Int. J. Engng Ed. Vol. 25, No. 3, pp. 585–594, 2009
Printed in Great Britain.

0949-149X/91 $3.00+0.00

SAE Formula Project for Developing Personal and Professional Skills in Automotive Engineers*

F. JAVIER SÁNCHEZ, FRANCISCO APARICIO, MIGUEL A. ÁLVAREZ and FELIPE JIMÉNEZ
University Institute for Automotive Research, INSIA, Universidad Politécnica de Madrid, Campus Sur UPM, Ctra. Valencia km 7, 28031 Madrid (Spain). Email: javsanchez@etsii.upm.es

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 present the basic features of the SAE Formula project, an international university competition consisting of designing, manufacturing and competing in formula-type vehicles and analysing to what extent 24 basic skills have been promoted in the students taking part compared with other activities carried out during their Mechanical Engineering degree course.

Keywords: professional skills; personal skills; automotive; engineering education

INTRODUCTION (PROFESSIONAL SKILLS IN THE TRAINING OF ENGINEERS)

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. Bowen *et al.* [2] and Chadha and Nicholls [3], for instance, raise the issue of studying and assessing skills promotion in different university departments in the United Kingdom.

Put 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, with the exception of 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 that 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, putting less importance on 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

* Accepted 19 February 2009.

Table 1. 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

Table 2. Social skills valued by Spanish companies according to the level of training [9]

Social skills	Doctors and university graduates (%)	Vocational training (%)
Ability to work as part of a team	89.5	92.3
Ability to adapt/be flexible	80.0	84.6
Ability to learn	67.6	66.7
Capacity for organisation and planning	57.1	53.8
Willingness	53.3	61.5
Capacity for self-improvement	55.2	51.3
Interpersonal relationships	52.4	59.0
Problem solving	52.4	56.4
Analytical and summarising skills	55.2	41.0
Oral and written communication	51.4	46.2
Command/leadership qualities	37.1	30.8
Work in an international context	29.5	10.3

Table 3. Personal qualities valued by Spanish companies according to the level of training [9]

Personal qualities	Doctors and university graduates (%)	Vocational training (%)
Responsibility	86.7	94.9
Initiative/decision-making ability	87.6	76.9
Ethical commitment	58.1	59.0
Tenacity	50.5	64.1
Quality motivated	51.4	59.0
Creativity	44.8	41.0
Intellectual ability	41.0	41.0
Self-confidence	38.1	38.5
Sincerity	36.2	41.0
Loyalty	34.3	38.5
Discretion	33.3	33.3
Information management skills	29.5	25.6
Critical reasoning	21.0	20.5

graduates and employers. A summary of this study is shown in Table 1.

Along the same lines, a recent study conducted by the University-Business Foundation and the Madrid Chamber of Commerce has brought to light the social skills and personal qualities most appreciated by Spanish companies [9] both for university graduates and for those finishing Trade Schools or Vocational Training; these are shown in Tables 2 and 3.

Aware of all this, those who designed the great European university paradigm (Bologna Declaration [10]) recognise the importance of introducing activities into the training programmes that help to promote abilities and skills in students.

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.

Table 4. The skills and abilities most appreciated in the automotive sector (rated 0 to 4)

		Vehicle manufacturer		Components manufacturer	
	Skills and abilities	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

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, aware of the need to introduce change into the teaching activities consisting of promoting the skills most demanded 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.

Knowing which skills our undergraduate and graduate students need to acquire and develop would help us to organise the teaching activities and adapt the available methods and resources. It would also help us 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 eight professionals representing different posts in each of the two types of company.
- A draft questionnaire was prepared that 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 4. 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

[1] The Delphi questionnaire was developed in the United Status in the 1960s. Its name comes from the famous Greek oracle in Delphos, who 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 5. Description of Formula SAE competition trials [11]

Tests	Points	Description
Preliminary tests	*0*	*Pre-competition safety tests*
Technical inspection	–	General check of car by judges
Tilt	–	Car inclination up to 60° 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 with 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	

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 dynamic industrial fabric devoted to the design and manufacture of automotive components.

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.

Once we had learned the expectations of the companies, several interesting automotive-related international competition alternatives were looked at, finally choosing the SAE Formula as the one that could best meet those expectations.

UPM RACING TEAM AND THE PROMOTION OF PERSONAL AND PROFESSIONAL SKILLS IN AUTOMOTIVE ENGINEERS

SAE Formula competition

Years before people became fully aware of the importance of promoting personal and professional skills in the university sphere, companies in different sectors recognised the gap existing between university and business, and on some occasions proposed activities to try and narrow this gap.

For instance, 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 SAE Formula.

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 cm^3) 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

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

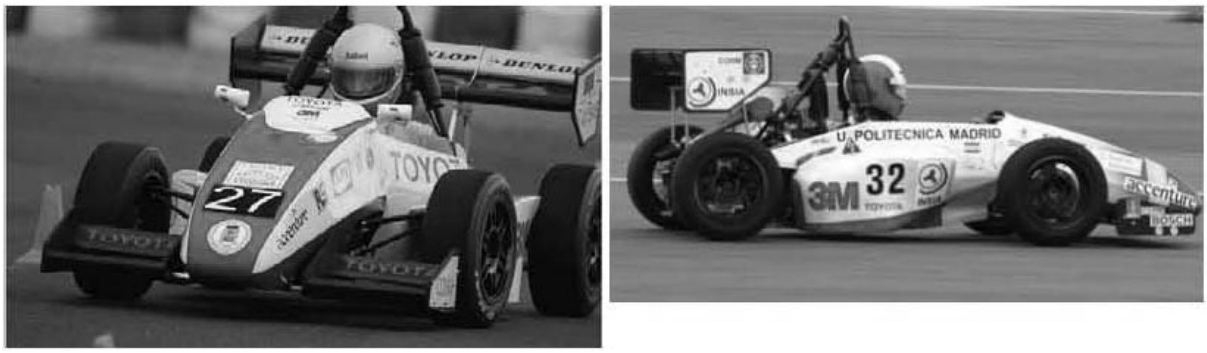

Fig. 2. Competition pictures with the UPM-03 and UPM-04 vehicles.

and after electronically changing the engine torque and power curves.

Other restrictions refer to vehicle size (minimum 1520 mm wheelbase, and minimum 9 m slalom track pass), which means that the vehicles are around 2700–3000 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 5 shows the tests together with a brief description of each one.

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 take 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 finally four of them must 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 SAE Formula. For this it has been necessary to extend the competitions to other countries, such as England, where it is called Formula Student[2], Australia, etc., as well as the original in Michigan.

UPMracing team setting up

As previously stated, after selecting the SAE Formula 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 SAE Formula 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 (Fig. 1). In the years that followed, several students from other university schools joined in, such as the Aeronautic Techniques and Industrial Techniques schools, which lead to important improvements in the performance (Fig 2).

Currently UPMracing has accumulated four years' experience with the same number of single-seaters built that have taken part in the 2004–2007 editions of the Formula Student in England.

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

1. Learn by applying.
2. Learn by doing.
3. Learn in a team.
4. 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 referred in the next epigraph.

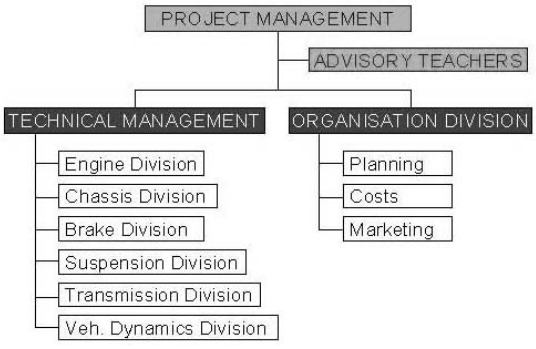

Fig. 3. UPMracing team organisation chart.

[2] http://www.imeche.org.uk/formulastudent

With the aim of reproducing similar work conditions to those in real companies, the team has been organised into several departments according to the main vehicle systems. These divisions, supervised by a small team of teachers, conform to an operative organisation, which is charted in Fig. 3.

Training organisation

Although there are students who only participate for one year, currently we are trying to persuade students to remain in the team for two courses. In this way, in the first year they get comprehensive training in the technologies they are going to need, and in the second year begin the computer design of the vehicle they will manufacture, test and finally compete with.

From an academic point of view, every year they stay in the team, if their performance has been satisfactory, will serve for them to pass one of the two free choice subjects[3] prepared to this effect, called 'Application of Automotive Technologies I. Design' and 'Application of Automotive Technologies II. Manufacturing' and they can likewise present their End-of-Course Project with the work done during the two years.

Training is done in several stages. First, on joining the team, all the students take a short course in the different parts of the vehicle, so that they get an overview of it before choosing a division or area on which they are to be examined in-depth and which they will work on during their time in the team.

Self-learning teaching material has been developed for this first introduction, consisting, among other things, of videos showing the life cycle of every vehicle part, as well as articles and summaries prepared by former students. These materials can be consulted whenever and as many times as required.

In addition to this introduction, all team members attend courses in 3D design (CATIA), project planning and management (MS Project), and structural analysis by finite elements (CATIA and ANSYS), etc. These generic courses are above all practical, implementing methods contrasted by numerous universities [12, 13], so that students get the most out of the work.

The main difficulty in instructing students comes later when small groups of around three students have to be formed in a wide variety of techniques so that each student can take complete responsibility for some part of the vehicle. The three entrusted with the whole engine, for instance, receive specific training in engine tuning with programs such as 'Virtual Engine', but from then on, training is practically individual: only one of them will receive instructions on how to design the engine intake. This means that he or she will have to learn the theory and specific programs, and the same goes for the student entrusted with the exhaust and the other involved with the electronic management.

Although each of the first vehicles were designed and built in a single academic year, the latest ones have a two-course time cycle, the first year being used for training and computer design, and the second for manufacture, testing and the competition itself in England. In this way students have more time to consolidate knowledge and make their designs more robust and reliable.

The number of courses and specific training programmes that need to be repeated year after year is extremely large. For this reason, the students themselves play an essential role, since those participating for the second year have to tutor the newcomers, thereby reducing the enormous teaching load of the teachers. Thus, after several editions, we have managed to reach a position where a high level of knowledge is maintained among students and where teachers only need to intervene with advice in the final stages when training becomes more specialised.

Another important point of project control is the tutorials and the periodic update meetings between students where each student must present the work that they have committed themselves to, as well as raising any questions or consulting with teachers or other team members. To supplement and support training there is also a library containing specific bibliographies, educational videos and end-of-course tasks and projects completed by former students, etc.

A basic component both in training and team coordination is the figure of the technical manager, a former student who has participated in the SAE Formula, and who has now been taken on full-time to take care of the team and manage it directly.

As already mentioned, after a general training period in all vehicle areas, each student is assigned to a specific division that has specific duties, objectives and subject to work. In the same way, each one has specific quality, costs and timeframe standards. The main tasks of each division can be seen in Table 6.

On the other hand, it should be noticed that the responsibility given to each student is real: each is aware that a mistake made by them is a mistake for the team. The 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.

To sum up, the educational experience provided by taking part in the project 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 7 shows 16 different learning situations related to different moments or activities

[3] The free choice subjects are voluntary, although the student must choose from those offered by the university in order to cover the free choice credits.

Table 6. Main tasks of each Division

Chassis and aerodynamics	Chassis design, modelling and building. Driving seat ergonomics and seat manufacture. Aerodynamic study and bodywork building. Crash calculation and simulation of front part.
Electronics	Engine control and ECU programming. Fitting sensors, data acquisition, management and telemetry. Wiring, switches, brake light, control panel on steering wheel.
Brakes	System requirements and components selection. Bench tests. Designing, calculating and manufacturing the uprights, etc. Designing, calculating and manufacturing the pedal box.
Engine	Design, calculation and construction of the intake and exhaust system. Fuel tank and filler neck. Computer simulation and power bench.
Suspension	Study and design of A-arms, actuators and bell cranks. Choosing shock absorbers and designing stabiliser bars. Steering column geometry and rack location.
Transmission	Sprocket and housing support design. Selecting of differential, design of its housing and their support. Adapting axles and CV joints.
Vehicle Dynamics	Vehicle stability analysis in track performance. Racing strategies.
Organisation and Marketing	Setting up organisation, working methods, communications and information channels, and control procedures. Cost and budget control. Search for sponsors and presence in mass media.

Table 7. Promotion of personal and professional skills according to different activities and learning situations

Skills \ Learning situations	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			×	×	×	×		×	×	×	×	×		×	×	×
2. Leadership qualities			×	×	×	×		×	×	×	×	×		×	×	×
3. Ability to motivate			×	×	×	×		×		×	×	×		×	×	×
4. Capacity for responsibility and commitment		×	×	×	×	×	×	×	×	×	×	×		×	×	×
5. Capacity for innovation				×		×	×			×		×	×	×		
6. Negotiating skills			×	×	×	×	×	×	×	×	×	×		×	×	×
7. Capacity for self-motivation	×	×	×	×		×	×		×					×	×	
8. Analytical skills	×	×	×	×	×	×	×	×	×				×	×		
9. Ability to summarise				×	×	×	×			×		×	×	×	×	×
10. Capacity for criticism and self-criticism		×	×	×	×	×	×	×		×	×	×	×	×	×	×
11. Ability for self-learning	×	×	×	×			×						×	×		
12. Organisational and planning skills		×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
13. Ability to identify problems			×	×	×	×	×	×	×	×	×	×	×	×	×	×
14. Ability to resolve conflicts				×	×	×		×	×	×	×	×	×		×	×
15. Ability to generate new ideas (creativity)				×		×	×	×	×			×	×	×	×	×
16. Ability to take up new initiatives				×	×	×	×		×	×		×	×	×		×
17. Ability to adapt to changing circumstances	×		×	×	×	×			×	×	×	×	×	×	×	×
18. Ability to work on one's own	×	×		×	×	×	×						×			
19. Ability to make decisions				×	×	×	×	×	×	×	×	×	×	×	×	×
20. Interpersonal skills			×	×	×	×		×	×	×	×	×		×	×	×
21. Ability to assimilate and apply knowledge	×	×		×		×	×			×	×	×	×		×	
22. Capacity for dynamism				×	×	×	×		×	×	×	×		×	×	×
23. Capacity for discipline and self-control	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
24. Oral and written communication in a second language	×	×							×			×		×	×	×

of the project, cross-referenced with 24 skills that, 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.

Evaluation process

In addition to the whole project being accomplished with students working as a team under the supervision of the teachers in charge, subject assessment is achieved in the same way: there is a maximum of 10 points for each student, of which the teachers award 6 points and the other students 4. The procedure is as follows:

- Before being marked, students are told that what they must mark is the contribution to the team, the extent of involvement, the work, responsibility, willingness to collaborate with fellow-students, etc., and not simply favour those who are friends.
- To avoid everyone marking using the maximum four points they can award, each student has an average of 2 points per student. So, if 30 students are enrolled in a subject, for example, each one will have 58 points (29×2) to share between the 29 companions each awarding between 0 and 4 points.
- In the light of the average marks given by students, the teachers add theirs (up to six points per student, with no global restrictions). Therefore, passing or failing depends entirely on the teachers, thereby avoiding any unfairness due to circumstances that are unconnected with the project.

Although the assessment system surprised students at first, it is now seen as normal and fair. In the four years in which this practice has been carried out, only on one occasion was there a problem with a student who, although she had an excellent performance in the project, received a protest vote from her companions due to personal differences with the team. Thanks to the higher weight of the teacher's mark, the student could pass, but with a lower global mark that what she would have got if it was only qualified by the teachers.

ASSESSING THE EXPERIENCE

Right from the start of the project we 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 the students' personal and professional skills compared with the traditional activities.

Students taking part were given a survey presenting the 24 most important skills for an engineer in the automotive sector in order to find out 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 SAE Formula training process.

Various conclusions can be drawn from the general results of the survey, which are shown in Table 8.

Table 8. 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 secondlanguage	4.4	1.6	3.1
Mean value	4.2	2.3	3.6

- 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 1.
- 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 SAE Formula project is 3.6 points.
- 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 almost double, 3.7 points, for the SAE Formula project.

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, in the opinion of the automotive sector, have been found thanks to the Delphi questionnaire.

Formula SAE has been selected as the most interesting and complete competition for automotive engineering students for the improvement of those desired skills. At the Madrid Polytechnic University, UPM, a whole set of learning situations is been planned for the students, as well as the methods and means to solve them.

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

It has also been showed that the involvement of the students in the whole activities of Formula SAE, amounting to about 1000 hours over two years, has contributed more to the improvement of the personal and professional abilities and skills than the rest of the activities performed during a whole five-year career.

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

Finally, it should be noted that, although this study has exclusively referred to the automotive engineering sector, the methodology used and the principal conclusions could be applied to any other sector. Indeed, the 24 skills selected to evaluate the project do not belong specifically to the automotive industry, they are also appreciated by other types of industry, and the initial professionals' opinion serve to prioritise them.

REFERENCES

1. F. Aparicio, R.M. González and 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, *International Journal of Engineering Education*. **21**(6), 2005, pp. 1159–1167.
3. D. Chadha and G. Nicholls, Teaching transferable skills to undergraduate engineering students: recognising the value of embedded and bolt-on approaches, *International Journal of Engineering Education*. **22**(1), 2006, pp. 116–122.
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. Alianza Editorial, Madrid, (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, *International Journal of Engineering Education*, **15**(3), 1999, pp. 191–198.
8. J. González and R. Wagenaar, Tuning educational structures in Europe, Universidad de Deusto, (2003).
9. Fundación Universidad-Empresa. Guía de las empresas que ofrecen empleo 2006–2007. Fundación Universidad-Empresa, (2006).
10. Bologna Declaration. Joint declaration of the European Ministers of Education, 19th June (1999).
11. Formula SAE Rules (2008), www.formulastudent.com/universities/Rules.htm, accessed February 2009.
12. R. Devon, S. Bilen A. McKay, A. de Pennington, P. Serrafero and J. Sanchez Sierra, Integrated design: what knowledge is of most worth in engineering design education? *International Journal of Engineering Education*, **20**(3), 2004, pp. 424–432.
13. R. Zavbi and J. Travcar, Preparing undergraduate students for work in virtual product development teams, *Computers and Education*, **44**(4), 2005, pp. 357–376.

F. Javier Sánchez graduated in Mechanical Engineering in 1997 and obtained his Ph.D. degree in 2005 at the Polytechnic University of Madrid, UPM. Since 1997 he has been a part-time teacher of Engineering Projects at that university, as well as holding different

positions in automotive companies. Since 2003 he has also been a researcher and director of the Formation Division at the University Institute for Automotive Research, INSIA-UPM, where he has specialised in vehicle design and hybrid motorisation, and serves as the Faculty Advisor for the University's Formula SAE team, called UPMracing.

Francisco Aparicio obtained his Industrial Engineering Ph.D. degree in 1978 at the Polytechnic University of Madrid, UPM. Since 1981 he has been Professor of Vehicle Engineering and Transport at that university, as well as being the Director of the Automobile Research Institute (INSIA). Amongst other positions, he is the Spanish representative in the Working Party on General Safety provisions of the Economic Commission for Europe of the UN (GRSG) and the European Enhanced Vehicle-Safety Steering Committee (EEVC), the Chairman of the Spanish Association of Automotive professional, and the Vice-chairman of the Ibero–American Federation of Mechanical Engineering. He also has been the main researcher on more than twenty research projects and the author of several technical and engineering books and papers in the field of automobile, traffic safety and transportation.

Miguel A. Alvarez graduated in Mechanical Engineering in 2002 at University Simon Bolivar (USB), Venezuela, and received a Master in Automotive Engineering in 2004 from the Polytechnic University of Madrid (UPM). Since 2004 he has been a full time researcher in the Institute for Automotive Research INSIA-UPM, specialising on vehicles design and fabrication; he also serves as Advisor Assistant for the University's Formula SAE Team, called UPMRacing.

Felipe Jimenez obtained his Master's Degree in Industrial Engineering from the Polytechnic University of Madrid (UPM), his Master's Degree in Physical Science from the National University of Distance Education of Spain and his Ph.D. in Mechanical Engineering from the UPM in 2001, 2005 and 2006, respectively. Currently, he is Associate Professor at the UPM. He has been involved in several research projects and innovative education programmes and has developed engineering studies for relevant national firms. His fields of interest are the automotive industry, vehicle safety, mechanical design, educational software and the application of new educational approaches in university studies.