Teaching Engineering Design to a Multidisciplinary Audience at Master's level: Benefits and Challenges of the CDIO Approach

Enrique Chacón Tanarro, Juan Manuel Munoz-Guijosa, Andrés Díaz Lantada, Pilar Leal Wiña, Javier Echávarri Otero, José Luis Muñoz Sanz, Julio Muñoz García, Óscar Nava Rodríguez, Sergio Garre Mondéjar

Mechanical Engineering Dept., Teaching Innovation Group in Machines Engineering
Escuela Técnica Superior de Ingenieros Industriales (School of Industrial Engineering),
Universidad Politécnica de Madrid (ETSII – TU Madrid)
c/ José Gutiérrez Abascal 2, 28006 Madrid, Spain, Contact: adiaz@etsii.upm.es

ABSTRACT

"Engineering Design" is a discipline aimed at improving our understanding about the development processes of novel and successful products, processes and systems in general, and at providing engineers with methodical steps for enhancing such processes. It may well be the engineering discipline more linked to the CDIO approach and to the conceive-design-implement-operate process. The benefits of applying "Engineering Design" principles are better appreciated when facing the development of complex systems. In the field of Mechanical Engineering some of the more complex systems an engineer can develop are advanced mechanical systems and machines.

In this study we present the complete development of a novel subject on "Engineering Design" for the Master's Degree in Industrial Engineering at ETSII – TU Madrid. The subject is based on the CDIO approach, as we consider it a very remarkable way of promoting student active learning and of integrating, with impact, novel concepts into curricula evolving from more traditional methodologies. During the subject, groups of students live through the complete development process of several advanced mechanical systems and machines aimed at providing answers to unsolved problems, usually involving relevant social needs. Computer-aided engineering, rapid prototyping technologies, open-source electronic platforms and a wide set of testing facilities are used as support tools for their designs and prototypes, so as to reach the implementation and operation phases with enough time for a re-design cycle.

Main benefits, lessons learned and challenges, linked to this CDIO-based subject, are analyzed, taking into account the results from 2014-2015 academic course and comparing them with results from a previous subject, taught in the old plan of studies, more limited in time and scope due to curricular restrictions. Students from several specializations of our Industrial Engineering MSc (i.e. Mechanical Engineering, Energy, Manufacturing Technology, Materials Science, Chemical Engineering, Automation and Electronics, Industrial Organization…) have taken part in the subject, what has helped the groups to tackle very complex mechanical systems and machines and to implement them with success. To our knowledge it constitutes the first subject following a complete CDIO cycle in the field of Engineering Design, not directly linked to automotive engineering, in our country.

KEYWORDS

CDIO as Context, Integrated Curriculum, Integrated Learning Experiences, Active Learning, Engineering Design, Mechanical Systems, Machines Engineering.
(Standards: 1, 3, 5, 7, 8).

INTRODUCTION

Student motivation and active engagement to their own learning process is a key success factor in Higher Education, especially in Science and Engineering paths, as recognized and highlighted in several studies, reports and declarations, such as the Bologna Declaration and the subsequent related declarations from Prague, Berlin, Bergen, London, Leuven and Budapest-Vienna, aimed at the implementation of the European Higher Education Area (EHEA). Making students drivers of change is perhaps the most effective part of a global strategy, for the promotion of professional skills in Engineering Education (Shuman, et al. 2005, Díaz Lantada, et al. 2013). Problem- or project-based learning (typically PBL) methodologies clearly tend to motivate students to participate and become involved in their own learning process and is an excellent way of analysing whether students have acquired the basic concepts taught in the theory classes and if they are capable of applying them in real situations.

In direct connection with the promotion of project-based learning methodologies worldwide, even though its holistic approach to engineering education development goes far beyond project-based learning, the CDIO™ Initiative (www.cdio.org) is probably the most ambitious approach. The CDIO™ Initiative is focused on the establishment of an innovative educational framework for producing the engineers of the future, by means of providing students with an education stressing engineering fundamentals by means of “Conceiving - Designing - Implementing – Operating” (CDIO) real-world systems, processes and products (Crawley, et al. 2007). Throughout the world, CDIO Initiative collaborators are adopting CDIO as the framework of their curricular planning and outcome-based assessment. CDIO also promotes collaboration and sharing of good practices among engineering educational institutions worldwide.

“Engineering Design” is an engineering discipline aimed at improving our understanding about the development processes of novel and successful products, processes and systems in general, and at providing engineers with methodical steps for enhancing such processes. It may well be the engineering discipline more linked to the CDIO approach and to the conceive-design-implement-operate process (Crawley, 2007). The benefits of applying “Engineering Design” principles are better appreciated when facing the development of complex systems and, in the field of Mechanical Engineering, some of the more complex systems an engineer can develop are advanced mechanical systems and machines. Being a discipline involving applied tasks, in direct relation with real and complex problems and systems, it can potentially be taught and promoted by means of project-based learning CDIO-related approaches.

In this study we present the complete development of a novel subject on “Engineering Design” for the Master’s Degree in Industrial Engineering at ETSII – TU Madrid. The subject is based on the CDIO approach, as we consider it a very remarkable way of promoting student active learning and of integrating, with impact, novel concepts into curricula evolving from more traditional methodologies. During the subject, groups of students live through the complete development process of several advanced mechanical systems and machines, aimed at providing answers to unsolved problems. Computer-aided engineering, rapid prototyping technologies, open-source electronic platforms and a wide set of testing facilities are used as support tools for their designs and prototypes, so as to reach the implementation and operation phases with enough time for a re-design cycle. Main benefits, lessons learned and challenges, linked to this CDIO-based subject, are analyzed, considering the results from 2014-2015 academic course.

THE "INGENIA" INITIATIVE:
INTEGRATED PROMOTION OF CDIO INITIATIVES AT ETSII – TU MADRID

The implementation of Bologna process has culminated at ETSII – TU Madrid with the beginning of the Master's Degree in Industrial Engineering, in current academic year 2014-15. The program was successfully approved in 2014 by the Spanish Agency for Accreditation (ANECA), with the inclusion of a set of subjects based upon the CDIO methodology denominated generally "INGENIA", an acronym from the Spanish verb "*ingeniar*" (to provide ingenious solutions), also related etymologically in Spanish with the word "*ingeniero*" (engineer). INGENIA students experience the complete development process of a complex product or system and there are different kinds of subjects (and projects), within the initiative, covering most of the engineering majors at ETSII-UPM. Students choose among the different INGENIA subjects (and projects), depending on their personal interests.

The INGENIA subjects are compulsory for all students enrolled in the first year of the Master's Degree program at ETSII – TU Madrid (a two-year program with 120 ECTS after a four-year Grade in Industrial Technologies with 240 ECTS). The subjects (with a similar CDIO orientation but offering different topics and projects) are 12 ECTS equivalent, which correspond to a student workload between 300 to 360 hours, distributed along two semesters with the following structure: 120 hours of supervised work plus between 180 to 240 hours of personal student work, organised usually in teamworks. Professor supervised part of the subjects is divided into 30 hours dedicated to adapt basic theoretical knowledge derived from other subjects to those directly related with the project, and a second set of 60 hours is devoted to practical work in the lab, with professor supervised sessions. Students also receive two seminars of 15 hours; one oriented to transversal outcomes, in particular, workshops on teamwork, communication skills and creativity techniques, and the other one about social responsibility issues such as environmental impact, social, political, security, health, etc. These lectures, practical sessions, seminars and workshops, are distributed along the 28 weeks of the two semesters of the first year, resulting in 5 hours per week of lectures or practical sessions in the regular schedule of students. Placing the INGENIA subjects in the first year of a 120 ECTS program is indeed interesting, as additional 12 ECTS are devoted to the final degree thesis normally during the second year. Therefore, at least 20% of the whole Master's Degree is devoted to project-based learning aimed at the complete development of engineering products and systems. Program structure is detailed in Figure 1 and the integration of CDIO activities can be easily appreciated (INGENIA subjects in pale blue and Final Master's Thesis in pale green).

Hours/week	THIRD SEMESTER	ECTS	Hours/week	FOURTH SEMESTER	ECTS
	Final Master's Thesis	6		Final Master's Thesis	6
6	Curricular configuration	9	6	Curricular configuration	9
2	3 specialization subjects (Automation & Electronical, Chemical, Electrical, Energetic, Materials, Mechanical, Construction, Org.)	3	2	3 specialization subjects (Automation & Electronical, Chemical, Electrical, Energetic, Materials, Mechanical, Construction, Org.)	3
2		3	2		3
2		3	2		3
2	1 subject on Industrial Installations	3	2	1 subject on Industrial Management	3
2	1 subject on Industrial Technologies	3	2	1 subject on Industrial Technologies	3

Hours/week	FIRST SEMESTER	ECTS	Hours/week	SECOND SEMESTER	ECTS
4	INGENIA (first part)	6	4	INGENIA (second part)	6
2	2 subjects on Industrial Management	3	2	2 subjects on Industrial Management	3
2		3	2		3
2	2 subjects on Industrial Installations	3	2	2 subjects on Industrial Installations	3
2		3	2		3
2	4 subjects on Industrial Technologies	3	2	4 subjects on Industrial Technologies	3
2		3	2		3
2		3	2		3
2		3	2		3

Figure 1. Program structure (Master's Degree in Industrial Engineering).
120 ECTS program with at least 20% devotion to project-based learning activities.

In addition, the INGENIA subjects are helping us to complement our competence-based strategy, in accordance with CDIO Standards 1, 3, 7 & 8, by placing special emphasis on several professional skills difficult to obtain in more traditional teacher-centred activities, such as conventional master classes and expert talks. Expected outcomes include the promotion of: students' ability to apply knowledge of mathematics, science and engineering, students' ability to design experiments and interpret data, students' ability to design engineering systems and components to meet desired goals, students' ability to communicate effectively and to work in multidisciplinary teams, or students' ability to use modern resources, in accordance with the ABET professional skills our program tries to promote (Shuman, et al. 2005). Different subjects within the INGENIA framework cover diverse disciplines such as: automotive engineering, mechanical engineering, automation and electronics, construction, materials science, energy engineering and biomedical engineering. Next sections describe and analyze the implementation and first experience with our new subject on "Engineering Design", as a relevant example of success within the INGENIA framework.

FIRST IMPLEMENTATION OF "ENGINEERING DESIGN" WITHIN THE INGENIA INITIATIVE: MAIN RESULTS, LESSONS LEARNED AND CHALLENGES

The "Engineering Design" subject at ETSII – TU Madrid was prepared during academic courses 2012-2013 and 2013-2014, supported by the "Engineering Design" TU Madrid Teaching Innovation Project, on the basis of 15 years of the research work and teaching activities in the field of product development. Preparing the new subject was considered a strategic opportunity for the collaboration of all the teachers and laboratory technicians of our teaching unit and a challenging and motivating experience, as always happens with multidisciplinary subjects. The Teaching Innovation Project was focused on the adaptation of a previous one-semester subject, also linked to Engineering Design (Muñoz-Guijosa, 2011), so as to obtain a more complete 12-ECTS equivalent subject on "Engineering Design". The new two-semester structure is much better, as in the previous subject we could never achieve the implementation and operation stages due to schedule limitations. The topics covered in the new subject are listed below and provide an excellent introduction to systematic product development, engineering design, creativity promotion strategies, modeling and simulation technologies, machine engineering, real industrial practice, security issues, standardization and quality management:

- Content block 1: Introduction to systematic product development.
- Content block 2: The conceptual design: From the product idea to the concept.
- Content block 3: The basic engineering: From the concept to the product.
- Content block 4: The detailed engineering: The challenge of reaching market.
- Content block 5: Design and simulation of machines and mechanical systems.
- Content block 6: Security issues, standardization and quality management.

The Teaching Innovation Project was also devoted to the development of case studies and of new laboratory facilities for the promotion of hands-on activities and for supporting the development of medical devices to be carried out by groups of students, in a PBL-approach, as main part of their assessment. Figure 2 includes some of the new case studies, work-benches, testing facilities and supporting resources developed. The subject counts with the support of the "Product Development Lab" and the "Machine Engineering Lab", where several design and simulation software, testing facilities and rapid prototyping technologies by means of additive manufacturing and rapid form copying are available. Such facilities are very relevant for letting students live trough the complete development process of a new mechanical system, from the conceptual and design phases, to the implementation and operation stages, which are normally more difficult to achieve (Díaz Lantada, 2013).

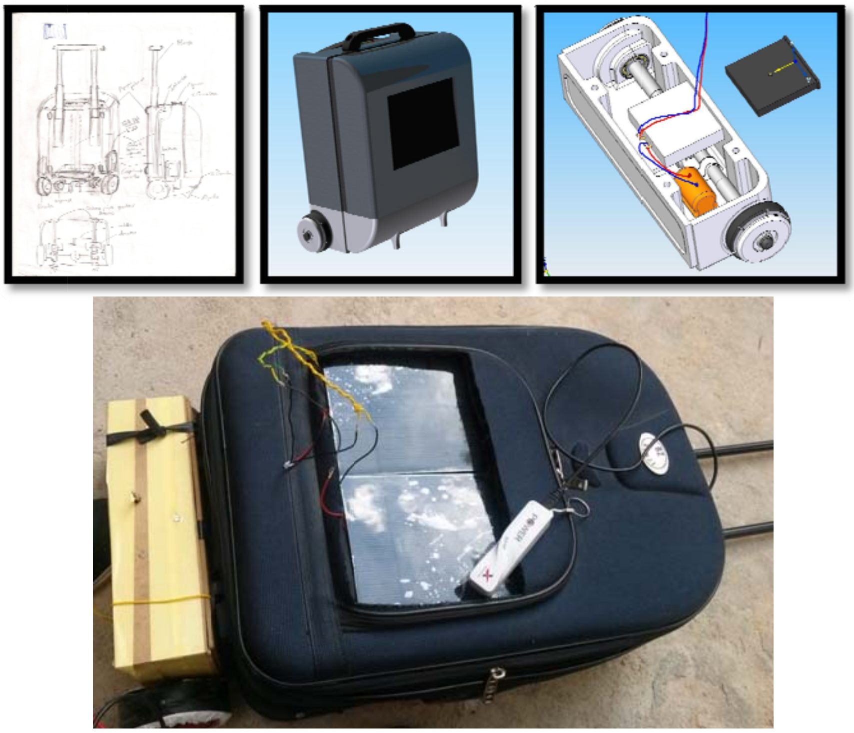

Figure 2. Example of a case study (linked to the complete development process of a self-powered trolley with connection to smart phone) as infrastructure for the subject.

During academic course 2014-2015, 22 students from the first promotion of our Master's Degree in Industrial Engineering (among a total of 180 engineering graduates) have taken part in the "Engineering Design" subjects of the INGENIA Initiative. At the beginning of the subject, the different students were divided into 5 groups and each group proposed at least 5 different machines or mechanical systems, which could potentially be developed within the subject. All the proposals were written down and a voting session was carried out, with participation of students and teachers, so as to decide the final devices to be developed in parallel to the subject. In the end, the 5 mechanical systems selected (one assigned to each group) were:

- Innovative fishing mechanism for beginners.
- Door-opening mechanism for disabled people.
- Articulated shelf for disabled people.
- Mechanical coin counter.
- Plastic bag manager for supermarkets.

In the subject, the conceptual stage is supported by creativity-promotion tools such as TRIZ, morphological boxes and systematic procedures for promoting the generation, combination and selection of ideas (Figure 3). The design stage counts with industrial state-of-the-art modeling and simulation software of main engineering disciplines. The aforementioned labs help with the implementation and operation stages with resources including: 3D printers, rapid prototyping facilities, Arduino kits, libraries of sensors and actuators and conventional manufacturing and testing resources. Some results from students' designs and prototypes, from previous courses, used as case studies, are included in Figure 4. The final results of current academic course will be obtained along the second semester just before the 11th International CDIO Conference, where we hope to discuss them with colleagues from partner universities.

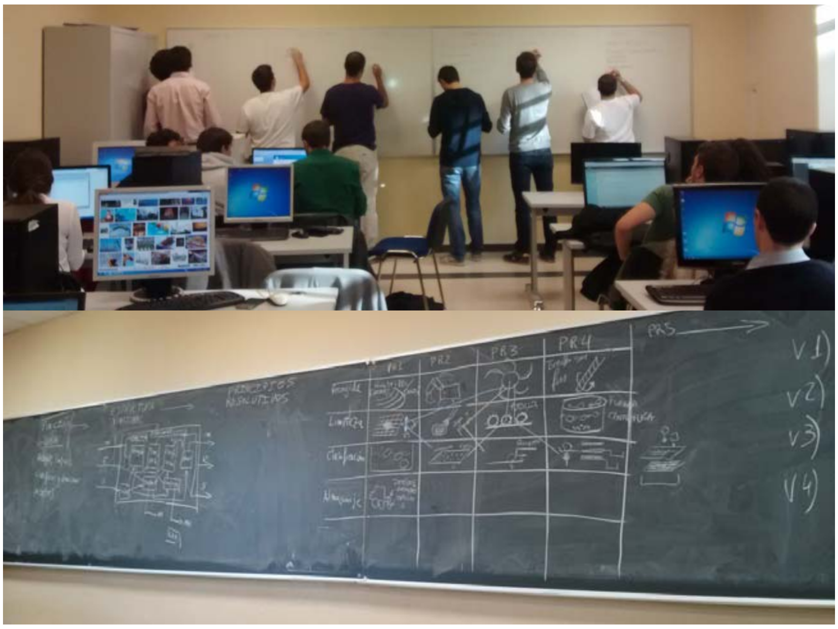

Figure 3. Picture of collaborative sessions for the conceptual design stage: Generation, assessment and selection of the best concept based on engineering criteria.

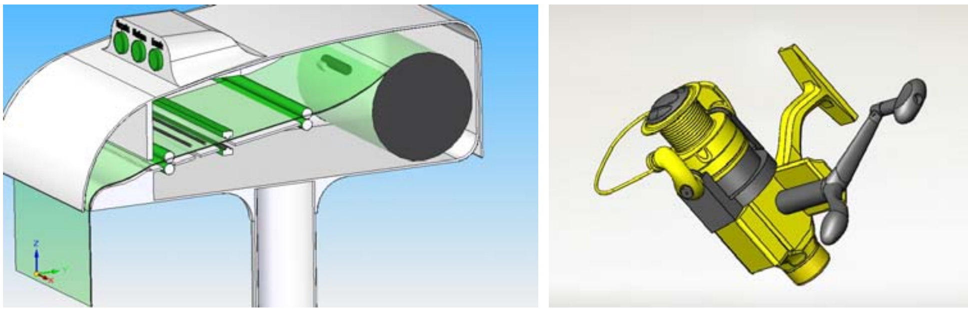

Figure 4. Some preliminary results from students' designs, simulations, prototypes and trials. a) Conceptual design of a plastic bag manager. b) Detailed design of a fishing mechanism.

Among already detected positive results within the subject of "Engineering Design", it is very important to highlight the following aspects, which we believe are intrinsically connected with a well implemented CDIO framework within the Master's Degree in Industrial Engineering and with a successful PBL-based subject:
-- Students' success ratio and attendance to formal lessons is importantly improved.
-- The interaction between teachers and students has experienced a relevant increase.
-- Intra- and inter-departmental communication has been promoted.

As preliminary summary of results, Table 1 includes some figures related to student and teacher success, motivation and implication in the subject, which is compared with mean values of other department subjects. The positive effect of shifting towards CDIO related methodologies can be clearly appreciated. It is necessary to indicate that the benefits affect not only learning and acquisition of outcomes, but also student and teacher motivation and mutual relation in a very special way, which is starting to influence the overall ambience of learning, collaboration and respect present in our novel Master's Degree in Industrial Engineering.

Such positive aspects clearly rely on an important increase of teacher dedication outside the classroom to the CDIO-based subject, but the general impression among the different teachers is that such additional dedication is compensated by the highly satisfactory results. In addition, the practical activities of the new subject are more expensive to implement, than more traditional practicals, as can be appreciated from the data in Table 1. However, the additional amount is between 1000€ and 2000€ for a whole subject, allowing all the students to live through the complete development process of a complex mechanical system. Again, the general impression is that the results are worth the effort.

Table 1. Some figures related to student and teacher motivation and implication in their subjects before and after the INGENIA Initiative. *According to data of the first semester. **In previous subjects of Industrial Engineering Degree (8 subjects from the 4th and 5th years).

Control aspect	In conventional subjects of our department**	In the CDIO subject on "Engineering Design"*
Success ratio (student completion rate)	65% – 75%	100%
Student attendance to scheduled lessons	45% – 65%	>80%
Typical number of answers to debate questions	1 – 3	5 – 7
Typical number of student questions / hour	2 – 5	5 – 8
Number of teachers inside the classroom at once	1	2 – 6
Frequency of meetings between the teachers of the same subject	2 / semester	5 / month
Frequency of meetings between the teachers of different departments	1 / semester	1 / month
Number of interactions with students outside the classroom / week	0 – 3	9 – 11
Resources needed for practical activities	0 – 100 € / student for practical sessions	75 – 100 € / student for practical sessions 800 – 1.200 € / group for prototyping tasks
Number of professional skills promoted and assessed	1 – 4	9
Hours devoted by the teachers outside the classroom / class hour	1 – 1.5	4 – 5

As additional reflection, the proposed two-semester structure for the INGENIA subject on "Engineering Design" is very appropriate, as the "conceive" and "design" phases are adequately carried out during the first semester and the "implement" and "operate" stages are tackled in the second semester. A whole academic year is ideal for maturing the development process of complex products and systems and is helping us to improve several prior experiences (Muñoz-Guijosa, 2011), limited to design and simulation activities, with the benefits from obtaining final prototypes and carrying out operational trials. It is also important to note that students from several specializations of our Industrial Engineering MSc (i.e. Mechanical Engineering, Energy, Manufacturing Technology, Materials Science, Chemical Engineering, Automation and Electronics…) have taken part in the subject, what has helped the groups to tackle very complex biodevices and implement them with success. **To our knowledge it constitutes the first subject following a complete CDIO cycle in the field of "Engineering Design" in our country.**

Regarding assessment, we are facing and managing the typical problems that arise when assessing teamwork activities. First of all, the proposed machines and mechanisms are complex enough to promote positive interdependence between members of the team, so that each of the members is needed for the overall success and that there is enough workload to let all students work hard and enjoy the experience, thanks to learning a lot. In addition, we are encouraging individual assessment, complementing the teamwork activities with individual deliveries and during the public presentations of their final results (which account for a 30% of the global qualification). The evaluation of professional skills counts with the help of ad hoc designed rubrics, as part of an integral framework for the promotion of engineering education beyond technical skills, consequence of recent educational innovation projects (Hernández Bayo, et al., 2014). Main results are to be presented at Cheng-Du after forthcoming analyses. It is important to highlight that there have been several drivers of change, not just political (transition to the EU Area of Higher Education), but also institutional, as the management board has systematically promoted these subjects and provided ways of supporting them (i.e. seminars for teachers, funding of supplementary activities…). Lastly, teachers' motivation and students' involvement have been probably main keys for success.

Considering future challenges, we would like to incorporate the developed products of 2014-2015 academic course as case studies, in a continuous improvement cycle, which hopefully will help us complete a large library of mechanical systems. Counting with a library of designs and prototypes of several devices will be positive, not only for teaching purposes, but also for research activities. The detailed subject may be the first seed towards the creation of a mechanism & machine engineering research centre at ETSI Industriales – TU Madrid, based on the current mechanism & machine lab. We are also confident that students have clearly perceived the relevance and potential of mechanical engineering and of systematic product development. We are sure that several of them will enroll with us in research activities, linked to their master theses or even to their PhD theses, which may result in an excellent input for an eventual research centre and constitute an excellent way of linking teaching and research.

CONCLUSIONS

Present study has detailed the complete development of a novel subject on "Engineering Design", in the framework of the "INGENIA" Initiative, for the Master's Degree in Industrial Engineering at ETSII – TU Madrid. The subject has been implemented with the CDIO approach in mind, as we consider it a very remarkable way of promoting student active learning and of integrating, with impact, novel concepts into ongoing curricula. During the subject, groups of students have lived through the complete development process of different mechanical systems aimed at providing answers to relevant unsolved problems. Computer-aided engineering and rapid prototyping technologies have been used as support tools for their designs and prototypes, so as to reach the implementation and operation phases with enough time for a re-design cycle. Main benefits, lessons learned and challenges, linked to this CDIO-based subject, have been analyzed and discussed, considering the results from 2014-2015 academic course. Finally, our attendance to the 2015 Cheng-Du 11th International CDIO Conference will help us to discuss our new subject with experts of CDIO framework. Their comments and proposals for improvement will help us to adjust our views and strategy, so as to obtain optimal results. We understand that the CDIO framework is a continuous improvement process and we are already expectant to experiment its results. We would like to acknowledge our students for their motivation, implication and proposals for improvement, which will be taken into account in forthcoming editions of the "INGENIA" Initiative and in its "Engineering Design" subject.

REFERENCES

Crawley, E.F., Malmqvist, J., Östlund, S., Brodeur, D.R. (2007) Rethinking Engineering Education: The CDIO Approach. *Springer,* 1-286.

Shuman, L.J., Besterfield-Sacre, M., Mc Gourty, J. (2005) The ABET professional skills, can they be taught? Can they be assessed? *Journal of Engineering Education, 94,* 41-55.

Díaz Lantada, A., Lafont Morgado, P., Muñoz-Guijosa, J.M., Muñoz Sanz, J.L., Echávarri Otero, J., Muñoz García, J., Chacón Tanarro, E., De la Guerra Ochoa, E. (2013) Towards successful project-based learning experiences in Engineering Education. *Int. Journal of Eng. Education, 29(2),* 476-490.

Muñoz Guijosa, J.M., Díaz Lantada, A., Rodríguez de la Cruz, V., Chacón Tanarro, E., De la Guerra Ochoa, E., Lafont Morgado P., Muñoz Sanz, J.L. (2011) Preparing mechanical engineering students for product design professional practice through PBL: planning and execution of the subject. *ASME 8th International Conference on Design and Design Education*.

Hernandez Bayo, A., Ortiz Marcos, I., Carretero Díaz, A., De la Fuente, M.M., Lumbreras Martín, J., Martínez Muneta, M.L., Riveira Rico, V., Rodríguez Hernández, M. (2014) Integral framework to drive engineering education beyond technical skills. *International Journal of Engineering Education, 30(6B), 1697-1707.*

CDIO Standards 2.0: http://www.cdio.org/implementing-cdio/standards/12-cdio-standards

BIOGRAPHICAL INFORMATION

Dr. Enrique Chacón Tanarro is Professor in the Department of Mechanical Engineering at ETSII – TU Madrid. His research activities are linked to several fields of Mechanical Engineering, including most areas of tribology and contact phenomena, machine performance assessment and systematic product development applied to energy engineering. He incorporates research results to subjects on “Machine Design”, “Tribology”, and “Engineering Design”, and participates in several public- and private-funded research projects. He has recently been awarded the UPM Extraordinary Prize for his PhD on elasto-hydrodynamic lubrication.

Dr. Juan Manuel Muñoz Guijosa is Professor in the Department of Mechanical Engineering at ETSII – TU Madrid. His research activities are linked to several fields of Mechanical Engineering, including vibrations theory, composite materials, microsystem technology and systematic product development. After his PhD he was visiting researcher at MIT and worked some year for Bosch GmbH linked to the automotive industry. Since his reincorporation to TU Madrid he has been linked to subjects on “Mechanism and Machine Theory”, “Vibrations Theory”, “Engineering Design”, among others, and participated in several research projects. More recently he has been visiting research professor at the Technical University of Tokio (twice, one semester each time) and at Drexel University. He is very active in the field of project-based learning.

Dr. Andrés Díaz Lantada is Professor in the Department of Mechanical Engineering at ETSII – TU Madrid. His research activities are aimed at the development of biodevices, based on special geometries and on the use of smart materials, with the support of computer-aided engineering resources and solid freeform manufacturing technologies. He incorporates research results to subjects on “Bioengineering Design”, “Design and Manufacturing with Polymers” and “Computer-aided Mechanical Engineering”.

He has been guest editor for the International Journal of Engineering Education for the special issues on “Learning through play in Engineering Education”, “Collaboration between Academia and Industry on Engineering Education”, “Engineering Education: Beyond technical skills” and “Engineering Education for all”. He has received the “TU Madrid Young Researcher Award” and the “TU Madrid Teaching Innovation Award” in 2014. He is currently Deputy Vice-Dean for University Extension at ETSII – TU Madrid.

Ms. Pilar Leal Wiña studied industrial engineering and joined TU Madrid as special lab technician. She carries out research tasks linked to machine security and systematic product development applied to energy engineering, and collaborates in subjects including “Engineering Design” and “Mechanism and Machine Theory”. She has taken part in several public- and private-funded projects, including a European project.

Dr. Javier Echávarri Otero is Professor in the Department of Mechanical Engineering at ETSII – TU Madrid. His research activities are linked to several fields of Mechanical Engineering, including most areas of tribology and contact phenomena, machine performance assessment and systematic product development. He incorporates research results to subjects on “Machine Design”, “Tribology”, and “Engineering Design”, and participates in several public- and private-funded research projects. He leads a project funded by the Spanish Ministry of Science and Innovation.

Dr. José Luis Muñoz Sanz is Professor in the Department of Mechanical Engineering at ETSII – TU Madrid. His research activities are linked to several fields of Mechanical Engineering, including most areas of machine security, machine performance assessment and systematic product development. He incorporates research results to subjects on “Mechanism and Machine Theory”, “Machine Design” and “Machine Security”, and participates in several public- and private-funded research projects, including a European project. He leads the “Mechanism & Machine Lab” at ETSII – TU Madrid.

Dr. Julio Muñoz García is Professor in the Department of Mechanical Engineering at ETSII – TU Madrid. His research activities are linked to mechanical systems, vibration theory, tribological phenomena, biomechanics and biomedical product development. He has been involved in teaching-learning tasks in the fields of Biomechanics and Biomedical Engineering for more than 20 years, being a pioneer in these topics in our University.

***Mr.* Óscar Nava Rodríguez and Mr. Sergio Garre Mondéjar** are industrial engineers specialized in the field of Mechanical Engineering. They have carried out their Master Theses supporting the ETSII – TU Madrid Machines Engineering Division with the first implementation of the “Engineering Design” subject within the “INGENIA Initiative”. Their help has been especially useful for preparing complete case studies and practical sessions.

Corresponding autor

Dr. Andrés Díaz Lantada
ETSI Industriales – TU Madrid
c/ José Gutiérrez Abascal 2,
28006 Madrid, Spain
+34913363120
adiaz@etsii.upm.es