Use of real world examples in engineering education: the case of the course *Electric Circuit Theory*

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ABSTRACT: Real world examples are used in science and engineering education with the intention of promoting effective learning. Using qualitative instruments, the study described in the article characterised the attitudes of seventy-two electrical engineering students at the Technion - Israel Institute of Technology towards the incorporation of real world examples in a basic electric circuits course. The examples focused on the areas of study offered by the Department of Electrical Engineering and electrical engineers' fields of practice in the industry. Based on the findings, in the cognitive domain the examples make a triple contribution spanning the timeline. The examples illustrate the relevance of mathematics and physics courses studied in the past, contribute to improved understanding in the current course, and ultimately help in selecting future courses in the programme and in becoming acquainted with the students' future work as electrical engineers.

INTRODUCTION

The use of real world examples is widespread in mathematics education [1][2], physics education [3][4], chemistry education [5][6] and engineering education [7][8], with the objective of increasing students' interest and promoting effective learning.

Given the lack of interest in the basic mandatory course *Electric Circuit Theory* (ECT) of electrical engineering students at the Technion - Israel Institute of Technology (hereinafter, the Technion), a decision was made to incorporate real world examples in the course. These examples describe the areas of study offered by the Department of Electrical Engineering, electrical engineers' fields of practice in the industry and electronic devices the students are familiar with from their everyday life. It is important to state that the lack of interest displayed by the students - who see the course (without real world examples) as a technical course, which provides nothing but circuit analysis skills - is not unique to the Technion, but rather occurs in many universities [9][10]. These institutions provide other solutions in order to raise the students' interest in the course, such as problem-based learning [11] or integrating laboratories into the syllabus [12].

A recent study found a significant gap between the intrinsic motivation to study among electrical engineering students who attended the course that included real world examples and that of their counterparts who completed the course in its original format, without examples [13]. The gap, in favour of the former, was accompanied by a small-medium effect size. The study described in this article examined the course from another, broader perspective, and characterised students' attitudes towards the incorporation of real world examples into the curriculum.

The article begins with a theoretical background, which focuses on the incorporation of real world examples in the syllabi of science and engineering courses. This is followed by a description of the ECT course and the examples included therein. After presenting the research objective and methodology, the main findings and the emerging conclusions are discussed.

THEORETICAL BACKGROUND

As mentioned at the beginning of the article, real world examples are often used in teaching science and engineering courses [3-8]. Real world examples may include examples referring to students' field of knowledge and to their future field of occupation and/or examples from students' everyday life. It is important to note that there might be some overlap between the two groups of examples, such as devices at the core of electrical engineers' field of practice, which have an everyday use in students' lives. Prime examples are smartphones and tablets. However, for the purpose of the discussion, the authors shall refer to the two groups of examples separately.

The idea of incorporating examples from students' field of knowledge and future field of practice stems from self-determination theory [14], according to which, examples of this kind could fulfil students' need for relatedness to their professional community, increase their intrinsic motivation to study and even reduce the dropout rate [15].

Brawner et al showed that the use of examples demonstrating engineers' work in industry enhanced the interest female chemical engineering students found in the profession and contributed, in their opinion, to improving their understanding [8]. Moreover, the use of examples reinforced the students' desire to persevere in this course of study. Similarly, Yazici et al incorporated real-life scenarios taken from the software engineer's field of practice in the course *Parallel Computing* [16]. Their students thought that the use of examples was interesting and contributed to improving their programming skills.

The idea behind the incorporation of examples from everyday life is based on Piaget's theory of cognitive development [17]. According to this theory, effective learning occurs when new content is linked to content that is already familiar to the learner from previous experience. Furthermore, this connection may even reduce anxiety in the learner [18] and stimulate his/her interest [19]. The use of such examples is common in textbooks in a variety of engineering branches, e.g. electrical engineering [20] and mechanical engineering [21].

Worthy of note in the field of physics is the series of textbooks Supported Learning in Physics Programme (SLIPP), which is based on connections to everyday life [22]. Thus, for example, the unit dealing with the physics of sports discusses statics and dynamics relevant to mountaineering, and the unit focusing on the physics of music deals with oscillations and waves. A study examining learning based on the aforementioned series found that it increased students' interest in the learnt material and contributed to improving memory [3].

The concept of incorporating examples from everyday life in engineering education gained momentum with the establishment of the ENGAGE programme, which works with over seventy institutions of higher education in the United States [23]. This initiative was intended to promote the education of engineering students and reduce the percentage of students dropping out during the course of their studies. This is achieved by implementing a number of teaching strategies, one of which is incorporating examples from everyday life in the relevant courses at universities.

Bi and Mueller incorporated everyday life examples, such as pocketknives and scooters, in the course *Solid Modelling*. They reported positive response from mechanical engineering students - a response which manifested, *inter alia*, in the interest they found in the course [24].

In a similar manner, in the course *Mechanics of Materials*, Nilsson incorporated examples dealing with bicycles and skateboards and, thus, increased the interest of civil and mechanical engineering students taking part in the course, especially that of the women. Moreover, the students' academic achievements improved, both in the short and long term [7].

THE COURSE *ELECTRIC CIRCUIT THEORY*

The semester-long, basic course *Electric Circuit Theory* (ECT) is intended for sophomore students in the Department of Electrical Engineering. The course, which is based on the textbook Basic Circuit Theory [25], deals mainly with lumped circuits, frequency domain analysis, time domain transients, capacitive and inductive coupling and operational amplifiers. The course aims to provide the students with knowledge and skills mostly relevant in consecutive courses on electronic devices and circuit design. The lecture-based course is comprised of three hours of lecture, a tutorial hour and a workshop hour.

As stated above, with the goal of increasing students' interest in the course, real world examples have been incorporated into the curriculum. Table 1 classifies some of the examples according to the following division: examples reflecting the Department's areas of teaching and research, examples presenting electrical engineers' fields of occupation in the industry, and examples of electronic devices, which the students are familiar with from their everyday life. In addition, the table notes the context in which the example was presented.

Below are some of the examples and the context they were presented by the instructor:

- Modulation techniques (FDMA, TDMA, CDMA) were presented during the sessions dedicated to frequency domain analysis. Additionally, the Department's teaching and research activities in the field of communications were discussed.

- The Fabry-Pérot optical resonator and the Department's teaching and research activities in the field of electro-optics and photonics were presented in the lesson focusing on resonance in electric circuits.

- A spectral analysis of an ECG signal followed by a review of the Department's teaching and research activities in the field of physiological signals concluded the lessons dealing with frequency domain analysis.

- The principle of operation of the amplifying circuit attached to the microphone on the instructor's lapel was discussed during the sessions covering operational amplifiers. On this occasion, the Department's teaching and research activities in the fields of micro- and nano-electronics were described.

- An inverter maximum clock frequency, based on an RC circuit model, was calculated during the lessons about time domain transients.

- The structure and principle of operation of touchscreens and mobile phone wireless chargers were discussed in the lesson dealing with capacitive and inductive coupling.

Table 1: Classification of real world examples.

Criterion	Context	Real world examples
Teaching and research fields in the Department of Electrical Engineering	Frequency domain analysis	Communications Electro-optics and photonics Signal processing (physiological systems)
	Operational amplifiers	Micro- and nano-electronics
Electrical engineers' fields of occupation in the industry	Frequency domain analysis	FDMA, TDMA, CDMA modulation techniques Fabry-Pérot resonator Spectral analysis (physiological signals)
	Time domain transients	Inverter maximum clock frequency
Electronic devices from everyday life	Capacitive and inductive coupling	Touch screens (smartphones and tablets) Mobile phone wireless chargers
	Operational amplifiers	Amplifying circuit attached to a microphone

RESEARCH GOAL AND METHODOLOGY

The study characterised students' attitudes towards the incorporation of real world examples in the ECT course. Seventy-two second-year electrical engineering students, who expressed their agreement, participated in the study.

The students completed an anonymous open-ended questionnaire at the end of the course. Additionally, nine semi-structured interviews were conducted with students at the end of the course. In the questionnaire and interview, the students were asked for their opinion regarding the incorporation of the examples in the course.

The qualitative data were categorised by content analysis, based on the tricomponent attitude model [26]. This model was chosen to serve as the theoretical framework in view of the extensive use made of it to analyse attitudes in diverse fields of study, including education [27-30]. Only information that came up at least five times in the various research tools was included in the analysis.

FINDINGS

Content analysis indicates cognitive and affective components in students' attitudes towards the incorporation of the examples in the course. From the cognitive aspect, the students are of the opinion that the incorporation of the examples illustrated, for the first time, the relevance of mathematical and physical tools studied in previous courses: …*Unlike any other course I have taken* [throughout the course of this programme], *I noticed how* [during this course] *I put to use mathematical and physical tools I had previously learned about, and I saw how they are expressed in real life in electronic devices, such as personal computers* (questionnaire). In addition, in the students' opinion, the incorporation of examples contributed to improved understanding of specific issues: …*The examples were good and relevant... They helped in specifically understanding some issues* (interview), and in a wider context: …*Now* [after being exposed to the examples], *I understand how it* [what I am studying] *is related to the programme and why I've been studying it… Now everything makes sense* (interview).

The students feel that the examples will help them both later on in the programme: …*The examples contributed by introducing subjects we will study later on... Nearly every example dealt with a different subject... The examples touched on a variety of topics and provided information about the elective courses I may be interested in taking later on* (interview), and during their future work as electrical engineers: …*The examples showed how what we are learning is part of the electrical engineer's job* (questionnaire).

From the affective aspect, the examples created interest and enjoyment among the students: …*The examples aroused my curiosity... I really enjoyed it when the instructor presented real-life examples... It was very interesting* (interview).

The cognitive component in students' attitudes towards the course is presented in Table 2.

Table 2: Incorporation of real world examples: cognitive component in students' attitudes.

Category	Subcategory	Example	Interpretation
Recognising the relevance of basic courses in mathematics and physics		The examples in the course [the current course] illustrated for me the subject matter I studied in *Physics 2* [a course on electromagnetism], in which you use mathematical tools and do not understand what the purpose is (questionnaire).	The examples illustrate the relevance of mathematical and physical tools acquired in previous courses
Contribution to better understanding	Specific topics	The examples helped in understanding the topic being taught (questionnaire).	The examples contribute to a better understanding of specific topics
	Broad context	Only now [after being exposed to the examples], I understand what the programme is about (questionnaire).	The examples contribute to better understanding of the boarder context of the programme
Contribution to the academic - professional future	In the programme	I have not yet been exposed to the elective courses [in the programme]... The examples gave me an idea of what I would like to choose (interview).	The examples help to select future courses in the programme
	In the industry	[Thanks to the examples] I was introduced to the mind-set of an electrical engineer (interview).	The examples help in becoming acquainted with electrical engineers' work in the industry

DISCUSSION AND CONCLUSIONS

The findings indicate the existence of affective and cognitive components in students' attitudes. From the affective perspective, the real word examples generate interest and enjoyment. This aspect, which is closely related to intrinsic motivation, is discussed by Gero et al [13].

From the cognitive point of view, the students think that the examples made a triple contribution spanning the timeline, as described in Table 3. The examples illustrate the relevance of mathematical and physical tools studied in the *past*, contribute in the *present* to improving the understanding in specific and broader contexts, and ultimately, help the students in choosing *future* courses in the programme and becoming acquainted with their *future* work as electrical engineers in the industry.

Table 3: Contribution of real world examples: cognitive domain.

Timeline	Contribution
Past	Retrospectively recognising the relevance of the programme's basic courses in mathematics and physics
Present	Improving the understanding of • The course *Electric Circuit Theory* • The broad context of the programme
Future	Assisting students in • Selecting continuation courses in the programme • Becoming acquainted with their future work as electrical engineers in the industry

The finding regarding the contribution of the examples in relation to the past is significant. This originates from the great importance the faculty see in obtaining electrical engineering students' recognition of the relevance of basic courses in mathematics and physics [31].

The finding regarding the contribution of the examples in the present is in keeping with the conclusions of previous educational studies. These studies, which showed improved understanding due to real world examples, focused on high school students who participated in engineering courses [32-34], as well as on chemical [8], software [16] and mechanical engineering [24] students.

In respect to the contribution of the examples in the future, the finding that the students see the ECT course (in its new format) as relevant to the continuation of their studies and their future work, is notable. This stems from the literature, which indicates that students see the course (in its original format) as a technical course providing skills, which are of minor relevance to their academic - professional future [9].

The authors, therefore, recommend incorporating real world examples in the ECT course and similar courses. This recommendation is especially valid given the low cost of the implemented change. The course has maintained its original teacher-centred format and the only change made was in the incorporation of relevant examples into the syllabus.

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