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Academic motivation in beginning students of electrical engineering: a case study of Danish and Israeli universities

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ABSTRACT: In light of the acute shortage of engineers in the Western world, nurturing academic motivation is a primary goal of engineering education. The study described in this article focused on the mapping and analysis of the factors driving beginning students to study electrical engineering. One hundred and seventy-six Danish and Israeli students took part in the study. The participants filled out a closed-ended anonymous questionnaire used to measure their academic motivation. Based on the findings, beginning students of electrical engineering are mostly driven by intrinsic motivation (i.e. interest in studying engineering) and identified regulation (i.e. recognition of the value inherent to these studies), regardless of their semester of study (first, second or third). It has also been found that despite the differences between Danish and Israeli students and their programmes, their motivational factors are very similar.

Keywords: Academic motivation, beginning students, electrical engineering

INTRODUCTION

In view of the lingering shortage of engineers in the Western world, it is highly important to both attract candidates to undergraduate engineering programmes, and to reduce dropouts among engineering students [1]. The actions taken to increase the number of engineering students are wide-ranging and expansive; among them are the development of high-school science and engineering curricula [2][3], exposure days for high-school students [4][5] and the establishment of innovative courses for engineering students [6][7].

As nurturing motivation plays a central role in the aforementioned efforts [8][9], studies have characterised academic motivation among relevant populations: high-school students majoring in science and engineering [10-12], students enrolled in engineering preparatory programmes [13][14] and sophomore and junior engineering students [6][15][16]. The study described in this article aimed to add to the existing findings, and focused on the mapping and analysis of the factors driving beginning students (first to third semester of study) at two technical universities, Danish and Israeli, to study electrical engineering.

The article opens with a theoretical background which classifies, according to self-determination theory, the main motivational factors. The research questions and methodology are then presented. A discussion of the findings concludes the article.

CLASSIFICATION OF MAIN MOTIVATIONAL FACTORS

One of the common definitions of motivation is the person’s wish to invest resources (i.e. time and effort) in a certain activity, even when it involves difficulties or failures.

Self-determination theory, currently one of the leading motivation theories, positions the factors driving the person to participate in a particular activity (herein, motivational factors) on a continuum [17].

This spectrum ranges from the pole of perceived control (coercion), characterised by low autonomous motivation that does not allow self-actualisation, to the other extreme of perceived autonomy, which is characterised by high autonomous motivation permitting self-actualisation [18].

The motivational factor with the highest level of perceived control is external regulation (Figure 1). This factor expresses the person's wish to obtain material compensation for the activity, or alternatively, a fear of consequences from a failure to complete it. A clear example of this is a student studying engineering out of a fear that if he/she does not do so, he/she would be drafted by the military.

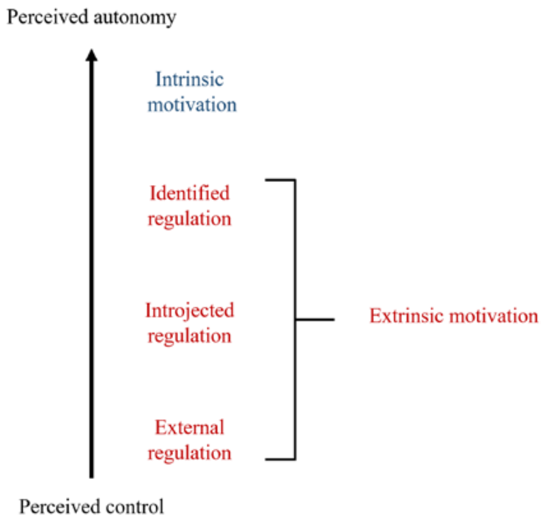

Figure 1: Classification of the four main motivational factors.

The next motivational factor characterised by a lower level of perceived control (and a higher level of perceived autonomy) compared to external regulation is introjected regulation. This factor represents the person's desire to be positively esteemed for finishing the activity, or alternatively, his/her wish to avoid the guilt tied to a failure to complete it. A typical example of this is a student studying engineering in order to please his/her family.

Moving on the continuum towards the pole of perceived autonomy, one comes across the next motivational factor, identified regulation. This factor stems from identifying the importance of the activity with regards to the person's goals or the values he/she holds. Thus, for instance, a student who recognises the importance of engineering studies since through them he/she obtains an in-demand job in industry is a student driven by identified regulation. It should be noted that self-determination theory treats the three motivational factors mentioned above as extrinsic factors.

On the other extreme of the spectrum is intrinsic motivation, characterised by the highest degree of perceived autonomy and originating from the interest and pleasure the person finds in the activity.

The person's degree of autonomous motivation is often assessed by the relative autonomy index (RAI) [19]. This indicator is defined as a linear combination of the four motivational factors described above, appropriately weighted. The index assigns a higher weight in absolute value to a motivational factor when it closes to one of the extremes on the spectrum. Additionally, motivational factors with a relatively high level of perceived autonomy are assigned a positive weight, while those with a relatively high level of perceived control are assigned a negative weight. The indicator is as follows:

$$RAI = 3S_{Intrinsic} + S_{Identified} - S_{Introjected} - 3S_{External} \quad (1)$$

Where: $S_{Intrinsic}$ is the person's intrinsic motivation score, $S_{Identified}$ is his/her identified regulation score, and so forth. These scores are measured by relevant research tools, as explained later on.

According to self-determination theory, it is possible to raise the individual's level of autonomous motivation by meeting his/her needs: the need for autonomy - the need to feel that the activity was not imposed on the individual; the need for competence - the need to feel that the individual is able to fulfil challenging goals; and finally, the need for relatedness - the need to be part of a group [17].

RESEARCH GOAL AND QUESTIONS

The study aimed to map and analyse the motivational factors driving beginning students (first to third semester of study) at two technical universities, Danish and Israeli, to study electrical engineering.

The following research questions were formulated:

1. What drives Danish freshman students to study electrical engineering? Is there a difference between first- and second-semester students with regards to their motivational factors?
2. What drives students in their third semester to study electrical engineering? Is there a difference between Danish and Israeli students with regards to their motivational factors?

METHODOLOGY

Participants

One hundred and twenty-five Danish students from the Technical University of Denmark (DTU), Ballerup, Denmark, studying for a BEng degree, participated in the research. Their studies last three and a half years, including a six-month internship in industry and a capstone project, usually executed at the same company (Danish or international), where the internship takes place. The whole studies are practice-oriented and based on the concept of CDIO [20]. Eighty-seven of the DTU's participants were enrolled in the electronics programme (48 students in their first semester of study and 39 in their second semester). The remaining 38 students were enrolled in the electrical energy technology programme (third semester of study).

Additionally, 51 Israeli students from the Technion - Israel Institute of Technology, Haifa, Israel, took part in the study. The students were in their third semester of study for a BSc degree in electrical engineering. This four-year programme emphasises profound theoretical and practical training in all electrical engineering related fields, including electronics and electrical energy technology.

Procedure and Instruments

The participants filled out an anonymous questionnaire used to measure their academic motivation. This five level Likert-like scale, ranging from *strongly disagree* to *strongly agree*, was based on the Self-Regulation Questionnaire - Academic [21].

The questionnaire was comprised of 20 statements expressing the four motivational factors described above. Thus, with regards to the three extrinsic factors, the statement: *I am studying electrical engineering because I do not have a choice*, reflects external regulation; the statement: *I am studying electrical engineering because my parents want me to do so*, expresses introjected regulation; and the statement: *I am studying electrical engineering because I think working in electrical engineering would be a good job for me*, represents identified regulation. An example of a statement reflecting intrinsic motivation is: *I am studying electrical engineering because I think the studies are interesting*.

The statements were validated by two engineering education experts. Cronbach's alphas were within a range of 0.78-0.86, indicating good internal consistency. The data were statistically analysed and the corresponding effect sizes (Cohen's *d*) were calculated.

FINDINGS

Motivational Factors of Danish Students (Freshmen)

Table 1 presents the RAI (mean M, ranging from -16 to +16, with standard deviation SD) of Danish students in their first and second semester of study. It arises that among both groups, the mean value of the index is above the third quartile. A *t*-test indicates that there is no significant difference between the two groups ($p > 0.05$), and the gap between them (favouring the latter) is characterised by a small effect size ($d = 0.21$).

Table 1: Relative autonomy index (DTU - freshmen).

Semester	N	M	SD
1	48	9.25	3.76
2	39	9.96	2.93

Table 2 displays the scores given to the various motivational factors and the corresponding effect sizes. According to *t*-tests, there is no significant difference between the two groups in any of the factors ($p > 0.05$). MANOVA was not performed here since the motivational factors are highly correlated [6]. The differences between the groups are accompanied by small effect sizes.

Table 2: Motivational factor scores (DTU - freshmen).

Motivation	Regulation	Semester	M	SD	*d*
Intrinsic		1	4.22	0.61	0.10
		2	4.28	0.63	
Extrinsic	Identified	1	3.43	0.52	-0.33
		2	3.25	0.59	
	Introjected	1	1.71	0.57	-0.20
		2	1.60	0.55	
	External	1	1.71	0.71	-0.31
		2	1.51	0.57	

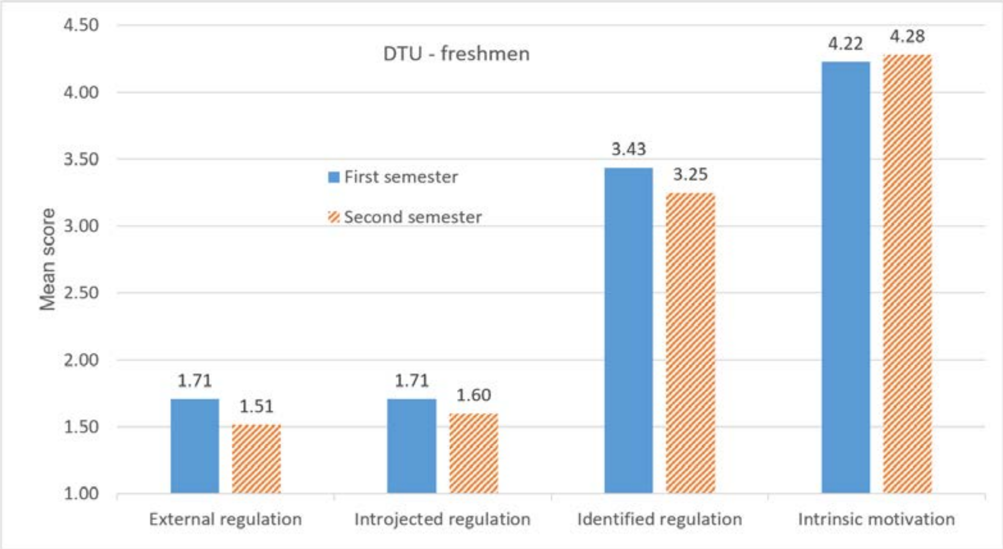

Figure 2: Mean motivational factor scores (DTU - freshmen).

Figure 2 shows the mean score (ranging between 1 and 5) of each of the four motivational factors for Danish freshman students (first and second semester of study). It is evident that among both groups of students, the intrinsic motivation score is the highest and the identified regulation score is in second place. The scores assigned to these factors are much higher than the scores given to introjected regulation and external regulation.

Motivational Factors of Danish and Israeli Students (Third Semester of Study)

Table 3 displays the RAI of Danish and Israeli students in their third semester of study. Among both groups, the mean value of the index is slightly under the third quartile. A *t*-test indicates that there is no significant difference between the two groups ($p > 0.05$), and the gap between them (favouring the former) is characterised by a small effect size ($d = -0.12$).

Table 3: Relative autonomy index (third semester of study).

University	N	M	SD
DTU	38	7.67	3.89
Technion	51	7.27	2.97

Figure 3 shows the mean score of the four motivational factors among Danish and Israeli students (third semester of study). In both groups, the intrinsic motivation score is the highest, the identified regulation score is in second place, close to the first and higher than the scores assigned to introjected regulation and external regulation.

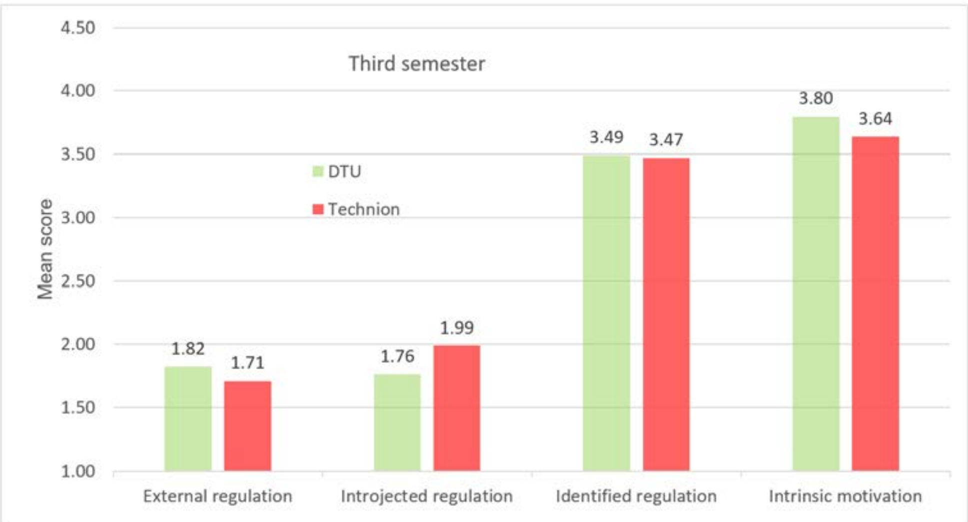

Figure 3: Mean motivational factor scores (third semester of study).

Table 4 presents the scores given to the various factors and the corresponding effect sizes; *t*-tests indicate that there is no significant difference between the two groups in any of the factors ($p > 0.05$). The gaps between the groups are accompanied by small effect sizes.

Table 4: Motivational factor scores (third semester of study).

Motivation	Regulation	University	M	SD	*d*
Intrinsic		DTU	3.80	0.69	-0.23
		Technion	3.64	0.68	
Extrinsic	Identified	DTU	3.49	0.49	-0.04
		Technion	3.47	0.69	
	Introjected	DTU	1.76	0.63	0.33
		Technion	1.99	0.74	
	External	DTU	1.82	0.68	-0.17
		Technion	1.71	0.66	

DISCUSSION AND CONCLUSIONS

The study shows that beginning students of electrical engineering are characterised by a relatively high RAI and that they are mostly driven by intrinsic motivation and identified regulation, regardless of their semester of study (first, second or third). Therefore, the students' level of autonomous motivation is high, and interest in studying engineering and recognition of the value inherent to the studies are the primary motivational factors of these students.

Additionally, it has been found that despite the differences between Danish and Israeli students and their programmes, their motivational factors are very similar. It is also worth noting that the distribution of motivational factors identified here is similar to that of junior electrical engineering students in Israel [16].

In order to further increase the students' level of autonomous motivation, it recommended to consider the following actions: allowing students to select a task out of a given set of tasks (meeting students' need for autonomy), solving challenging - yet not too challenging - problems (fulfilling the need for competence), and incorporating *real world* scenarios into the curriculum (meeting the need for relatedness) [22][23].

The study had two main limitations: a relatively small number of participants and the fact that only three programmes were investigated. However, the authors believe that even a study with this scope has both theoretical and practical contributions.

The theoretical contribution is in the analysis of the motivation towards electrical engineering studies among beginning students in Denmark and Israel. To the best of the authors' knowledge, such analysis was performed here for the first time. The study's practical contribution may be reflected in the implementation of its findings in order to reinforce autonomous motivation among beginning students of engineering. These contributions are further validated in view of the on-going shortage of engineers [1] and the primary role academic motivation fulfils in reducing dropout rates among students [8].

REFERENCES

1. Paku, L., Jensen, M. and Evans, R., Attracting future engineers through practical and collaborative initiatives. *Proc. 29th Aust. Assoc. of Engng. Educ. Conf*., 521-525 (2018).
2. Sohn, S.Y. and Ju, Y.H., Design and implementation of youth engineering adventure program in Korea. *Inter. J. of Engng. Educ.*, 27, **5**, 1107-1116 (2011).
3. Gero, A., Engineering students as science teachers: a case study on students' motivation. *Inter. J. of Engng. Pedagogy*, 4, **3**, 55-59 (2014).
4. Molina-Gaudo, P., Baldassari, S., Villarroya-Gaudo, M. and Cerezo, E., Perception and intention in relation to engineering: a gendered study based on a one-day outreach activity. *IEEE Trans. on Educ*., 53, **1**, 61-70 (2010).
5. Blonder, R. and Sakhnini, S., The making of nanotechnology: exposing high-school students to behind-the-scenes of nanotechnology by inviting them to a nanotechnology conference. *Nanotechnol. Review*, 4, **1**, 103-116 (2015).
6. Koh, C., Tan, H.S., Tan, K.C., Fang, L., Fong, F.M., Kan, D., Lye, S.L. and Wee, M.L., Investigating the effect of 3D simulation-based learning on the motivation and performance of engineering students. *J. of Engng. Educ*., 99, **3**, 237-251 (2010).
7. Yadav, A., Subedi, D., Lundeberg, M.A. and Bunting, C.F., Problem-based learning: influence on students' learning in an electrical engineering course. *J. of Engng. Educ*., 100, **2**, 253-280 (2011).
8. Carmichael, C. and Taylor, J.A., Analysis of student beliefs in a tertiary preparatory mathematics course. *Inter. J. of Math. Educ. in Science and Technol*., 36, **7**, 713-719 (2005).
9. Gero, A., Zoabi, W. and Sabag, N., Animation based learning of electronic devices. *Advances in Engng. Educ*., 4, **1**, 1-21 (2014).
10. Aeschlimann, B., Herzog, W. and Makarova, E., How to foster students' motivation in mathematics and science classes and promote students' STEM career choice: a study in Swiss high schools. *Inter. J. of Educ. Research*, 79, 31-41 (2016).
11. Gero, A. and Danino, O., High-school course on engineering design: enhancement of students' motivation and development of systems thinking skills. *Inter. J. of Engng. Educ*., 32, **1A**, 100-110 (2016).

12. Middleton, J.A., Mangu, D. and Lee, A., *A Longitudinal Study of Mathematics and Science Motivation Patterns for STEM-intending High Schoolers in the US*. In: Hannula, M.S., Leder, G.C., Morselli, F., Vollstedt, M. and Zhang, Q. (Eds), Affect and Mathematics Education. Fresh Perspectives on Motivation, Engagement, and Identity. Springer, Cham, 89-105 (2019).
13. Yelamarthi, K. and Mawasha, P., A pre-engineering program for the under-represented, low-income and/or first-generation college students to pursue higher education. *J. of STEM Educ*., 9, **3-5**, 5-15 (2008).
14. Gero, A. and Abraham, G., Motivational factors for studying science and engineering in beginning students: the case of academic preparatory programmes. *Global J. of Engng. Educ*., 18, **2**, 72-76 (2016).
15. Mamaril, N.A., Usher, E.L., Economy, D.R. and Kennedy, M.S., An examination of students' motivation in engineering service courses. In: *Frontiers in Educ. Conf*., 1825-1827 (2013).
16. Catz, B., Sabag, N. and Gero, A., Problem based learning and students' motivation: the case of an electronics laboratory course. *Inter. J. of Engng. Educ*., 34, **6**, 1838-1847 (2018).
17. Deci, E.L. and Ryan, R.M., The what and why of goal pursuits: human needs and the self-determination of behavior. *Psychological Inquiry*, 11, **4**, 227-268 (2000).
18. Deci, E.L. and Ryan, R.M., Intrinsic Motivation and Self-determination in Human Behaviour. New York, NY: Plenum Publishing Co. (1985).
19. Roth, G., Assor, A., Kanat-Maymon, Y. and Kaplan, H., Autonomous motivation for teaching: how self-determined teaching may lead to self-determined learning. *J. of Educ. Psychol*., 99, **4**, 761-774 (2007).
20. Crawley, E.F., The CDIO Syllabus: A Statement of Goals for Undergraduate Engineering Education. Cambridge, MA: Massachusetts Institute of Technology (2001).
21. Ryan, R.M. and Connell, J.P., Perceived locus of causality and internalization: examining reasons for acting in two domains. *J. of Personality and Social Psychology*, 57, **5**, 749-761 (1989).
22. Gero, A. and Mano-Israeli, S., Analysis of the factors motivating students at a two-year technological college to study electronics. *Inter. J. of Engng. Educ*., 33, **2A**, 588-595 (2017).
23. Trenshaw, K.F., Revelo, R.A., Earl, K.A. and Herman, G.L., Using self-determination theory principles to promote engineering students' intrinsic motivation to learn. *Inter. J. of Engng. Educ*., 32, **3**, 1194-1207 (2016).

BIOGRAPHIES

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 Assistant 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. Dr Gero has received the Israeli Air-Force Flight Academy Award for Outstanding Instructor twice and the Technion's Award for Excellence in Teaching 13 times. In 2006, he received the Israeli Air-Force Commander's Award for Excellence, and in 2016 was awarded the Yanai Prize for Excellence in Academic Education.

Anna Friesel is a Professor at the Centre for Bachelor of Engineering Studies at the Technical University of Denmark (DTU Diplom), Campus Ballerup. Her research and professional interests include developing international programmes and international collaboration, educational methods in engineering and in general, mathematical modelling, system dynamics and control theory. She served as the President of the European Association for Education in Electrical and Information Engineering (EAEEIE) between 2012 and 2019. Professor Friesel is a member of the IEEE Educational Activities Board (EAB) as a *Member-at-Large*. She is an Associate Editor of the IEEE Transactions on Education and the Treasurer of the International Division of the American Society for Engineering Education (ASEE).