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Article abstract

Based on self-determination theory, this research presents the development of a scale to assess motivation for engineering studies in a Francophone context. Three phases of data collection were conducted (N = 462, 545 and 864) for a total of 1871 engineering students (59.2% female). Results from both exploratory and confirmatory factor analyses support a seven-factor structure for the scale: 1) intrinsic motivation, extrinsic motivations characterised by 2) identified regulation – altruism, 3) introjected regulation – ego, 4) introjected regulation – conscience, 5) external regulation – security, 6) external regulation – social prestige and, finally, 7) amotivation. The dimensions of altruism and security are specific to engineering studies. The scale meets generally accepted criteria for reliability and verifies different types of validity evidence.

Developing a Motivation Scale for Engineering Studies in a Francophone Context*

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Key words: engineering studies, academic motivation scale, self-determination theory

Based on self-determination theory, this research presents the development of a scale to assess motivation for engineering studies in a Francophone context. Three phases of data collection were conducted (N = 462, 545 and 864) for a total of 1871 engineering students (59.2% female). Results from both exploratory and confirmatory factor analyses support a seven-factor structure for the scale: 1) intrinsic motivation, extrinsic motivations characterised by 2) identified regulation – altruism, 3) introjected regulation – ego, 4) introjected regulation – conscience, 5) external regulation – security, 6) external regulation – social prestige and, finally, 7) amotivation. The dimensions of altruism and security are specific to engineering studies. The scale meets generally accepted criteria for reliability and verifies different types of validity evidence.

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MOTS CLÉS : études d'ingénieurs, échelle de motivation scolaire, théorie de l'autodétermination

En prenant appui sur la théorie de l'autodétermination, cette recherche présente l'élaboration d'une échelle de mesure de la motivation aux études d'ingénieurs en contexte francophone. Trois collectes de données ont été menées (N = 462, 545 et 864) auprès d'un total de 1871 élèves ingénieurs (59,2% de sexe féminin). Les résultats des analyses factorielles exploratoires et confirmatoires appuient une structure à sept dimensions : 1) la motivation intrinsèque, les motivations extrinsèques par régulation 2) identifiée – altruisme, 3) introjectée – ego, 4) introjectée – conscience, 5) externe – sécurité, 6) externe – prestige social et, enfin, 7) l'amotivation. Les dimensions altruisme et sécurité sont spécifiques aux études d'ingénieurs. L'échelle proposée satisfait aux critères de fiabilité communément admis et réunit plusieurs éléments de preuves de validité.

PALAVRAS-CHAVE: estudos de engenharia, escala de motivação escolar, teoria da autodeterminação

A partir da teoria da autodeterminação, esta investigação apresenta a elaboração de uma escala de medida da motivação nos estudos de engenharia no contexto francófono. Foram realizadas três recolhas de dados (N = 462, 545 e 864) num total de 1871 estudantes de engenharia (59,2% do sexo feminino). Os resultados das análises fatoriais exploratórias e confirmatórias sustentam uma estrutura com sete dimensões: 1) a motivação intrínseca, as motivações extrínsecas caracterizadas pela 2) regulação identificada – altruísmo, 3) regulação introjetiva – ego, 4) regulação introjetiva – consciência, 5) regulação externa – segurança, 6) regulação externa – prestígio social e, finalmente, 7) desmotivação. As dimensões altruísmo e segurança são específicas aos estudos de engenharia. A escala proposta satisfaz os critérios de fiabilidade comummente aceites e contém várias provas de validade.

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Introduction

Background

The number of engineers in France increases by an average of 4% per year. While there were only 680,000 in 2009, the number grew to over one million by 2018 (IESF, 2018). In 2016, 33,500 engineering degrees were awarded, a 20% increase from 2009 (MESRI, 2018). The job market for engineers is extremely favourable, with a net employment rate of over 93% within 12 to 18 months of graduation (CGE, 2016). The unemployment rate for engineers is two to three times lower than the average level in France (APEC, 2017). Although the gap between degree levels is widening in the face of the financial crisis, engineers, regardless of their field, are protected from economic decline (Barret, Ryk and Volle, 2014).

As a profession, engineering is in high demand: certain industrial sectors such as electronics, informatics or energy sometimes have difficulty finding all the engineers they need. The range of career paths available to engineers is broad and diverse. Few degrees offer such an array of occupations. Engineers' salaries are very satisfactory (their median earnings are 16% higher than those of managers) and their career prospects are especially attractive.

Given their autonomy and the value of their jobs, engineers constitute a thriving workforce. Only around 10% are concerned about losing their jobs (IESF, 2018). The engineering professions cover a variety of disciplines, involving work from basic research to commercial functions in chemistry, aeronautics, civil engineering, agriculture, electronics, telecommunications, etc. Economies and industries that strive to be more competitive rely on the expertise and innovation of engineers. They are at the heart of major economic, social and environmental changes, ranging from the digital revolution to energy transformation.

In France, as in other European countries, engineering studies enjoy great prestige (European Commission, 2006). An engineering degree is training in excellence that is sometimes described as elitist. Students choose engineering school for a variety of reasons. Although some students acknowledge that they have been keenly interested in science and technology since childhood, a significant number do not wish to work in an engineering-related field later in life. Many are looking for job security, a good salary and a socially recognized status. When they decide to go to an engineering school, only about 50% express certainty that engineering is the right choice for them. In fact, in France, over half of students say they do not have enough information about the engineering profession (CDEFI, 2009). Nevertheless, engineering studies are considered the golden path to many career opportunities (European Commission, 2006).

The education level of the parents of engineering students is remarkably high compared to the overall level of the population: nearly half of the engineering students are the children of managers and people in higher intellectual professions. This category represented about 16% of the working population in France in 2013 (Insee, 2013). Parents play a decisive role in encouraging their children to choose engineering as a field of study: it is viewed as a good choice, as it leads to a prestigious profession with many opportunities (European Commission, 2006). Even though enrollment of women has tripled over 25 years, the population of engineering schools is still dominated by men (71% versus 29% in 2015). Women are in the minority in all engineering fields of study, except for agronomy and life sciences, where they account for approximately 62% of the students (Eloy, 2008; IESF, 2018).

Given the above, it seems seminal to examine the true nature of students' motivations in pursuing engineering studies. Their motives vary widely and range from an interest in engineering to job security, from intense social and family pressure to pursuing social prestige. However, students rarely think of this when they start school. There are many issues involved in better understanding their motivation.

For example, one of the issues is a need to diversify the student body by attracting more women and students from lower social classes. Parity and social openness in engineering schools are recurrent concerns that reflect the principle of equal opportunity to accessing higher education and economic and social positions (Compeyron, Baillé and Fruchard, 2010). Several studies show that European countries will gradually face a shortage of technical specialists (Sinclair, 2016). Here again, understanding the motivation to study engineering can help prevent a shortage of graduates when they are increasingly in demand in the job market. From an academic perspective, motivation is a central concept for understanding students' goals (Pintrich, 2003) and explaining their perseverance, performance, satisfaction, and well-being (Guay, Ratelle and Chanal, 2008).

Concepts

Self-determination theory (Deci and Ryan, 1985, 2000) proposes a motivation model frequently used in education (Guay et al., 2008; Ryan and Deci, 2013). The theory identifies several types of motivation, from intrinsic motivation to amotivation, and positions them on a continuum based on their degree of self-determination.

Intrinsic motivation

Intrinsic motivation occurs when people engage in an activity for the enjoyment and satisfaction it brings. As they perform the activity voluntarily and out of interest, the degree of intrinsic self-determination is high.

Amotivation

Amotivation is at the opposite end of the continuum. Individuals are amotivated when they do not perceive a relationship between their actions and the associated consequences. As a result, their level of self-determination is low. They cannot find meaning in their actions and wonder why they do them, eventually abandoning them.

Extrinsic motivation

Extrinsic motivation lies between these two extremes. It is a set of behaviours driven by instrumental reasons. Extrinsically motivated individuals engage in an activity because they want to benefit from it by earning a reward or avoiding something unpleasant. Extrinsic motivation is broken down into four components that differ in their degree of self-determination. In ascending order of self-determination, extrinsic motivations are distinguished by external, introjected, identified and integrated regulation (Ryan and Deci, 2000a)

By external regulation

Motivation by external regulation induces behaviours controlled by external forces or circumstances. Individuals act primarily to obtain a reward or avoid punishment (material, social) from their environment.

By introjected regulation

In motivation by introjected regulation, individuals are motivated by more or less conscious and internalized pressures. These pressures are diverse: to avoid feeling guilt, remorse, shame or anxiety, or to reinforce the ego, self-esteem or self-worth. A classic form of introjection involving the ego is where an individual is motivated to demonstrate their abilities in order to maintain their self-worth.

By identified regulation

Motivation by identified regulation means performing an activity and engaging in it voluntarily because they have consciously identified it to be important. Individuals engage in an activity not because they "have to" (introjected or external regulation), but because they "want to," even though the activity may be unpleasant (Blais, Brière, Lachance, Riddle and Vallerand, 1993).

By integrated regulation

In motivation by integrated regulation, the individual performs an activity because they believe it to be consistent with their value system and needs.

In self-determination theory, the distinction between intrinsic and extrinsic motivations has gradually been replaced by the contrast between autonomous motivation (intrinsic, integrated and identified regulation) and controlled motivation (introjected and external regulation).

Numerous studies show that, on the continuum of self-determination, the more motivation leans toward intrinsic regulation, the more positive the consequences are from an emotional, cognitive and behavioural perspective.

Conversely, when the level of self-determination decreases or when the individual is amotivated, the consequences are generally negative (Guay et al., 2008; Ryan and Deci, 2013). In the domain of education, the most self-determined forms of motivation are associated with higher performance (Chédru, 2015; Fortier, Vallerand and Guay, 1995; Kaufman, Agars and Lopez-Wagner, 2008; Komarraju, Karau and Schmeck, 2009; Kusurkar, Ten Cate, Vos, Westers and Croiset, 2013), better learning strategies, greater perseverance (Blanchard, Pelletier, Otis and Sharp, 2004; Ratelle, Guay, Vallerand, Larose and Senécal, 2007; Vallerand and Bissonnette, 1992; Vansteenkiste, Sierens, Soenens, Luyckx and

Lens, 2009; Vansteenkiste, Simons, Lens, Sheldon and Deci, 2004) and increased academic satisfaction and well-being (positive emotions, self-esteem; Baker, 2004; Black and Deci, 2000; Litalien, Guay and Morin, 2015; Ryan and Deci, 2000b). On the other hand, the more externally motivated or amotivated the student, the more likely they are to become disengaged and drop out of school (Hardre and Reeve, 2003; Litalien et al., 2015; Vallerand, Fortier and Guay, 1997); their performance is poorer and they experience negative emotions more frequently (stress, anxiety; Baker, 2004; Kaufman et al., 2008).

Assessment tools

In the numerous studies on the theory of self-determination in the context of education, two scales are mainly used (Guay et al., 2008): the Échelle de motivation en éducation [Motivation toward Education Scale] (EME; Vallerand, Blais, Brière and Pelletier, 1989) and the *Academic Self-Regulation Questionnaire* (SRQ-A; Ryan and Connell, 1989). The first scale is generally used in secondary school or higher, while the second is used in primary school.

When these scales cannot take into account certain specificities related to the context (e.g. the nature of the studies pursued or the age and maturity of the respondents), authors have proposed new tools. Thus, the Échelle de motivation aux études de doctorat [Motivation for PhD Studies Scale] (EMEPhD; Litalien et al., 2015) and the Échelle de motivation en formation des adultes [Adult Education Motivation Scale] (EMFA-24; Fenouillet, Heutte and Vallerand, 2015) were recently developed based on the self-determination theory.

To the best of our knowledge, there has been no motivation scale for engineering studies in a Francophone context proposed to date. By incorporating key elements of their motivation (e.g. participation in scientific and technological advancement, the quest for job security or social prestige), a specific measure would provide a better understanding of the diverse processes that regulate engineering students' behaviour.

Based on the theory of self-determination, the purpose of this article is to develop a motivation scale for engineering studies in a Francophone context and to evaluate its psychometric properties.

Methodology

The steps for developing the Engineering Studies Motivation Scale are based on the guidelines proposed by Churchill (1979) and updated by Roussel (2005) and DeVellis (2017), namely: 1) determining the purpose of the measurement in the light of a literature review, 2) generating the items, 3) determining the format of the measure, 4) verifying the clarity of the items, 5) pre-testing the questions with a sample whose characteristics are similar to those of the target population, 6) analyzing the items, and 7) verifying the validity of the factorial structure of the questionnaire within the target population.

Steps 1 to 4: Generating the scale

Besides the literature review, an exploratory qualitative phase was conducted to generate the measurement scale. This phase had three objectives:

1) Check the relevance of the chosen theoretical approach and its implicit understanding by the engineering students;
2) Formulate questions that speak more directly to respondents. When necessary, some items from the existing scales are rephrased;
3) Identify new items specific to the context of the study.

To achieve this, semi-structured interviews were conducted with 12 engineering students. These included six female students and six male students, six of whom were Licence 1 (L1) level and 6 at the Master 1 (M1) level. Three specialties are represented (nutrition-health, geology and agriculture), with four students per specialty. The average age was 19.5 years (SD = 2.7).

The first question addressed the topic of motivation generally. After providing a simple definition of motivation as “a force that drives action” (Villers, 2015), we asked the engineering students about their motives for pursuing this type of program. A series of questions were then posed to examine the various concepts of self-determination theory. In the case of extrinsic motivation, students were asked about the “behaviours they adopt under internal pressure” (introjected regulation) and about the nature of this pressure. The question about amotivation was: “How does not being motivated affect you?”

As the question of motivation is likely to raise very personal issues for the individuals interviewed, semi-directed individual interviews were preferred to group interviews. A climate of trust was established by recalling the strictly confidential nature of the exchanges and the data collected. The interviews lasted an average of 1.5 hours and were transcribed in their entirety for analysis (categorical content analysis). The total number of interviews (12) was determined by the semantic saturation of the data. An initial sample of 41 items (see Appendix) was selected from the exploratory qualitative phase and academic research. A general question asked respondents to specify their reasons for pursuing engineering studies by rating their response to each item on a seven-point Likert scale, from 1 “strongly disagree” to 7 “strongly agree,” with a mid-point of 4 “neither agree nor disagree.”

Steps 5 and 6: Pre-testing questions with a sample whose characteristics are similar to those of the target population and analysis of items

The pre-testing step took place in two phases. In the first phase, the responses of 462 engineering students from two specialties (nutrition-health and geology) were collected (see Table 1, first collection). A series of exploratory factor analyses was performed to eliminate items with unsatisfactory psychometric qualities. Internal consistency reliability was assessed using Cronbach’s alpha coefficient (α). At the end of this phase, 22 items were retained and seven dimensions were identified.

To verify the factorial stability of the previously obtained scale and to further refine the measurement instrument, if necessary, 545 engineering students enrolled in an agriculture specialty were surveyed in a second phase (see Table 1, 2nd collection). An exploratory factor analysis was conducted and Cronbach’s alpha coefficient was used as a measure of internal consistency reliability. With the same factorial structure as previously obtained, the results indicated that the seven-factor structure is stable regardless of the engineering students’ specialty (nutrition-health, geology, agriculture). Between the two measurement times, a return to the item-generation stage is ideally recommended (Churchill, 1979; Roussel, 2005). Due to lack of time, this recommendation could not be followed, with the result that the number of items per dimension was considered insufficient by some authors (Brown, 2015). This point will be mentioned in the limitations of the study.

Step 7: Verifying the validity of the factorial structure of the questionnaire with the target population

In the third data collection, 864 engineering students from three specialties (agriculture, nutrition-health, and geology) were surveyed. The seven dimensions identified by the exploratory factor analyses were validated by a confirmatory factor analysis. Internal consistency reliability was examined using Cronbach's alpha and Jöreskog's rhô coefficients (ρ; Fornell and Larcker, 1981; Jöreskog, 1971). An analysis of construct validity, broken down into convergent and discriminant validity (Campbell & Fiske, 1959), was also performed following the approach of Fornell and Larcker (1981), supplemented by Bagozzi and Yi (1989) and by Bagozzi, Yi and Phillips (1991). Due to the development of the confirmatory factor analysis, this approach facilitates the measurement of these two validities compared to Campbell and Fiske's traditional multitrait-multimethod approach (MTMM, 1959).

The scale refinement process thus took place in two phases. In the first phase, exploratory factor analyses conducted on the first two data collections allowed the factorial structure of the measure to emerge. The second phase, carried out from the third data collection, corresponds to the confirmatory factor analysis and the estimation of the reliability and the construct validity of the measure. Its purpose was to validate the factorial structure obtained.

The common factor extraction method (maximum likelihood) with oblique rotation (oblimin) was applied to carry out the exploratory factor analyses. This extraction method is preferable to principal component analysis for identifying latent factors and assigning items to them (Bourque, Poulin and Cleaver, 2006; Conway and Huffcutt, 2003). The choice of the oblique rotation is justified by the expected correlations among the factors that all measure the same concept (Bourque et al., 2006). For each of the three collections, descriptive statistics showed that the skewness and kurtosis indicators are respectively less than 2 and 3 in absolute value. According to Kline (2016), none of these indicators exceeds univariate non-normality thresholds that can be characterized as severe. In addition, from the three collections, 16 responses that contained extreme values, i.e. outliers, were eliminated based on the Mahalanobis distance calculation (Tabachnick and Fidell, 2007).

Table 1
Specialties and socio-demographic data of engineering students in the three data collections

	1st collection	**2nd collection**	**3rd collection**
N° of respondents	462	545	864
Speciality	– nutrition-health (n = 274) – geology (n = 188)	– agriculture	– agriculture (n = 411) – nutrition-health (n = 266) – geology (n = 187)
Sex	70.6% female	47.5% female	60.5% female
Average age	19.6 (SD = 2.1)	19.7 (SD = 2.1)	21.3 (SD = 1.3)
Year of study	– 54.5% L1 – 45.5% M1	– 49% L1 – 51% M1	– 100% M1

Note. SD = standard deviation; L1 = Licence 1; M1 = Master 1.

Following the recommendations of Anderson and Gerbing (1988), several confirmatory factor analyses were conducted to assess whether alternative models, specified in the light of the theoretical foundations, had better fit statistics. Four models were tested.

In the first model (Model 1), all items are linked to a single factor called motivation. The second model (Model 2) distinguishes three factors: autonomous motivation (intrinsic and identified regulation), controlled motivation (introjected and external regulation) and amotivation. The third model (Model 3) includes the seven subscales of motivation related to a second-order factor. Finally, the fourth model (Model 4) represents the seven identified subscales correlated with each other.

Several indices were used to estimate the adequacy of the theoretical matrix to the empirical data: the chi-square and its ratio to the degrees of freedom (χ^2/ddl; Jöreskog, 1969), goodness of fit index (GFI), adjusted goodness of fit index (AGFI; Jöreskog and Sörbom, 1984), root mean square error of approximation (RMSEA; Steiger, 1990), standardized root mean square residual (SRMR; Bentler, 1995), Tucker-Lewis index (TLI; Tucker and Lewis, 1973), comparative fit index (CFI; Bentler, 1990) and lastly, the Akaike information criterion (AIC; Akaike, 1987).

A χ^2/ddl value of less than 5 reflects a good fit of data to the model (Jöreskog and Sörbom, 1993). Models with GFI, AGFI, TLI and CFI values greater than or equal to 0.90 are generally considered adequate

(Bentler and Bonett, 1980; Marcoulides and Schumacker, 1996), while those with values greater than or equal to 0.95 are described as valuable (Hu and Bentler, 1999). With a RMSEA of less than 0.07 (Steiger, 2007) and a SRMR of less than 0.08 (Hu and Bentler, 1999), the models are considered satisfactory. As for the AIC, the most appropriate model should be the one with the lowest value (Bentler, 1995).

Results

Exploratory factor analyses

An initial exploratory factor analysis with oblimin rotation was performed on the 41 scale items from the first data collection. The suitability of the data to be analyzed with this type of analysis was verified: the Bartlett's test of sphericity was significant and the KMO index was 0.88. At this point, several items had low communalities (< 0.4). Other items had contributions greater than 0.3 on more than one factor and some had no contribution greater than 0.5 on any of the factors involved. These items were therefore removed and 22 items were kept for further analysis.

When the exploratory factor analysis was conducted on these 22 items, Bartlett's test of sphericity was significant and the KMO index was 0.80. Table 2 presents the factorial structure obtained after rotation. The results indicate that a seven-factor structure emerges, explaining 68.31% of the variance. The communality of the item "but I'm not interested in it" is relatively low, but, given its relevance from a theoretical viewpoint, and to keep a minimum number of items per factor, it was nevertheless retained.

Factor 1: introjected regulation – ego

The first factor relates to a dimension of extrinsic motivation by introjected regulation. It is about putting oneself forward (showing others one's abilities, taking up a personal challenge) and doing "whatever it takes" to succeed. The pressures behind this motivation are related to increasing one's self-esteem and strengthening one's ego.

Factor 2: identified regulation – altruism

The second factor corresponds to the answers that an engineer can provide for "the good of humanity": developing new technological solutions or contributing to sustainable development and scientific, technological and intellectual progress. This is a dimension of extrinsic motivation by identified regulation: the individual's level of self-determination is high because they engage in an activity they consider important.

Factor 3: external regulation – security

The third factor represents a facet of extrinsic motivation by external regulation, the quest for security: having the guarantee of a job on graduating from school and a satisfactory salary.

Factor 4: amotivation

The fourth factor is amotivation. This is the pursuit of a degree in engineering despite a lack of interest and a sense of wasting time.

Factor 5: introjected regulation – conscience

The fifth factor raises once again the dimension of extrinsic motivation by introjected regulation, but this time targets the desire to avoid unpleasant emotions. By enrolling in engineering studies, it is possible to avoid regret, self-pity and guilt.

Factor 6: external regulation – social prestige

The sixth factor defines a dimension of extrinsic motivation by external regulation. A quest for social recognition and prestige underlies all of the items that make up this factor: aiming for a recognized social status, a high hierarchical position and rapid career development.

Factor 7: intrinsic motivation

The seventh factor represents intrinsic motivation. The pursuit of an engineering degree is a stimulating activity that satisfies one's intellectual curiosity.

To assess the internal consistency of the measures, Cronbach's alpha coefficients were calculated for each of the seven factors. They ranged from 0.70 (intrinsic motivation) to 0.86 (ego) (see Table 2).

A second data collection from 545 agricultural engineering students was conducted to verify the stability of the identified factorial structure. An identical factorial structure was obtained after rotation (see Table 3). Bartlett's test of sphericity was significant and the KMO index was 0.82. The seven factors explained 68.84% of the variance. The reliability coefficients ranged from 0.72 (intrinsic motivation) to 0.87 (ego).

Table 2

Results of the exploratory factor analysis (Step 1, n = 462, excluding values below 0.30)

Dimension	**Item**	**Factor**							**Communality**
		F1	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	
Ego α = 0.86	because I want to prove to myself that I can do it	0.78							0.64
	to show others what I can do	0.74							0.55
	because I want to prove to myself that I can succeed, whatever it takes	0.63							0.57
	to meet a personal challenge	0.61							0.51
Altruism α = 0.77	because it will allow me to develop new technological solutions for the benefit of humanity		0.93						0.83
	because it will allow me to develop new solutions better adapted to sustainable development		0.63						0.42
	because it will allow me to contribute to scientific, technological and intellectual progress		0.52					0.32	0.54
Security α = 0.75	because it will guarantee employment after graduation (won't find myself unemployed)			0.73					0.56
	because I'm looking for job security			0.68					0.56
	because I'm looking for a comfortable salary to meet my daily needs (personal, family)			0.68					0.57
Amotivation α = 0.71	but I feel I'm wasting my time				0.71				0.58
	although I don't see what I'll gain from it				0.68				0.51
	but I'm not interested in it				0.56				0.30

Dimension	Item	Factor							Communality
		F1	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	
Conscience α = 0.76	because my conscience would bother me if I didn't do it					0.88			0.79
	because I'd be mad at myself if I didn't do it					0.70			0.51
	because I don't want to have any regrets					0.46			0.42
Prestige α = 0.76	because I'm looking for a high-ranking position						0.88		0.74
	because I'm looking for a recognized social status						0.64		0.54
	because I'm looking for a rapid career development						0.53		0.40
Intrinsic Motivation α = 0.70	for enjoyment							0.70	0.41
	to satisfy my intellectual curiosity							0.64	0.41
	because it's exciting/stimulating							0.53	0.61
	Eigenvalue	4.51	3.44	2.19	1.45	1.25	1.19	0.99	
	Explained variance (%)	20.48	15.65	9.94	6.61	5.70	5.42	4.51	

Table 3

Results of the exploratory factor analysis (Step 2, n = 545, excluding values below 0.30)

Dimension	**Item**	**Factor**							**Communality**
		F1	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	
Ego α = 0.87	because I want to prove to myself that I can do it	0.78							0.62
	because I want to prove to myself that I can succeed, whatever it takes	0.74							0.60
	to meet a personal challenge	0.68							0.57
	to show others what I can do	0.65							0.48
Amotivation α = 0.73	although I don't see what I'll gain from it		0.74						0.55
	but I'm not interested in it		0.64						0.44
	but i feel I'm waisting my time		0.60						0.52
Prestige α = 0.75	because I'm looking for a high-ranking position			0.79					0.70
	because I'm looking for a recognized social status			0.70					0.55
	because I'm looking for a rapid career development			0.52					0.43
Altruism α = 0.75	because it will allow me to develop new technological solutions for the benefit of humanity				0.87				0.72
	because it will allow me to contribute to scientific, technological and intellectual progress				0.60				0.59
	because it will allow me to develop new solutions better adapted to sustainable development				0.58				0.38

Dimension	Item	Factor							Communality
		F1	F2	F3	F4	F5	F6	F7	
Conscience α = 0.76	because my conscience would bother me if I didn't do it					0.81			0.70
	because I'd be mad at myself if I didn't do it					0.76			0.5
	because I don't want to have any regrets					0.49			0.41
Security α = 0.78	because it will guarantee employment after graduation (won't find myself unemployed)						0.84		0.71
	because I'm looking for a comfortable salary to meet my daily needs (personal, family)						0.67		0.64
	because I'm looking for job security						0.62		0.42
Intrinsic motivation α = 0.72	because it's exciting/stimulating							0.69	0.60
	for enjoyment							0.63	0.45
	to satisfy my intellectual curiosity							0.60	0.42
	Eigenvalue	4.84	3.26	2.20	1.38	1.29	1.20	0.97	
	Explained variance (%)	22.01	14.83	9.99	6.27	5.85	5.47	4.41	

The results of the exploratory factor analyses indicated that the seven-factor structure was stable regardless of the engineering students' specialty (nutrition-health, geology, agriculture). Confirmatory factor analyses could therefore be conducted on the 22 items relating to the seven dimensions of motivation.

Assessing the factorial structure of the scale

To confirm the factorial structure obtained, 864 engineering students from three specialties (agriculture, nutrition-health, and geology) completed the questionnaires. Confirmatory factor analyses were conducted using AMOS software, version 22.0 (Arbuckle, 2013). The estimation method used was maximum likelihood. Few data were missing (less than 1% for all data collected); these were systematically replaced by the mean of the item concerned. Note that there are many disadvantages to mean imputation (for more details, see Hair, Anderson, Tatham and Black, 1998). However, this method was chosen for its simplicity and the fact that it is acceptable when the percentage of missing values is low (Tabachnick and Fidell, 2007).

The factorial contributions (λ_i) were all significant. The data obtained by the Student's t-test were greater than 1.96 at the 5% significance level for all items. Squared multiple correlations (R^2) all have values close to or greater than the threshold of 0.5 (Fornell and Larcker 1981; see Table 4). We opted to keep the three items whose R^2 values fell markedly below the required threshold ("to satisfy my intellectual curiosity," "because I'm looking for job security" and "but I'm not interested in it"), so as not to weaken their corresponding subscale, which would then contain only two items. We also verified that each of these three items was consistent with its corresponding subscale, i.e. intrinsic motivation, quest for security and amotivation, respectively.

The four factor models were tested (see Table 5) and compared. The indices show that, compared to the other three models, the first-order seven-factor model (Model 4) corresponding to the seven postulated types of motivation best fit the data. The fit indices of this model were satisfactory.

Internal consistency reliability was examined in each of the seven subscales using Cronbach's alpha and Jöreskog's (1971) rhô coefficient measurements. With values between 0.72 and 0.87 for Cronbach's alpha and between 0.73 and 0.83 for Jöreskog's rhô (see Table 4) and according

Table 4

Results of confirmatory factor analysis on the Motivation Scale for Engineering Studies (n = 864)

Dimension	**Item**	λ_i	R^2
Intrinsic motivation $\alpha = 0.72$ $\rho = 0.73$	because it's exciting/stimulating	0.77	0.60
	for enjoyment	0.72	0.52
	to satisfy my intellectual curiosity	0.57	0.32
Altruism $\alpha = 0.76$ $\rho = 0.77$	because it will allow me to develop new technological solutions for the benefit of humanity	0.84	0.70
	because it will allow me to contribute to scientific, technological and intellectual progress	0.67	0.45
	because it will allow me to develop new solutions better adapted to sustainable development	0.66	0.43
Ego $\alpha = 0.87$ $\rho = 0.83$	because I want to prove to myself that I can do it	0.75	0.56
	because I want to prove to myself that I can succeed, whatever it takes	0.79	0.62
	to meet a personal challenge	0.75	0.56
	to show others what I can do	0.65	0.43
Conscience $\alpha = 0.79$ $\rho = 0.80$	because my conscience would bother me if I didn't do it	0.83	0.69
	because I'd be mad at myself if I didn't do it	0.70	0.49
	because I don't want to have any regrets	0.71	0.51
Prestige $\alpha = 0.77$ $\rho = 0.78$	because I'm looking for a high-ranking position	0.78	0.62
	because I'm looking for a recognized social status	0.70	0.50
	because I'm looking for a rapid career development	0.72	0.52
Sécurité $\alpha = 0.73$ $\rho = 0.76$	because it will guarantee employment after graduation (won't find myself unemployed)	0.74	0.54
	because I'm looking for a comfortable salary to meet my daily needs (personal, family)	0.78	0.61
	because I'm looking for job security	0.61	0.37
Amotivation $\alpha = 0.75$ $\rho = 0.76$	although I don't see what I'll gain from it	0.73	0.53
	but I'm not interested in it	0.61	0.38
	but i feel I'm wasting my time	0.80	0.64

Note. λ_i = factorial contribution; R^2 = squared multiple correlation.

Table 5

Post adjustment indices for the different models tested

Model Overall sample (n = 864)	χ^2	**ddl**	χ^2**/ddl**	**GFI**	**AGFI**	**RMSEA [90%]**	**SRMR**	**TLI**	**CFI**	**AIC (independent model)**
Model 1	4462.23	209	21.35	0.59	0.51	0.154 [0.150-0.157]	0.153	0.31	0.37	4550.23 (7035.34)
Model 2	2725.11	206	13.23	0.73	0.66	0.119 [0.115-0.123]	0.102	0.58	0.63	2819.11 (7035.34)
Model 3	1288.29	202	6.38	0.88	0.84	0.079 [0.075-0.083]	0.106	0.82	0.84	1390.29 (7035.34)
Model 4	722.50	188	3.84	0.93	0.91	0.057 [0.053-0.062]	0.049	0.90	0.92	852.50 (7035.34)

Note. Model 1 = 1 factor: all items are related to a single factor called motivation.
Model 2 = 3 factors: autonomous motivation (intrinsic and altruism), controlled motivation (ego, prestige, conscience, security) and amotivation.
Model 3 = the 7 motivation subscales linked to a second-order factor.
Model 4 = 7 first-order factors: the 7 subscales correlated to each other.

to the recommendations of Nunnally (1967) and Fornell and Larcker (1981) for Cronbach's alpha and Jöreskog's rhô coefficients, respectively, the results indicate good internal consistency reliability for each of the motivation subscales.

According to Campbell and Fiske (1959), construct validity aims to ensure that the scale measures perfectly and solely the given construct. It can be broken down into convergent validity and discriminant validity. A scale has good convergent validity when several measures of the same construct are sufficiently strongly correlated to each other. A scale has good discriminant validity when different measures of the construct have sufficiently low correlations with distinct constructs (Bagozzi et al., 1991). Convergent validity is assessed using two criteria (Fornell and Larcker, 1981): the t-test associated with each of the factorial contributions (λ_i) must be significant (> 1.96) and the average variance extracted (rhô of convergent validity or ρ_{cv}) must be greater than 0.5. Both conditions are met (see Table 6) for each construct, except for intrinsic motivation, for which the extracted average variance is close, yet slightly below the required threshold (ρ_{cv} = 0.48). However, an extracted average variance for new scales is considered acceptable starting at a value of 0.45 (Netemeyer, Bearden and Sharma, 2003). Given the threshold, we can therefore posit that the criterion of convergent validity of intrinsic motivation is also acceptable.

The principle of the discriminant validity test is to verify that each construct shares more variance with its measures than with the other constructs (Roussel, Durrieu, Campoy and El Akremi, 2002). Thus, it is necessary to ensure that the square root of ρ_{cv} of each construct is greater than the absolute values of the correlations shared between this construct and the other constructs (Hulland, 1999). This condition was verified (see Table 6).

Analysis of correlations between constructs partially supports the presence of a continuum of self-determination, as postulated by Deci and Ryan (1985). A pattern of "simplex" correlations (Guttman, 1954) occurs when correlations between adjacent constructs are relatively high, while correlations between distant constructs gradually decrease to negative. Overall, the results support the presence of a continuum of self-determination (see Table 6). The highest correlations are observed between adjacent constructs on the continuum, such as intrinsic motivation and identified

Table 6

Assessment of the discriminant validity of the Motivation Scale for Engineering Studies and correlations between constructs

ρ_{cv}	**T-tests confidence interval**	**Intrinsic**	**Altruism**	**Ego**	**Conscience**	**Social prestige**	**Security**	**Amotivation**
		0.48	**0.53**	**0.54**	**0.57**	**0.51**	**0.54**	**0.52**
1. Intrinsic	[13.7-14.3]	(0.69)						
2. Altruism	[14.9-17.0]	0.45**	(0.73)					
3. Ego	[17.6-18.3]	0.24**	0.17**	(0.74)				
4. Conscience	[17.5-18.6]	-0.05	-0.03	0.62**	(0.75)			
5. Social prestige	[17.2-18.6]	0.16**	0.01	0.40**	0.28**	(0.74)		
6. Security	[14.1-15.9]	0.10	-0.06	0.33**	0.28**	0.62**	(0.71)	

Note. The square roots of ρ_{cv} are shown on the diagonal in parentheses.
* $p < 0.05$; ** $p < 0.01$.

altruism motivation ($r = 0.45$ and $p < 0.01$). Conversely, the most distant constructs obtain lower or negative coefficients, such as intrinsic motivation and amotivation ($r = -0.63$ and $p < 0.01$). High correlations were also observed between the two introjected motivation constructs (ego and conscience, $r = .62$ and $p < .01$) and between the two external motivation constructs (security and social prestige, $r = .62$ and $p < .01$).

On the other hand, the pattern of correlations revealed several discrepancies. For example, the correlation between introjected ego motivation and identified altruism motivation ($r = 0.17$ and $p < 0.01$) should be higher than that found between introjected ego motivation and intrinsic motivation ($r = 0.24$ and $p < 0.01$). Several correlations were not significant, such as intrinsic motivation with introjected motivation conscience or with external motivation security. The significant correlations mostly support the self-determination continuum.

The results indicate that the Motivation Scale for Engineering Studies is reliable and has a variety of evidence to support its validity.

Discussion

Based on the theory of self-determination, the purpose of this study was to develop an instrument for measuring the motivation for engineering studies. The process for creating the scale followed the approach proposed by Churchill (1979) and updated by Roussel (2005) and DeVellis (2017). A literature review, semi-structured interviews and three rounds of data collection were used to develop a scale of 22 items divided into 7 dimensions: intrinsic motivation, extrinsic motivations characterised by identified regulation (altruism), introjected regulation (ego and conscience), external regulation (security and social prestige) and finally, amotivation.

The scale met commonly accepted reliability criteria. Its construct validity (broken down into convergent and discriminant validity) was verified. The results indicate that the relationships between the constructs partially supported the self-determination continuum. Further evidence of validity was gathered from that defined by Downing (2003) and Messick (1995), in particular face and content validity (literature review supplemented by an exploratory qualitative phase).

The dimensions of intrinsic motivation and amotivation covered settings comparable to those present in scales validated in the literature (Guay, Mageau and Vallerand, 2003; Vallerand et al., 1989). Extrinsic motivation by identified regulation (altruism) refers to the contributions for the "common good" that an engineer can bring to a society: participate in scientific and intellectual progress, develop new technological solutions, and contribute to sustainable development. This dimension is specific to the context of our study and has no equivalent in the literature among the scales derived from the self-determination theory. The two dimensions of extrinsic motivation by introjected regulation (ego and conscience) are present in similar forms in the literature (Guay et al., 2003; Vallerand et al., 1989), but never simultaneously in the same scale. Extrinsic motivation by external regulation (security) has no equivalent in the literature among the scales derived from self-determination theory. It reflects the desire to secure one's future and to have a guarantee of professional opportunities (not to become unemployed, to earn a decent living). Extrinsic motivation by external regulation (social prestige) appears in the scales addressed in the literature (Guay et al., 2003; Vallerand et al., 1989). It reflects strong social ambitions: a recognized social status, a high hierarchical position or rapid career development.

Developing a multi-dimensional motivation scale for engineering studies has valuable theoretical and practical implications. In terms of theoretical implications, it becomes possible to test hypotheses on the antecedents (such as teaching styles or the motivation climate established by the teacher) and outcomes (such as performance, perseverance, satisfaction, well-being) of the various types of motivation of engineering students. The scale thus opens up new avenues of research with this understudied population. From a more applied perspective, a detailed description and better understanding of the underlying motivations for pursuing engineering studies will, for example, help guide future interventions and actions aimed at attracting more females and students from lower social backgrounds to these paths.

Limitations

Various limitations of this study need to be highlighted. First of all, the scale consists mainly of three items per dimension; ideally, it should contain at least four (Brown, 2015). The temporal stability of the scale was not assessed. Although some evidence of validity was obtained, further analysis will have to be conducted to complete the concept of validation as defined, for example, by Downing (2003) and Messick (1995). Thus, additional proof of internal structure validity, but also of response process validity, relationship with other variables and with outcome will be required. Although the relationships between the constructs broadly support the self-determination continuum, correlations that do not match those expected or that are not significant will need to be scrutinized in further studies. The scale was tested by interviewing students with specialties in earth, life and environmental sciences, where the number of female students was relatively high. This study should be repeated with students from other fields of study (e.g. computer science and electronics) and, for cross-cultural validation of the scale, with students from other cultures and nationalities. Future research could focus on differentiating the motivation of students according to the socio-demographic data collected and their fields of study.

In conclusion, although the proposed scale represents a recent tool whose validation process will have to be continued in future novel research, the results of this study attest to the quality of its psychometric properties. These characteristics, as well as the seven-dimension spectrum of motivation, should make it a useful tool for conducting research among Francophone engineering students.

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Annexe. Phrasing and origin of the items selected in the initial questionnaire

The items were introduced by the general question: "Why are you pursuing engineering studies? I am pursuing engineering studies..."

After the exploratory qualitative phase, items from existing scales were reworded, where necessary, to speak more directly to respondents. For example, the item "because my studies allow me to continue to learn about many things that interest me" (Vallerand et al., 1989) became "because these studies are of interest to me."

Nº	Item	Source
1	for enjoyment	Vallerand et al., 1989
2	because these studies are of interest to me	Vallerand et al., 1989
3	because I enjoy learning	Guay et al., 2003
4	because I like pushing myself	Guay et al., 2003
5	because it’s fun	Ryan and Connell, 1989
6	to satisfy my intellectual curiosity	Exploratory qualitative phase
7	because I like these studies	Exploratory qualitative phase
8	because it’s exciting/stimulating	Exploratory qualitative phase
9	to acquire skills that will be useful in the future	Vallerand et al., 1989
10	to best prepare for my work future	Vallerand et al., 1989
11	to have many options to choose from when I graduate	Vallerand et al., 1989
12	because I chose it as a way to achieve my personal goals	Guay et al., 2003
13	because it will allow me to be involved in scientific, technological and intellectual progress	European Commission, 2006
14	because it will allow me to develop new technological solutions for the good of humanity	European Commission, 2006
15	because it will allow me to develop new solutions better adapted to sustainable development	European Commission, 2006
16	because it will allow me to prepare the ground for future generations	Qualitative exploratory phase
17	because I want to prove to myself that I can do it	Vallerand et al., 1989
18	because I don’t want to disappoint certain people around me (e.g. parents, friends, teachers, etc.)	Guay et al., 2003
19	because I’d be mad at myself if I didn’t do it	Guay et al., 2003
20	to show others what I can do	Guay et al., 2003
21	because my conscience would bother me if I didn’t do it	Guay et al., 2003

Nº	Item	Source
22	because I feel a «moral» or personal obligation	Guay et al., 2003
23	to be proud of myself	Ryan et Connell, 1989
24	to meet a personal challenge	Exploratory qualitative phase
25	because I don't want to have any regrets	Exploratory qualitative phase
26	because I want to prove to myself that I can succeed, whatever it takes	Exploratory qualitative phase
27	because I have a competitive mindset	Exploratory qualitative phase
28	because I want a high salary: free spending power	Vallerand et al., 1989
29	because I'm looking for a recognized social status	Vallerand et al., 1989
30	because I'm looking for a high-ranking position	Exploratory qualitative phase
31	because I'm looking for rapid career progression	Exploratory qualitative phase
32	for the prestige	Guay et al., 2003
33	because it will guarantee employment after graduation (won't find myself unemployed)	Exploratory qualitative phase
34	because I'm looking for job security	Exploratory qualitative phase
35	because I strive for excellence	Exploratory qualitative phase
36	because I'm looking for a comfortable salary to meet my daily needs (personal, family)	Exploratory qualitative phase
37	but I don't know why	Vallerand et al., 1989
38	but I feel I'm wasting my time	Vallerand et al., 1989
39	but I wonder if I should continue	Vallerand et al., 1989
40	although I don't see what I'll gain from it	Guay et al., 2003
41	but I'm not interested in it	Exploratory qualitative phase