea of their increased knowledge and little sense of advancement in their engineering capabilities. This research aims to develop metrics to measure improvements in the self-efficacy of senior engineering students through a set of increasingly more challenging laboratory exercises. The experimental setup consists of a programmable logic controller (PLC), a replica of an intersection of two roads with a set of traffic lights and road sensors, and a number of toy cars capable of triggering the sensors. Experiments progress from flashing red and yellow lights, through controlling a single traffic light, controlling the whole intersection, to implementing the sensors in creating a more complicated intersection control. The self-efficacy of students is assessed through a questionnaire. An analysis of the results shows the change in self-efficacy for engineering students who participated in this study.

Introduction

In his theory of motivation, Maslow[1] clarified the relationship between motivation and unmet needs. His Hierarchy of Needs defines the human needs from bottom up as follows: physiological needs such as food, water and shelter; safety needs such as security, freedom from fear and order; belongingness and love needs; esteem needs such as self-respect, achievement and reputation; and self-actualization needs. These needs must be satisfied from bottom up. It is assumed in this study that all of the lower level needs of our engineering students are sufficiently satisfied. They have food, shelter, are safe and feel they belong with their peers. Brandon[2] divides self-esteem into two interrelated components: self-efficacy (the sense of self-competence) and self-respect (the sense of personal worth). Self-efficacy is further related to one's confidence in the functioning of one's mind and in one's ability to think, understand, learn, and make decisions[3].

This work will concentrate on satisfying self-efficacy needs of engineering students. In relation to career, self-efficacy refers to one's beliefs regarding "career-related behaviors, educational and occupational choice, and performance and persistence in the implementation of those choices[4]." According to Bandura[5], self-efficacy is learned and self-efficacy expectations are acquired through performance accomplishments, vicarious learning, verbal persuasion and physiological/emotive states. Through successful accomplishments of course tasks students

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develop a self-perception of capability in performing similar tasks in the future. Vicarious learning refers to the development of self-efficacy in an activity after observing other similar persons engaging successfully in that same activity. Verbal persuasion refers to the development of self-efficacy when important referents tell a person that he/she has the capability to successfully perform an action[6]. Physiological/emotive state deals with the fact that stress and anxiety have a negative effect on self-efficacy as well as learning[7]. Caine and Caine[8] state that the brain learns optimally when appropriately challenged, but downshifts under perceived threat.

The aforementioned self-efficacy enhancement activities are applied in the Computer Integrated Manufacturing (CIM) course at the University of Southern Colorado in the Industrial Engineering Program. The CIM course is a senior-level design-based course dealing with modern technologies such as automation, computer-numerically controlled (CNC) machines and robotics. The CIM laboratory curriculum includes hands-on experiences with programmable logic controllers (PLC), CNC mills and robots. PLCs are industrial grade computers used extensively in automation. In this study, we concentrate on the PLC experience. A set of laboratory exercises based on traffic lights operation was developed to allow students to apply their knowledge and enhance their problem-solving skills using a familiar design problem. The idea came from an example presented by Swainston[9] and an independent design project.

Improving Self-Efficacy Prior to Laboratory Experience

In the classroom, after emphasizing the importance of being able to automate an industrial process, both theoretical and practical aspects of PLCs are explained. A number of design problems are worked out on the board. For some problems, students are encouraged to form small groups and produce group designs. One group is selected to present their design, which is then compared to other groups' designs. A design homework assignment dealing with an application of PLCs is assigned, corrected, and then explained in detail in the classroom. In addition, some successful student designs are emphasized. Afterward, students are assured by the instructor that they are ready and capable to apply their knowledge in the laboratory, just as their predecessors did. The above actions are intended to improve the self-efficacy of students using performance accomplishments (successful completion of a number of design problems), vicarious learning (in-class comparison of various students' designs) and verbal persuasion (instructor's statement, that based on his/her previous experience students are ready for laboratory design experiences).

Experimental Setup

The experimental setup for a series of laboratory exercises using a traffic light example is depicted in Figure 1. An Allen-Bradley SLC 100 PLC with a communication interface, cables and a bank of solid-state relays is used to obtain signals from inductive sensors, and for turning on and off two sets of traffic lights. A model of an intersection includes two pairs of traffic lights and four inductive sensors capable of detecting the presence of cars waiting at traffic lights or passing through the intersection. A PC with an installed PLC software package is used for programming the PLC (not shown). A pair of traffic lights is controlled by parallel outputs from the PLC, i.e. there are three outputs per one set of traffic lights (one for green, one for yellow and one for red lights).

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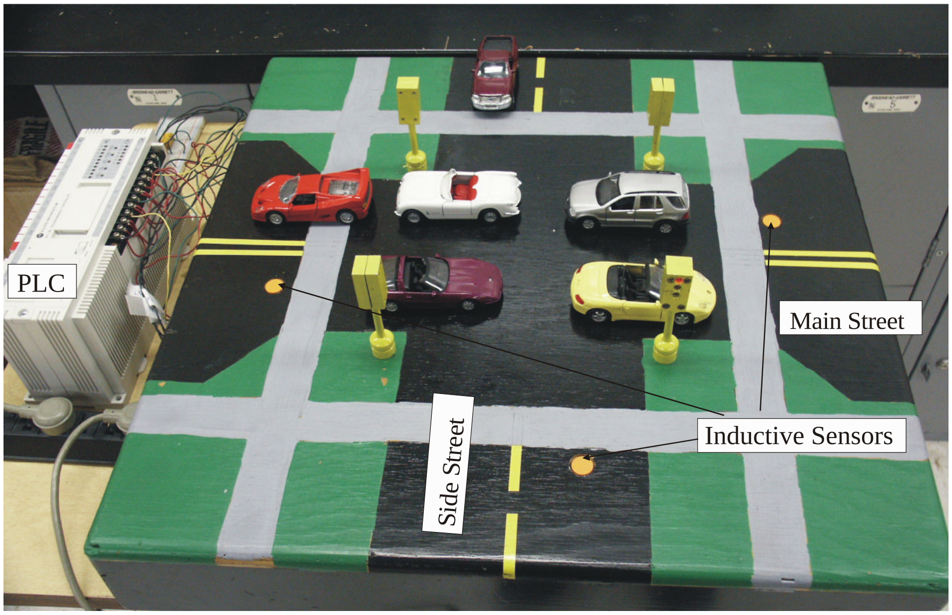

Figure 1. PLC based traffic light experimental setup

Enhancement of Self-Efficacy through Laboratory Exercises
Within the PLC set of experiments, students had to implement four design problems. The first exercise was designed to provide students with experience using the Allen-Bradley SLC 100 PLC and its programming package. While the problem was simple, the main emphasis was on becoming familiar with the PLC technology. In the second, progressively more challenging experiment, students were to design and implement solutions to a typical discrete system (a single set of traffic lights). Application of timers and basics of design procedures were emphasized. The third experiment, where students implemented automatic control of the entire intersection, stressed the relationship between the traffic lights. In the fourth exercise, students implemented sensor inputs to detect the presence of cars waiting at traffic lights, and controlled the intersection accordingly. All four experiments were completed within two weeks.

In the first experiment, logic for a blinking yellow traffic light was given in the form of a ladder logic diagram. Students were only to implement the solution.

The second experiment dealt with a single set of traffic lights. Students were to implement their own designs in controlling the lights. When the PLC was started, it should turn on red lights for 25 seconds, then green lights for 32 seconds and finally yellow lights for 3 seconds. The system should start as soon as the program was activated, and continue to operate until the program was removed.

The third experiment was built on top of the second. Students were to design and implement a ladder logic program to control two sets of traffic lights used in a typical intersection where one street (main street) was busier than the other (side street). For the main street, red lights should be on for 25 seconds, then green lights for 32 seconds and finally yellow lights for 3 seconds, as

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in the previous exercise. Students were expected to determine the traffic light behavior for the side street.

The fourth experiment used sensors. Initially, the green lights of the main street were to be on. When there were no vehicles triggering an inductive non-contact sensor on the main street and a vehicle on the side street triggered a sensor (used as a normally open switch in the PLC program), the light sequence should change. For the main street, yellow lights should turn on for 3 seconds, and then red lights for 10 seconds. During this period, the cars driving on the side street could go through the intersection (green lights should be on for 7 seconds and then yellow lights for 3 seconds). Then the system should reset and the sequence repeat.

Before each laboratory exercise, the instructor demonstrated a possible working design. This insured students that all the laboratory hardware performed correctly, and that the given task was possible to accomplish. While the performance accomplishment was a major tool for improving students' self-efficacy in the laboratory, the other methods were also applied. With a single experimental setup, students, working in pairs, had to use the machine a pair at a time. This created an environment conducive to vicarious learning. As soon as one group was able to present a working design, other groups' self-efficacy increased. They knew that the accomplishment of the task was possible (others did it) and within their capabilities.

A key to success in enhancing students' self-efficacy with challenging design problems was to keep stress and anxiety to a minimum. This was accomplished using different methods by the instructor. Students were informed beforehand that they were about to try and accomplish a challenging engineering design task, that the task is specifically created to increase their engineering capability necessary in the engineering work environment, and that they need to concentrate and pay attention to details to create a successful working design. Furthermore, students are told that typical designs rarely work the first time, and that they could learn from their mistakes by careful observation. Students were given ample time to finish the task. Frequent interactions with student teams allowed the instructor to gage and minimize the level of the teams' frustration. While the knowledge and skill gain were measured using an open-book design based test, the improvement in the students' self-efficacy was measured by using a survey described in the next section.

Survey and Results

A survey assessing students' improvement in self-efficacy is presented in Figure 2. It accounts for lecture as well as laboratory experience. Questions 1 through 7 are quantitative and question 8 is qualitative. While questions 1 through 4 and 7 can be directly related to students' self-efficacy, questions 5 and 6 are based on the notion that students' appreciation and positive attitude towards a subject of study are indirectly correlated to students' self-efficacy.

The results of the survey for 15 students (Fall 2001) are summarized in Table 1. On average, students have found the classroom/laboratory approach described effective in improving their self-efficacy. Question 7 results require additional clarification. The two students with zeros on question 7a, declared 10s on 7b thus showing a remarkable improvement in their self-efficacy. On average, the improvement in self-efficacy was 49.1% (maximum 100%, minimum 10%).

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There were no negative results recorded. Of the five responses to question eight, the two dealing with improving self-efficacy read "Practice is always good and helpful," and "I like the experience in the lab more than in the class. So I would prefer more labs."

Survey on PLC Experience at USC

By now, you have finished your PLC set of laboratory exercises in EN 473. In addition, through lecture, homework assignments, examples, and tests your working knowledge of this technology increased. Please, help me identify if, and how much, this educational experience improved your self-efficacy in dealing with difficult engineering problems.

On a scale from 1 to 5, (1 = not effective, 2 = somewhat effective, 3 = moderately effective, 4 = effective, 5 = very effective) please, grade the statements below:

1. The PLC lab set was effective in helping me develop skills to handle difficult engineering tasks.
   1 2 3 4 5
2. The PLC out-of-lab experience was effective in helping me develop skills to handle difficult engineering tasks.
   1 2 3 4 5
3. The PLC educational experience was effective in helping me link the theory to the real world.
   1 2 3 4 5
4. The PLC educational experience was effective in improving my problem-solving skills.
   1 2 3 4 5
5. The PLC educational experience was effective in developing my appreciation for PLCs.
   1 2 3 4 5
6. The PLC educational experience was effective in developing a positive attitude toward PLCs.
   1 2 3 4 5
7. An industrial engineer with 5 years of experience in automation is likely to succeed 9 out of 10 times when dealing with engineering problems similar to the traffic light intersection problem (with sensors). You just started your new job. Given the opportunity to solve a similar problem with high stakes involved (fired if unsuccessful or $10,000 salary increase if successful) please rate your willingness to try:

   a) If you didn't have the PLC educational experience:
   0 (no) 1 2 3 4 5 6 7 8 9 10 (yes).
   b) After the PLC educational experience:
   0 (no) 1 2 3 4 5 6 7 8 9 10 (yes).
8. Please write any other comments you may have that might be helpful in improving students' self-efficacy when dealing with difficult engineering problems.

Figure 2. Student Survey

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	Answer											
Question	0	1	2	3	4	5	6	7	8	9	10	Average
1				4	2	5						4.09
2				5	1	5						4.00
3				2	4	5						4.27
4				1	4	6						4.45
5				2	4	5						4.27
6				3	5	3						4.00
7a	2			3	1	2	1	1	1			4.00
7b								2	1	4	4	8.91

Table 1. Survey results

Conclusions

A set of four laboratory exercises was devised and hardware was constructed to improve self-efficacy of senior-level engineering students in the Computer Integrated Manufacturing class. As an assessment instrument, a survey was developed and delivered to the participating students. The results of the survey showed considerable enhancement in the students' self-efficacy. For a more thorough analysis of the results, the study requires a larger number of student subjects.

Bibliography

[1] Maslow, A. H., *Motivation and Personality*, Second Edition, pp. 35 – 58, Harper & Row, New York, NY, 1970.

[2] Branden, N., *The Psychology of Self-Esteem: A New Concept of Man's Psychological Nature*, pp. 103 – 143, Nash, Los Angeles, CA, 1969.

[3] Landis, R. B., *Studying Engineering: A Road Map to a Rewarding Career*, Second Edition, pp. 158 – 160, Discovery Press, Los Angeles, CA, 2000.

[4] Betz, N. E., and Hackett, G., "Applications of Self-Efficacy Theory to the Career Assessment of Women" *Journal of Career Assessment*, pp. 383 – 402, no. 4, Fall 1997.

[5] Bandura, A., *Self-Efficacy: The Exercise of Control*, Freeman, New York, NY, 1997.

[6] Ponton, M. K., Edmister, J. H., Ukeiley, L. S., and Seiner, J. M., "Understanding the Role of Self-Efficacy in Engineering Education," *Journal of Engineering Education*, Vol. 90, No. 2, pp. 247 – 251, April 2001.

[7] Brown, B. L., *Self-Efficacy Beliefs and Career Development*, The Educational Resources Information Center (ERIC) Clearinghouse on Adult Career and Vocational Education Digest No. 205, Columbus, OH, 1999. http://www.ed.gov/databases/ERIC_Digests/ed429187.html

[8] Caine, R. N., and Caine, G., "Understanding a Brain-Based Approach to Learning and Teaching, "*Educational Leadership* 48, No. 2, pp. 66-70, October 1990.

[9] Swainston, F., *A Systems Approach to Programmable Controllers*, pp. 101 – 104, Delmar, Albany, NY, 1992.

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