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JUNE 22 - 26, 2020 #ASEEVC
Paper ID #30266

Analyzing Innovative Behavior Outcomes of Early-Career Engineering Graduates

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Analyzing Innovative Behavior Outcomes of Early-Career Engineering Graduates

Abstract

It is widely acknowledged that engineers “are foundational to technological innovation and development that drive long-term economic growth and help solve societal challenges” [1]. Consequently, it is a major goal in engineering education to ensure and further improve the development of innovation skills among its students. While many studies focus on current engineering students and their innovation goals and skills, it is also informative to see how these goals and skills are translated into realized innovative behavior in the workplace. By studying the characteristics of innovative behavior of engineering graduates we reveal valuable insights and draw conclusions for engineering educators.

Our quantitative study is based on a dataset of 559 early-career engineering graduates who participated in the Engineering Majors Survey (EMS). EMS is a longitudinal U.S. nationwide survey designed to explore engineering students’ and then later graduates’ technical, innovation, and entrepreneurial interests and experiences. Innovative behavior outcomes are analyzed considering socio-demographic characteristics such as gender and underrepresented racial/ethnic minority (URM) status, and characteristics of the workplace such as industry and company size. Furthermore, we elaborate on the interrelation of innovative behavior and leadership responsibility.

We find no significant differences in innovative behavior of female and male engineering graduates. The same is true for URM and non-URM participants in the study. The data suggest that employees in R&D are engaged more strongly in innovative behavior than the average engineering graduate not employed in R&D. At the same time no significant difference is revealed across a wide range of industries. Interestingly, the fraction of participants who indicated having work assignments involving leadership responsibility report a much higher level of innovative behavior than do their counterparts. This raises questions about the relationship between leadership skills and innovative behaviors, and whether leadership skills should be more strongly taken into consideration when thinking about building innovation skills in engineering education.

1 Introduction

Fostering innovation skills in students has become a major goal in engineering education. This is reasonable since it is widely acknowledged that engineers “are foundational to technological innovation and development that drive long-term economic growth and help solve societal challenges” [1]. Especially at this moment as humanity is facing fundamental transformations such as digitalization or climate change, it is part of the societal responsibility of engineering educators to equip future engineers with the abilities to develop visionary innovations which help solve these problems.

Earlier publications have identified positive effects of targeted education on innovativeness for students studying engineering, e.g. [2-7]. In this current research study, we investigate the actual realized innovative behaviors of engineering graduates at the workplace. This allows us to not only see how/if recent graduates are exhibiting innovative behaviors, but also allows us question how aligned these behaviors are with current educational goals and even teaching strategies.

The empirical results are based on a sample of 559 early-career engineering graduates (average age of 25) who were full-time employed in small to large business organizations at the time of the survey. These data come from a U.S. nationwide survey called Engineering Majors Survey (EMS) [8] and give us insights into career decisions of early career engineering graduates as well.

More specifically, the focus of this study addresses two main research questions:

- **Research Question 1:** Where are early-career engineering graduates working?
- **Research Question 2:** What are the characteristics of individual innovative behavior of early-career engineering graduates with regard to socio-demographic characteristics, industry, business unit, size of business organization, and leadership responsibility?

2 Theoretical background and literature review

This section lays out the theoretical ground for the empirical analyses presented in the subsequent parts of this research study and explores relevant literature. While section 2.1 elaborates on the theory of the innovation process, section 2.2 presents information on factors influencing individual innovative behavior.

2.1 The innovation process and individual innovative behavior

The term *innovation* lacks an explicit definition agreed upon by all scientists. Rather, there is much debate on the topic depending on disciplines or research areas [9, 10]. One definition that is often used in organizational research and reasonably covers the focus of our study is formulated by Thompson [11]: “innovation is the generation, acceptance and implementation of new ideas, processes, products or services”.

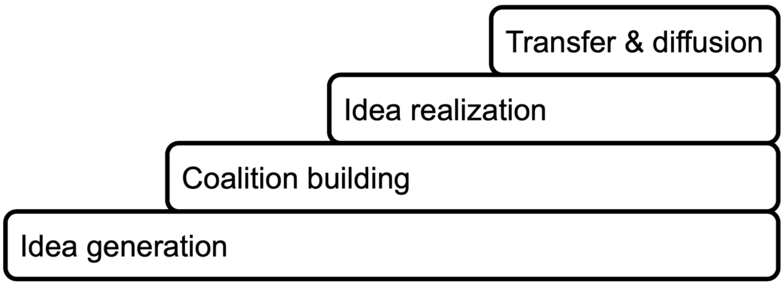

Figure 1: The four innovation tasks according to Kanter [12].

In contrast to all the debate about the definition of the term, there is broad consensus among various researchers that innovation occurs as a process. This current research study follows the perspective of Kanter [12] who describes this process as the cumulation of individual actions of employees (the micro-level) that are embedded in the structure of the enclosing organization (the macro-level). She distinguishes four different tasks that need to be fulfilled for successful innovation: idea generation, coalition building, idea realization and transfer & diffusion (see Figure 1).

The process perspective in Figure 1 directly leads to the concept of individual innovative behavior. It is considered as all actions performed by an individual which are part of the innovation process consisting of idea generation, coalition building, idea realization and transfer & diffusion [13, 14]. Thus, individual innovative behavior can be operationalized as a multi-dimensional measure [13], as has been done in several research studies, e.g. [15-19]. In order to draw a more illustrative and tangible image of what is meant by these actions or behaviors we look deeper into the single innovation process parts in the following paragraphs.

Idea generation marks the beginning of the innovation process [20]. It is the point where innovation and creativity meet, as generating new ideas is an act of creativity [21]. These two concepts are often mixed up but need to be distinguished. Whereas creativity is a major part in the task of generating new ideas, innovation further includes the subsequent steps of implementing the idea [22-24]. While ideas can be developed within an organization a major source of inspiration are needs that are expressed by customers [12, 25, 26]. A national study in the United States reported that more than three-fourths of a set of 500 industrial innovations originated in user suggestions [27]. The concept of opening up the innovation process toward external input (and also output) has gained strong traction over the last decade under the term “open innovation” [28, 29].

Once an idea is born, it is still a long way to bring it to life. And furthermore, it is often not clear in the beginning if an idea is actually useful and thus an innovation to the organization or a “mistake” [30]. The following steps can be seen as a filter to find the good ideas and to stop the “mistakes”. However, the danger is significant that barriers in the organization are too high and also good ideas are lost on the way.

The task of **coalition building** can be described as the task of selling the idea [12]. Selling the idea in this context means finding potential allies for its implementation. Thus, a large part in the management of innovation is the management of attention [30]. The process can be described as an interplay of several roles that are taken by several individuals. There is the “champion” of an idea who is usually the person or the team who generated the idea or was/were early advocates [31, 32]. The champion tries to gain the attention of people in the organization that s/he evaluates as indispensable for the realization of the idea [12]. These are usually people in the higher hierarchy of the organization. Galbraith [33] distinguishes between two different roles: “the sponsor” and “the orchestrator”. The sponsor is usually located in the middle management. This person is close enough to employees to discover new ideas but has enough power to distribute funding and human resources for the growing development efforts. Finally, it is the top management who plays the role of the orchestrator. They define the underlying attitude of the overall organization for or against openness towards new ideas and innovation. New ideas always require a change in the organization. They are destructive in nature by destroying investments in capital equipment and people and therefore, are never smooth and often not wanted by many surrounding people who also would have to change their daily routines. The orchestrator needs to give the sponsor and the champion the legitimization to test the idea in this negative establishment [33]. Many studies on innovation confirmed the importance of supporters for the successful implementation of new ideas [34, 35].

The successful building of a supporting coalition of the idea ensures enough political power and available resources to move the idea further to the next stage of **idea realization** which is briefly expressed as the stage of actually executing the vision of the idea. That means, building the "concrete and tangible object" whether it is a physical product or a way of behaving in a process innovation [12]. This includes bringing the idea to the point it can be tested by others and if the assessment is positive, to be ready for the transfer to the affected units of the organization. In contrast to the previous two innovation tasks that are characterized by openness toward information and other people in the organization, the idea realization stage requires a deep focus on the idea vision and favors a decreased influence from external distractions [12].

At this point, the innovation has come far. The theoretical and also the practical validity (at least on the level of a prototype) are recognized in the innovation team and by the required supporting units in middle or top management. However, the last step of getting the innovation to be used at the place it was envisioned for is still missing---this is **transfer and diffusion**. Process innovations need to be transferred into the affected units which includes transferring information to the employees and training them in order to change their behavior and interactions [36, 37]. Product innovations (especially physical ones) require a transfer to production and distribution lines. The necessary effort usually correlates with the radicalness of the innovation. Minor incremental innovations can be smoothly integrated into existing processes whereas radical innovations may demand a complete change in production and distribution channels [38]. Thus, radical product innovations are often accompanied by major process innovations in the organization [39]. When the product or service is in reach for the customer, the process of diffusion starts and can be supported by marketing efforts [40].

2.2 Factors influencing individual innovative behavior

There are many different theories and perspectives on the factors fostering or impeding creativity and innovation in organizations. They acknowledge both personal factors (e.g. gender, personality, intelligence attitudes and mindsets) and contextual factors (e.g., social interactions, work environment) as crucial determinants of innovative behavior [12]. Examples for different theoretical frameworks on organizational creativity and innovation can be found in West and Farr [14], Amabile [21], Amabile [41] or Woodman, et al. [42].

This study analyzes characteristics of individual innovative behavior among early-career engineering graduates regarding factors from both areas, those conceived for this paper as personal (or "socio-demographic characteristics") relating to one's own social identity and structural location in the world (gender, URM status, First-Generation College-FGC status) and those conceived as contextual, relating to workplace characteristics (type of company, type of job position). In the following, we present earlier scientific findings on these factors.

Gender is a variable that is mostly not explicitly studied in the context of innovative behavior of employees but is sometimes considered as a control variable in various research studies. One paper about the innovative behavior in a Dutch industrial organization in the food sector reports significant lower values of innovative behavior among female participants compared to their male colleagues [18]. A similar study (but different dataset) by the same scientist however revealed a small correlation in the opposite direction [19]. Still, in many studies gender is not included in the analysis of factors influencing innovative behavior, e.g. [15-17, 43]. As results are so far rather ambiguous, this current study contributes to gaining more information on this matter.

Regarding underrepresented minority (URM) status and first generation college (FGC) status we could not find other relevant research studies which looked at associated innovative behavior in the workplace. In previous research papers working with data from the first Engineering Majors Survey administration (EMS 1.0), a measure named innovation self-efficacy was analyzed regarding URM and FGC status [7]. Self-efficacy refers to an individual's belief and confidence about his or her ability "to organize and execute courses of action required to attain designated types of performances" [44]. Consequently, innovation self-efficacy does not measure realized behaviors but only one's belief in the ability to perform these. Since EMS 1.0 was exclusively distributed to undergraduate engineering students, actual behaviors as employees could not be determined. This earlier study does not find any significant differences in innovation self-efficacy between people of URM or FGC status and the ones who are not part of these groups.

Beyond these personal factors, this paper investigates differences in individual innovative behavior regarding characteristics of the company the engineering graduate is employed at. We look at industry sector, as well as the size of the company. Whereas the latter topic of company size has developed a broad and deep collection of research literature, comparing industry sectors with respect to the innovative behavior of their early-career engineers seems to not have been studied. Most publications elaborate on companies within one industry sector and try to find characteristics of innovation through case studies, e.g. [45-48].

The effect of the size of an organization on innovation is hotly debated in research. There is a widely held belief that smaller companies and especially startups are more innovative and creative than large and established business corporations. However, research has a very controversial discussion about the question of whether smaller or larger companies are more innovative [49]. This is caused, in part, by many different approaches to measuring innovativeness (e.g., number of innovations, R&D expenditure, innovations per employee etc.) and the heterogeneity of the research object (namely business organizations). There are several studies which support a positive relation of organizational size to innovativeness. For example Damanpour and Schneider [9] observed a positive effect of size to three separated stages of the innovation process (initiation, adoption decision, implementation), whereas many other studies report the opposite relationship [50].

Noteworthy is the integrative study conducted by Damanpour [51] that analyzed various empirical publications and revealed that around 60 percent of primary studies reported a positive relationship between company size and both, product and process innovations. However, most of these findings are based on absolute, not relative, values of innovation measures. Audretsch and Acs [49] calculated a parameter which they term "innovative intensity" and which is simply the ratio of innovations per employee, arguably a reasonable measure of a firm's innovativeness. Based on this parameter, the smaller firms clearly beat the larger ones as they produce significantly more innovations per employee in their sample of 1695 companies provided by the U.S. Small Business Administration. Furthermore, the relations of innovativeness and size of firm vary regarding the type of innovation and the industry sector.

Kanter [12] argues that product innovations are more likely in young companies whereas process innovations in established ones. Another publication describes a low level of innovation contributions by small firms if the industry is characterized by high R&D costs, as capital intensive and concentrated [52]. To this overall discussion, the present study adds valuable insights about innovativeness on the individual employee level within companies which is particularly relevant for engineering educators whose interest is to develop in their students skills and behaviors on the individual person's level.

Finally, we look at job position characteristics of the participants and their respective levels of individual innovative behavior. This includes business unit affiliation and if the job includes leadership responsibility. The research literature on innovativeness with respect to the business unit is similarly limited, as is the type of industry sector. In contrast, the literature body on the interrelation of leadership and innovative behavior is very large. However it is usually studied in terms of Leader-Member Exchange (LMX) theory, thus looking at the effects of a certain type of leadership *on* the innovative behavior of the employees [15-17, 43, 53, 54]. However, characteristics of innovative behavior of people in leadership responsibility compared to those without are largely under-explored. Studies analyzing LMX dynamics reveal (sometimes as a side-product) insights on the innovative behavior of the leaders themselves. For example, the study by Volmer, et al. [55] finds a positive correlation of leadership position and creative work involvement. Similar findings are reported by Ibarra [56] and Tierney, et al. [57] on innovation activities and hierarchical level.

3 Methods

This section outlines the methodological information being relevant for this research paper. Since it is an empirical study, Section 3.1 describes the background information of the dataset and the sample selection while Section 3.2 illustrates the operationalization of the utilized variables.

3.1 The dataset

The dataset which is analyzed in this study is drawn from the Engineering Majors Survey (EMS). The EMS is part of a research project initiated by the National Center for Engineering Pathways to Innovation, or for short EPICENTER. It was designed to investigate "engineering students' career goals surrounding innovation, and the experiences and attitudes that might influence those goals" [8]. In 2015, the initial survey (EMS 1.0) of this longitudinal project was administered to over 30,000 undergraduate engineering students enrolled at 27 universities across the United States. A total number of 7,197 students filled out the survey questions. A second (EMS 2.0) and third (EMS 3.0) wave of surveys were sent out in 2016 and 2017, respectively, to approximately 3,500 participants who voluntarily agreed in EMS 1.0 to be contacted again. EMS 3.0, which constitutes the primary data for this study, received 1,058 responses.

While in EMS 1.0 and 2.0 either the total population or the majority of the survey participants were still full-time students (in particular not full-time employed), this changed in EMS 3.0 with 636 full-time employees who successfully finished a bachelor's degree in engineering of the 1,058 respondents (61.7%). At this point, it needs to be noted that we exclusively built the dataset from full-time employees and excluded for example interns or part-time employees. This is based on the assumption that most of the full-time working engineering graduates have presumably made a strong (well-developed) first career decision. In contrast, an intern position etc. might not represent a final career decision.

The final dataset is further shrunk to the engineering graduates who are full-time employed in business organizations; this is 87.9 percent of the full-time respondents. This is due to the fact that the samples of respondents in other settings such as non-profit organizations or public/government agencies are rather small and would not allow for meaningful statistical conclusions (more details in Table 1). Based on these considerations, the final sample size adds up to 559 full-time working engineering graduates who were employed by business organizations of either small or medium to large size (marked by the blue box in Table 1) at the time of EMS3.0. EMS 3.0 was carried out two years after EMS 1.0 when all participants in the sample were enrolled as undergraduate engineering students. Within this time they have finished their bachelor's degree and entered into the workforce. Therefore, the sample is considered to consist of early-career employees who are at most 2 years out of college.

Table 1: Distribution of employment type of full-time working engineering graduates in EMS 3.0. The blue box marks the two groups of business organizations that are selected for the final sample of 559 participants.

Employment type	Number	Percentage
Employee for small business or start-up	116	18.2 %
Employee for medium- or large-size business	443	69.7 %
Employee for non-profit organization	12	1.9 %
Employee for government, military or public agency	47	7.4 %
Faculty member at university/college	5	0.8 %
Teacher/educational professional	8	1.3 %
Founder of for-profit organization	2	0.3 %
Founder of non-profit organization	0	0 %
Missing	3	0.5 %
Total	636	100 %

Because survey participants were allowed to skip some questions, choose the response option "prefer not to answer," or to discontinue the survey at any point in time, some of the data points are incomplete and therefore, data points are excluded from certain analyses if the respective and necessary information is missing. Incomplete data points are kept within the sample in order to maximize the sample size and hence the information base for analyses where answers are given.

3.2 The variables

The theoretical background of the variables and their meaning within the investigation of the research questions stated in this study have been elaborated in the preceding sections. This section describes the associated measures which were derived from the survey questions of EMS 3.0 and which represent the theoretically conceptualized variables in an operationalized way.

All information that feeds into the measures is self-reported by the participants. This approach has some disadvantages but also confers some valuable advantages. The self-report might be affected by subjectivity of the participant and perhaps short term mood fluctuations distorting the actual longer-term, more balanced perception [58]. At the same time, a person's own perception and reporting (rather than for example his/her supervisor perception, which have been used as an alternative research strategy) may be more detailed since the individual has more information about the historical, contextual, intentional and other backgrounds of his/her own activities [18, 59]. This argument is especially important concerning the supporting or suppressing circumstances of innovative behavior since the self-perceived environment is ultimately the basis for individual judgements and decisions on behavior. Furthermore, any type of supervisor (third party observation) could miss a lot of activities which are either not captured by a seemingly more objective scale or which are not in the scope of perception of the supervisor [60]. Some studies even use quantitative measures such as patents to gain information on innovativeness, argued in these studies as a more objective measure [49, 52]. However, this approach completely misses the nature of innovation being a process and only acknowledges the outcome. Furthermore, certain types of innovations such as process innovations might not be tracked.

Table 2: The question (Q136) and the six sub-items which build the individual innovative behavior measure in EMS 3.0. The sub-items are related to the four tasks of the innovation process as described by Kanter (1988).

In your current job, how often are you engaged in the following activities?		**Innovation Task (Kanter, 1988)**
Q136_1	Searching out new technologies, processes, techniques, and/or product ideas. (Search new technology)	Idea generation
Q136_2	Generating creative ideas. (Generate ideas)	
Q136_3	Promoting and championing ideas to others. (Champion ideas)	Coalition building
Q136_4	Investigating and securing resources needed to implement new ideas. (Secure resources)	Coalition building & Idea realization
Q136_5	Developing adequate plans and schedules for the implementation of new ideas. (Develop plans)	Idea realization & Transfer/diffusion
Q136_6	Selling a product or service in the marketplace. (Sell product)	Transfer/diffusion

Individual innovative behavior: Individual innovative behavior is the central variable in this research study. As described earlier, individual innovative behavior is summarized as all individual actions that contribute to a collective, even organization-level innovation process consisting of idea generation, coalition building, idea realization and transfer/diffusion, as described by Kanter [12]. Therefore, the final variable is based on six different single questions which represent single tasks and cover all tasks of the innovation process [8]. The question in the survey of EMS 3.0 (Q136) and its six sub-items are illustrated in Table 2 where the relation to the respective innovation task is also shown. We decided to deviate slightly from the initial assignment in the Technical Report of the EMS [8]. We saw a strong connection of the securing resources item not only to idea realization but also to coalition building, since its success is highly dependent on interpersonal and political skills. Each sub-item is answered on a five-point frequency Likert scale including “Never” (0), “Rarely” (1), “Sometimes” (2), “Often” (3), “Very often” (4) with the respective coded numerical representation in the brackets. The final value of the variable is obtained by taking the arithmetic mean of the numerical sub-items. The sample of this study shows a Cronbach's alpha of 0.79 for this measure which is usually considered as acceptable or even good level of internal consistency [61, 62].

Company size: The information for the variable company size is obtained from the participant's statement on the organizational type of the employer (choice options are presented in Table 1). Consequently, the resolution of this measure is rather low with only two options: small/start-up vs medium/large business organization. Furthermore, the sizes are not defined by a certain number of employees. Thus, this distinction is based on the individual judgement of the participant.

Industry sector: EMS 3.0 asks the people who are employed for the type of industry they work in. The response options provide a broad range of different areas of the national economy. All options which were chosen by more than 5 participants (13 different sectors) are included in the analyses. Each respondent had to choose only one industry sector.

Business unit: The type of job position is further characterized by the business unit the respondents relate themselves to. A list of 15 business units was presented on the survey. All options with more than 10 positive responses (12 different business units) are considered for the analyses. In contrast to the industry sector question, the participants could choose more than one business unit.

Leadership responsibility: A binary variable "leadership responsibility" was built from the survey question: "Since starting your current job, how often have your assignments included leading or directing others?". The response options on a five-point Likert scale are grouped according to the following rule: "Never", "Rarely" and "Sometimes" is assigned to low leader responsibility while "Often" and "Very often" is assigned to high leader responsibility.

Gender: The question for the gender identity of the participants presented three response options: female, male and a write-in "other (please specify)" option. For the purpose of these analyses, we use a dichotomous recode of this survey question (female/male only) given the extremely small number of "other" responses.

Underrepresented minority: If the survey respondent belongs to an underrepresented racial/ethnic minority group (URM), it is captured in this binary variable. Everyone who reports belonging to a Latino/a, black/African American, Native American/Alaska Native or Native Hawaiian/Pacific Islander racial/ethnic group is considered "URM" and everyone else (predominantly those marking white and/or Asian/Asian American groups) is considered "Not URM".

First generation college student: The variable first generation college ("FGC") student is defined as an individual whose both parents have not at least an associate degree as post-secondary education. This definition is regarded as more expansive [7, 63]. All others are seen as "Not FGC".

4 Results

This section presents the results of our empirical analyses. Section 4.1 describes the socio-demographic information of the sample and Section 4.2 presents data on the distribution of industry sectors as well as business units. Section 4.3 compares individual innovative behavior regarding the industry sector and business unit. Section 4.4 reports levels of individual innovative behavior with respect to socio-demographic factors. Finally, Section 4.5 elaborates on individual innovative behavior regarding the company size and leadership responsibility.

4.1 Demographics

Table 3 shows several socio-demographic factors of the analyzed survey. Over one third and two thirds of the sample are women and men, respectively. This is close to the percentages in the > 7000 initial sample of EMS 1.0 (30% female), but represents an overrepresentation of women compared to the overall engineering student population at the 27 EMS schools (18% female) [8], and to the overall U.S. engineering workforce as reported by NSF (14.5% female) [1].

Underrepresented minorities (URM) and first generation college (FGC) EMS3.0 graduates at 11 percent and 14 percent are also close to the fractions of the initial EMS 1.0 sample with 14 percent and 16 percent, respectively [3]. The former number (URM fraction) is almost identical to the overall engineering workforce, where the NSF reports 11.5 percent minority groups employed in engineering [1]. The age of the sample participants is calculated to an average of 25.0 years (SD=3.3 yrs), which further justifies the assumption of early-career employees.

Table 3: Socio-demographic characteristics of the sample. Residual percentages are due to missing data.

		Number	Percent
Gender	Female	190	34.0 %
	Male	367	65.7 %
	Other	0	0 %
URM status	URM	62	11.1 %
	Not URM	483	86.4 %
FGC status	FGC	79	14.1 %
	Not FGC	476	85.2 %
Total		559	100 %

4.2 Industry and business unit-where are they working?

Our data allow us to say a few things about where these early-career graduates are working, which gives a hint on the future development of the engineering workforce. These findings also complement data on the overall engineering workforce presented in the report on Understanding the Educational and Career Pathways of Engineers by the National Academy of Engineering [1].

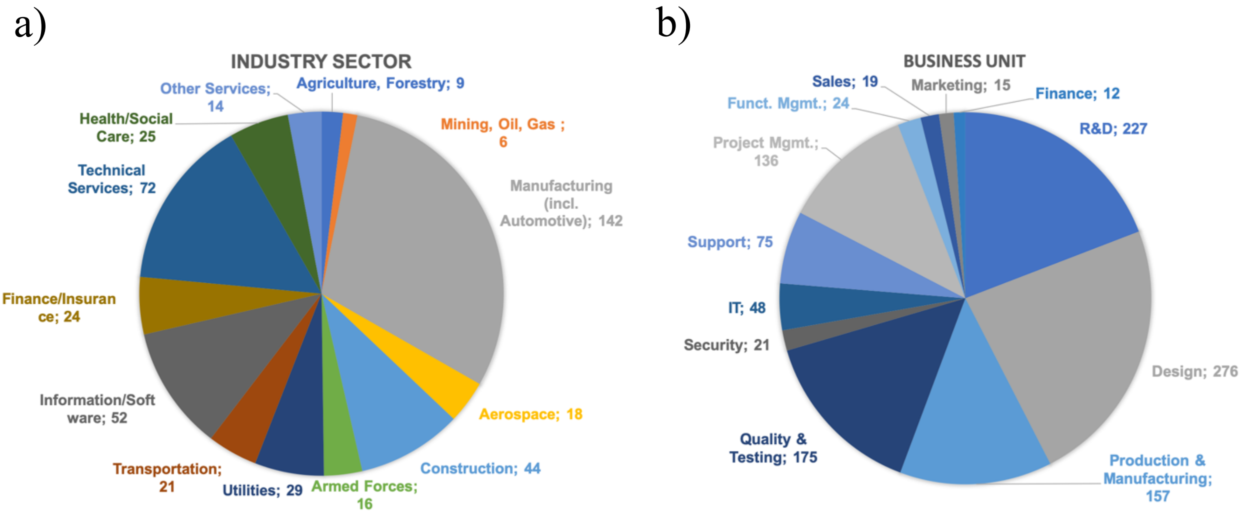

Figure 2: Distribution of (a) industry sector and (b) business unit of the job position among early-career engineering graduates. (N=559) The business unit variable is a "marked-all-that-apply"-format whereas for the industry sector only one option could be marked.

Figure 2 shows diagrams on the distribution of industry sectors and business units of the job positions among the EMS3.0 early-career engineering graduates. Concerning the industry sector (Figure 2(a)), most engineering graduates work in manufacturing (26%), professional/technical services (13%), information/software (10%), construction (8%), and utilities (5%). All others like health, finance/insurance, transportation, aerospace, armed forces, other services, agriculture and mining are below 5 percent, in descending order.

As related to business unit (Figure 2(b)), large fractions of respondents indicate that they work in design (51%), R&D (42%), quality and testing (32%), production and manufacturing (29 %) and/or project management (25%) whereas business units like support (14%), IT (9%) and functional management, security, sales, marketing, and finance (all < 5 %) are less populated.

4.3 Individual innovative behavior regarding the industry sector and business unit

Since the industry sector was built as an exclusive choice question in the survey an analysis of variance (ANOVA) can be performed in order to determine potential, statistically significant differences among the different group means of individual innovative behavior. However, the ANOVA analysis reveals no statistically significant difference between the single group means of individual innovative behavior and also not for the measure's single items.

Since an ANOVA test does not allow for identification of which group shows significant different mean levels of individual innovative behavior, we performed the following analysis in addition. Each group mean was checked on its statistical significant difference compared to the group mean of all residual respondents combined. The results are shown in Table 4a for the aggregated variable individual innovative behavior and in Appendix A for its single items. No statistically significant differences on individual innovative behavior were observed among the various industry sectors. There are only some deviations within the single items. For example, the construction group engages less in generating ideas by 0.33 ($p < .05$) and more in selling product by 0.30 ($p < .05$). The utilities group scores higher on develop plans by 0.48 ($p < .05$, two-tailed t-test) and the information/software employees are lower on secure resources by 0.32 ($p < .05$).

Table 4a: Results of the t-tests comparing individual innovative behavior regarding industry sector of the employer organization. T-tests always calculated between the respective group and all residual respondents combined.

Industry sector	n	Individual innovative behavior	Δ
Agriculture, Forestry	9	1.78 (0.61)	-0.07
Mining, Oil, Gas	6	1.89 (0.55)	+0.04
Manufacturing (incl. Automotive)	142	1.89 (0.65)	+0.06
Aerospace	18	1.88 (0.98)	+0.03
Construction	44	1.78 (0.76)	-0.07
Armed Forces	16	1.76 (0.85)	-0.09
Utilities	29	1.86 (0.74)	+0.02
Transportation	21	1.79 (0.71)	-0.06
Information/Software	52	1.82 (0.66)	-0.03
Finance/Insurance	24	1.98 (0.81)	+0.14
Technical Services	72	1.80 (0.78)	-0.05
Health/Social Care	25	2.01 (0.80)	0.17
Other Services	14	1.65 (0.64)	-0.20

Table 4b: Results of the t-tests comparing individual innovative behavior regarding business unit of the employee‘s position. T-tests always calculated between the respective group and all residual respondents combined.

Business unit	n	Individual innovative behavior	Δ
R&D	227	1.97 (0.69)	**+0.21****
Design	276	1.87 (0.70)	+0.06
Production & Manufacturing	157	1.93 (0.67)	+0.12^{+}
Quality & Testing	175	1.90 (0.73)	+0.07
Security	21	2.07 (0.90)	+0.23
IT	48	1.84 (0.73)	-0.00
Support	75	1.77 (0.78)	-0.09
Project Mgmt.	136	2.13 (0.66)	**+0.38*****
Funct. Mgmt.	24	2.09 (0.74)	+0.26^{+}
Sales	19	2.25 (0.89)	**+0.41***
Marketing	15	2.36 (0.82)	**+0.52****
Finance	12	1.94 (1.00)	+0.10

N = 559, *** p < .001, ** p < .01, * p < .05, $^{+}$p < .10 (two-tailed t-test)
Levene's test justifies the assumption of equal variances for the aggregated variable individual innovative behavior. However, for several single items this is not true (listed in Appendix A on Industry Sector and Appendix B on Business Unit), therefore for these pairs Welch's t-test is applied [64].

The engagement in individual innovative behavior of early-career engineering graduates is further investigated regarding the characteristics of the business unit (see Table 4b). Analyzing differences among the various business units forms a more detailed image of characteristics of innovative behavior along the value chain within companies. While the industry sector was built as an exclusive choice question in the survey, for the business unit question multiple answers were possible simultaneously. Consequently, an analysis of variance (ANOVA) cannot be performed. This is the case because ANOVA requires independency of the group means which is not fulfilled in particular if data points are part of more than one group [65]. Consequently, only the analysis comparing the group of one business unit to the residual sample population by a two-tailed t-test was performed.

The large group of engineers working in R&D shows a significantly higher engagement in individual innovative behavior by 0.21 (p < .01) which is especially fueled by strong activity in searching for new technology (Δ = 0.73, p < .001) and generating new ideas (Δ = 0.42, p < .001). In contrast, these early career graduates score significantly lower on selling product (Δ = 0.26, p < .01, two-tailed Welch's t-test). The design respondents do not score differently on the overall innovation behavior measure, but engage more in generating ideas (Δ = 0.36, p < .001) and championing ideas (Δ = 0.22, p < .01), and score lower on selling product (Δ = 0.26, p < .01, two-tailed Welch's t-test).

The respondents who indicated working in project management engage more intensively in individual innovative behavior by 0.38 (p < .001) and in all single items as well. Means on individual innovative behavior among the small number of respondents marking sales and marketing are significantly higher than are those among respondents who did not mark these categories, by 0.41 (p < .05) and 0.52 (p < .01), respectively. This observation may be driven by very high values in selling product with Δ = 2.32 (p < .001, two-tailed Welch's t-test), for the sales people and Δ = 1.59 (p < .01, two-tailed Welch's t-test) for the marketing people. Furthermore, the business unit marketing scores significantly stronger on championing ideas by 0.67 (p < .01).

4.4 Individual innovative behavior regarding the socio-demographic characteristics

The net sample of 545 early-career engineering graduates who provided valid responses to the individual innovative behavior items reveals an average value of 1.85 (SD=0.71) (Table 5). There is variation at the individual item level, with respondents reporting more activities related to generating and championing ideas (on average, between sometimes and often) than securing resources and selling products (on average, between never and rarely).

Table 5: Results of the t-tests comparing individual innovative behavior and its six single items regarding socio-demographic characteristics.

	n	**Individual innovative behavior**	**Search new technology**	**Generate ideas**	**Champion ideas**	**Secure resources**	**Develop plans**	**Sell product**
Total sample	545	1.85 (0.71)	2.10 (1.05)	2.39 (0.95)	2.15 (0.96)	1.71 (1.07)	2.08 (1.07)	0.65 (0.98)
Female	185	1.86 (0.71)	2.02 (1.02)	2.36 (0.95)	2.11 (0.93)	1.84 (1.05)	2.18 (1.11)	0.63 (0.99)
Male	358	1.84 (0.71)	2.14 (1.08)	2.39 (0.95)	2.16 (0.98)	1.65 (1.07)	2.03 (1.05)	0.66 (0.98)
Δ		0.02	0.12	0.03	0.05	**0.19**$^{+}$	0.15	0.04
URM	58	1.74 (0.73)	1.97 (1.07)	2.24 (0.94)	1.98 (0.98)	1.69 (0.99)	2.00 (1.11)	0.62 (0.93)
Not URM	473	1.85 (0.70)	2.09 (1.05)	2.40 (0.96)	2.16 (0.96)	1.72 (1.08)	2.07 (1.07)	0.64 (0.98)
Δ		0.10	0.13	0.16	0.18	0.02	0.07	0.02
FGC	76	1.95 (0.64)	2.25 (0.91)	2.53 (0.87)	2.20 (0.88)	1.86 (0.99)	2.16 (1.10)	0.71 (0.94)
Not FGC	465	1.83 (0.72)	2.07 (1.07)	2.36 (0.96)	2.14 (0.97)	1.69 (1.08)	2.07 (1.07)	0.64 (0.99)
Δ		0.12	0.18	0.17	0.06	0.17	0.09	0.07

N = 559, *** p < .001, ** p < .01, * p < .05, $^{+}$p < .10 (two-tailed t-test)
On the individual item level: 0="Never" 1="Rarely", 2="Sometimes", 3="Often" and 4="Very Often"
Each value is written down together with its respective standard deviation in brackets. Furthermore, for each pair the difference of the values is displayed and marked with regard to statistical significance according to the result of a two-tailed t-test.

When considering Females v. Males, URM v. non-URM, and FGC v. non-FGC, between-group differences in innovative behavior are not statistically significant, as shown in Table 5.

The only between-group difference on the individual item level reaching marginal significance (p<.10) is between women and men, with women more likely to have engaged in activities related to securing resources.

4.5 Individual innovative behavior regarding the size of the business organization and leadership responsibility

Another variable which characterizes the company of the engineer's position is the size of the business organization. Table 6 illustrates the differences of individual innovative behavior and its single items comparing small/startup business and medium/large business.

Table 6: Results of the t-tests comparing individual innovative behavior and its six single items regarding the size of the business organization.

	n	Individual innovative behavior	Search new technology	Generate ideas	Champion ideas	Secure resources	Develop plans	Sell product
Total sample	545	1.85 (0.71)	2.10 (1.05)	2.39 (0.95)	2.15 (0.96)	1.71 (1.07)	2.08 (1.07)	0.65 (0.98)
Small/startup business	114	2.05 (0.75)	2.34 (1.06)	2.63 (0.94)	2.27 (1.02)	1.83 (1.15)	2.26 (1.00)	0.94 (1.08)
Medium/large business	431	1.79 (0.69)	2.03 (1.05)	2.32 (0.95)	2.11 (0.94)	1.68 (1.05)	2.04 (1.09)	0.58 (0.94)
Δ		**0.25****	**0.31****	**0.31****	0.16	0.16	**0.23***	**0.36*****

N = 559, *** p < .001, ** p < .01, * p < .05, $^{+}$p < .10 (two-tailed t-test)
Levene's test confirms the equality of variances for all compared pairs. Between the group of early-career engineering graduates working in small/startup business organizations and the group working in medium/large business organizations are some statistically significant differences.

The aggregated variable individual innovative behavior is significantly higher by 0.25 for individuals working in a small/startup business, as compared with a medium/large business (p < .01). The survey respondents working in small/startup businesses score significantly higher than the ones working in medium/small businesses on the behavior of search new technology by 0.31 (p < .01), generate ideas by 0.31 as well (p < .01), develop plans by 0.23 (p < .05) and sell product by 0.36 (p < .001, two-tailed t-test). On the innovative behavior items champion ideas and secure resources they are also slightly higher but not significantly different.

Finally, we look at how a particular aspect of an early career graduates' work, namely leadership responsibility, might affect their innovative behavior. A question in the EMS survey captured information about the responsibility of leading other people at work. Perhaps surprisingly, given that the participants only recently started working, almost one-third of survey respondents report that their work assignments involve leading or directing others "Often" or "Very Often". The comparison of the levels of individual innovative behavior and its single items between the high leadership responsibility and the low leadership responsibility group is presented in Table 7.

Table 7: Results of the t-tests comparing individual innovative behavior and its six single items regarding leadership responsibility.

	n	Individual innovative behavior	Search new technology	Generate ideas	Champion ideas	Secure resources	Develop plans	Sell product
Total sample	545	1.85 (0.71)	2.10 (1.05)	2.39 (0.95)	2.15 (0.96)	1.71 (1.07)	2.08 (1.07)	0.65 (0.98)
High leadership responsibility	171	2.26 (0.64)	2.35 (1.03)	2.71 (0.90)	2.62 (0.89)	2.20 (1.03)	2.65 (0.94)	0.98 (1.13)
Low leadership responsibility	373	1.66 (0.66)	1.98 (1.05)	2.24 (0.94)	1.93 (0.92)	1.48 (1.01)	1.82 (1.03)	0.50 (0.87)
Δ		**0.60*****	**0.38*****	**0.47*****	**0.69*****	**0.72*****	**0.83*****	**0.47*****

N = 559, *** $p < .001$, ** $p < .01$, * $p < .05$, $^{+}p < .10$ (two-tailed t-test)
Levene's test confirms the equality of variances for all compared pairs except of the sell product item. Therefore, in order to compare these two values the Welch's t-test is used again instead of the regular independent samples t-test [64].

The early-career engineering graduates who are highly involved in leading other people score significantly higher on the aggregated individual innovative behavior scale by 0.60 (p < .001,) as well as on every single item. They engage particularly intensively in championing ideas (Δ = 0.69, p < .001), securing resources (Δ = 0.72, p < .001) and developing plans (Δ = 0.83, p < .001, two-tailed t-test). The other items still reveal significantly higher values for the high leadership responsibility group: search new technology (Δ = 0.38, p < .001), generate ideas (Δ = 0.47, p < .001) and sell product (Δ = 0.48, p < .001, two-tailed Welch's t-test).

5 Limitations

Several limitations of these results need to be noted. The Engineering Majors Survey consists of self-reported data, therefore all information gained from participants is subject to their individual perceptions. As mentioned earlier, this has some advantages, but some studies take additional quantitative or third party information into account [15].

All empirical analyses were executed as t-tests on the basis of paired groups. This approach does not take into account the effect of omitted variables and thus, statistically significant effects cannot be interpreted as causalities (e.g., one cannot conclude that leadership responsibilities cause innovative behavior). Future research is needed to show if the results can be validated in empirical analyses such as regression methods, which take into account various omitted variables in order to gain more confidence.

6 Discussion, implications & conclusion

Our findings let us paint a nation-wide picture of the industry and business unit placement of recent U.S. engineering graduates, showing that many are working in Manufacturing, and in Professional/Technical Services. As has historically been the case, both women and underrepresented racial/ethnic minorities (URMs) are underrepresented among these recent engineering graduates compared with the overall population, pointing to the continued importance of diversity, inclusion, and equity efforts in engineering at a large scale.

Furthermore, our research has measured real behavioral outcomes in the workplace of individuals with engineering degrees, and as such is in contrast to intentions or ability beliefs (a shortcoming that was mentioned by earlier publications [7]). We have reported on the innovative behaviors of these recent graduates, noting that some behaviors (e.g., generating and championing ideas) are engaged in fairly often by many of the graduates, whereas others are rarely engaged in (securing resources and selling products). We do show that the extent of these behaviors varies by business unit, organizational size, and level of leadership responsibility.

Noteworthy is that our results show that women and men, URM and non-URM, and FGC and non-FGC graduates generally report the same statistically similar levels of individual innovation behavior, as well as the individual behavior items. As mentioned in the literature section, other studies show a mixed picture for innovative behaviors comparing men and women [18, 19]. In order to gain a clearer picture, it will help in the future if studies include a gender variable more consequently as it is often not the case so far [15-17, 43]. If we look at findings on innovation self-efficacy (the belief of being able to perform innovative behaviors but not the actual behavior) our results are in line. A study led by Schar, et al. [7] did not reveal differences across gender, minority or parents' education background groups.

Interestingly, there are no significant differences revealed between jobs in different industry sectors suggesting that there is no specific industry which engineering students might think to focus on in order to work innovatively. However for the business units, our results suggest that the innovation process goes partly along the value chain of a company. R&D and design jobs score higher on the idea-initiating creative stage whereas marketing and sales score very high on the diffusion stage. This has implications for career advising for students, helping those who have particular interest in the innovation-initiating activities to seek out the roles in organizations that are close to R&D or design.

Our results on the size of the business organization are consistent with prior work that small companies or startups motivate stronger innovative behavior compared to medium and large businesses [49, 51]. But only 1 in 4 early-career engineering graduates actually start working in small companies. This is probably driven by a larger number of job opportunities offered by bigger companies. But it still is a strong argument for another highly discussed topic in engineering education: entrepreneurship [66-68]. With this line of thinking, if we motivate more engineering students to become entrepreneurs after graduating (by entrepreneurship focused education programs/offers), the proportion of job opportunities in startups would grow, providing more engineers with more innovative job positions. For engineering educators this would mean thinking about how to include associated knowledge, skills and abilities through curricular (e.g., taking a business planning course teaching the lean-launchpad method) and availability of extra-curricular activities (e.g., competing in a elevator pitch competition) [3]. A number of engineering schools have organized opportunities for students on these topics through specialized centers [69].

The result on leadership responsibility is perhaps not surprising. The group of engineering graduates who report frequently leading other employees score significantly higher on every innovative behavior item. One possible interpretation is that individuals who are trusted with this kind of responsibility at an early career stage are overall highly performing people (e.g. intelligent, passionate, determined) and do so also in innovativeness. This would not be a highly informative conclusion for educators. However, if we look in more detail on the level of the single innovative behavior items, there might be an important takeaway for engineering education. The participants with leadership responsibility are particularly active on items in the middle of the innovation process: championing ideas, securing resources and developing plans. Championing ideas and securing resources are both behaviors which are assigned to the coalition building stage of innovation (see Figure 1). Returning to the description of coalition building in the beginning of this paper it appears to involve highly political and socially constructed type of activities. The idea champion needs to have to be adept at creating and maintaining interpersonal connections, and a good sense of how the idea can make the sponsor and the orchestrator care [12]. Developing plans for the implementation of an innovative idea requires strategic thinking and the ability to foresee future developments. As a consequence, preparing engineering students for innovative work behavior is more than just educating creativity techniques or design thinking courses. Our results suggest that it may be valuable to help engineering students develop their social-awareness and engagement skills, as well as interpersonal skills (even beyond teamwork) as well as their strategic thinking with regard to innovativeness.

Despite the limitations of our work, this research paper reveals important information on the level of innovativeness of early-career engineering graduates. Furthermore, it opens up a starting point for research on the interconnection of leadership skills and innovation skills which should be explored through future research if the goal is to enhance innovativeness of future engineering graduates. With regards to all the urgent and fundamental transformations such as digitalization or climate change which call for technological innovations by people trained in engineering skills, this must be the major ambition of engineering education in order to meet our responsibilities toward society.

7 Acknowledgement

The Engineering Majors Survey (EMS) study was conducted with support from the National Center for Engineering Pathways to Innovation (Epicenter), a center funded by the National Science Foundation (grant number DUE-1125457) and directed by Stanford University and VentureWell, formerly the National Collegiate Inventors and Innovators Alliance (NCIIA). EMS research continued with support from the National Science Foundation (grant number 1636442).

Appendix

Appendix A: Results of the t-tests comparing the six single items of the individual innovative behavior variable regarding industry sector. T-tests are always calculated between the respective group and all residual respondents combined.

Industry sector	**n**	**Search new technology**	**Δ**	**Generate ideas**	**Δ**	**Champion ideas**	**Δ**	**Secure resources**	**Δ**	**Develop plans**	**Δ**	**Sell product**	**Δ**
Agriculture, Forestry	9	2.33 (0.71)	+0.24	2.22 (0.83)	-0.17	1.89 (1.17)	-0.26	1.78 (0.83)	+0.07	2.11 (0.78)	+0.03	0.33 (0.50)	-0.32
Mining, Oil, Gas	6	2.14 (0.90)	+0.05	2.29 (0.76)	-0.10	2.33 (0.82)	+0.19	2.00 (1.16)	+0.29	2.00 (1.00)	-0.09	1.00 (0.89)	+0.35
Manufacturing (incl. Automotive)	142	2.17 (1.02)	+0.09	2.43 (0.89)	+0.07	2.24 (0.87)	+0.12	1.86 (1.02)	+2.01$^+$	2.09 (1.11)	+0.01	0.54 (0.85)	-0.15$^+$
Aerospace	18	2.28 (1.36)	+0.19	2.17 (0.99)	-0.23	1.94 (1.06)	-0.21	1,94 (1.21)	+0.24	2.06 (1.06)	-0.03	0.89 (1.28)	+0.25
Construction	44	1.80 (0.88)	**-0.33***	2.14 (0.93)	-0.27$^+$	1.93 (1.11)	-0.23	1.77 (1.20)	+0.07	2.14 (1.15)	+0.06	0.93 (1.07)	**+0.30***
Armed Forces	16	1.94 (1.00)	-0.17	2.50 (1.27)	+0.12	1.94 (1.12)	-0.22	1.63 (1.09)	-0.09	2.06 (1.12)	-0.02	0.50 (0.82)	-0.16
Utilities	29	1.76 (0.91)	-0.36+	2.28 (1.03)	-0.12	2.17 (0.97)	+0.03	1.93 (1.07)	+0.23	2.52 (0.99)	**+0.46***	0.52 (0.87)	-0.14
Transportation	21	1.81 (1.08)	-0.30	2.29 (0.96)	-0.10	2.24 (0.83)	+0.10	1.67 (1.02)	-0.05	2.10 (0.94)	+0.01	0.62 (0.87)	-0.03
Information/Software	52	2.19 (1.03)	+0.10	2.38 (0.99)	-0.00	2.15 (0.98)	+0.01	1.42 (0.89)	**-0.32***	2.02 (0.96)	-0.07	0.73 (1.16)	+0.09
Finance/Insurance	24	2.38 (1.17)	+0.29	2.54 (0.98)	+0.16	2.38 (0.92)	+0.24	1.79 (1.18)	+0.09	2.29 (1.16)	+0.22	0.50 (0.78)	-0.16
Technical Services	72	2.07 (1.16)	-0.03	2.33 (0.96)	-0.06	2.03 (0.93)	-0.14	1.49 (1.13)	-0.26$^+$	2.06 (1.12)	-0.03	0.85 (1.15)	+0.23
Health/Social Care	25	2.36 (1.11)	+0.27	2.48 (1.19)	+0.10	2.24 (1.13)	+0.10	1.96 (1.02)	+0.26	2.32 (1.15)	+0.25	0.72 (0.94)	+0.07
Other Services	14	1.57 (1.09)	-0.54$^+$	2.00 (0.78)	-0.40	1.86 (0.86)	-0.30	1.71 (0.99)	+0.00	1.79 (1.12)	-0.31	1.00 (1.30)	+0.36

N = 559, $^+$p < .10, *** p < .001, ** p < .01, * p < .05, $^+$p < .10 (two-tailed t-test)

Levene’s test indicates that equal variances cannot be assumed for the following t-tests: manufacturing – sell product, aerospace – search new technology, technical services – sell product. For these, the Welch’s t-test is performed instead of the regular independent samples t-test.

Appendix B: Results of the t-tests comparing the six single items of the individual innovative behavior variable regarding business unit. T-tests are always calculated between the respective group and all residual respondents combined.

Business Unit	**n**	**Search new technology**	**Δ**	**Generate ideas**	**Δ**	**Champion ideas**	**Δ**	**Secure resources**	**Δ**	**Develop plans**	**Δ**	**Sell product**	**Δ**
R&D	227	2.52 (0.96)	**+0.73*****	2.63 (0.91)	**+0.42*****	2.25 (0.97)	**+0.17***	1.80 (1.11)	+0.15	2.11 (1.03)	+0.04	0.50 (0.85)	**-0.26****
Design	276	2.19 (1.04)	**+0.20***	2.56 (0.90)	**+0.36*****	2.25 (0.95)	**+0.22****	1.65 (1.11)	-0.13	2.06 (1.08)	-0.04	0.53 (0.82)	**-0.26****
Prod. & Manufact.	157	2.19 (1.08)	+0.14	2.48 (0.93)	+0.14	2.30 (0.95)	**+0.21***	1.87 (1.06)	**+0.23***	2.24 (1.02)	**+0.22***	0.51 (0.80)	**-0.21***
Quality & Testing	175	2.20 (1.12)	+0.16	2.40 (1.00)	+0.02	2.20 (0.98)	+0.08	1.80 (1.06)	+0.13	2.20 (1.07)	+0.18^{+}	0.57 (0.90)	-0.12
Security	21	2.57 (1.12)	**+0.49***	2.62 (1.02)	+0.24	2.33 (1.07)	+0.19	1.90 (1.26)	+0.20	2.43 (1.29)	+0.36	0.57 (0.81)	-0.08
IT	48	2.29 (1.15)	+0.21	2.21 (0.97)	-0.19	2.10 (0.91)	-0.05	1.67 (1.12)	-0.05	2.04 (1.07)	-0.05	0.75 (1.00)	+0.11
Support	75	2.03 (1.07)	-0.08	2.13 (0.96)	**-0.29***	2.05 (1.06)	-0.11	1.63 (1.10)	-0.10	2.05 (1.13)	-0.04	0.72 (0.99)	+0.08
Project Mgmt.	136	2.34 (1.02)	**+0.33****	2.58 (0.91)	**+0.26****	2.44 (0.92)	**+0.39*****	2.05 (1.11)	**+0.46*****	2.55 (0.98)	**+0.62*****	0.83 (1.02)	**+0.24***
Funct. Mgmt.	24	2.20 (1.04)	+0.11	2.36 (1.08)	-0.03	2.36 (0.95)	+0.22	1.88 (1.15)	+0.17	2.36 (1.11)	+0.29	1.28 (1.31)	**+0.66***
Sales	19	2.21 (1.27)	+0.12	2.32 (1.25)	-0.07	2.37 (1.01)	+0.23	1.84 (1.26)	+0.14	1.84 (1.39)	-0.25	2.89 (1.10)	**+2.32*****
Marketing	15	2.31 (1.30)	+0.22	2.50 (1.21)	+0.12	2.80 (1.15)	**+0.67****	2.00 (1.16)	+0.30	2.44 (1.32)	+0.36	2.20 (1.37)	**+1.59****
Finance	12	2.25 (1.49)	+0.16	2.33 (1.16)	-0.05	2.42 (1.24)	+0.28	2.00 (1.41)	+0.30	2.00 (0.95)	-0.09	0.67 (0.89)	+0.02

N = 559, $^{+}$p < .10, *** p < .001, ** p < .01, * p < .05, $^{+}$p < .10 (two-tailed t-test)

Levene's test indicates that equal variances cannot be assumed for the following t-tests: R&D – selling product, design – sell product, production & manufacturing – sell product, quality & testing – search new technology & sell product, functional management – sell product, sales – generate ideas & sell product, marketing – sell product, finance – generate ideas. For these, the Welch's t-test is performed instead of the regular independent samples t-test.

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