Motivation in Engineering Education

A framework supported by evaluation instruments and enhancement resources

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Abstract: *Motivation is a critical factor in the academic performance, especially in the EHEA context, where the active learning must be promoted. In the case of engineering education, it is particularly necessary to care the student motivation by several reasons. The difficulty of engineering degrees can hinder the motivation of students and it can affect the high levels of absenteeism and dropping out. Thus, it is important to work up frameworks to evaluate and enhance, in addition to technical competences, other competences such as motivation. This paper presents the definition of a motivational framework composed by several instruments, resources, mechanisms and technologies. It allows teachers and academic institutions to evaluate and enhance the motivation of their students. But the most innovative characteristic of the framework lies in the student side; it also allows students to self-evaluate and enhance their motivation by performing questionnaires, recommendations and complementary training activities. In order to validate the proposed solutions, a case study has been successfully performed with 152 students of the Technical University of Madrid. The empirical experience has enabled to confirm the usefulness of the provided framework and to explore motivational aspects related with the engineering education.*

Keywords: *Motivation, Engineering, Teaching, Evaluation instruments, Learning paths, Empirical studies*

I. INTRODUCTION

The European Higher Education Area (EHEA) [1] has placed the student at the center of education, supposing a shift from a teaching-centered education to a learning-centered education. Currently, the students should be trained to be lifelong learners by acquiring several transversal and specific competences [2]. They must set objectives, manage and update the knowledge, learn continuously and be able to adapt themselves to new and changing situations [1, 2]. Consequently, it is important not only to evaluate and enhance technical competences but also other transversal ones like motivation.

As it is depicted in the Figure 1, several factors, like abilities and aptitudes of the students or their academic conditions, affects their performance. Nowadays, it is clearly established that motivation is one of these factors [3, 4]. This is especially true in the case of students of engineering degrees because its difficulty can result in the student a sense of low self-efficacy. It might hinder the student motivation increasing the levels of absenteeism and dropping out to worryingly high levels [5, 6]. Therefore, in recent years, several theoretical and practical studies have provided findings and resources to meet and stimulate engineering student motivation [4, 6, 7].

Since a long time ago there are instruments useful to conduct motivation researches like the MSLQ (Motivational Strategies for Learning Questionnaire) [8], the *Zoller test* [9] or the MAPE- 3 (Motivation to Learning and Execution) [10]. But these instruments are not particularized for the engineering students. The motivational particularities of these students invite to develop new tools to help them to understand and stimulate their motivation [3, 7, 11]. Good examples of this are motivational instruments recently designed for engineering education like the MAE (Motivation and Attitudes in Engineering) [7] or the EMQ-B (Environment Motivational Quality Questionnaire) [11]. The first one is focused on the motivational attitudes of engineering students, and the second on the strategies that engineering teachers can apply to motivate their students.

However, the identified instruments [7, 8, 9, 10, 11] are not very useful to the students because they do not provide them self-diagnosis in motivation aspects neither learning resources nor personalized training plans to develop their motivation. This is especially important in the EHEA context described above, where the students have an active role in their learning process [1, 2]. Consequently, it is necessary to define and validate frameworks designed for engineering students that help them to understand and improve their motivation. These frameworks could be composed by instruments and resources such as diagnosis questionnaires, recommendation systems and learning opportunities.

Fig. 1. Factors that affects the student performance

II. CONTEXT AND OBJECTIVES

At this point it should be mentioned the "Development of socio-emotional skills in UPM" Educative Innovation Project (EIP) from the Technical University of Madrid (UPM) [18], where the present study has been partially performed. The main goal of this Project is to support students and professors in the acquisition of transversal skills, much appreciated in the EHEA as well as in the professional world. Its main hypothesis is as follows: "*Training tools from Emotional Intelligence & Coaching can be used to increase the transversal skills of University students and teachers*".

In this context, the motivation has been one of these transversal skills. The study presented in this contribution is guided by the following hypothesis: "*The motivation of engineering students can be evaluated and enhanced using diagnosis instruments and learning resources*". In this line, the main objectives of this research are:

- To provide a motivational framework for engineering students supported by instruments and resources to evaluate and enhance their motivation
- To use and empirically validate the motivational framework with engineering students
- To study the benefits and outcomes that can be obtained by applying the motivational framework

III. PROPOSAL OF A MOTIVATIONAL FRAMEWORK FOR ENGINEERING EDUCATION

This section contains the definition of a motivational framework tailored to the engineering education. As it is depicted in Figure 2, this framework is composed by several elements designed to enable to the students the self-evaluation of motivation aspects and its enhancement performing recommendations and training activities related to motivation aspects. The framework also allows to teachers and academic institutions to evaluate and enhance the motivation of their students.

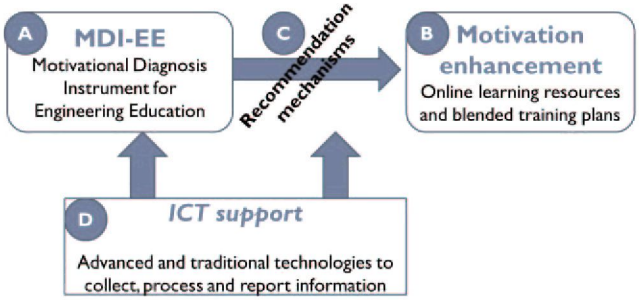

Fig. 2. Components of the Motivational Framework for Engineering Education

A. MDI-EE: An instrument for motivation diagnosis

The main resource provided to evaluate the motivation of the engineering students is the Motivational Diagnosis Instrument for Engineering Education (MDI-EE). The main characteristics of this instrument are as follows:

- Based on consolidated motivation theories, hereinafter called "classical", from well-known authors (McClelland, Adams, McGregor, Vroom, Locke, and Herzberg).
- Represented through 7 motivational areas and 27 motivational indicators adapted to the engineering education.
- Composed by 49 items, which score from 1 to 4, and 2 textual items.
- Available in two versions: student self-evaluation and student-evaluation by teachers.

As it can be observed in the table I, the indicators of the MDI-EE are based on "classical" theories or models (M) and they explore the motivation of engineering students in several ways. M1 does it through their motivational needs (achievement, power and affiliation). M2 considers the rewards received (marks, knowledge, experiences, etc.) and the efforts required (economic costs, temporal dedication, intellectual involvement, etc.). M3 explores the work attitude of the students (comfortable and active predispositions) and M4 their expectative (trust in their own capabilities and the desire and utility of the learning). M5 studies the activity performance of the students using different parameters in the goals definition (difficulty, specificity and participation degree). Lastly, M6 explores several intrinsic (achievement sense, personal and intellectual growth, etc.) and extrinsic (professors, academic conditions, etc.) elements.

TABLE I. MOTIVATIONAL INDICATORS OF THE MDI-EE

Theory [a]	**Indicators**	
	Id	***Name***
Needs (McClelland)	M1.1	Achievement need
	M1.2	Power need
	M1.3	Affiliation need
Equity (Adams)	M2.1	Effort/Reward
	M2.2	Equity
X-Y (Gregor) & Z (Ouchi)	M3.1	Comodity
	M3.2	Proactivity
	M3.3	Integrative climate
Expectatives (Vroom)	M4.1	Desire
	M4.2	Trust
	M4.3	Utility
Goals definition (Locke)	M5.1	Difficulty
	M5.2	Especificity
	M5.3	Participation
Dual factor (Herzberg)	M6.1a	Academic politics
	M6.1b	Teacher supervision style
	M6.1c	Academic conditions

Theory [a]	Indicators	
	Id	*Name*
	M6.1d	Relation with teachers
	M6.1e	Reward in ECTS
	M6.1f	Relation with classmates
	M6.1g	Personal life conciliation
	M6.2a	Accomplishment feeling
	M6.2b	Recognition
	M6.2c	The study itself
	M6.2d	Responsibility
	M6.2e	Progress feeling
	M6.2f	Personal and intellectual growth
General	MGen1	General motivation degree

[a] The motivational indicators are based on "classical" theories adapted to the Engineering Education

The 49 items of the instrument transform the defined indicators in concrete considerations and behaviors of the students. Due to space limitations, these items are presented further together with the case study results.

The analysis and processing of the student responses to the MDI-EE items allow to different actors working over the student motivation in two ways:

- **Teachers and academic institutions**: In this case, the responses of the participating students are jointly treated safeguarding the confidentiality conditions. This treatment generates the global results in a report containing the scores of the dimensions, indicators and items obtained in average by the participating students. This report also contains certain ad-hoc analysis that could be useful like results per school, professor, course, gender, etc. All of this helps teachers and academic institutions to become aware the motivation of their students, improve their teaching style, modify certain policies or academic conditions, and other actions aimed to enhance the student motivation. This approach can be considered more traditional but, as it was presented in previous works [17], remains equally important.
- **Each participating student**: In this case, they receive their individual results with the motivational self-diagnosis and other outcomes generated by the rest of the components of the framework. It helps students to understand the dimensions that affect their motivation and promote its active role in the further work to enhance their motivation. This approach can be considered more innovative because it centers the motivation issue in the student side providing them instruments and resources to evaluate and enhance autonomously their motivation. The rest of the presented framework components are mainly designed under this approach.

B. Motivation enhancement: Learning oportunities

Once the motivational diagnosis of one student has been performed, he/she can consider different actions aimed to improve its motivation but probably he/she needs additional support or training to deal with that. In this sense, and facing the importance of the active role of the students in their learning process, academic institutions should make available to their students opportunities to enhance by themselves certain transversal competences like motivation. Learning Management System (LMS) or face to face workshops of transversal competences are good example of this.

In the context where this contribution took place, the online platform named "*Puesta a Punto*" (PAP) [13] was essential to offer learning opportunities that complement the MDI-EE diagnosis. This LMS provides the students and workers of the UPM resources to deal with transversal competences such as foreign languages, personal skills, project management, etc. Recently, in the context of the mentioned project, an online classroom named "Socio-Emotional Skills Development" has been incorporated.

This online classroom contains resources and activities to deal with several personal competences through different online possibilities like written manuals, interactive exercises, recorded classes, practical videos, and so on. Concretely, the motivation issue is tackled in the self-motivation section of the intrapersonal intelligence module as well as the motivation section of the professional abilities module. Moreover, blended learning in motivation is possible by seminars ECTS-recognized complementary offered to the students to consolidate their online learning.

C. Recommendation mechanisms: Linking MDI-EE and PAP

Normally, the LMS related with complementary skills like the described PAP platform contains many large courses and the students usually follow the proposed learning path. To personalize the learning process of the students to meet their needs using diagnosis instruments and recommended learning paths can be more productive and attractive for them. In this sense, a component to link the MDI-EE diagnosis with PAP resources is incorporated in the proposal framework.

As long as the students have available learning resources like the deployed in PAP platform to deal with motivation competence, the MDI-EE can be complemented by mechanisms to recommend the student personalized learning paths. These recommendations depend on the student diagnosis provided by the MDI-EE. The values obtained in the motivational indicators assessed are used to identify improvement areas and recommend learning paths that will serve to address such areas.

As it is presented in table II, the recommendation rules link the motivational diagnosis of the MDI-EE with the online learning resources of the PAP platform.

TABLE II. RECOMMENDATION RULES LINKING MDI-EE & PAP

Learning path	***Indicators Spring***	***Recommendation (Module/Section/Paragraph)***
LP1	3 x MX.X	EI/Self-motivation/Operation
LP2	3 x MX.X + MGen	EI/Self-motivation/Tools
LP3	M1.X	Proffesional abilities/ Motivation/ Needs Theory
LP4	M2.X	Proffesional abilities/ Motivation/ Equity Theory
LP5	M3.X	Proffesional abilities/ Motivation/ X-Y Theory
LP6	M4.X	Proffesional abilities/ Motivation/ Expectative Theory
LP7	M5.X	Proffesional abilities/ Motivation/ Goals definition Theory
LP8	M6.1.X	Proffesional abilities/ Motivation/ Dual Factor Theory – Intrinsic
LP9	M6.2.X	Proffesional abilities/ Motivation/ Dual Factor Theory – Extrinsic

For example, if the diagnosis of a concrete student reveals that his motivation for achievement (M1.1) is low, these mechanisms would recommend one learning path (LP3) to be followed in order to acquire theoretical knowledge and perform practical exercises to promote their achievement motivation. In short, these mechanisms are intelligent and custom links between the motivational diagnosis and the motivational training.

D. ICT support: Collecting, processing and reporting information

The usage of the MDI-EE and the recommendation mechanisms requires ICT support. They can be applied using traditional methods (physical survey with written test, manual application of recommendations, etc.) but the information processing with ICT tools like spreadsheets or SPSS are necessary. Anyway, the use of advanced ICT will facilitate, improve and extend the framework application.

The proposed framework is supported by the web application *fib360.memgroup.es* [12]. It was initially developed to support multi-subjective surveying processes about transversal competences with configurable test models. Recently, in order to cover the needs arisen from the proposed framework, it has been developed a new module to incorporate at once the use of indicators and recommendation mechanisms.

The MDI-EE test model and the defined recommendation rules have been configured in the mentioned application in order to run the following functionalities:

- Online gathering of the student responses to the MDI-EE test
- Processing of the collected information and application of methods and rules
- Generation of motivational diagnosis using tabular, textual and graphical representations

IV. RESEARCH METHOD: A CASE STUDY

This section presents the case study used as research method to validate empirically the proposed framework. It is described through its research questions, sample description, instruments and methods.

A. Research questions

This case study is designed in order to provide answers, at least, to the following Research Questions (RQ):

- RQ1: Are the "classical" theories of motivation appropriate to evaluate and enhance the motivation of engineering students?
- RQ2: Can be motivation of engineering students evaluated through reliable research instruments?
- RQ3: Can be personalized and blended training plans to enhance the motivation of engineering students provided?
- RQ4: Do engineering students who receive training in motivational skills develop greater motivation than other engineering students? If so, in which sense?

B. Sample description

The **population** under study is engineering students of the UPM. In order to describe the whole population it can be noted that UPM is one of the biggest universities of Spain, with more than 36.000 undergraduate students and 23 schools, in which a total of 39 undergraduate degrees are offered. It is a very national-renowned technical University in Spain and its graduates are highly regarded and demanded by engineering firms.

The **sample** of this study is composed by 152 students from UPM schools of different areas: Computing, Topography and Aeronautics engineering. For the research purposes, the sample can be categorized in the following two groups:

- Non-trained: 92 individuals who made obligatorily the MDI-EE when recommendation mechanisms and PAP were not still available, acting as control group.
- Trained: 60 individuals who made voluntarily personalized blended learning plans on motivation using all the solutions of the framework (MDI-EE, recommendation mechanisms and training).

C. Instruments and methods

The research instruments are the presented MDI-EE, as well as questionnaires designed to know (in a scale from 1 to 4) the student satisfaction with the framework usage. The data collection techniques used was the survey, physical and online. The information collected has been processed using ICT support tools like Excel or SPSS. In the last phases of the research, *fib360.memgroup.es* web application has been also used to collect and report the information. The results have been discussed with motivational skills trainers and engineering teachers.

V. RESULTS

This section contains the results obtained in the case study. They will allow discussing motivation aspects in engineering education and solving empirically the RQ arisen in the study.

A. Validity, consistency and reliability MDI-EE results

The MDI-EE expert revision performed by 4 experts in engineering teaching, pedagogy and motivation discloses that the content validity of the MDI-EE is adequate. This revision also points out that the statistical techniques used to determine validity, consistency and reliability parameters should reveal positive results.

The presented case study, where the MDI-EE has been empirically tested, allow using several statistical techniques like factorial or correlation analysis and KMO and α Cronbach coefficients to make sure the expert revision forecast:

- The factorial analysis (a technique used to found the most important factors and to study the variance distribution) reveals that the 71.27% of the variance is due to 15 factors. Also, it is worth mentioning that the 60% of variance can be explained by 10 factors.
- The correlations analysis (a technique used to found the correlations among the test elements) between the motivation general item and the rest of the items has been performed. All the theories (6 out 6), almost all of the indicators (22 out 27) and the majority of the items (31 out 49) are statically correlated with the general motivation of students.
- The KMO (a coefficient to determine the sampling adequacy of the study) is 0,741.
- The resulting α Cronbach (a coefficient to determine the consistency and reliability of the test) is 0,826.

Following the established findings about the use of these techniques [14, 15], these results are considered positive due to the percentage of variance in the factorial analysis and the number of correlations among the test elements are high, the KMO is between 0,7 and 0,8 (acceptable level) and the α Cronbach is between 0,8 and 0,9 (good level). Consequently, the validity, consistency and reliability of the MDI-EE designed to evaluate the motivational dimension of engineering students have been empirically checked.

B. Descriptive and comparative MDI-EE results

As it can be observed in the Table III, in general (column Total) the results reveal a good motivation level of the 152 engineering students who fulfilled the MDI-EE. Looking at the comparative results (columns Training group and Non-trained group), several descriptive differences can be found between both groups. Furthermore, differences statistically significant ($p\text{-value} < 0.05$) have been found using the T-Student technique for independent samples [16].

TABLE III. COMPARATIVE MDI-EE RESULTS BETWEEN STUDENTS TRAINED AND NON-TRAINED IN MOTIVATION SKILLS

Area (*MX.Model*)| Item [b]	***Total***	***Trained group***	***Non-trained group***
OPPORTUNITIES (*M1.NEEDS*)			
I appreciate the opportunity to develop and surpass difficult tasks *	3,50	3,65	3,40
I appreciate the opportunity to pursue excellence in the tasks that I perform	3,28	3,42	3,24
I appreciate the opportunity to influence positively on my peers *	3,42	3,60	3,31
I appreciate the opportunity to obtain recognition of my teachers *	3,17	3,00	3,29
I appreciate the opportunity to have friendly relationships with colleagues	3,57	3,57	3,59
I appreciate the opportunity to work collaboratively with my classmates	3,37	3,44	3,34
EFFORTS & REWARDS (*M2. EQUITY*)			
I think that my effort (hours of dedication, energy, etc.) is offset by the reward receipt (credit, qualification, knowledge, etc.)	2,57	2,54	2,60
I think the effort is greater than the reward received	2,74	2,72	2,76
I think the effort is less than the reward received	1,93	1,86	1,99
I think teachers assess me with a rating according to my effort and capabilities	2,72	2,58	2,82
I am confident that evaluation of teachers are fair and equitative to all students	2,67	2,53	2,77
STUDY PREDISPOSITION (*M3.X-Y*)			
I consider myself a student who tries to avoid the hard work and academic responsibilities as far as possible	1,78	1,70	1,84
I consider myself academically a bit ambitious student, I try to meet the minimum established and not push myself too	1,82	1,85	1,80
I consider myself an active learner who seeks and accepts academic responsibilities as far as possible	3,09	3,15	3,05
I consider myself a person with a high desire to develop myself academically, I try to beat me as much as I can *	3,30	3,37	3,26
I believe teachers and University care about my personal and academic well-being. *	2,29	2,07	2,44
I think that the concern of the teachers and University for my welfare favor my predisposition to academic activities	2,53	2,38	2,63
DESIRES (*M4. EXPECTATIVES*)			
I have a high desire to pursue my studies, I usually like going to class, doing practical works, studying, etc.	3,03	3,03	3,04
I have a strong desire to finish my studies, I like the idea of getting an engineering degree	3,75	3,63	3,84
I think I have enough skills to overcome my studies	3,64	3,67	3,63
I believe that with reasonable effort I will achieve to complete my studies successfully	3,71	3,69	3,73
I expect that the effort I am making in the University will be useful to develop my future career	3,32	3,28	3,35
I believe that the effort that I am making in the University is worth it	3,37	3,37	3,37
PERFORMANCE (*M5.GOALS*)			
I think that I perform better when the activities have a difficulty level that I estimated initially high	2,93	3,02	2,88

Area (*MX.Model*)| Item [b]	*Total*	*Trained group*	*Non-trained group*
I believe that high academic, but achievable, challenges lead me to perform better	3,24	3,32	3,20
I think that I perform better when the activities are clearly defined *	3,58	3,43	3,67
I think that I perform better when the activities are explained both verbally and in writing	3,48	3,51	3,48
I think that I perform better when I can participate in the definition of the activities that I carry out	3,15	3,26	3,09
I consider that my level of commitment towards the activities increases when I can participate in their definition	3,08	3,15	3,03
EXTRINSIC ELEMENTS (*M6.1.DUAL-1*)			
The physical resources available at the University are appropriate: facilities, classrooms, laboratories, library, transportation, etc. *	2,92	2,64	3,10
Virtual resources providing me by the University are suitable: virtual campus, email, etc.	3,23	3,12	3,30
In general, virtual classrooms have all necessary materials, being a great repository of information	2,86	2,76	2,93
In general, virtual classrooms are a good place to exchange ideas with peers and / or teachers *	2,33	2,05	2,52
Academic relationships with colleagues are good *	3,40	3,23	3,52
Personal relationships with colleagues are good*	3,48	3,32	3,59
The teachers masters the subjects they teach and know how to teach me *	2,58	2,35	2,74
The teachers know well how to motivate me, their styles and attitudes stimulate my motivation *	1,97	1,68	2,18
Teachers supervise my work properly, I think they are good tutors *	2,23	1,83	2,51
The number of hours required by my college allows me to have personal life	2,49	2,41	2,54
INTRINSIC ELEMENTS (*M6.2.DUAL-2*)			
I appreciate the sense of accomplishment that I get when I learn something new or acquire a new skill	3,76	3,80	3,75
I appreciate the sense of accomplishment that I get when I make a work or practice successfully	3,78	3,78	3,78
I appreciate the sense of accomplishment that I get when passing a course with a good grade	3,75	3,67	3,82
I enjoy the knowledge that I learn at the University, I can say I like my career	3,44	3,37	3,49
I enjoy the advancement feeling I get pursuing my studies, I can say I like to surpass myself	3,58	3,58	3,58
I believe that studying is an opportunity to grow with challenging activities *	3,41	3,53	3,34
I consider myself primarily responsible for my learning process	3,37	3,38	3,37
I consider myself primarily responsible for my academic results *	3,40	3,47	3,36
I believe that through college I am developing myself personally and academically	3,50	3,48	3,51
GENERAL MOTIVATION (N/A)			
In general, I consider myself a person with a high degree of motivation	3,23	3,27	3,19

[b.] Statistical differences at p-value < 0.05 are indicated through '*' symbol

C. *Satisfaction of the students using the motivational framework*

Table IV presents the results obtained surveying the 60 students (previously referred as 'Trained group') who were able used completely the motivational framework, including the performed personalized and blended training. As it can be observed, the opinion of the participating students about their experience with the presented framework is very positive.

TABLE IV. STUDENT´S SATISFACTION SURVEY RESULTS

Item	Results
I have found helpful the contents of the training program	3,79
I have acquired tools to understand and develop my motivations	3,71
I consider that MDI-EE is a good instrument to self-evaluate my motivation	3,76
I consider this experience as a good complement to the usual training in college	3,61
I consider recommendation mechanisms for learning a good addition to the usual online training	3,78
I think the face component a good addition to the usual online training	3,72
In general, the experience with the motivational framework is an useful and innovative way to develop my motivation	3,82

VI. DISSCUSSION

This section contains the discussion of the results. It allows exploring motivation aspects in engineering education and answering empirically the RQ arisen in the study.

A. *Are the "classical" theories of motivation appropriate to evaluate and enhance the motivation of engineering students?(RQ1)*

Several indications allow affirming that the theories selected to evaluate and improve the motivation are appropriate in the engineering education. From the theoretical perspective, the mentioned expert revision and the use of widely extended motivational theories provide a solid basis.

From the empirical perspective, the correlations analysis results with evaluation instrument confirm that most of the indicators extracted from the motivational theories (concretely, 22 of 27) are correlated with the motivation of the engineering students and all the selected theories contains correlated indicators. Furthermore, the motivational enhancement, which is partially based in these theories, seems useful by observing the results of the satisfaction survey. The participating students have founded the contents of the training program helpful (3,79) and they have acquired tools to understand and develop their motivations (3,71).

Consequently, it can be said that the theories referred in this paper as "classical" are appropriate to evaluate and enhance the student motivation in the engineering teaching. Thus, these theories can be considered by engineering students, teachers and academic institutions in order to understand and work over the student motivation.

B. Can be the motivation of engineering students evaluated through reliable research instruments? (RQ2)

As stated above, there are instruments to evaluate motivation aspects in higher education such as the MSLQ [8], the Zoller test [9] or the MAPE-3 [10], and also instruments particularized for the engineering education such as the MAE [7] or the EMQ-B [11]. These instruments have been previously used to perform motivation studies with University students from different disciplines, also in engineering areas [7, 11]. It aims that the motivation of engineering students can be evaluated using reliable research instruments.

Moreover, focusing in the presented case study, the results related to the validity, consistency and reliability of the MDI-EE have been positives. The results obtained in the statistical analysis (factors, correlations, KMO and α Cronbach) that have been done over the MDI-EE have successfully passed the acceptability levels related with the validity, consistency and reliability of this kind of evaluation instruments. So, it can be said that the designed instrument evaluate reliably the motivational dimension of the engineering students. Also, from the user point of view, it can be observed that the students who have used the motivational framework consider that MDI-EE is a good instrument to self-evaluate their motivation (3,76).

In short, RQ2 can be answered affirmative based on four facts: the motivational instruments previously designed [7, 8, 9, 10, 11], other studies performed with engineering students [7, 11], the favorable results obtained in the statistical analysis of the MDI-EE and the positive opinion about it of the participating students. Thus, the MDI-EE can be used by students, teachers, researches and academic institutions to facilitate the self-evaluation and/or the evaluation of the engineering student motivation.

C. Can be personalized and blended training plans to enhance the motivation of engineering students provided? (RQ3)

The positive experience with the learning resources presented above to support the motivation training plans allow to confirm the utility of the blended training plans. The "Socio-Emotional Skills Development" online classroom incorporated into the PAP platform, as well as the complementary seminars certified by the University and ECTS-recognized, enable to students performing blended training plans to increase socio-emotional skills such as the motivation. In fact, up to date, more than 3000 UPM members have used the online classroom and 150 UPM students have completed the associated blended training programs.

Looking at the survey results, the 60 students who completed blended training programs on motivation skills consider their experience with the proposed framework as a good complement to the usual training in college (3,61) and they think that the face component in a motivational training is a good addition to the usual online training (3,72). The blended training plans have been founded helpful by the students (3,79) and they have acquired tools to understand and develop their motivations (3,71).

Furthermore, as stated above, new efforts to personalize the learning process of the students to their needs should be done. Normally, online campus related to transversal competences like PAP platform contains several materials and the students are suggested to follow a standard learning path. The use of instruments like the MDI-EE and its recommendation mechanisms allow to personalize the student training to their needs. By adopting this kind of approach, the students can follow their own path founding the learning process more attractive.

In fact, the participating students value very positively this personalization aspect that the framework provides. They consider that MDI-EE is a good instrument to self-evaluate their motivation (3,76) and they found the recommendation mechanisms linking MDI-EE diagnosis and PAP resources a good addition to the usual online training (3,78). In general, they think that the experience with the motivational framework has been an useful and innovative way to develop their motivation (3,82).

In conclusion, all of this allows answering affirmatively RQ3: personalized and blended training plans on motivation can be successfully provided to engineering students. Thus, approaches like the presented (based on reliable diagnosis, personalized recommendations and blended training plans) can be adopted by engineering universities to deal with the student motivation challenge.

D. Do engineering students who receive training in motivational skills develop greater motivation than other engineering students? If so, in which sense?(RQ4)

The results obtained by applying the MDI-EE confirm that the engineering students trained in motivation skills develop "greater" motivation, in some aspects, than non-trained students. But actually, in view of the results, it would be more properly to say that trained students develop their motivation in different ways than non-trained ones. In general, the scores of both groups are not too different, but a considerable number of differences (15) statistically significant ($p\text{-value} < 0.05$) have been found in the comparative analysis previously done.

By observing the comparative results between both groups and taking into account the theories and indicators of the motivational framework, the following discussion can be done. The students trained in motivation skills are distinguished, in comparison with the non-trained students, by the following characteristics:

- **Develop greater achievement motivation**. They appreciate more the opportunity to develop and surpass with difficult tasks and to pursue excellence in the tasks that they perform.
- **Develop different affiliation and power motivations**. They are more focused in working together with their classmates and influence positively on them, but do not appreciate overmuch the teacher recognition.
- **Slightly more critical in the effort-reward relation**. There are no significant differences in this aspect but they think, a little more, that the invested effort (hours of dedication, energy, etc.) is not offset by the reward receipt (credit, qualification, knowledge, etc.).
- **Their study predisposition is more active**. They look like active learners who seek and accept academic responsibilities as far as possible. In line with the greater achievement motivation, they show a high desire to develop academically trying to beat them as much as they can.
- **Similar levels at desire, trust and expectative levels**. There are no significant differences in this sense and they score very similar in aspects like the desire to pursue their studies, the valuation of their capabilities or the hope in the usefulness of their degrees.
- **More prone to challenges, participation and autonomy**. They increase their performance when the proposed activities are considered difficult. Also, by enhancing their participation in the activities definition, their commitment is also increased. They need lower levels of clearly and concretion in the activities that they perform.
- **Highly sensitized with the shortcomings of their environment**. They are more critical in almost all the extrinsic elements: the physical and virtual resources of the University, the opinion about the teacher capabilities, etc.
- **Greater levels of intrinsic motivation**. In general, they value more the opportunity to grow with challenging activities, they feel the principal responsible for their learning process and their academic results and they appreciate the sense of accomplishment obtained by studying their degree.

As it was expected, the main differences are related to the areas deeply tackled in the training provided to the students such as proactive attitudes, achievement motivation, learning responsibility, intrinsic motivators, etc. These differences can be considered clearly favorable, but there are other differences that could be seen by teachers and academic institutions as unfavorable. The participating students also develop higher sensitive and critical sense with their environment. But, in opinion of the authors, the demanding and exigent students can also help to improve the engineering teaching.

As will be described in the limitations section, it cannot be guaranteed that founded differences are exclusively caused by the framework usage. In any case, this experience provides a solid basis for expecting, on average, some improvements to occur on the motivational skills of engineering students who use the enhancement resources of the presented framework.

VII. CONCLUSIONS

The obtained results and discussion allow to reach the targeted objectives and to answer the arisen RQ. The presented case study has enabled to check empirically the validity and usefulness of the diagnosis instruments and the enhancement resources that conforms the proposed framework.

A set of conclusions related with the presented framework can be extracted from this contribution:

- The theoretical base of the presented framework has been found appropriate to represent the motivation of engineering students.
- The MDI-EE has been found reliable and useful to evaluate the engineering student motivation.
- The online and blended training programs have been found useful to enhance student motivation.
- The recommendation mechanisms linking the diagnosis with enhancement have been found useful to personalize the motivation training.
- The personalized and blended training programs related to motivational skills have been considered helpful.
- In general, the framework usage has been found an useful and innovative way to develop student motivation.

Furthermore, a set of conclusions about the benefits of taking care of motivation in engineering education can be also extracted from this contribution:

- The engineering students aware and trained in motivation aspects can obtain several benefits that impact positively in their academic performance and, probably, in their future professional success.
- The most remarkable benefits founded at motivational level by applying the proposed framework are as follows: a) Develop the achievement motivation and direct affiliation and power motivations to classmates. b) Cultivate a study predisposition active and favor the student trend to challenges, participation and autonomy. c) Encourage, in general, high levels of intrinsic motivators like personal growth or responsibility. d) Promote in the students a critical thinking that allows improving the shortcomings of their environment.

In short, the validity and usefulness of the proposed framework have been empirically tested. By using this framework, several benefits at motivational level in the engineering students have been founded. Guidelines and materials are available under request.

VIII. LIMITATIONS & FUTURE WORK

There are some shortcomings inherent to the setting of the EIP and the University where the enhancement resources of the framework has been validated. The usage of the learning resources of the PAP Platform and the participation in EIPs are not mandatory, and the students cannot be forced to participate in this kind of initiatives. This makes that the 60 students of the sample who have used the enhancement resources of the presented framework have done it voluntarily, thus it can be assumed that they start with some interest in the motivation issue. A contrast with a control group (a random sample of the student population of UPM who use obligatorily all the framework components) would help to the inference of the results. Anyway, the presented experience provides a solid basis for expecting some improvements to occur at motivational levels of engineering students who use the framework enhancement resources.

Furthermore, it can be noted that the student development has been evaluated using self-reported methods. The performed statistical analysis around the MDI-EE reveals that random or dishonest answers have not been, in general, provided by the students. Either way, the data collection could be richer by incorporating 360º approaches that would enable to the participants receive feedback about from a close 'other' such as teachers, classmates, etc. In this sense, future research will involve the use of the 360º capabilities of the *fib360.memgroup.es* web application.

Regarding over other future work several actions could be done in order to increase the strength of the presented conclusions. Interesting research questions have arisen conducting this study like "*How can we measure accurately the motivation impact on the academic performance of the student?"* or "*Are the learning results of motivated students better than non-motivated?".* A research scenario, based on the framework usage by engineering students, and further comparison between their academic records, IQs and motivation degree could be performed in order to answer to these and others motivation issues related to the engineering education. Furthermore, the application of pre-post evaluation strategies, the involvement of students from other engineering disciplines, the incorporation of student marks to the research data and a comparative between LMS supported and non-supported by mechanisms to recommend learning paths also would help to enlarge and to strengthen the conclusions presented in this contribution.

Finally, it is mentionable as future work than the presented motivational framework has been adapted to professional engineering contexts. It has been defined and currently it is being validated in engineering firms with favorable results.

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