Improving Intrinsic Motivation among Sophomore Electrical Engineering Students by an Introductory Project

A. Gero
Technion – Israel Institute of Technology, Haifa, Israel

Abstract—**In 2011, the Technion – Israel Institute of Technology decided to open a new elective course designed for sophomore electrical engineering students. The course was devised to expose students to the discipline of electrical engineering and improve their motivation. The core of the course was a team-based design project of a window cleaning robot. The present mixed-method study indicates a significant improvement in intrinsic motivation of the students who took the course.**

Index Terms—**Electrical engineering education, introductory engineering course, project based learning, motivation.**

I. INTRODUCTION

In 2011, the Department of Electrical Engineering of the Technion – Israel Institute of Technology decided to open a new elective course designed for undergraduate students in the third semester of their studies. The course, Introductory Project in Electrical Engineering, was devised to expose students to the discipline of electrical engineering and enhance their sense of relatedness to the Department in order to improve their motivation.

Introductory courses with similar goals are offered by universities to freshman and sophomore electrical and computer engineering students [1]-[3] and mechanical engineering students [4]. Some of these courses combine theoretical lectures with lab experiments [3] while other focus on design projects [4]. The core of the course discussed in this paper was a system design project carried out by teams of students.

The research described below examines changes in students' motivation following their participation in the course. Studies that focused on the introductory courses quoted above related to motivation as a single entity. In the present study, we discern between different types of motivation in view of the self determination theory [5]-[6] and thus refine the findings.

II. THEORETICAL FRAMEWORK

A. Motivation & Self Determination Theory

Motivation is defined as an individual's wish to invest time and effort in particular behavior. The source of motivation is explained by a large variety of theoretical approaches. The self determination theory [5]-[6] argues a person has three inherent needs:

- The need for autonomy – the individual's need to feel his/her behavior was not imposed on him/her, but is based on the individual's requirements.
- The need for competence – the individual's need to feel he/she is able to fulfill challenging objectives.
- The need for relatedness – the need to love, be loved and be part of a group.

When a person's needs are fulfilled, he/she will reach a higher level of motivation, while deprivation would hurt it.

Deci et al. [5] describe the source of motivation on a continuum that lies between extrinsic and intrinsic factors. On the one side is extrinsic motivation that includes four types of regulation:

- External regulation - based on the hope of gaining some material reward or fear of punishment.
- Introjected regulation - caused by ego enhancement considerations or the will to fulfill expectations of people of importance to the individual.
- Identified regulation - based on identification of the value of a particular behavior. The behavior is a means that enables other activities that provide interest and enjoyment, or alternatively, the behavior is of a moral value.
- Integrated regulation - based on viewing behavior as reflecting the individual's identity.

On the opposite side of the scale is intrinsic motivation, based on interest and enjoyment. The theory claims that the more the motivation stems from intrinsic factors, the more its quality is high. Since this theory has recently become a leading theory of motivation in general and educational motivation [7] in particular, we shall use it in this study.

B. Project Based Learning

Thomas [8] defines project based learning as a model that organizes learning around complex tasks based on challenging problems. According to him, projects on which project based learning is based should fulfill the following criteria:

- The project plays a key role in the curriculum and constitutes the major teaching method.
- The project focuses on problems that expose the students to the major terms and principles of the subject.
- The students are involved in investigative activities during the project.

- The project is led by the students who receive a high measure of independence.
- The project is realistic and deals with real-world scenarios.

From the cognitive aspect, project based learning improves students' thinking skills [9], while from the affective aspect, learning of this type increases students' motivation [10] and their sense of competence [11].

III. DESCRIPTION OF THE COURSE

The course Introductory Project in Electrical Engineering that took place for the first time in the winter semester of 2011 was comprised of one two-hour weekly meeting and awarded the students with one credit. The course was based on the books Creative Problem Solving and Engineering Design [12] and Thinking Like an Engineer: An Active Learning Approach [13].

The course was divided into two equal parts. The first half of the course included lectures and instruction that provided the students with the tools they would use throughout the course, particularly in the second half that focused on carrying out a design project. The opening lecture compared science and engineering, described prominent engineering achievements through history, named the Draper Prize winners and presented the great engineering challenges of the 21st century. Additionally, it specified the abilities required of an engineer, including teamwork. In the second meeting, major engineering databases and popular search engines were reviewed, and training was provided on efficient search of these information sources and how to build an effective presentation. In the third lesson, an overview of the various topics of electrical engineering was provided. At the end of the meeting, the students were requested to prepare, based on search of databases, presentations that include profound reviews of a particular teaching and research topic at the

Technion's Department of Electrical Engineering, comparing it to leading departments around the world. This task was carried out by teams of five students, with personal instruction by a mentor, a senior engineer in the Department. In the fourth session, every team presented its work to their colleagues and the course teachers. The next two meetings focused on the engineering approach to problem solving. After a short discussion of mathematical and scientific problems, the engineering approach to problem solving was presented, including the following stages: defining the problem, collecting data, examining alternatives, making a decision, detailed design, examining the proposed solution, and documenting the above process. This approach was demonstrated using the well-known travelling salesman problem. The seventh session was dedicated to a discussion of systems thinking. The concept of system was introduced and the characteristics of systems thinking were presented. A weekly syllabus of the introductory lectures and accompanying tasks is specified in Table I.

As mentioned, the core of the course was a design project carried out in teams counseled by mentors from the eighth week of the semester. The project selected in view of Thomas' criteria [8] presented in the theoretical section dealt with designing a window cleaning robot. The project opened with an introductory lecture about robotics and presentation of design stages on a weekly basis. Each week dealt with one of the following focused subjects: defining the robot's structure and movement (week 8), physical design (week 9), block diagram, (week 10), integrating sensors (week 11), selecting microcontrollers and drivers (week 12), and navigation algorithms (week 13). Additional details in Table I. Every stage opened with a review of the design subject at hand and at the end the students received a task they were requested to complete using the engineering approach to problem solving in the

TABLE I. WEEKLY SYLLABUS

Week	Subject	Description	Team task
1	The essence of engineering	Comparison between science and engineering, great engineering achievements, Draper Prize winners, 21st century engineering challenges, abilities required from engineers, teamwork	
2	Database searching and building an effective presentation	Engineering databases, search engines, efficient searching. Types of presentations, presentation structure, building an effective presentation	
3-4	The discipline of electrical engineering	Overview of the various topics of electrical engineering, teaching and research activities at the Technion's Department of Electrical Engineering	In-depth review of a particular teaching and research topic at the Technion's Department of Electrical Engineering
5-6	Engineering approach to problem solving	Classification of problems, problem solving methods, the engineering approach to problem solving, the travelling salesman problem	
7	Systems thinking	Definition of system, characteristics of systems thinking	
8	Introduction to robotics, defining the robot's structure and movement	Introduction to robotics, pros and cons of window cleaning robots, robot requirements, major challenges	Collect data on window cleaning robots, examine alternatives, choose a solution
9	Physical design	Motors: types, properties Energy sources: types, properties	Select motors and energy sources for the robot
10	Block diagram	objectives, structure of block diagrams, examples (mobile phone, robot)	Draw block diagram of the robot
11	Integrating sensors	Light sensors, position sensors, tactile sensors, proximity sensors, bend sensors	Select sensors for the robot
12	Micro-controllers and drivers	Microcontrollers: history, basic components, properties Drivers: types, properties	Select microcontroller and drivers for the robot
13	Navigation algorithms	Vehicle positioning, path planning, map making	Prepare final presentation
14	Project presentation		

first part of the course. On the final week (week 14) every team presented the design of its robot to their colleagues and the teaching staff.

In carrying out the different tasks, the students used tools acquired in the introduction lectures. Beyond ongoing application of the engineering approach to problem solving described above, the students examined alternatives for their robot and selected the different components (motors, energy sources, sensors, microcontrollers and drivers) after carrying out a comprehensive search through online databases. Additionally, the block diagram of the robot was based on the lecture on systems thinking and the final presentation was built and displayed based on the principles taught during the relevant lesson.

Division of the design into weekly sub-tasks was devised to respond to the students' need for competence, according to the self determination theory mentioned in the theoretical section. The students were told their mentor was at their disposal and they could consult him directly, but they were responsible for their design decisions since the teaching staff acknowledge their independence and ability to make such decisions at this stage of their studies. This work method was devised to respond to the students' needs for relatedness and autonomy.

IV. RESEARCH GOAL & METHODOLOGY

The research goal was to characterize changes in the motivation of students taking the course Introductory Project in Electrical Engineering. The research population comprised 25 students in their third semester of studies for an undergraduate degree at the Technion's Department of Electrical Engineering who chose to take the course in the winter semester of 2011. These students, comprising the experimental group, were asked to complete an anonymous questionnaire at the beginning and end of the course. The questionnaire was designed to characterize the students' motivational factors. Furthermore, at the end of the course, five semi-structured interviews were carried out with students in order to complete the information received from the questionnaires. Additionally, 30 undergraduate electrical engineering students in their third semester of studies who did not participate in the course took part in the research. These students, used as the control group, were requested to complete the questionnaire at the beginning and end of the semester.

The questionnaire that characterizes motivational factors is a Likert-like questionnaire based on the SIMS questionnaire [14] and the SRQ-A questionnaire [15]. The questionnaire includes 20 statements reflecting four of the motivational factors mentioned in the theoretical section: intrinsic motivation, identified regulation, introjected regulation, and external regulation. Similar to Guay et al. [14], in order to refrain from making the questionnaire too lengthy and cumbersome for respondents, we did not include statements describing integrated regulation in this questionnaire. For example, the statement "I am studying electrical engineering because I think it is interesting" expresses intrinsic motivation; the statement "I am studying electrical engineering because I am doing it for my own good" reflects identified regulation; the statement "I am studying electrical engineering because my parents want me to study it" and the statement "I am studying electrical engineering because I want people to think I am smart" express introjected regulation; while the statement

"I am studying electrical engineering because I am supposed to do it" represents external regulation. The statements were validated by two experts on education in electrical engineering. Cronbach's alphas for each of the motivational factors were: 0.84 (intrinsic motivation), 0.80 (identified regulation), 0.78 (introjected regulation), and 0.86 (external regulation). These values indicate good levels of internal consistency.

V. FINDINGS

Figure 1 displays the average score (between 20 and 100) assigned by the experimental group members to each of the four motivational factors. Scores were given on the pretest, completed at the beginning of the course, and the posttest, completed at the end. The chart shows intrinsic motivation improved from a mean value of 69.50 to a value of 80.43 and identified regulation increased from a mean value of 68.48 to 74.66. Additionally, the introjected regulation rose a bit while external regulation declined some. Figure 2 displays the average score assigned by the control group members to each of the four motivational factors.

Table II displays the score (mean M and standard deviation SD) assigned by members of the two groups – experimental and control – to different motivational factors. The t-tests show no significant difference between the pretest scores of the experimental group and the pretest scores of the control group on the four motivational factors. However, when it came to intrinsic motivation and identified regulation, there is a significant difference (P<0.01) between the posttest scores of the experimental group and the posttest scores of the control group. In the case of introjected regulation and external regulation, no significant difference was found between the posttest score of the experimental group and the posttest score of the control group.
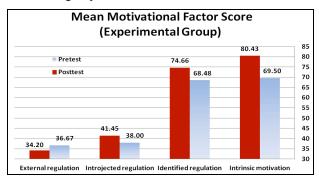

Figure 1. Mean motivational factor score among experimental group members

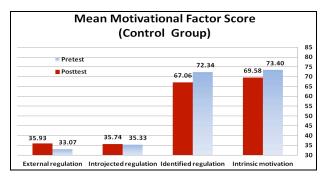Figure 2. Mean motivational factor score among control group members

TABLE II. MOTIVATIONAL FACTOR SCORE (MEAN M AND STANDARD DEVIATION SD)

Motivation	Regulation	Test	Group	M	SD	t	P-value
Intrinsic		Pretest	Experimental	69.50	10.53	1.39	n.s.
			Control	73.40	10.07		
		Posttest	Experimental	80.43	8.91	3.19	<0.01
			Control	69.58	17.13		
Extrinsic	Identified	Pretest	Experimental	68.48	10.62	1.37	n.s.
			Control	72.34	10.09		
		Posttest	Experimental	74.66	8.23	2.50	<0.01
			Control	67.06	15.08		
	Introjected	Pretest	Experimental	38.00	11.33	0.89	n.s.
			Control	35.33	10.63		
		Posttest	Experimental	41.45	13.74	1.65	n.s.
			Control	35.74	12.44		
	External	Pretest	Experimental	36.67	18.84	0.87	n.s.
			Control	33.07	9.12		
		Posttest	Experimental	34.20	15.87	0.35	n.s.
			Control	35.93	18.12		

Based on quotes from students (experimental group) in interviews, one may relate improvement in intrinsic motivation to the students' exposure throughout the course to the interesting topics included in electrical engineering:

"Before the course I didn't know what electrical engineering was… The course acquainted me with interesting areas of electrical engineering."

The improvement in identified regulation may be related to the fact that following exposure to the diverse subjects included in electrical engineering, many of the students acknowledge the high employment value of the profession:

"The course exposed me to the multiple employment options of an electrical engineer."

The students' high motivation level at the end of the course may be explained in view of the self determination theory, whereby satisfying an individual's needs increases motivation, as specified below with relation to the three above mentioned needs. The need for autonomy was satisfied by the independence afforded the students during the project:

"I felt independent in everything… raising ideas and applying them. That was wonderful."

The need for competence was fulfilled due to guidance and focused definition of sub-tasks throughout the project:

"We received guidance and every lesson had a design task that was different and focused… Because of that I felt I was able to design the robot."

Finally, the need for relatedness was satisfied due to the personal approach of the teaching staff:

"Before the course I felt extremely disconnected from the Department. Due to the personal approach and care of my mentor I now definitely feel I belong!"

VI. DISCUSSION & SUMMARY

The study results attest to significant improvement in intrinsic motivation and identified regulation of the students who took the course. The above improvement may be attributed to the students' exposure to the interesting topics included in electrical engineering and the high employment value of the profession.

The high level of motivation among students at the end of the course may be explained in view of the self deter-

mination theory [5]-[6] whereby satisfaction of an individual's needs increases his/her motivation. The need for autonomy was fulfilled by giving students independence during the project; the need for competence was realized by guidance and focused definition of the sub-tasks throughout the project; and finally, the need for relatedness was satisfied due to the personal attitude provided by the teaching staff. These results conform to the recent findings of Koh et al. [16] who showed that a course that provided the three above mentioned needs improved intrinsic motivation among mechanical engineering students.

In a continuation study we intend to examine whether the differences found in the current research between the experimental and control group scores will be retained in the students' more advanced years.

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AUTHOR

A. Gero holds a B.A. in physics, a B.Sc. in electrical engineering, an M.Sc. in electrical engineering, and a Ph.D. in theoretical physics, all from the Technion – Israel Institute of Technology. In addition, he has an MBA from the University of Haifa, Israel. Dr. Gero is a faculty member at the Department of Education in Technology and Science of the Technion (e-mail: gero@technion.ac.il). His research focuses on electrical engineering education and interdisciplinary education that combines physics with electronics, such as electro-optics and microelectronics education.