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Engineers do not grow on trees

Andrej Šorgo & Mateja Ploj Virtič

University of Maribor
Maribor, Slovenia

ABSTRACT: A deficit of engineers all over the world requires stakeholders to promote engineering careers among young people and especially females, who are stereotypically uninterested. The authors built predictive models of factors influencing career choices to become an engineer, and explored the differences between genders. Six hundred and twenty-four general upper secondary school students from Slovenia were surveyed by questionnaire. Statistical analysis included unidimensional, exploratory (EFA) and confirmatory factor analyses (CFA), and structural equations modelling (SEM). Models were of students' intentions to become an engineer. The top three factors influencing this career choice were self-interest, employability and school grades obtained. Considering all the findings, it can be concluded that the global shortage of engineers cannot be solved in an *ad hoc* fashion or intuitively. Schools at the pre-university level should provide information and promote engineering as a career path.

Keywords: Global shortage of engineers, career choice, gender difference, predictive models

INTRODUCTION

The low interest of young people in engineering careers is a world problem from which Slovenia is not exempt [1]. Little has been done to improve the situation, as reflected in enrolments in engineering courses in higher education. For example, in the study year 2018/19 only 18.4% of Slovenian students were enrolled in engineering, manufacturing technologies and construction programmes [2]. To help decision-makers to introduce measures to raise the number of young people who pursue career opportunities in engineering, the authors have tried to find explanations for the relative unpopularity of these careers and to identify levers to improve the situation.

Career aspirations and realised careers are shaped by several intrinsic and extrinsic factors, which are elaborated in the social cognitive theory of career development [3]. The theory links together: a) the formation and elaboration of career-relevant interests; b) selection of academic and career choice options; and c) performance and persistence in educational and occupational pursuits for STEM (science, technology, engineering, mathematics) subjects [4].

Career choices are shaped by a large number of external factors, such as the influence of others, support systems, enrolment criteria, perceived quality of schools, first-hand experiences and available employers. Among the most important factors that can shape career choices are teachers and school curricula [4]. Therefore, schools can be used as a lever to encourage enough students into career paths to satisfy the employment market [5].

Engineering educators primarily are concerned with the influence of schools and teachers: should engineering education at the elementary and secondary school levels be dedicated to a select few or should it promote technological literacy for all students [6] in combination with the development of entrepreneurship [7].

The aims of the research on students of upper secondary schools were:

1. to determine the attractiveness of engineering careers;
2. to find relative order of 14 factors (Table 1) influencing career choices;
3. to find how a number of factors (Table 1) correlate with a wish to work in engineering;
4. to build predictive models (Figure 1) using factors influencing career choices;
5. to explore gender differences.

METHODOLOGY

The sample consisted of 624 (N) Slovenian g*imnazija* school students. Gimnazija is an elective upper secondary school with a four-year programme that follows nine years of compulsory education. This does not produce vocational qualifications, but is regarded as a preparatory school for tertiary education. It ends with the *general matura* examinations, which allow enrolment in most tertiary study programmes. In particular, the general matura qualifies students to pursue engineering tertiary programmes. In the sample, there were 62.8% girls and 37.2% boys being students from the fourth grade (41.7%), the third grade (58.0%) and two (0.4%) from lower grades. Sampling was conducted anonymously and was part of a larger study [8].

The instrument used in this study was part of questionnaires from a larger study, designed to explore the influence of STEM subjects and a number of STEM-related factors on the career aspirations of upper secondary school students. From the larger study [8] items from three parts were used. In the first part students were asked: *After finishing my studies, I would prefer to be employed in an organisation best labelled as*, followed by 15 options (e.g. research and development, education, engineering) based on the classification of the Slovenian Statistical Agency.

The response format was a 7-point Likert scale from 1 (completely true) to 7 (completely untrue) [8]. Given the aims of this research, the models tested the intention to become an engineer, and not the other options.

The predictor variables were a list of 14 factors influencing career choice (Table 1). The response format was a 7-point Likert scale with students following the instruction: *On a scale from 1 (strong impact) to 7 (no impact), clearly (unambiguously) indicate the extent to which each statement applies to you. Indicate only one number for EACH of the following statements* - followed by a list of statements.

Statistical procedures were unidimensional, exploratory (EFA) and confirmatory factorial analyses (CFA) using structural equations modelling (SEM) [9-11]. Hypothetical models were subject to scrutiny and procedures provided by analysis of moment structures (AMOS) [11] to improve fits. The models are presented in Figure 1 and Figure 2. They were analysed with IBM SPSS 27 and AMOS 27 software.

RESULTS

Results presented in Table 1 and Table 2 and Figure 1 and Figure 2 are discussed in the Discussion and Conclusions section.

Table 1: Factors influencing the career aspiration to work as an engineer (N = 624).

Potentially important factors influencing career aspirations	M	Med	Mod	SD	PC1	PC2	PC3	PC4	*r*	*p*
Self-interest	1.51	1	1	1.12	-0.38		0.39		-0.075	0.061
Employability	2.43	2	1	1.65			0.76		0.117	0.004
Obtained school grades	2.75	2	1	1.74		0.59			-0.088	0.028
Expected salary	2.97	3	1	1.66			0.59		0.110	0.006
Assessment of the complexity of study	3.29	3	3	1.81		0.90			0.019	0.638
Expected amount of effort	3.30	3	3	1.79		0.87			0.026	0.515
Reputation of the profession in society	3.61	3	4	1.92			0.82		0.150	<0.001
Expected amount of costs associated with the study	3.77	4	4	1.85		0.38			0.082	0.042
Possibility to influence others	4.17	4	4	1.84			0.51		0.152	<0.001
Family	4.25	4	4	1.87	0.75				0.130	<0.001
Friends	4.61	5	7	1.78	0.48				0.154	<0.001
Close to home	4.65	5	7	2.06	0.81				0.135	<0.001
High school teachers	4.94	5	7	1.87				0.89	0.137	<0.001
Primary school teachers	5.56	6	7	1.72				0.88	0.157	<0.001
Variance					30.91	14.02	8.83	7.41		
Eigenvalue					4.33	1.96	1.24	1.04		
Cronbach's alpha					0.72	0.75[1]	0.68[2]	0.78		

Note: Cronbach's alpha for the instrument was 0.82 (0.83 if items Q1c deleted, 0.78 if Q58n deleted, 0.70 if Q58c deleted)

Career aspiration to work as an engineer was used as an outcome variable in the models (Figure 1 and Figure 2). Descriptive statistics of the variable is as follows: mean = 4.46; SD = 1.98; med = 4, and mode = 7.

Table 2: Differences between genders (N = 624; N_{Boys} = 232; N_{Girls} = 392). Results are sorted by descending effect sizes.

	Boys		Girls					Effect
	M	SD	M	SD	U	*p*	Cohen's *d*	size
Career aspiration to work as an engineer	3.69	1.86	4.91	1.91	29216	<0.001	0.65	Medium
Obtained school grades	3.13	1.75	2.53	1.69	35479	<0.001	0.35	Small
Friends	4.26	1.77	4.81	1.76	37540	<0.001	0.31	Small
Self-interest	1.65	1.28	1.43	0.99	41431.5	0.013	0.19	Small
High school teachers	4.73	1.84	5.06	1.88	40708	0.025	0.18	Small
Primary school teachers	5.37	1.78	5.67	1.67	40793.5	0.023	0.17	Small
Possibility to influence others	4.03	1.71	4.25	1.91	42256.5	0.134	0.12	NS
Expected amount of costs associated with the study	3.91	1.76	3.69	1.90	42258.5	0.135	0.12	NS
Assessment of the complexity of the study	3.41	1.76	3.22	1.83	42025	0.108	0.11	NS
Expected salary	2.86	1.65	3.03	1.67	42593	0.177	0.10	NS
Close to home	4.54	2.02	4.72	2.08	43022.5	0.251	0.09	NS
Expected amount of effort	3.40	1.71	3.24	1.84	42554	0.173	0.09	NS
Employability	2.53	1.72	2.38	1.61	43435	0.329	0.09	NS
Reputation of the profession in society	3.52	1.88	3.67	1.94	43508	0.361	0.08	NS
Family	4.27	1.80	4.24	1.92	45241	0.914	0.02	NS

Table 3: Model fits.

Model	NPAR	$\chi 2$	df	$\chi 2$/df	IFI	CFI	SRMR	RMSEA
Threshold values				< 3	> 0.95	> 0.95	< 0.08	<0.07
Hypothesised model - all	39	465.62	81	5.75	0.86	0.86	0.08	0.09
Final model	31	149.64	35	4.28	0.94	0.94	0.04	0.07
Hypothesised model - boys	39	266.19	81	3.29	0.84	0.83	0.08	0.10
Final model	31	88.23	35	2.52	0.93	0.93	0.06	0.08
Hypothesised model - girls	39	309.63	81	3.82	0.86	0.86	0.08	0.09
Final model	31	113.30	35	3.24	0.93	0.93	0.05	0.08

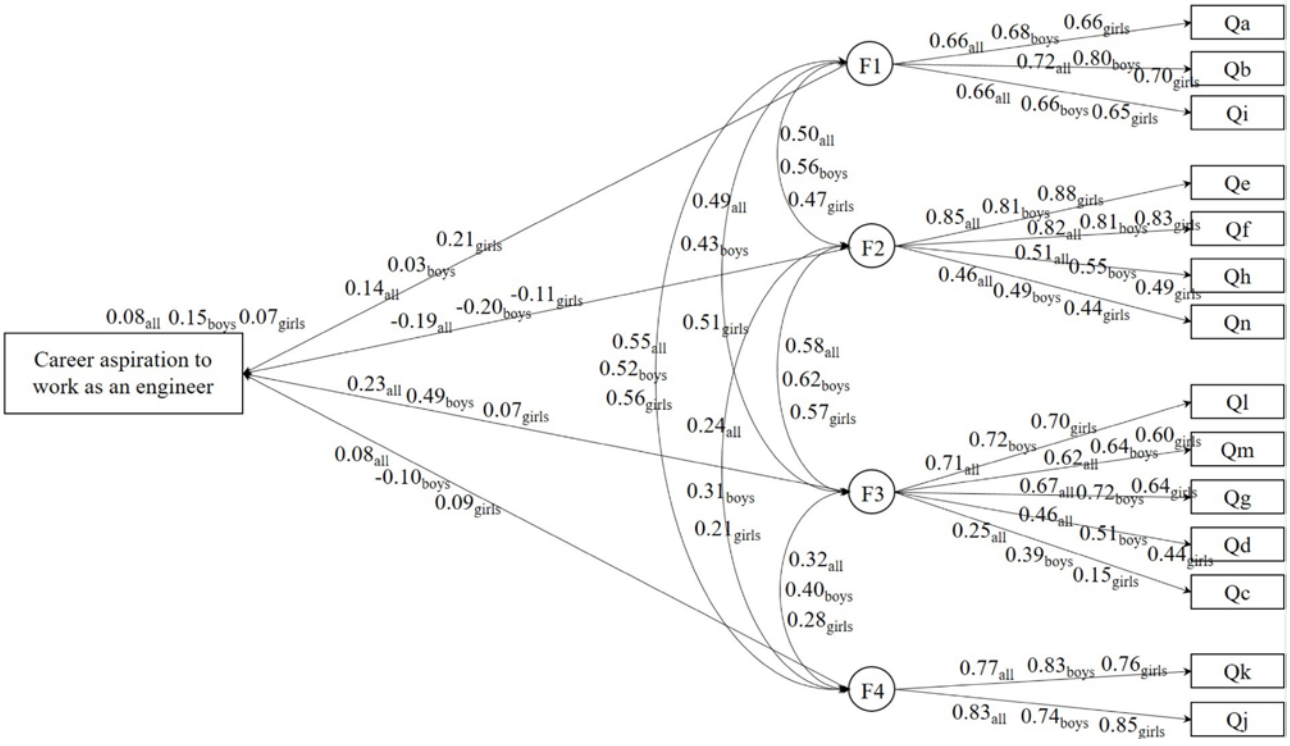

Figure 1: CFA hypothesised model.

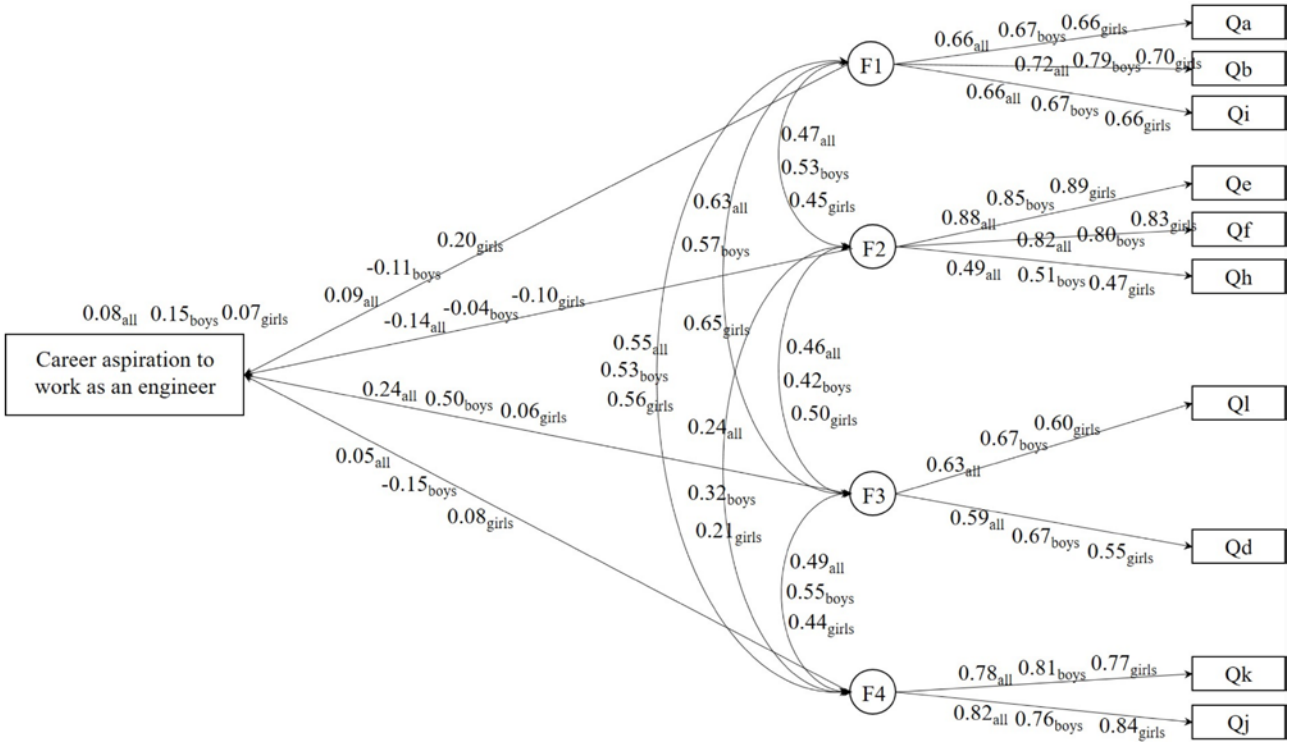

Figure 2: CFA final model.

DISCUSSION AND CONCLUSIONS

From Table 1 the aspiration to become an engineer is below the midpoint on the 1 - 7 scale. Recall that this is an inverted scale with lower means indicating more impact and higher means less impact. The most important factors influencing career choice are self-interest followed by employability and obtained school grades. The least important are the influence of primary and secondary school teachers. The analysis identified four factors explaining about 61% of variance, using eigenvalue > 1 as the criterion. However, parallel analysis [12] indicated that only the first three factors should be retained.

The first of these factors is a composition of three less-influencing items, viz. close to home, family and friends. The second factor relates to the quantity and the nature of the effort needed to achieve the goal. The third factor involves the quality of a workplace and the influence of teachers. Correlations between career aspirations and factors are low or even non-existent. However, they may be statistically significant, since the results may be more to do with the sample than their real influence on career aspiration.

The authors decided to include all four components in the CFA and SEM models (Figure 1 and Figure 2). Stereotypically, the interest of boys in aspiring to become an engineer is higher than girls, as seems to be confirmed by the means in Table 2. Hence, the models were examined for gender differences affecting careers; these effects were small to non-existent (Table 2). The final model had satisfactory fit indices, slightly better than the initial model (Table 3).

The most influential factor in the model for all participants is the quality of the working place (Figure 1; F3) followed by the reputation of the profession. This is far more important for boys than for girls; emphasising stereotypes [13-15]. This implies the need for better communication of the appropriateness of engineering careers for girls by presenting them with the career opportunities and benefits [16], and connecting them with female engineers [17] as role models and as suggested by Cadaret et al *Promoting positive identity and constructive interaction with the environment may support women's career development in engineering fields* [13].

The second factor reflects the effort to be invested in an engineering career. The path has negative coefficients and is a little bit more negative for girls. Most probably this can be explained by engineering studies including subjects, where mathematics and physics at advanced levels are required, which can be perceived as a barrier [4][18].

The home factor (F1) is much more important for girls than for boys. This probably stems from traditional views of the role of women in society. This implies that girls should be influenced to find self-interest in engineering by the promotion of such careers. Another target should be families, especially where a traditional role of girls is reinforced by culture. Influencing families can involve individual counselling and the provision of perspective at parent meetings. However without a guarantee for success [4].

The last factor (F4) is the influence of education at school. This was the least influential factor (Table 1) and even had a negative influence on boys. Educators cannot influence the quality of a workplace or the salary, and can barely

influence families. A teacher works as an influencer promoting their self-interest in study [19]. However, school subjects are classic disciplines, e.g. biology or history, and at general secondary schools do not include different streams of engineering (e.g. mechanical, civil, computer, biotechnology, …) or entrepreneurship essential for developing and implementing engineering concepts [20].

Considering all the findings, it may be concluded that the global shortage of engineers cannot be solved in an *ad hoc* fashion or intuitively. Stereotypes that are deeply ingrained in traditional society can be broken by an approach, guided by research, to improve the reputation of engineers and promote their employment. Girls should be encouraged to value working away from home.

Finally, schools at the pre-university level should provide information and promote engineering as a career path. This cannot be done simply by the replacement of content or the inclusion of additional topics, but also requires the enrichment of the existing teaching [20][21].

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BIOGRAPHIES

Andrej Šorgo is a professor of biology didactics in the Department of Biology at the Faculty of Natural Sciences and Mathematics, and a part-time researcher at the Faculty of Electrical Engineering and Mathematics, both at the University of Maribor, Slovenia. He is a visiting professor at Charles University in Prague, the Czech Republic. He is teaching several subjects in the fields of biology/science education, research methodology and evolution. His research interests are in the exploration of factors influencing acceptance and related behaviour of educational technology in education, information and digital literacy, as well as environmental issues.

Mateja Ploj Virtič is an associate professor of technical education, working in the field of innovative pedagogy. She is Deputy Head of the Department of Technical Education. At present, she is working on two research projects, developing innovative methods for the application of modern technology in the classroom. As a member of the National Commission for Curriculum Development for Technical/Engineering Education, she is co-operating with schools in the national framework. She co-operates with numerous international researchers from Europe, South Africa and South America. Since 2019, she has been a member of the Inter-Divisional Teaching Commission.