A course on contemporary issues in engineering education: students' attitudes

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ABSTRACT: A unique course focusing on contemporary issues in engineering education is held at the Technion - Israel Institute of Technology, Haifa, Israel. The course aims to expose senior engineering students to the main challenges faced by academics engaged in training engineers. The course deals with cognitive, affective and social aspects in higher engineering education, such as systems thinking, abstract thinking, motivation and soft skills. In the final project, the students present, in teams, major topics in engineering education based on a comprehensive literature review. The research described in this article characterised students' attitudes towards the course. Thirty-nine undergraduate engineering students took part in the study. At the end of the course, the participants filled out a survey comprised of closed- and open-ended questions. According to the results, students hold positive attitudes towards the course. They claim that the course is interesting, provides a critical perspective on engineering programmes and promotes soft skills, but is also demanding.

Keywords: Contemporary issues in engineering education, undergraduate students, attitudes

INTRODUCTION

For many years, studies have pointed to a gap between the skills of engineering graduates and those needed in the industry [1][2]. Therefore, rectors and deans are debating about the ways in which engineers should be educated. One of the key questions is what the optimal mix of technical skills (e.g. code writing) and soft skills (e.g. teamwork) among engineering graduates should be [3][4]. Another important dilemma is how to integrate project-based learning, which usually promotes these abilities, into the curriculum [5][6].

Generally, undergraduate engineering students are not exposed to the above issues. These topics are regularly discussed as part of graduate courses only [7]. Thus, the Technion - Israel Institute of Technology initiated a unique undergraduate course entitled *Contemporary Issues in Engineering Education*.

This course aims to expose senior engineering students to the main challenges faced by academics who train engineers. It is important to note that most senior engineering students at the Technion work in industry. Therefore, they have sufficient knowledge, both theoretical and practical, to experience meaningful learning in the course and gain a new perspective on their engineering programmes.

The research described in this article aimed to characterise students' attitudes towards the course *Contemporary Issues in Engineering Education*. The research findings contribute to the body of knowledge dealing with engineering education and may improve the training of engineers.

The article opens with an overview of the course. Next, the study objective and methodology are presented. Finally, the main findings are discussed.

CONTEMPORARY ISSUES IN ENGINEERING EDUCATION COURSE

The course *Contemporary Issues in Engineering Education* is a semester-long elective course (13 weeks, two hours of lecture per week, two credit points) designed for senior engineering students. At the end of the course, the student should be able to analyse contemporary topics in higher engineering education. Class discussions are the primary teaching method.

The course opens with a comparison between science and engineering [8], followed by a historical review of the engineering achievements that won the Draper or Russ Prizes (Table 1). For example, the development of the turbojet engine, fibre optics and cochlear implants [9]. Next, the grand challenges for engineering in the 21st century, as formulated by the US National Academy of Engineering (NAE), are listed. Among these challenges are: making solar energy economical, providing access to safe drinking water and engineering more efficient medicines with fewer side effects [10].

The skills required of engineers are then derived from the above challenges. These capabilities are comprised of both technical and soft abilities. According to the Accreditation Board for Engineering and Technology (ABET), technical skills include, among other things, the ability to identify, formulate and solve complex engineering problems, and the ability to carry out engineering design, while taking into account economic, environmental and social considerations. Soft skills refer to the capabilities to communicate effectively, function on a heterogeneous team, acquire new knowledge, and identify ethical issues and make informed judgments [11]. The course then examines the extent to which the current engineering curriculum imparts the technical and soft skills mentioned.

Subsequently, the course investigates how to change (if at all) the curriculum so that it promotes technical and soft skills. In this context, project-based learning is reviewed in depth, including theoretical basis, advantages (cognitively and socially) and challenges [5]. In addition, other options are offered. For example, adding new mandatory courses that deal with soft skills (e.g. an ethics course) or integrating modules that advance soft skills in existing compulsory technical courses (e.g. a chapter on ethics in a genetic engineering course) [12].

Next, two types of thinking relevant to engineers, i.e. systems thinking and abstract thinking [13], are addressed. The discussion emphasises their importance and interrelations [14], especially in light of the Industry 5.0 framework [15]. Then, the course deals with ways to promote these types of thinking, e.g. by studying interdisciplinary courses [16] or courses that combine several levels of abstraction [17].

In the affective aspect, freshman engineering students' motivation is analysed. Their motivation is often undermined by the fact that the first-year curriculum focuses on mathematics and physics rather than engineering [18]. Several ways to foster intrinsic motivation are suggested, such as integrating relevant engineering examples into mathematics and physics courses [19] or holding introductory engineering courses that expose students to the engineer's work in industry [20].

Course evaluation is based on active participation in class (20%) and a final project (80%). In the project, heterogeneous teams (consisting of four-five students from various departments) present issues in engineering education based on a comprehensive literature review. These 45-minute presentations take place in front of the students and faculty. Among the topics selected are women in engineering education, co-operation with industry and continuing education in engineering. It is worth noting that this assignment was chosen out of a desire to practice teamwork, and written and oral communication, which as mentioned, are essential engineering skills.

Table 1: *Contemporary Issues in Engineering Education* course - syllabus.

Week	Section	Topics
1	Introduction	Science vs. engineering; Draper and Russ Prizes; grand challenges for engineering
2-3	Engineering skills	Technical skills; soft skills; engineering curriculum
4-5	Project-based learning	Constructivism, social constructivism and constructionism; characteristics, advantages and challenges of project-based learning
6	Systems thinking	Relevance, characteristics and promotion of systems thinking
7	Abstract thinking	Relevance, characteristics and promotion of abstract thinking; interrelations between systems thinking and abstract thinking
8	Motivation	Motivational factors, fostering intrinsic motivation
9-13	Final project presentations	Women in engineering education; co-operation with industry in engineering education; entrepreneurship in engineering education; globalisation in engineering education; dropout in engineering education; continuing education in engineering, etc.

STUDY OBJECTIVE

The study aimed to characterise students' attitudes towards the *Contemporary Issues in Engineering Education* course.

METHODOLOGY

Participants

Thirty-nine senior engineering students at the Technion took part in the study. The participants' programmes were: electrical and computer engineering, mechanical engineering, civil and environmental engineering, chemical

engineering, biomedical engineering and industrial engineering. The age range of the students was 22-30 years, and about 65% of them worked in the industry during their studies. All participants were similar in their characteristics to students who usually study in the relevant programmes.

Method

At the end of the course, the participants filled out an anonymous survey comprised of closed- and open-ended questions. The closed-ended part consisted of questions about various aspects of teaching. In the open-ended section, the students commented on the course in free text. The quantitative data were analysed statistically (descriptive statistics), and the qualitative data underwent content analysis and were classified into categories by two engineering education experts. The tri-component attitude model [21] served as the theoretical framework for the qualitative analysis. Only information mentioned by at least three different participants was included.

Tools

The closed-ended questionnaire was a five-point Likert-like scale ranging from *to a very little extent* (1) to *to a very large extent* (5). The survey was comprised of four questions that dealt with the following aspects of teaching: organisation, interest, relevance and active learning. The questions were validated by two experts in engineering education and are given in Table 2.

Table 2: Closed-ended survey - items.

Aspect	Question
Organisation	To what extent was the course content well organised?
Interest	To what extent was the course content interesting?
Relevance	To what extent was the course content relevant to your studies or your current/future occupation?
Active learning	To what extent were the students active during the course?

FINDINGS

Table 3 shows the scores obtained in the closed-ended section (mean $1 \leq M \leq 5$ and standard deviation SD).

Table 3: Closed-ended survey - scores.

Aspect	M	SD
Organisation	4.90	0.31
Interest	4.79	0.57
Relevance	4.56	0.74
Active learning	4.44	0.97

Content analysis of the open-ended part of the questionnaire revealed cognitive, affective and behavioural components in students' attitudes towards the course.

From the cognitive aspect, students claim that the course broadens horizons by providing a critical viewpoint on engineering studies: …*The course substantially enriched my knowledge. …It* [the course] *broadened my horizons when it comes to undergraduate engineering programmes. …It* [the course] *provided us with a different and critical perspective on our engineering programme.*

In addition, students argue that the final project promotes soft skills, such as communication and teamwork: …*Thanks to the final project, I gained experience in presenting in front of a critical audience. …It was nice to see that in the course we not only learned about communication skills, but also developed them. …We had to work in teams* [while executing the final project], *it was very educational. …The course provided a good opportunity to develop soft skills, such as teamwork.*

At the same time, students claim that the course is demanding: …*The final project took considerable amount of time. …The course, especially the final project, required a lot of work from the team. It was not easy.*

Affectively, students believe that the course is interesting: …*A very interesting course. …A fascinating course,* and enjoyable: …*One of the most enjoyable courses I have ever taken. …It was real fun.*

Finally, in the behavioural aspect, students strongly recommend their peers to participate in the course: *…I would recommend this course to my friends. …I definitely recommend this course.*

Figure 1 summarises students' attitudes towards the course.

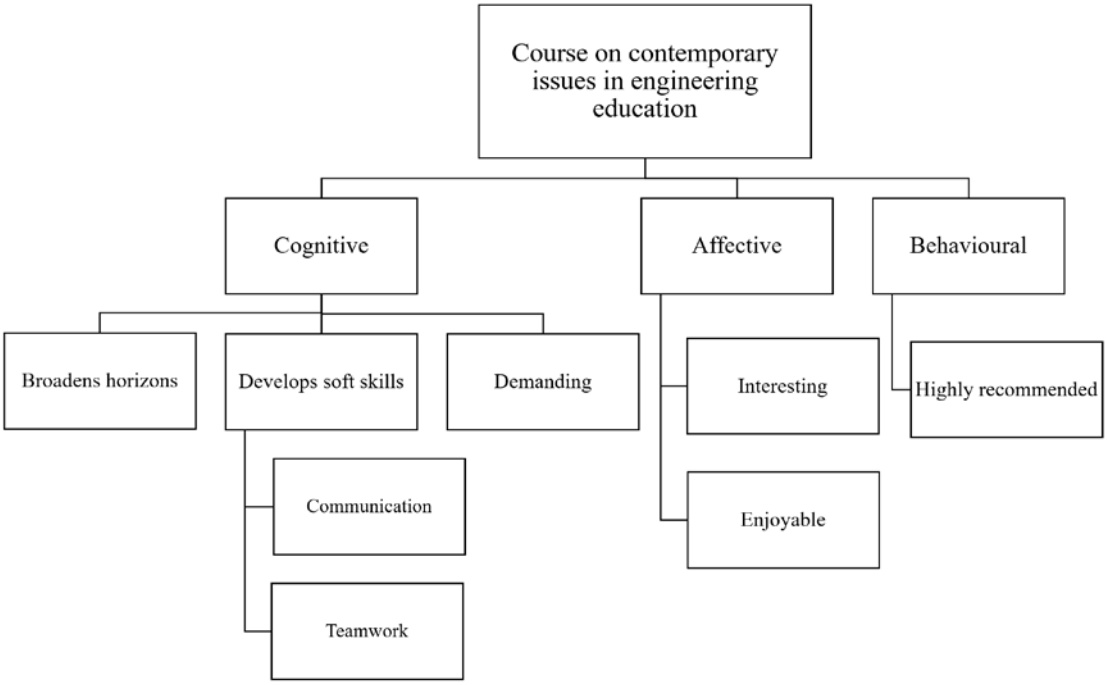

Figure 1: Students' attitudes towards the course.

DISCUSSION

According to the quantitative and qualitative findings, the participants hold positive attitudes towards the *Contemporary Issues in Engineering Education* course. Cognitively, students claim that the course broadens horizons by providing a different perspective on engineering programmes. In addition, it promotes soft skills, such as effective communication and teamwork. In the affective domain, students find interest in the course and think it is pleasurable. The behavioural component, according to which students strongly recommend their peers to attend the course, is consistent with the other two components.

In view of self-determination theory, in their participation in the course the students are driven by both intrinsic (i.e. interest and enjoyment involved in the behaviour) and identified (i.e. recognition of values embodied in the behaviour) factors. This result is important, since these motivational factors are autonomous, and as such, permit the person to persist in the behaviour over time [22].

At the same time, students argue that the final project, which is carried out in heterogeneous teams, is demanding and requires a lot of resources. This claim is in line with the literature, reporting the difficulty of students working in teams in general and in heterogeneous teams in particular [23]. As a possible solution to this challenge, it is recommended to provide students with preliminary training on teamwork.

The major limitation of the study is the relatively low number of participants, which stemmed from the small number of students who attended the elective course. Yet, the research findings contribute to the body of knowledge dealing with engineering education and may improve the training of engineers.

REFERENCES

1. Ramadi, E., Ramadi, S. and Nasr, K., Engineering graduates' skill sets in the MENA region: a gap analysis of industry expectations and satisfaction. *European J. of Engng. Educ.*, 41, **1**, 34-52 (2016).
2. Akdur, D., Analysis of software engineering skills gap in the industry. *ACM Trans. on Computing Educ.*, 23, **1**, 1-28 (2022).
3. Caeiro-Rodríguez, M., Manso-Vázquez, M., Mikic-Fonte, F.A., Llamas-Nistal, M., Fernández-Iglesias, M.J., Tsalapatas, H., Heidmann, O., De Carvalho, C.V., Jesmin, T., Terasmaa, J. and Sørensen, L.T., Teaching soft skills in engineering education: an European perspective. *IEEE Access*, 9, 29222-29242 (2021).
4. Gero, A. and Mano-Israeli, S., Importance of technical and soft skills: electronics students' and teachers' perspectives. *Global J. of Engng. Educ.*, 22, **1**, 13-19 (2020).
5. Chen, J., Kolmos, A. and Du, X., Forms of implementation and challenges of PBL in engineering education: a review of literature. *European J. of Engng. Educ.*, 46, **1**, 90-115 (2021).

6. Mazikowski, A. and Wierzba, P., Extra-curricular project-oriented education in optoelectronics in the Faculty of Electronics, Telecommunications and Informatics at Gdańsk University of Technology, Poland. *Global J. of Engng. Educ.*, 26, **2**, 82-87 (2024).
7. Virginia Tech**,** ENGE 5214 - Issues in Engineering Education, 30 July 2024, https://www.coursicle.com/vt/courses/ENGE/5214/
8. Waks, S., Science-technology dimensions in physics education: prospects and impact. *Physics Educ.*, 29, **2**, 64-70 (1994).
9. National Academy of Engineering, NAE Awards (2024), 30 July 2024, https://www.nae.edu/166043/Awards
10. National Academy of Engineering, *NAE Grand Challenges for Engineering*. NAE (2017).
11. Accreditation Board for Engineering and Technology, *Criteria for Accrediting Engineering Programmes.* ABET (2023).
12. Almeida, F. and Morais, J., Strategies for developing soft skills among higher engineering courses. *J. of Educ.*, 203, **1**, 103-112 (2023).
13. Shekh-Abed, A., Hazzan, O. and Gero, A., Promoting systems thinking and abstract thinking in high-school electronics students: integration of dedicated tasks into project-based learning. *Inter. J. of Engng. Educ.*, 37, **4**, 1080-1089 (2021).
14. Gero, A., Shekh-Abed, A. and Hazzan, O., Interrelations between systems thinking and abstract thinking: the case of high-school electronics students. *European J. of Engng. Educ.*, 46, **5**, 735-749 (2021).
15. Ghani, A., Engineering education at the age of Industry 5.0 - higher education at the crossroads. *World Trans. on Engng. and Technol. Educ.*, 20, **2**, 112-117 (2022).
16. Gero, A., Essami, H., Danino, O. and Kornblum, L., Students' attitudes toward interdisciplinary learning: a high-school course on solar cells. *Inter. J. of Engng. Educ.*, 38, **4**, 1130-1140 (2022).
17. Hadish, M.A., Kvatinsky, S. and Gero, A., Learning and instruction that combine multiple levels of abstraction in engineering: attitudes of students and faculty. *Inter. J. of Engng. Educ.*, 39, **1**, 154-162 (2023).
18. Gero, A. and Friesel, A., Academic motivation in beginning students of electrical engineering: a case study of Danish and Israeli universities. *Global J. of Engng. Educ.*, 22, **3**, 204-209 (2020).
19. Harrison, M.C., Mathematics support for engineering undergraduates. *Proc. Inter. Conf. on Engng. Educ.*, 1-9 (2008).
20. Vallim, M.B., Farines, J.M. and Cury, J.E., Practicing engineering in a freshman introductory course. *IEEE Trans. on Educ.*, 49, **1**, 74-79 (2006).
21. Rosenberg, M.J. and Hovland, C.I., *Cognitive, Affective and Behavioural Components of Attitudes*. In: Rosenberg, M.J., Hovland, C.I., McGuire, W.J., Abelson, R.P. and Brehm, J.W. (Eds), Attitude Organization and Change: An Analysis of Consistency among Attitude Components. Yale University Press, 1-14 (1960).
22. Deci, E.L. and Ryan, R.M., *Self-determination Theory*. In: Van Lange, P.A.M., Kruglanski, A.W. and Higgins, E.T. (Eds), Handbook of Theories of Social Psychology. Sage Publications, 416-436 (2012).
23. Gero, A., Wilczynski, V., Krumholtz, N. and Danino, O., Project-based learning in international teams composed of excelling high-school and first-year engineering students: high-school students' perspective. *Global J. of Engng. Educ.*, 25, **2**, 83-89 (2023).

BIOGRAPHY

Aharon Gero holds a BA in physics (*summa cum laude*), a BSc in electrical engineering (*cum laude*), an MSc in electrical engineering, and a PhD in theoretical physics, all from the Technion - Israel Institute of Technology, Haifa, Israel. In addition, he has an MBA (*cum laude*) from the University of Haifa, Israel. Dr Gero is an Associate Professor in the Department of Education in Technology and Science at the Technion, where he heads the Electrical Engineering Education Research Group. Before joining the Technion, he was an instructor at the Israeli Air-Force Flight Academy. Dr Gero's research focuses on electrical engineering education and interdisciplinary education that combines physics with electronics, at both the high school and higher education levels. His research interests also include quantum optics and atomic physics. Dr Gero has received the Israeli Air-Force Flight Academy Award for Outstanding Instructor twice and the Technion's Award for Excellence in Teaching 16 times. He received the Israeli Air-Force Commander's Award for Excellence (2006), the Yanai Prize for Excellence in Academic Education (2016) and the Technion's Award for Continuing Excellence in Teaching (2022). Dr Gero is a Senior Member of IEEE and serves as an Associate Editor of IEEE Transactions on Education.