The developing of personal and professional skills in automotive engineers through university competitions

Francisco J. Sánchez-Alejo, Francisco Aparicio, Miguel A. Álvarez
University Institute for Automobile Research, INSIA-UPM
Polytechnic University of Madrid, UPM
Madrid, Spain
javsanchez@etsii.upm.es

Ernest Galindo
Institute of Automotive and Transport Engineering (ISAT)
University of Bourgogne
Nevers, France
ernest.galindo_isat@u-bourgogne.fr

Abstract—**Promoting personal and professional skills is becoming an issue of interest and major concern in university environments and this, in turn, is being driven by the demands of business. In this paper the authors, teachers from UPM and ISAT, present the basic features of the Formula SAE project and some other international competition such as Eco-Shell Marathon, Formula Baja or Formula Low-Cost, and analyze the way these competitions helps to promote 24 basic skills in the students, compared to other activities carried out during their engineering degree courses.**

Keywords-component;, automotive engineering, skills, competition, Formula SAE

I. INTRODUCTION

Universities are ever more concerned to open up students' training perspectives towards aspects that are not always a part of their studies, such as enhancing their personal and professional skills [1]. Thus, for several years the experiences of educational programmes have been regularly published where the enhancement of theoretical-practical knowledge is only one of the goals sought. E. Bowen [2], and D. Chadha [1][3], for instance, raise the issue of studying and assessing skills promotion in different university departments in the United Kingdom.

In a simplified way what is understood by skills is "a combination of knowledge, abilities and attitudes that are suited to particular circumstances" [4]. De Miguel et al [5] offer a fuller definition when they say, "by skills is understood the set of knowledge, abilities, behaviour and attitudes that favour work being done properly and which the organisation is interested in developing or recognising in its co-workers when it comes to achieving the company's strategic goals".

The European Commission [4] has recently highlighted eight key skills for continuous learning as a goal to be achieved by every citizen who aspires to "live and work in the new information society". These are communication in the mother tongue, communication in foreign languages, mathematical skills and basic skills in science and technology, digital skills, learning to learn, interpersonal, intercultural and social skills, citizens' skills, the spirit of enterprise and cultural expression.

The second definition of skills makes reference to the four successive psychological learning levels: knowledge, ability, behaviour and attitude. In the light of these, it can be said that, excepting some initiatives, university training has been focused mainly on strengthening technical knowledge and abilities, since these first two levels are the ones that can be attained with the traditional system of classroom lectures.

So, a genuine promotion of personal and professional skills has not been a generally sought after goal, since trying to make students change their behaviour and attitudes involves using other teaching methods that are usually more costly regarding time, space and personal resources, although on occasions these methods simply need to be more imaginative.

Likewise, student assessment has usually been based almost exclusively on their knowledge and skills in solving problems on paper in an environment where time is scarce, where information is restricted to the data given in the written instructions and a lack of sources for consultation. Therefore, certain personal qualities such as memory and speed are overvalued to the detriment of other qualities which are at least just as important.

However, the human resource managers of the major companies rate basic personal skills very highly in the graduates that they take on; skills such as the ability to work in a team, leadership, self-motivation and team motivation, a capacity for self-learning, etc, giving less importance to the level of technical knowledge possessed at the time of their being taken on [6], [7].

The study entitled "Tuning Educational Structures in Europe" [8], financed by the European Commission reveals the large discrepancies existing between the priorities given to different skills and personal abilities by university teachers, new graduates and employers. A summary of this study is shown in Table I.

Aware of all this, those who designed the great European university paradigm (Bologna Declaration [9]), recognise the importance of introducing activities into the training programmes that help to promote abilities and skills in students.

978-1-4244-6571-2/10/$26.00 ©2010 IEEE April 14-16, 2010, Madrid, SPAIN
IEEE EDUCON Education Engineering 2010 – The Future of Global Learning Engineering Education

TABLE I. ASSESSMENT OF THE ORDER OF IMPORTANCE OF DIFFERENT PERSONAL SKILLS AND ABILITIES AS SEEN BY GRADUATES, ACADEMICS AND EMPLOYERS [8].

Personal skills and abilities	Academics	Graduates	Employers
Analytical and summarising skills	2	1	3
Ability to apply knowledge in practice	5	3	2
Basic general knowledge of the study area	1	12	12
Basic knowledge of the profession	8	11	14
Oral and written communication in own language	9	7	7
Knowledge of a second language	15	14	15
Basic computer usage skills	16	4	10
Research skills	11	15	17
Learning skills	3	2	1
Capacity for self-criticism and criticism	6	10	9
Ability to adapt to new situations	7	5	4
Capacity to generate new ideas	4	9	6
Decision making	12	8	8
Interpersonal skills	14	6	5
Ability to work as part of an interdisciplinary team	10	13	11
Appreciation of diversity and multiculturalism	17	17	16
Ethical commitment	13	16	13

The European Convergence process is now bringing about a change in the outlook of university teaching staff. Educational actions in the University in future years will need to be channelled towards becoming adapted to the European Higher Education Space, in addition to achieving an enhancement of training programmes and the incorporation of new goals aimed at developing personal and professional skills.

II. PRINCIPAL SKILLS OF AUTOMOTIVE ENGINEERS

In this context, a group of teachers and professors from Madrid Polytechnic University, UPM, belonging to the University Institute for Automobile Research, INSIA, being aware of the need to introduce changes into the teaching activities that would help to promote the most demanded skills by a sector as competitive and complex as the automotive sector, decided to get to know these skills at first hand. One of the reasons for conducting the study was their conviction that these skills might not literally coincide with those demanded by other sectors.

If they should know which skills the undergraduate and graduate students should need to acquire and develop, it would help them to organise the teaching activities and adapt the available methods and resources. It would also help them to set the goals to be attained by teaching staff as well as providing them with the tools needed for them to attain these goals.

A two-round Delphi questionnaire[1] was used to conduct the study which was directed towards professionals in the major companies in the Spanish automotive sector. These companies are divided into two large groups: vehicle manufacturers and component manufacturers. Thus, since their tasks are highly complementary but different, the experts were questioned as to the most important abilities and skills for new engineers taken on in their companies as well as in the complementary ones. In other words, each vehicle manufacturing company professional was asked their opinion about the most important skills for a new engineer in a vehicle plant, and also for one in a component plant; and vice-versa.

The procedure followed was as below:

- A "Panel of Experts" was set up, comprising 8 professionals representing different posts in each of the two types of company.
- A draft questionnaire was prepared which gave a choice of 30 personal and professional skills sought after in an automotive engineer. These skills were submitted to the "Panel of Experts" for approval so they could then be finally included in the questionnaire.
- The questionnaire was sent to selected persons in the automotive industry ("Consultative Panel"). 24 professionals were chosen in all. Mainly those holding technical positions and human resources managers in both types of company.
- A month and a half later 21 replies were received (87.5%) with an average response time of 23 days. During this time those polled were sent two reminders by e-mail until the survey was answered.
- The questionnaire was then dispatched a second time to the experts so they could ratify or change their responses in the light of the average given by the experts as a whole.
- Finally, after another month and a half's wait, 20 replies were received (83,3%), with an average response time of 17 days, where two reminders were also sent out.
- A statistical analysis of the survey results was carried out and a final report written.

The results obtained are shown in Table II. The first column shows the importance given by a vehicle manufacturer to a new engineer working in a vehicle manufacturing company, and the second column the importance for workers in a components manufacturing company. The third and fourth columns are the responses from the components manufacturers.

In spite of the profound mutual knowledge of both types of company, the table reflects significant differences concerning the type of work that each person thinks is done by the others.

The responses from both sides are also quite a fair reflection of the situation in the Spanish sector, where vehicle manufacturers are mainly concerned with production and to a much lesser extent with vehicle design, whereas there is a much larger and dynamic industrial fabric devoted to the design and manufacture of automotive components.

[1] The Delphi questionnaire was developed in the United States in the 60s. Its name comes from the famous Greek oracle in Delphos, which the ancient Greeks turned to in order to know their future. It is commonly used to conduct forecasts among professionals using surveys that are sent out in two rounds: in the second round the expert is informed of the response of the other persons polled, giving them a chance to change their initial response.

TABLE II. THE SKILLS AND ABILITIES MOST APPRECIATED IN THE AUTOMOTIVE SECTOR (RATED 0 TO 4).

	Skills and abilities	Vehicle Manufacturer		Components Manufacturer	
		Vehicle Man.	Comp Man.	Vehicle Man.	Comp Man.
1	Team leadership	4	4	4	4
2	Team motivation	4	4	4	4
3	Responsibility at work	4	4	4	4
4	Teamwork	3	4	4	4
5	Capacity for innovation	4	3	3	4
6	Common sense	3	4	3	4
7	Communication skills	3	3	4	4
8	Negotiating skills	3	3	4	4
9	Financial awareness	3	3	4	4
10	Capacity for initiative	3	3	3	4
11	Ability to convince	3	3	3	4
12	Sales ability	2	3	3	4
13	Emotional Intelligence	3	3	3	3
14	Non-verbal communication	2	3	2	3

The most appreciated skills were leadership and team motivation, responsibility at work and teamwork. Also highly rated are the capacity to innovate, and communication and negotiating skills.

III. THE AUTOMOTIVE UNIVERSITY COMPETITIONS FOR ENGINEERS

Nowadays, there are several automotive competitions oriented to undergraduate students in which the multidisciplinary groups of each university have to build a vehicle. Each competitions have different objectives on education as is teamwork, leadership, innovation, solve problems, among others. The most important are the following ones:

A. The Formula SAE competition

In 1982 engineers from Ford, DaimlerChrysler and General Motors, grouped together in the SAE (Society of Automotive Engineers), in the United States, being aware of how little newly graduated engineers were adapted to automotive companies, designed a competition for universities throughout the world, which involved conceiving, designing, manufacturing and competing with a single seat formula-type vehicle. This competition was called the Formula SAE.

They were of the opinion that this challenge would serve to accelerate engineering students' professional profiles, forcing them to work as part of a team, with high levels of communication, responsibility and motivation, forcing them to use in their work a large part of the knowledge acquired in their degree.

For there to be project uniformity and equal opportunities in the competition, the SAE sets strict standards as to the design and manufacture of the different vehicle parts in addition to severe safety standards. In spite of this, the participants enjoy a wide autonomy and capacity to innovate, as can be seen in the differences in the models from each university.

Each university must present a project as if it involved a company that manufactured 1000 vehicles per year for an amateur public competing at weekends, and with a cost of less than 25,000$.

The main condition refers to vehicle power, restricted by engine cylinder capacity (maximum 600 cm3) and by a restricted air intake. Therefore, most machines use motorbike engines which are standard engines of around 110 HP, but by restricting the air intake their capacity is reduced to around 70 HP after appropriately designing the intake and exhaust with fluid dynamics programs and after electronically changing the engine torque and power curves.

Other restrictions refer to vehicle size (minimum 1,520 mm wheelbase, and minimum 9 m slalom track pass), which means that the vehicles are around 2,700 to 3,000 mm long. There is also an exhaustive materials check of the materials making up the chassis, and close attention is paid to safety and driving seat ergonomics.

Competition score cards are divided into two kinds: static and dynamic. Also, there are some preliminary tests that do not score, but need to be overcome in order to compete. Table III shows the tests together with a brief description of each one.

TABLE III. DESCRIPTION OF FORMULA SAE COMPETITION TRIALS.

Events	Points	Description
Preliminary tests	**0**	Pre-competition safety tests.
Technical inspection	-	General check of car by judges.
Tilt	-	Car inclination up to 60º checking its stability and that no type of liquid is leaking.
Brakes	-	Simultaneous blocking of all four wheels after a brief acceleration.
Noise	-	Check to ensure vehicle emits less than 110 dB under certain acceleration conditions.
Static	**325 in total**	Presentations and oral defence in front of the judges of technical solutions adopted.
Design	150	Technical defence of vehicle design and solutions proposed.
Presentation	75	Marketing presentation, convincing the judges to choose their car compared to the others.
Costs	100	Written report detailing cost of each part and component of the unit built.
Dynamic	**675 in total**	Different on-track trials with the single-seater.
Acceleration	75	Cover 75 m on a straight run in the shortest possible time
Manoeuvrability (Skidpad)	50	Manoeuvrability to run a 9 metre circle in both directions.
Sprint	150	Quick lap of the circuit
Endurance	350	Overall vehicle performance and reliability in 22 laps of a circuit.
Fuel	50	Minimum consumption in endurance trial
Total	**1000**	

As can be seen, this is an authentic engineering competition where in addition to vehicle speed and performance the project and the product achieved are also appreciated. In this competition the students have a totally leading role. They have to organise themselves, find the resources needed, administer project time, costs, etc, and all this under the supervision and advice of the advisory teachers and the Faculty Advisor. They have to design and build the

parts by hand (the fewer purchased the better), and four of them must finally drive the car.

What is new about this project, apart from it being a new, innovative educational methodology where the vehicle is simply the means to get the best possible training, is the challenge posed to the students by having to take on and participate in an entire vehicle development life cycle. This can only be achieved by forming a strong working team, promoting active participation, the assumption of responsibilities, decision making and involvement in reaching a common objective. In exchange the student gets the satisfaction of being able to take the vehicle built by their own effort to an actual competition.

Currently, more than 200 universities throughout the world take part each year in the Formula SAE. For this it has been necessary to extend the competitions to other countries, like England, where it is called Formula Student, Australia, etc, as well as the original in Michigan.

B. The Baja SAE competition

Baja SAE is a university competition whose aim is to improve the preparation and education of young engineers through an event that simulates a real engineering project where students have to design, manufacture, test, and compete with an off-road vehicle.

The participating teams have to assume that they have been hired by a manufacture firm to build an off-road vehicle capable of competing in any field. The restrictions are on the design of chassis, and the engine modifications are prohibited, as the engine is the same for all teams. Unlike Formula SAE standards these restrictions limit the design and innovation in these areas, leaving the engineer's imagination for other areas of the vehicle. This, in turn, results in a reduction in costs and activities compared with Formula SAE. The target for selling the prototype is the non-professional weekend racer, as well as the Formula SAE, and the teams must develop a product that has high performance in acceleration, traction, with common parts and easy maintenance. It is a competition that also simulates a case study of the life cycle of a vehicle, where students also have to get organized sponsorship for their project.

The engine is a 10HP, and it is not allowed to make any changes or modifications. The overall dimensions of the vehicle recommended to be on lengths of 275cm are the track is restricted to a maximum of 190cm. The cage in the chassis is very limited in terms of innovation to ensure the safety at all situations, as in the event of rollover or impacting with another vehicle.

Is highly valued by the judges the manufacturing capacity with conventional tools that are available to anyone. Teams will be evaluated on design, and marketing costs (not all of Baja competitions own this event). In the dynamic performance, the students must demonstrate their ability to accelerate, steer, and drive the vehicle to finally be evaluated in endurance where they are able to repair the vehicle in the race. Table IV shows the events with a brief description of each one.

The Baja SAE competition began in 1976, and currently has 6 competitions in the USA, Brazil, South Africa and South Korea are involved in more than 250 university total more than 4000 students participating.

TABLE IV. DESCRIPTION OF FORMULA BAJA COMPETITION TRIALS

Event	Points	Description
Static Events -	**300 in total**	Presentations and oral defence in front of the judges
Design Report & Evaluation	150	Technical defence of vehicle design and solutions proposed
Cost Report & Cost Production	100	Writing report dealing cost of each part and component of the unit built
Presentation	50	Marketing presentation, convincing the judges to choose their car.
Dynamic Events -	**700 points**	**Different on-track trials with the off-road vehicle**
Acceleration/Speed	85	Cover 30m o 45m on a straight run in the shortest possible time
Traction/Hill Climb or Pulling Event	75	The traction event will be either hill climb or pulling an object
Manoeuvrability	75	Manoeuvrability including tight turns, pylon manoeuvres, ruts and bumps, drop-offs, sand, rocks, gullies, logs, and inclines.
Specialty Rock Crawl or Suspension Traction	75	A special event to test the vehicle on unique off-road conditions
Endurance	400	Maximum distance performed in 4 hours
Total Points	**1000**	

C. Eco-Shell Marathon

This university and college competition has the goal to compete with more efficient vehicle for a given distance. There are two categories, one corresponding to futuristic vehicles where reducing drag and maximizing efficiency is the major premise and the second category corresponding to four-wheeled vehicle using conventional or alternative fuels.

Competition rules limit the size in wheelbase, track and height of vehicles, chassis design (to ensure safety), the type of propulsion (it can be used combustion, fuel cell or solar) and deposit size is limited to 30cc to 250cc. limiting the size of engine to use. The following list outlines the types of fuel that can be used:

- Shell Unleaded 95 (Europe & Asia) / Shell Regular 87 (U.S.)
- Shell Diesel
- Liquefied Petroleum Gas (LPG)
- Shell Gas to Liquid (GTL 100%)
- Fatty Acid Methyl Ester (100% FAME)
- Ethanol E100 (100% Ethanol)
- Hydrogen

Vehicles must meet travel between 22 km or 25 km depending on the category in which they participate. The assessment of efficiency is done in accordance with a table of equivalence developed by the competition.

The aim of the competition is to simulate a real art project where teams work for a year designing and building a vehicle. The event organizers also want students to integrate, design and develop a product that is sustainable, that controls the energy used and that is concern about environmental protection. This target causes that the greatest number of team efforts are focused in engines, transmissions and aerodynamics.

D. Formula Low Cost

Created by ISAT in 2008 with the aim of extend these kind of competitions to universities all around the world, regardless their economic possibilities, Low Cost Formula is a competition aimed at extending university engineering education through the construction of a kart type vehicle. The main difference with Formula SAE is the budget, which can not exceed 2.000€ for its build, based on fixed prices of components.

In this competition the teams have to assume they have been contracted to manufacture a vehicle whose main feature is that it has not suspension. For the chassis, the rules establish that they must be designed to ensure the safety, and the materials allowed are only steel and aluminium. The engine can not exceed 12KW and are well worth the innovations that can be made. Although the size of vehicle is complete free, the possibilities with the 2,000€ restriction are limited.

As an engineering competition, teams valuation is done through a set of tests, both static (where it is evaluated the technical and cost features) and dynamic (where it is evaluated the track vehicle performance). The statics events have the aim to assess the designs, innovations and cost of the prototype. The dynamic events are composed of three: a classification, a sprint race (15 laps) and resistance (60 laps).

This competition also provides an opportunity for students to participate throughout the life cycle of a real project, in order to prepare engineers to manage projects, budgets and learn to work as a part of a team. Table V shows the events with a brief description of each one.

TABLE V. DESCRIPTION OF FORMULA LOW COST COMPETITION TRIALS

Event	Points	Description
Static Events -	**478 in total**	Presentations and oral defence in front of the judges
Cost Report	183	Writing report detailing cost of each part and component of the unit built
Innovations	183	Technical evaluation of innovations
Design	112	Technical defence of vehicle design and solutions proposed
Dynamic Events -	**441 points**	**Different on-track trials with the off-road vehicle**
Acceleration/Speed	75	Cover a straight run in the shortest possible time
Sprint	183	A event to classified the vehicle for the main event
Endurance	183	60 laps to a circuit
Total Points	**919 points**	

IV. THE PARTICIPATION OF THE MADRID POLYTECHNIC UNIVERSITY, UPM, ON THESE COMPETITIONS.

As previously stated, after selecting the Formula SAE as the project to be embarked upon by our students, in October 2003 the University Institute for Automobile Research, INSIA, was set up; the first Spanish Formula SAE competition team, called UPMracing. It was made up of about 35 students from the final courses in the School of Industrial Engineering of the UPM, and the Master's course in Automotive Engineering (Figure 1). In the years that followed, several students from other university schools joined in, like the Aeronautic Techniques and Industrial Techniques schools, what lead to important improvements in the performance (Figure 2).

Figure 1. The team in England with the UPM-01 and UPM-02 cars

Figure 2. Competition pictures with the UPM-03 and UPM-04 vehicles

At present the UPMracing has accumulated six years of experience with the same number of single-seaters built that have taken part in the 2004 – 2009 editions of the Formula Student in England.

From the beginning the project has been based on four principles that are a statement of the teaching method used:

- Learn by applying
- Learn by doing
- Learn in a team
- Learn by competing

Moreover, in order to maximise student performance and progress, a whole strategy of learning situations has been planned which participants must pass through during their period in the team, as it will be referred in next epigraph.

With the aim of reproduce similar conditions to the work carried out in real companies, the team has been organized in several departments according to the main systems of the vehicle. These divisions, supervised by a small team of teachers, conform an operative organisation whose chart is shown in Figure 3.

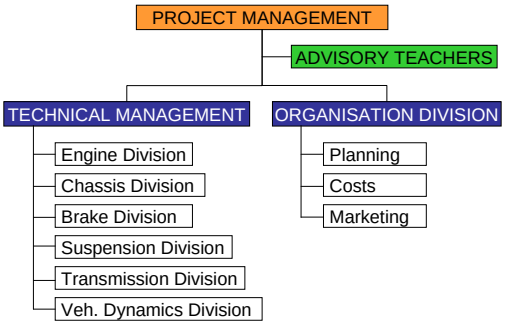

Figure 3. UPMracing team organisation chart

The students usually spend the last two years of their careers working at a division on the team: on the first one they do the training and computer design, and on the second the manufacture, testing and also attend the competition in England. Although there are planned two short non mandatory subjects and the most of them uses the work performed as the Final Career Project, the joining at the team is completely voluntary and the students have to develop the most of the work on their free time.

V. The Participation Of The Institute Of Automotive And Transport Engineering, ISAT, On These Competitions.

The Institute of Automotive and Transport Engineering (ISAT) in Nevers (France) is a state-run school committed to the comprehensive training of engineers, with a particular interest in the automotive sector.

The main aim of ISAT is to cover the whole range of jobs and skills related to the automotive and transport industries, with a strong expertise in mechanics: mechanical design and development, industrialisation, manufacturing, quality assurance.

Based on sound scientific and technological foundations, the training of the students during the 5-year programme (Master's Degree) is extended and strengthened by long periods of work experience and placements with various companies.

During the third year, as a part of the course's mandatory activities, the most of the students join in one of the four automotive competitions ISAT is taking part: Formula Student (Figure 4), Formula Baja (Figure 5), EcoShell Marathon (Figure 6) and Formula LowCost (Figure 7).

Each team is formed by 12 to 15 students that have to specialized into the different technologies involved. Although the schedule al ISAT is planned to work every Wednesday of the third year on these projects, the students used to employ many hours of their free time.

Figure 4. The Formula Student team at Magny Cours tracks

Figure 5. The Formula Baja team at the USA competition

Figure 6. The whole EcoShell Marathon team at ISAT

Figure 7. Some Formula LowCost members at the workshop.

All the work is supervised by teachers and workshop employees, but the students have a high level of autonomy and responsibility both in the technical areas as well as in the planning and budgeting activities.

Finally for INSIA-UPM and ISAT these projects represent opportunities to develop teaching programs, methods and activities oriented to improve the engineering education, with the special interest on the automotive industry.

VI. The Activities Performed At The Competitions And The Developing Of Personal And Professional Skills.

Although there are many differences between these competitions, all of them have in common the way the students do the work (with technical, schedule and budget requirements and constraints) and assume their responsibilities

On this point, it should be noticed that the responsibility given to each student is real: each is aware that a mistake by them is a mistake for the team. Equivalent responsibility would only be found in any company after a couple of years' work. The students themselves even take it upon themselves to raise part of the financial resources needed, and it is they, under the supervision of the teachers, who manage these resources.

The educational experience provided by taking part in these projects and the teaching methods used mean that the student must face up to specifically designed situations that will challenge them and promote their personal and

professional skills. Table VI shows 16 different learning situations related to different moments or activities of the project, cross-referenced with 24 skills, which in the light of the literature consulted and the studies and surveys presented, are deemed to be the most sought after in an engineer getting ready to work in the automotive sector.

TABLE VI. PROMOTION OF PERSONAL AND PROFESSIONAL SKILLS ACCORDING TO DIFFERENT ACTIVITIES AND LEARNING SITUATIONS.

Learning situations / Skills	1. Initial training in all knowledge areas	2. Supplementary material and in-process tutorial sessions	3. Division into sub-groups according to work areas	4. Assigning duties, objectives and responsibilities.	5. Organisation and planning according to general costs and schedules	6. Every student is responsible for their work and collaborates with the others	7. Wide personal autonomy and possibilities for innovation	8. Periodic presentation and update meetings	9. Resources searches and usage management	10. All take part in vehicle manufacture	11. Former students coordinate activities of newcomers	12. Participation in a real experience	13. Putting acquired knowledge into practice	14. Competing against the world's best universities	15. Presenting and defending work done in front of a panel	16. Need to disseminate the experience and the results
1. Ability to work as part of a team			X	X	X	X		X	X	X	X	X		X	X	X
2. Leadership qualities			X	X	X	X		X	X	X	X	X		X	X	X
3. Ability to motivate			X	X	X	X		X		X	X	X		X	X	X
4. Capacity for responsibility and commitment		X	X	X	X	X	X	X	X	X	X	X		X	X	X
5. Capacity for innovation				X		X	X			X		X	X	X		
6. Negotiating skills			X	X	X	X	X	X	X	X	X	X		X	X	X
7. Capacity for self-motivation	X	X	X	X		X	X		X					X	X	
8. Analytical skills	X	X	X	X	X	X	X	X	X				X	X		
9. Ability to summarise				X	X	X	X			X		X	X	X	X	X
10. Capacity for criticism and self-criticism		X	X	X	X	X	X	X		X	X	X	X	X	X	X
11. Ability for self-learning	X	X	X	X			X						X	X		
12. Organisational and planning skills		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
13. Ability to identify problems			X	X	X	X	X	X	X	X	X	X	X	X	X	X
14. Ability to resolve conflicts				X	X	X		X	X	X	X	X	X		X	X
15. Ability to generate new ideas (creativity)				X		X	X	X	X			X	X	X	X	X
16. Ability to take up new initiatives				X	X	X	X		X	X		X	X	X		X
17. Ability to adapt to changing circumstances	X		X	X	X	X			X	X	X	X	X	X	X	X
18. Ability to work on one's own	X	X		X	X	X	X						X			
19. Ability to make decisions				X	X	X	X	X	X	X	X	X	X	X	X	X
20. Interpersonal skills			X	X	X	X		X	X	X	X	X		X	X	X
21. Ability to assimilate and apply knowledge	X	X		X		X	X			X	X	X	X		X	
22. Capacity for dynamism				X	X	X	X		X	X	X	X		X	X	X
23. Capacity for discipline and self-control	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
24. Oral and written communication in a second language	X	X							X			X		X	X	X

VII. ASSESSING THE EXPERIENCES

Right from the start of their own projects, both universities have been interested to know the opinion of the students taking part, what needs to be kept as it is, what needs improving, and obviously, to what extent the project's goals have been achieved. And among these goals is the distinguishing improvement in students' personal and professional skills compared to traditional activities.

At UPM, for instance, students taking part were given a survey with the 24 most important skills for an engineer in the automotive sector in order to get to know their opinion of the importance of these skills when working in their profession, as well as the level of their success in the subjects taken as part of their degree, and likewise during the Formula SAE training process.

Various conclusions can be drawn from the general results of the survey that are shown in Table VII:

- Students consider the most important skills to be a capacity for responsibility and commitment, teamwork, decision making, creativity, solving conflicts and communication in English. This classification is in total harmony with the opinion of companies, which shows that the training experience suitably orients students towards the labour market, especially if we compare the results with those shown in Table I.
- The average score given by students to the list of 24 skills is 4.2 points out of 5, their average level of success during their degree being given 2.3 points,

while achievement during the Formula SAE project is 3.6 points.

TABLE VII. SCORES FROM 0 TO 5 POINTS OF THE IMPORTANCE GIVEN BY STUDENTS TO THE 24 MOST IMPORTANT PERSONAL AND PROFESSIONAL SKILLS FOR AN ENGINEER IN THE AUTOMOTIVE SECTOR, AS WELL AS THE EXTENT OF SUCCESS DURING THEIR DEGREE AT THE SCHOOL OF INDUSTRIAL ENGINEERS (ETSII-UPM) AND DURING THEIR TIME ON THE PROJECT (F SAE).

Skills	Level of importance for students	Degree of success in ETSII	Degree of success in F SAE
1. Ability to work as part of a team	4.9	2.0	4.1
2. Leadership qualities	4.2	1.1	3.6
3. Ability to motivate	4.4	1.3	3.8
4. Capacity for responsibility and commitment	5.0	3.2	3.8
5. Ability to innovate	4.2	1.3	3.6
6. Negotiating skills	3.6	1.2	2.8
7. Capacity for self-motivation	4.0	2.2	3.2
8. Analytical skills	4.4	2.8	3.4
9. Ability to summarise	4.0	3.1	3.3
10. Capacity for criticism and self-criticism	4.0	2.1	3.6
11. Ability for self-learning	4.2	3.9	4.3
12. Organisational and planning skills	4.0	3.2	3.2
13. Ability to identify problems	4.8	2,6	4.0
14. Ability to resolve conflicts	4.4	1.9	3.3
15. Ability to generate new ideas (creativity)	4.4	1.3	3.6
16. Ability to take up new initiatives	3.7	1.3	3.3
17. Ability to adapt to changing circumstances	4.1	2.7	3.9
18. Ability to work on one's own	3.4	3.8	3.2
19. Ability to make decisions	4.9	2.0	4.0
20. Interpersonal skills	3.8	2.7	4.3
21. Ability to assimilate and apply knowledge	4.1	3.0	4.0
22. Capacity for dynamism	3.8	2.0	3.7
23. Capacity for discipline and self-control	3.8	3.0	3.3
24. Oral and written communication in a second language	4.4	1.6	3.1
Mean value	**4,2**	**2,3**	**3,6**

The average score of importance given to the 7 most appreciated skills is 4.7 points out of 5, with a score during their degree of 1.9 points and practically double, 3.7 points for the Formula SAE project.

Similar results are given by ISAT student's evaluations: the students taking part in the four competitions highly appreciate their own experiences as an important tool to improve the most important personal and professional skills appreciate by companies, more than other activities and experiences carried out during their studies.

VIII. CONCLUSIONS

In this work we have reflected on the growing importance being given by universities to the promotion of personal and professional skills, and the most important of them, on the opinion of the automotive sector, have been found out thanks to the Delphi questionnaire.

The automotive university competitions are very useful activities for the improvement of those desired skills. In the competitions analyzed both at the UPM and at ISAT, a whole set of learning situation is been planned for the students, as well as the methods and means to solve them.

At the end of the experience, students' valuation of the most important abilities and skills highly agree with the requirements of companies.

It has also been showed that the involvement of the students in the whole activities of four competitions, has more contributed to the improvement of the personal and professional abilities and skills than the rest of the activities done during the whole career of five years.

Despite of the good educational results, the advisory teachers have designed a new set of experiences to improve the useful and time profitably of our students.

Although this study has been exclusively referred to the automotive engineering sector, the methodology used and the principal conclusions can be applied to any other sector. Indeed, the 24 skills selected to evaluate the project do not specifically belong to automotive industry, but they are really appreciated by any other kind of industry. The fact of had asked the opinion of their professional served us only to prioritize them.

REFERENCES

[1] F. Aparicio, R.M. González, M.A. Sobrevila, "Formación de Ingenieros. Objetivos, métodos y estrategias", Instituto de Ciencias de la Educación, UPM, (2005).

[2] E. Bowen, S. Lloyd and S. Thomas, Embedding Personal Development Planning into the Curriculum Via a Key Skills Assignment, Int. J. Engng Ed. Vol. 21, No. 6, pp. 1159±1167, (2005).

[3] D. Chadha and G. Nicholls, Teaching Transferable Skills to Undergraduate Engineering Students: Recognising the Value of Embedded and Bolt-on Approaches, Int. J. Engng Ed. Vol. 22, No. 1, pp. 116±122, (2006).

[4] Recommendation 2006/962/EC of the European Parliament and of the Council on key competences for lifelong learning: OJ L 394, 30.12.2006; Bull. 12 (2006).

[5] M. De Miguel, I.J. Alfaro, P.M. Apocada, J.M. Arias, E. García, C. Lobato and A. Pérez Metodologías de enseñanza y aprendizaje para el desarrollo de competencias. Madrid: Alianza Editorial. (2006).

[6] Bolívar C., "Más allá de la formación: el desarrollo de competencias" http://www.arearh.com/formación/masallaformacion.htm, (2001).

[7] H. A. Davies, J. Csete and L. K. Poon, Employer's Expectations of the Performance of Construction Graduates, Int. J. Engng Ed. Vol. 15, No. 3, pp. 191±198, (1999).

[8] J.González, R.Wagenaar, "Tuning Educational Structures in Europe". Universidad de Deusto, (2003).

[9] Bologna Declaration. Joint declaration of the European Ministers of Education, 19th June (1999).