UMA Racing Team: An experience in participation in a competition between universities

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Abstract- This paper presents the experience of the UMA Racing Team of the University of Málaga in the Motostudent Competition. In this competition, university students have to design a racing motorcycle. Not only is the motorcycle designed and manufactured, but an industrial project must also be developed for the commercialization of the motorcycle. The developed project is evaluated from a technical, economic and also esthetic point of view by an external committee made up of experts in the sector. In addition, the prototypes are also evaluated in dynamic tests and a race. The UMA Racing Team has participated in five editions of this competition with outstanding results. For students, it represents an opportunity to work on a real project with a limited budget and deadlines and to exhibit the result of their work to professionals who have extensive knowledge of the sector. The interaction between students, companies and professionals contributes to the participants achieving new skills and abilities that are highly valued by companies. The experience confirms that the incorporation of participants into the labor market has been very satisfactory.

Keywords: Project-based learning, university competition, design and manufacturing.

1. Introduction

The UMA Racing Team has been participating in the Motostudent Competition since 2008, starting its activity as a participant in this international competition in the first edition, in which 25 university teams were already registered. The team has achieved outstanding success in all editions of this competition. For each edition of the competition, a team has been formed by students from various degrees, mainly from the School of Industrial Engineering of the University of Malaga, but also from other degrees related to the objectives of the competition, such as Business Administration and Management and Commerce. Members developed their capacity in creation and innovation and the ability to directly apply their technical skills to the designed prototypes. The team's work has been tutored by two professors from the School of Industrial Engineering of the University of Malaga. Likewise, lecturers with expertise in aspects related to the design of prototypes and industrial projects have also collaborated regularly with the team. This has also meant that the teaching staff has supervised a large number of bachelor and master theses of the team members.

2. Context

Motostudent is an international competition promoted by the Moto Engineering Foundation and TechnoPark Motorland. It is a challenge among Spanish, European and international university teams to design and develop a prototype of a racing motorbike with characteristics similar to those of the Moto3 World Championship category. Initially, the developed prototype had to make use of a combustion engine, which was provided by the organisation. Since the 3rd edition, a new category has been created in which the prototype has had to make use of an electric motor. The interest in electric vehicles is growing every year among users and manufacturers as one of the main commitments, along with renewable energies or recycling, for a sustainable and environmentally friendly lifestyle. Thus, this new category has quickly attracted the attention of participants. The competition has its culminating event at the Motorland Aragón Circuit (Alcañiz, Teruel). The competition is held every two years.

The developed project is evaluated from a technical, economic and esthetic point of view by an external panel of experts in the sector. This phase is called MS1 and students have to present their industrial, technical and innovation projects and answer questions posed by the panel. As mentioned above, a key part of this assessment is innovation. Students have to come up with innovative ideas related to the world of two-wheel vehicles. This activity encourages students' creativity and proactivity, always looking for new proposals that will surprise the evaluation committee.

Finally, after passing a series of static and dynamic tests, a race between the prototypes of the different universities takes place. Riders are selected by the teams themselves. This phase is called MS2. Teams finally obtain an overall score that includes static and dynamic tests and the race.

The number of universities participating in the electric category of this competition has increased considerably in the last edition compared to the previous ones. In the last editions of this competition, teams from universities all over the world took part, including teams from Italy, the United Kingdom, Germany, India, the Czech Republic, Canada, Portugal…

3. Description

As indicated above, the UMA Racing Team has participated in several editions of this competition. In the first two editions, it developed prototypes that made use of a combustion engine, within the so-called 'petrol' category. In the fourth edition, the 'electric' category was introduced. In that edition, the team participated with two prototypes, one in each category. Finally, in the last two editions, it only took part in the electric category. From our point of view and with a view to the most advanced training for students, we consider that this is where most innovations can be made. Thus, in addition to what is involved in developing an electric vehicle, students are trained in the use of new energies, innovative applications, care for the environment, sustainable mobility, and so on. A clear commitment to innovation and development focused on a green future. The implementation of participation in this activity in the format of a competition team has proved to be a very effective tool for our students' learning and has increased their professional and human experience, acquiring new skills and clearly favouring their capacity in innovation and entrepreneurship. Thus, during the usual development of an edition of the competition, and under the supervision of tutors, group formed by students must:

- Carry out a real project with the commitments of the industrial world:
    - Working within a team
    - Working in competition
    - Working tied to a restricted budget
    - Working with a fixed timetable
- Work in connection with companies and institutions in the world of top motorbike racing.
- Handle the most advanced design and analysis tools and systems to carry out a real project.

The team has maintained its uniformity throughout the different editions, with facilities, tools and resources that have continuously been increased. It also has repositories where generated information, projects, plans and documents, in general from each of the editions, are collected and stored.

A fundamental aspect in order to take part in the competition is the search for funding by students through the presentation of the project to potential sponsors. Usually, team members move to companies to present the team and the objectives of the competition, using dossiers and catalogues developed by the team members. As with any competition team, visibility and publicity are provided to the sponsoring company in exchange for the contribution of economic or material resources to the team. In addition, the university itself and other public institutions have provided economic resources for the development of projects, generally through participation in competitive calls in which, to a greater or lesser extent, the team has obtained funding.

The competition has a purely academic objective, being a multidisciplinary project with great weight in the areas of engineering, economics, marketing and project management. Although the project is based on the development and manufacture of a prototype racing motorbike, it is not a typical speed championship. For these reasons, eligibility is limited to active university students. Once this premise has been met, students are selected on the basis of their degree qualifications. In the case of undergraduate students, selected students must have passed 50% of the credits leading to their degree. This limitation is not considered for Master students. Other criteria considered for selection are: previous experience in fields of interest for the project (e.g. design, electronics, industrial organisation, ...), availability and experience in the field of two-wheeled vehicles.

Once the students who make up the team to participate in an edition have been selected, they are distributed into departments. Each department is responsible for the development of a fundamental part, component or system of the motorbike (Table 1).

For the development of mechanical systems, the experience of tutors in this field and that of the rest of the teaching and research staff of the Mechanical Engineering Area is resorted. Similarly, teaching staffs from other areas, such as Fluid Mechanics, Economics and Business Administration, Electronics and Mechanics of Continuous Media and Theory of Structures, have regularly collaborated in the monitoring and supervision of the work and in tutoring the bachelor and master theses of the team members who have developed their activity in subjects related to their areas.

Table 1
Team structure

Dept.	Category	Description
General modelling and ...		Integration of components and calculation of performance, time, consumption, ...
Mechanic	**Chassis**	Chassis design
	Swingarm	Swingarm design
	Mechanical parts	Clamps, foot pegs, brake supports, steering damper support, mounting and dismounting tools
	Transmission	Transmission calculation and design
	Suspension	Rear suspension simulation, calculation and design
	Rear cowl	Carbon fiber rear cowl design
Aerodynamics	**Aerodinamycs**	Aerodynamic and thermal simulation, design and manufacturing of fairing, tank cover and mudguard.
Electronics	**Battery**	Battery design. Includes mechanical and electrical parts.
	BMS	Commercial BMS programming and in-house BMS design
	DAQ	Data acquisition and recording, display on screen,

		telemetry and program for data processing on the computer.
	Controller	Commercial controller programming and in-house controller design (simulation, control electronics and power electronics)
Organiza-tion	**Industrial project**	Market study, business and manufacturing plan, economic study, facility design and virtual reality visit.
Team general task	**Team general tasks**	Search for sponsors, image, advertising, public relations, accounting, purchase of components, organization of events.

To achieve the team's objectives, the CDIO methodology has been implemented for the development of the assigned sub-projects (Sáez López, J. M. 2018, Crawley, E.F. et al, 2007). To do so, students have to perform a series of tasks and report periodically to the project tutors on the activities related to each of the stages of this methodology (Conception, Design, Implementation and Operation). The following table lists the CDIO stages, the activities or material that students have to deliver to verify and evaluate their degree of compliance (Table 2).

Table 2
CDIO Stages

Stage	Task	Delivery
Conceiving	Analyze the requirements to be met by the sub-system. Consider technological possibilities, resources and team needs, strategy and regulations. Include conceptual and technical development and business plans.	Preliminary project sheet
Designing	Component design proposals / solutions to formulated problems. Component modeling. Detailed drawings, schematics and algorithms, if applicable, describing the product, process or system.	Report with dimensioned drawings, calculations, representations, pseudo-codes. Codes or programs with 3D modeling of components.
Implementing	Transformation of the design into a product, hardware manufacturing, software programming, integration, testing and validation.	Prototype, component or code manufactured. Report of the manufacturing process, incidents and cost.
Operating	Complete system assembly, verification of compliance with assumptions.	Report on the use of the product or subsystem. Report improvement possibilities.

To achieve these objectives, students were first trained in the PBL-CDIO methodology. Regular meetings (weekly and fortnightly) were held to monitor the progress of each of the individual projects. In these meetings, the progress made by each group was openly presented. Results achieved are discussed globally and proposals for improvement are made (Rodríguez Lozano et al, 2020). To this end, during the last edition, the following stages were carried out:

1. General training of students in PBL methodology.
2. General training of students in specific aspects of two-wheeled vehicles and in competition.
3. Specific training in the fields assigned to each group of students.
4. Design of all mechanical, electrical and electronic components of the motorbike.
5. Manufacture and assembly of the energy storage system. This system is made up of the battery pack, the battery management system and all the necessary electrical installation.
6. Design of the electric motor controller.
7. Setup of the electric motor provided by the organisation.
8. Battery Management System charging and management tests.
9. Electric motor dyno tests.
10. Tests with the controller designed to optimise the response of the electric motor.
11. Design of the industrial plan for marketing the motorbikes. Preparation of meetings with experts in the sector to capture innovative ideas.

Although the competition establishes a system for the fulfillment and evaluation of the work, the researchers involved in the project regularly evaluate and report with students to assess the degree of fulfillment of the proposed objectives. To this end, control is kept of the activities carried out by students, the degree of compliance with deadlines and the objectives and tasks to be carried out. On the other hand, students themselves are also involved in the evaluation of their peers, contributing with their own point of view regarding the work and results achieved by the rest of team members.

The number of students involved in the project is limited to a maximum of 40. They are grouped according to the tasks assigned in groups of a maximum of 4 students. Although it is not usual, there may be more than one group of students working in the same category. In this case, internal competition in each team is encouraged. In the case of promoting different solutions to the same problem or system, it is the team itself that, in its regular meetings, decides which of the options is the most viable or innovative.

The number of hours of student work is estimated at a total of 90 hours, distributed as follows (Table 3):

Table3
Distribution of student work.

Activity	Periodicity	Duration	Total hours
Full group meetings	Biweekly	0.5 hours	8
Area meetings	Biweekly	1 hour	16
Group work	Weekly	1 hour	32
Personal work	-----	-----	20
Other activities (attendance to talks, appointments with sponsors, …).	On demand	-----	14
		TOTAL	90 h.

The project fosters the development of numerous transversal competences, recognised as fundamental according to most reports, which favour and enhance employability of the students involved [Informe-infoempleo-adecco, 2020]. Among them, we would like to highlight the following, justifying activities carried out by students related to each one of them:

- Teamwork. The project is presented as group work in which all members must collaborate and cooperate to develop all the components of the motorbike. It should be noted that communication and interaction between members is essential for the proper integration of all the components of the prototype (Figure 1).

Figure 1. Initial group meetings.

• Result orientation, commitment. This competence is inherent to the competition. Not only do results have to be obtained, but students know that their work will be evaluated in competition with other teams as well. On the other hand, the organisation itself establishes milestones in which the work done and the solutions reached must be justified. Otherwise, the team is penalised.

- Time management and planning skills. As indicated in the problem-solving competence, the prototype is composed of numerous subsystems that are designed by groups of students. Meetings are held periodically to monitor and evaluate the progress of tasks, prioritising and allocating resources according to needs.

- Problem solving, decision making. Students must be decisive, present their own proposals and provide solutions to all technical complexities of the project. The prototype is made up of numerous subsystems (chassis, swingarm, control, batteries, etc.). Students must cope with difficulties presented by the design of each of these components and the integration of all of them.

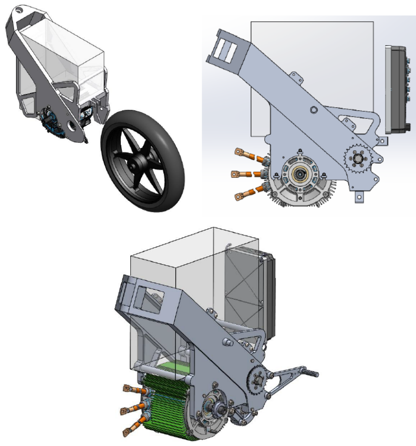

Figure 2. From left to right: first, second and final version of the motorcycle chassis. 2019-2020 Edition.

As an example, the evolution of the chassis design of the 2018-2019 edition from the first version to the final version is shown in Figure 2. This evolution was necessary in order to meet the weight, stiffness and manufacturability requirements of the design.

- Communication skills. Firstly, it should be pointed out that, during the periodic meetings, students have to explain their work, difficulties encountered and progress made, interacting with the teaching staff in charge and with the rest of the group in these meetings. This activity clearly improves their communication skills. Members must also interact with sponsors, collaborating companies, suppliers, etc., so they also get used to expressing their proposals and requirements in different environments. However, it should also be remembered that a fundamental part of the competition is the presentation in front of an evaluation panel made up of experts in the work carried out. In these presentations, they must present their project brilliantly, communicating its advantages clearly, defending their proposals and answering the panel's questions.

- Adaptability, tolerance to change, flexibility. The very fact that the prototype to be designed is electric is already proof of students´capacity to adapt to change. But, what is more, we are facing a technology that is constantly changing and to which numerous novelties, which emerge periodically, can be incorporated. Thus, we find that from the first to the second prototype developed, there have been numerous changes, fundamentally in the sections related to electronics and control. The students have had to adapt to these developments. On the other hand, the difficulties that arise in any project and the need to have a final result mean that the group has to adapt and modify its decisions according to obstacles encountered (Figure 3).

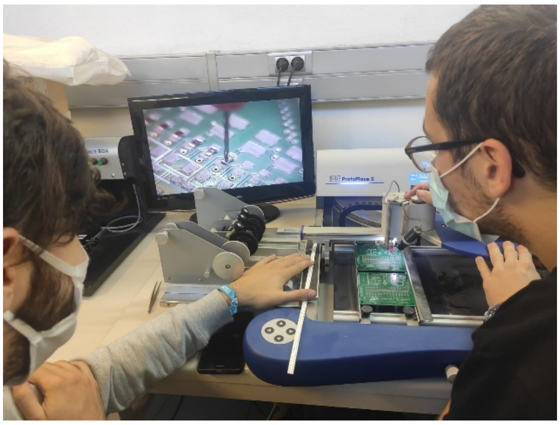

Figure 3. Fabrication and final design of battery control board. 2019-2020 Edition.

Creativity. In addition to what has been indicated in the previous competence, students have to constantly provide innovative and original ideas, solutions and proposals to encountered problems. But not only that, the organisation itself stimulates creativity by incorporating a section with a high score in which students must propose a relevant innovation. This means that one of the group's objectives in its meetings is to encourage the contribution of new ideas, systems, gadgets, controls, which could be applied to the world of two wheels. This autonomous operation, although always supervised by tutors, has contributed to the fact that students themselves have taken initiatives and have contributed with solutions, in some cases very innovative ones, to encountered difficulties. Proof of this is, for example, the design of the motorbike's transmission system or the subframe, mudguards and tank cover made of carbon fibre, developed for the 2019-2020 edition (Figure 4).

- Initiative, proactivity, learning, leadership. As indicated above, the novelty of the project, the appearance of new technical solutions, the need to resort to knowledge not acquired during studies and deadlines set by the organisation make it strictly necessary for students to take initiatives, do research and study fields that are new to them, in search for solutions when encountering problems.

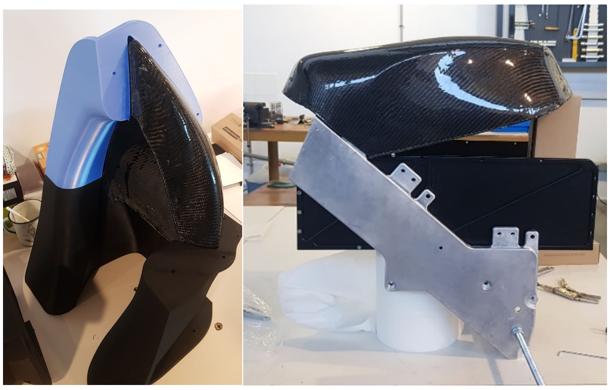

Figure 4. Mold, fender and tank cover. 2019-2020 Edition.

4. RESULTS

Participating students put knowledge acquired during their university studies into practice and prepare themselves for the world of work by taking on a real project and its implications: working in a multidisciplinary team, restricted to a budget, and fulfilling a schedule. This project brings a clear educational benefit to students involved in it. Among these benefits we can highlight:

- Learning of new competencies not integrated in their syllabus.

- Experience added to their curriculum in terms of teamwork, manufacturing, innovation and resource management.

- Organisation of an industrial project for the manufacture of a motorbike.

- Completion of Bachelor or Master degree final projects.

These results confirm that the creation of a university team for the development and manufacture of a real and viable prototype by means of a technical and industrial project that is evaluated externally is a very effective tool in the learning process of our students. It increases their professional and human experience, acquiring new competencies and clearly favouring their capacity in innovation and entrepreneurship.

Finally, it should be noted that the team has maintained a successful line of action throughout all the editions. In all of them, the team has managed to present its prototypes to the competition, obtaining outstanding results in all editions. It is necessary to highlight the absolute victory in the 'electric' category achieved in the last edition, despite having a clearly lower budget than many other teams.

The team has also consolidated itself as another tool at the service of transferring research results to the business world.

The assessment of this activity has been very satisfactory on the part of students and teaching staff. For its evaluation, a survey was carried out among participants from previous editions. The average evaluation of this activity was 4.76 out of 5. Other relevant aspects that the survey showed was that 88% of respondents indicated that participation in this activity helped them to complete their university education, 94.1% indicated that it provided them with skills that they had not acquired during their studies. Regarding the employability of participants, the survey showed that more than 90% of participants considered that this activity facilitated their incorporation into the labour market and a better and quicker adaptation to work in a company. Finally, 45.4% were incorporated in the labour market in less than 3 months from the end of this activity and 88% in less than one year (Figure 5). This figure is 30 points higher than the average for engineering degrees in the centre where this activity is carried out. This last figure was obtained from the insertion rates included in the Quality Management System report published by the University of Malaga. It is noteworthy that in 91% of cases it was indicated that, during job interviews, human resource managers showed special interest in discussing the candidate's participation in this activity in depth.

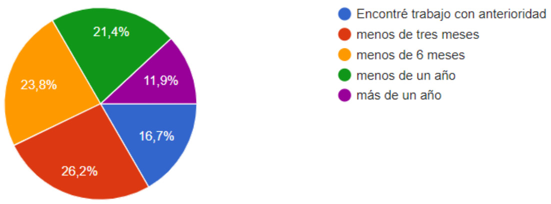

Figure 5. Average time between completion of participation and entry into the labor market.

5. CONCLUSIONS

The Motostudent project has had a strong appeal to students since its inception. It represents an opportunity for them to make use of knowledge acquired during their studies in a real application with the added attraction of a competition format. Thus, more than 200 students have been involved, to a greater or lesser extent, since the first edition. From our own experience, we know that the employability of these students has been excellent. The vast majority of them managed to enter the job market within a short period of time, generally even before finishing the competition. In many cases, participants from previous editions have reached positions of responsibility in companies related to the automotive industry and advanced technologies.

Participating in Motostudent involves working in a group, meeting a time schedule, sticking to a limited budget, learning about production processes and the latest technologies. We believe that this project fosters the acquisition of skills that are in great demand in today´s industry, such as teamwork, creativity, innovation, adaptation to change, decision-making, result orientation, management and planning, proactivity and leadership.

It is also worth highlighting the number of entities that have collaborated with the team. This has served to develop an up-to-date prototype. This search for external collaborators contributes to students' communication, negotiation and knowledge of business and technological reality. Communication with companies, promoting interrelationships with them and the creation of links are a very important part of this project, favouring the development of students and opening doors for their insertion in the labour market.

Regarding contribution to the university, we could approach it from two points of view. On one hand, it has contributed to the training of teaching and research staffs in new technologies related to the automotive industry, manufacturing and business. The teaching staff guides and trains students, but the involvement of students and their own work makes the teaching staff evolve and contributes to their training, acquiring new knowledge, which is subsequently transmitted to students. An example of this is the high level achieved in the knowledge of new manufacturing methods, new materials, battery system design and advanced motor control.

On the other hand, Motostudent has also contributed to the visibility of this activity developed at the University of Malaga. It has appeared in numerous media in written press, radio and television. The prototypes are usually shown on open days at the university and in activities developed within schools and faculties.

For all these reasons, we consider that this project is an activity whose cost-benefit ratio is very favourable for students and the university.

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