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Study of Collaboration Activities between Academia and Industry for Improving the Teaching-Learning Process*

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Present study is focused on assessing the success, implementation time and cost of the most common teaching-learning activities carried out in collaboration between academia and industry, as well as of those aimed at a greater connection between studies and "real" industrial world, considering both the opinions of teachers and students. Final aim is to analyze such opinions, together with the "success vs. implementation cost" and "success vs. implementation time" ratios for the different activities, so as to improve our understanding on the most efficient ones and reinforce our subjects trying to prioritize these collaborative actuations.

Main results show the beneficial effects of project-based learning activities and of students' taking part in real projects for developing their final degree theses. In addition several actuations easy to implement, such as visits to enterprises or invited talks, in fact provide more remarkable teaching-learning outcomes, than other expensive and more complicated activities, including longer educational trips.

Keywords: university extension; academia and industry; teaching-learning process; learning strategies; real-life learning

1. Introduction: typical collaborations between academia and industry for improving the teaching-learning process

Industrial innovation clearly benefits from research and development tasks accomplished in the departments and laboratories of all kinds of universities. In a similar way, state-of-the-art industrial limitations and problems are a continuous source of motivation and ideas for research activities, as well as for collaborative projects, carried out at universities. Hence, University-Industry collaborations have proved to be helpful for continuously enhancing the quality of commercial products, the efficiency of industrial processes and for improving the functionalities of novel devices.

At the same time such contact between University and Industry is greatly beneficial for the teaching-learning process in Higher Education. It helps to renew the syllabi and the topics covered, so as to keep up with the pace of a changing industry, thus making students more prepared for their future tasks. In many cases these relations promote the direct employment of students, probably by means of an assessment of their capabilities during their Masters' degree projects or theses. Such collaborations seem to be especially adequate for technical universities, as their graduates typically end up working in all kinds of industries and industrial experience is an asset for securing the most demanding (and interesting) engineering jobs. Therefore, it is important to methodically analyze the various aspects of the impact of University-Industry collaboration on the teaching-learning process, so as to promote its advantages, improve some the lacking aspects and mitigate the possible negative effects.

Figure 1 describes schematically the typical collaborations between universities and their industrial partners grouped in "research & development", "industrial innovation" and "teaching-learning activities", although the three groups are also closely related. Typically universities receive proposals from enterprises, for collaboration in research and development tasks or in innovation projects, which are funded by the enterprises themselves or by public-private collaborative calls. In many cases results from the projects are directly applied by the collaborative enterprises and it is also common (and highly desirable) that research activities from universities end up with the establishment of novel enterprises, start-ups or spin-offs, or with other technological transfer strategies, such as patent licensing or further collaborative research [1–3]. Enterprises also benefit from services provided by university labs, including product redesign, process reengineering, auditing services and multidisciplinary study and characterization services; while universities usually resort to enterprises for the manufacture of components, acquisition of facil-

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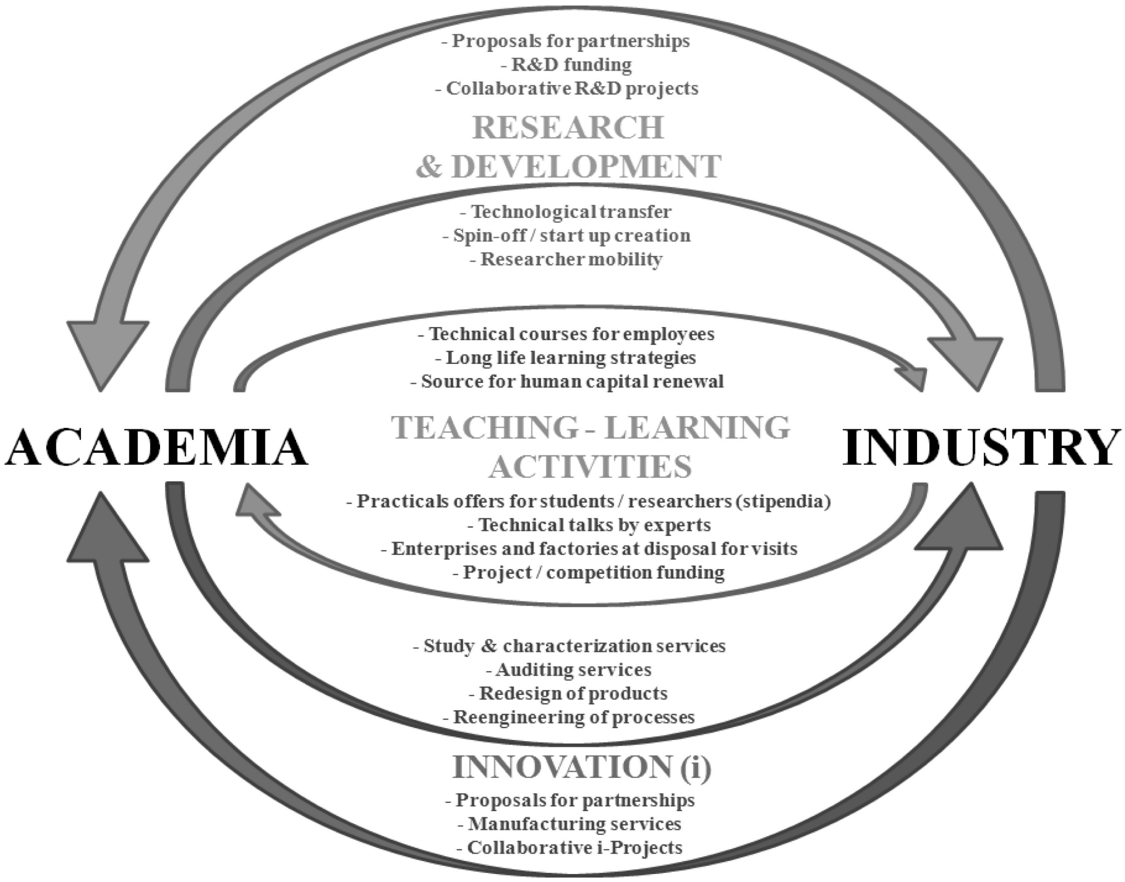

Fig. 1. Schematic description of collaboration activities between Academia and Industry.

ities for their laboratories and of course for promoting researchers' mobility and students' employability.

Regarding teaching-learning activities, technical universities offer a wide range of courses for employees (design, simulation, technical software, regulations and standards, management and business administration . . .) for promoting long-life learning strategies. At the same time enterprises are becoming more and more interested in being involved in teaching-learning activities for university students, including funding and supervising practices and stipendia for students, either at the enterprises' dependencies or at university departments, offering their factories and laboratories for visits and practical lessons, giving technical talks at universities and even funding of final degree theses and student competitions, among several interesting activities, which are discussed in the following sections. As well as universities are a continuous source for human capital renewal at enterprises, academia also benefits from industrial professionals who, normally due to a teaching (and learning) vocation, wish to devote some hours per week to teaching classes at universities, providing the point of view acquired by a more continued industrial practice.

Present study is focused on assessing the success, implementation time and cost of the most common teaching-learning activities carried out in collaboration between academia and industry, considering both the opinions of teachers and students. Final aim is to analyze such opinions, together with the "success vs. implementation cost" and "success vs. implementation time" ratios for the different activities, so as to improve our understanding on the most efficient ones and reinforce our subjects trying to prioritize these collaborative actuations, as a systematic complement to results and proposals from previous successful case studies [4].

2. Assessment of conventional collaboration activities between academia and industry: success, implementation time and cost

Present assessment focuses on most typical teaching-learning collaboration activities between universities and their industrial partners and main strategies aimed at improving learning outcomes at universities, by enhancing contact with the "real world", including: invited talks by industrial experts, organization of meetings and industrial events practical sessions with real systems and elements, visits to enterprises and factories, visits to fairs and congresses, educational trips with organized visits, project-based learning activities, funded final degree theses in enterprises, funded final degree theses at University, funded final degree theses linked to spin-offs, contests for technology-based enterprise creation, enterprise-funded design and engineering competitions, collaboration activities promoted by enterprise-university chairs and collaboration activities promoted by official entrepreneurial organizations.

These kinds of activities have impact on different stages of the teaching-learning process and dissimilar influence on students' acquisition of knowledge, abilities and professional skills, what we believe to be an important issue for this study. Therefore we prepared a survey for analyzing the effect of the aforementioned activities on the following aspects:

- Acquisition of generic knowledge in the field of Industrial Engineering.
- Acquisition of specialized knowledge.
- Acquisition of generic abilities (information and communication technologies, conventional software).
- Acquisition of specific abilities (specialized technical software, use of standards. . .).
- Acquisition of generic professional skills (teamwork, oral and written communication . . .).
- Acquisition of general knowledge about the surrounding industrial reality.
- Preparation for the working environment in industry.
- Promotion of employability.

The survey was structured in form of matrix (see Tables 1 and 2), for assessing the effect of each type of activity on the different aspects of interest of the teaching-learning process. Each effect was valued from 0 (irrelevant) to 10 (essential) and the implementation time and cost of the different activities was also valued from 0 (very low) to 10 (very high). The survey was carried out by a total of 7 teachers (the authors of the study) and 7 students of the Mechanical Engineering specialization from the Masters' Degree in Industrial Engineering at Universidad Politécnica de Madrid (UPM—www.upm.es).

The teachers represent a 25% of the total teachers from the Mechanical Engineering Department at UPM, in charge of the aforementioned specialization of the Masters' Degree, and the 7 students account for around a 15% of the students linked to such specialization. The opinions of students and teachers are both relevant (as previous studies have also put forward [5, 6] and provide several similar results, as well as some interesting reflections and a couple of contradictions, as discussed in the following Section 3, where results are presented and analyzed.

3. Main results and discussion taking account of the opinion of students and teachers

After the surveys were completed by teachers and students, mean results were analyzed and are presented here in Tables 1 and 2 respectively, showing how the different teaching-learning collaborative experiences or "real life" oriented activities have an influence on the acquisition of several knowledge, abilities and professional skills. As the resources (time- and cost-related) devoted to a subject or a whole plan of study are limited, the implementation cost and time of the different activities have also been considered, as already mentioned, and results are also included in Tables 1 and 2. The standard deviations obtained are typically in the range 10–15% and we believe the number of teachers and students involved in the assessment process is representative enough, at least for preliminary conclusions and for the establishment of some main future directions for continuously improving our subjects and plans of study, aiming at a more comprehensive preparation of our students for their professional development.

The "global" success of a collaborative action can also be assessed as the mean value of its contributions to the acquisition of the different knowledge, abilities and professional skills considered. Results of the global success of the different collaborative or "real life" teaching-learning activities are summarized in Fig. 2, including again the opinion of teachers and students. Regarding the effectiveness of the different actions, we have used "success vs. implementation cost" and "success vs. implementation time" ratios for the different activities, again considering the "success" as the mean value of the contributions of an activity to the acquisition of the different knowledge, abilities and professional skills. This assessment is presented in Fig. 3 and presented in form of Kano's diagrams in Fig. 4 for providing a more visual insight on whether final success of an activity is linked to its final implementation time and cost. The different Tables 1–2 and Figs 2–4 are included further on and our main reflections are presented subsequently, towards the end of present Section 3.

Among the best valued relationships (see Tables 1 and 2) it is important to note the important impact of project-based learning activities on the acquisi-

Table 1. Assessment of the impact of different collaboration activities between universities and enterprises on different aspects of the teaching-learning process and evaluation of related implementation cost and time, according to the opinions of teachers

	Master classes by invited professionals	Organization of meetings and industrial events	Practicals with real systems and elements	Visits to enterprises and factories	Visits to fairs and congresses	Educational trips with organized visits	Project-based learning activities	Funded final degree theses in enterprises	Funded final degree theses at University	Funded final degree theses linked to spin-offs	Contests for technology-based enterprise creation	Enterprise-funded design / engineering competitions	Collaboration activities promoted by enterprise-university chairs	Collaboration activities promoted by official entrepeneurial organizations
Acquisition of generic knowledge in the field of Industrial Engineering	4,8	4,2	7	7,4	5,8	6,8	7,8	7,8	7,8	8,6	7,6	7,6	7,8	7,8
Acquisition of specialized knowledge	6,2	4	9,2	8,2	6,6	7,2	9,2	7,6	8,6	8,6	7,4	8	7,8	6,8
Acquisition of generic abilities (information and communication technologies, conventional software)	4,4	2,4	7,8	4,2	4,2	3,8	7,8	8,2	8,2	7,8	6,8	7,8	7,2	6,8
Acquisition of specific abilities (specialized technical software, use of standards…)	5	2,6	9	3,6	4	3,8	8,4	7,4	8,2	8	6,4	7,6	7	6,4
Acquisition of generic professional skills (teamwork, oral and written communication...)	4,4	4,4	7,2	4	4,6	6,4	9	8,2	7,6	7,8	8	8,2	7,2	6,6
Acquisition of general knowledge about the surrounding industrial reality	5,8	7	6,6	8,4	7,2	7,2	7,4	8,6	7,4	7,6	7,2	7,6	7	7
Preparation for the working environment in industry	2,6	6,8	6,6	6,2	5	5,2	7,8	8,8	7,2	7,8	8	7,4	6,6	6,2
Promotion of employability	5,8	8,2	4,8	5	4	3,8	6,2	8,4	6,8	7,4	7,2	7	6,8	5,4

	Master classes by invited professionals	Organization of meetings and industrial events	Practicals with real systems and elements	Visits to enterprises and factories	Visits to fairs and congresses	Educational trips with organized visits	Project-based learning activities	Funded final degree theses in enterprises	Funded final degree theses at University	Funded final degree theses linked to spin-offs	Contests for technology-based enterprise creation	Enterprise-funded design / engineering competitions	Collaboration activities promoted by enterprise-university chairs	Collaboration activities promoted by official entrepeneurial organizations
Implementation cost	2,6	6,2	5,4	2	3,4	7	5,2	4,6	5	6,2	5	4,8	4,4	4
Implementation time	2,2	7,2	6,2	2,6	3	5,2	6,8	5	4,2	6	6,8	6,2	6,2	5

Table 2. Assessment of the impact of different collaboration activities between universities and enterprises on different aspects of the teaching-learning process and evaluation of related implementation cost and time, according to the opinions of students

	Master classes by invited professionals	Organization of meetings and industrial events	Practicals with real systems and elements	Visits to enterprises and factories	Visits to fairs and congresses	Educational trips with organized visits	Project-based learning activities	Funded final degree theses in enterprises	Funded final degree theses at University	Funded final degree theses linked to spin-offs	Contests for technology-based enterprise creation	Enterprise-funded design / engineering competitions	Collaboration activities promoted by enterprise-university chairs	Collaboration activities promoted by official entrepeneurial organizations
Acquisition of generic knowledge in the field of Industrial Engineering	6,2	3,6	7,8	7,6	6	6,4	8	8,4	8	8,2	7,8	7,6	7	5,8
Acquisition of specialized knowledge	7,6	3,6	9	8	5,4	6,8	8,8	8	9,4	8,6	7	7,4	7	5,4
Acquisition of generic abilities (information and communication technologies, conventional software)	3,8	1,4	7,6	2,4	3,2	3	7,2	8,4	8	7,4	7	8	6,6	5,8
Acquisition of specific abilities (specialized technical software, use of standards…)	4,6	1,8	8,4	2,6	3	3	7,6	7,6	9,2	8	7,2	7,8	6,4	5,8
Acquisition of generic professional skills (teamwork, oral and written communication...)	5,8	3	6,8	3	2,8	3,4	8,2	9,2	8,8	8,4	8	8,6	7,8	6,6
Acquisition of general knowledge about the surrounding industrial reality	8	7,4	7	9,6	8,4	8	7	8,2	7,8	7,4	7,8	7,8	7,8	7
Preparation for the working environment in industry	7	7,8	5,2	7	6,2	5,4	6,4	7,8	7,2	7,8	7,4	7,6	7,4	6,6
Promotion of employability	3,2	8,8	2,8	3,8	5,8	4,6	3,4	5	5,2	7,4	7,6	7	7,4	5,6

	Master classes by invited professionals	Organization of meetings and industrial events	Practicals with real systems and elements	Visits to enterprises and factories	Visits to fairs and congresses	Educational trips with organized visits	Project-based learning activities	Funded final degree theses in enterprises	Funded final degree theses at University	Funded final degree theses linked to spin-offs	Contests for technology-based enterprise creation	Enterprise-funded design / engineering competitions	Collaboration activities promoted by enterprise-university chairs	Collaboration activities promoted by official entrepeneurial organizations
Implementation cost	4,4	6,2	4,8	3,8	5,4	7,8	5	5,4	4,4	5,6	6	6,8	5,8	5,6
Implementation time	3,8	7,8	5,2	4,2	5,2	7,6	6,6	5,6	5,2	5,6	7,2	7,8	6,8	6,6

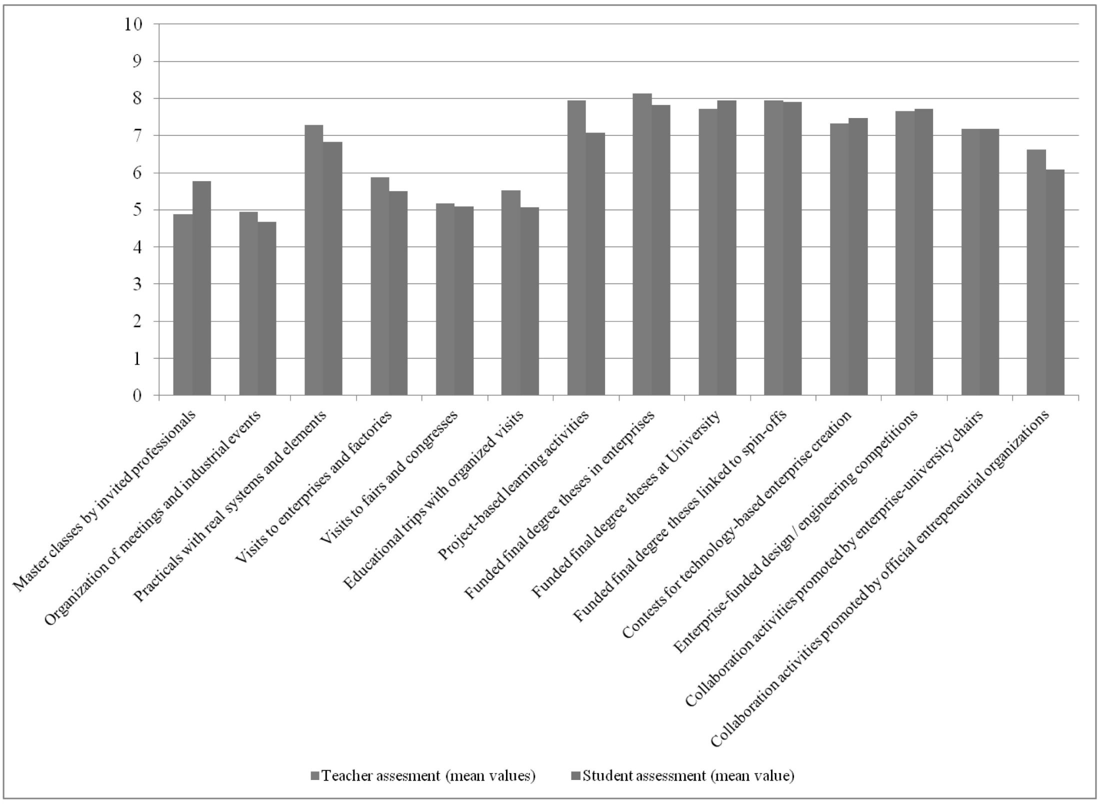

Fig. 2. Assessment of the impact on the teaching-learning process of typical collaboration activities between universities and enterprises, taking account of the opinion of students and teachers.

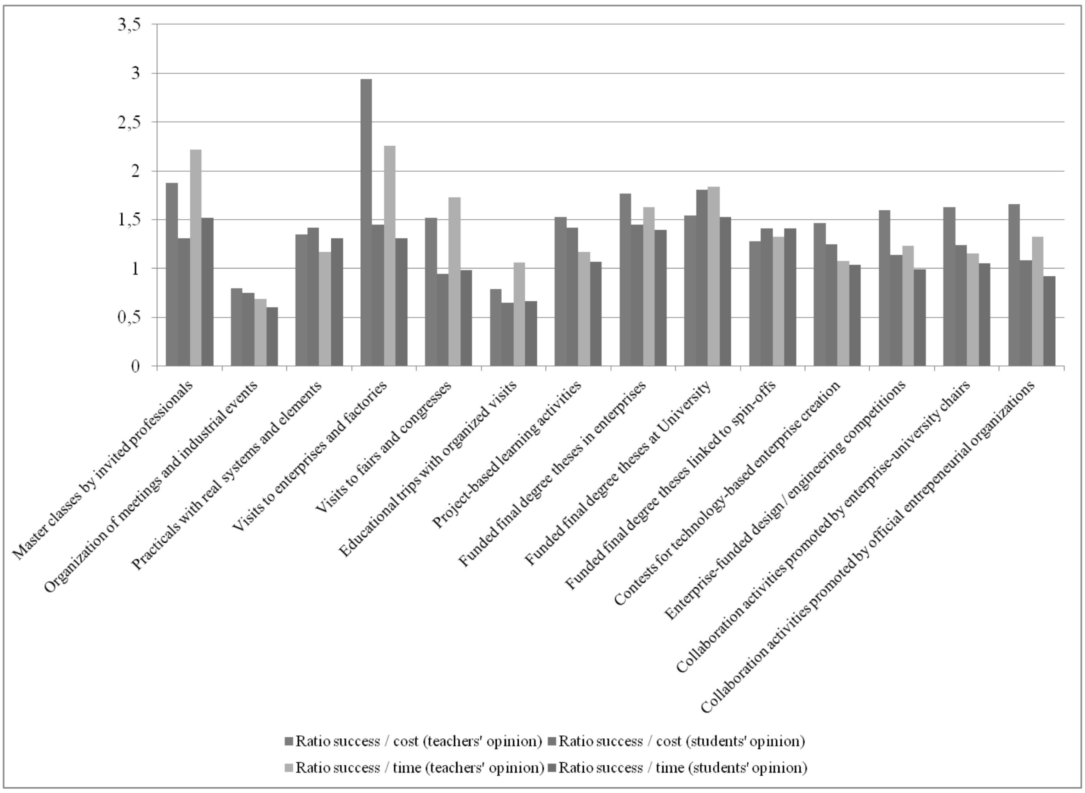

Fig. 3. Assessment of the "success/cost" and "success/implementation time" ratios of collaboration activities between universities and enterprises, taking account of the opinion of students and teachers.

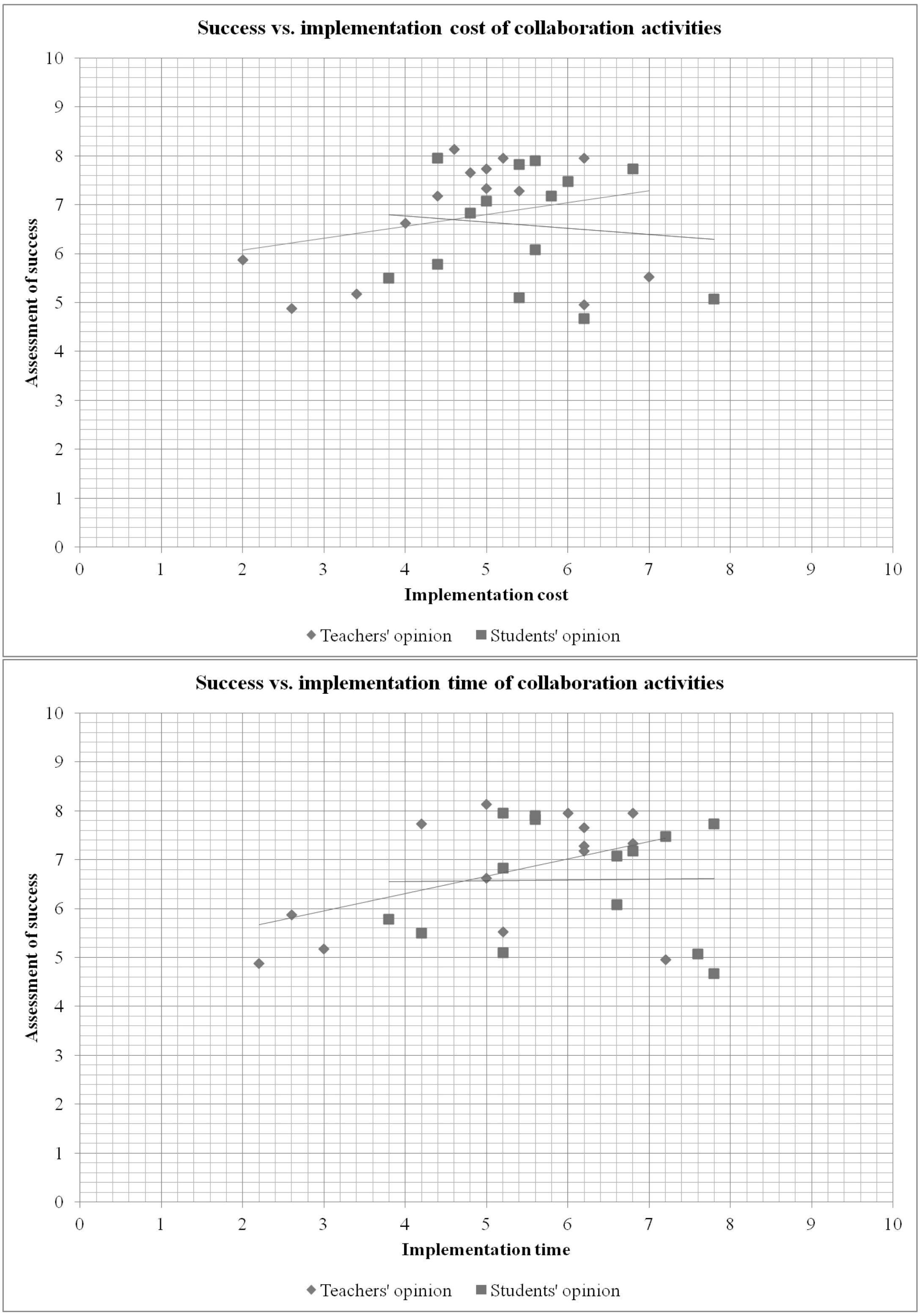

Fig. 4. Kano diagrams for "Success" vs. "Cost" and vs. "Implementation time" of typical collaboration activities between universities and enterprises, taking account of the opinion of students and teachers.

tion of specialized knowledge, technical abilities and professional skills, with values around 90% as valued by teachers and around 80% as valued by students. We admit that, as our team highly promotes the use of project-based learning activities due to their several benefits for Engineering Education [7–12], our opinion might have been somehow influenced, but in any case students' assessment is also in accordance with our line of thought, as well as previous remarkable research on active learning styles [13]. Remarkable punctuations are also given to the effects of funded final degree theses, either carried out at university laboratories or departments, normally connected to research & development or innovation tasks, or developed at enterprises, usually under a temporary practice contract. The opinions of teachers and students regarding these possibilities are very similar and we do not appreciate significant differences between the successful effects of realizing final degree projects at universities or at enterprises, both possibilities are well valued. Perhaps, during their final project at universities students acquire more technical skills, while at enterprises the professional "soft" skills are promoted [14].

Furthermore, when overall effects are considered (see Fig. 2), the application of project-based learning activities and the promotion of funded final degree projects linked to real industrial problems or processes are the most valued strategies for linking University with the "real" industrial world. Contest and competitions are also well valued, although their implementation time and related costs limit their effectiveness, when compared to project-based learning actuations and to the participation in real projects. In fact they are also a relevant way of promoting professional skills such as teamwork, communication skills, leadership, among others, as several experiences have previously described [15–17].

The impact of collaboration with entrepreneurial organizations and the tasks carried out by enterprise-university chairs are not so well valued as initially expected; probably because our national network of old-student associations, official professional colleges and similar "lobbies" are not so well-established and do not have a traditional impact on students' professional development, as in countries like the United States, the United Kingdom, France or Germany, where professional associations probably work more properly for the rights and professional competencies of their members [18]. In addition the assessment of such university collaborations with industrial associations and industrial partnerships articulated through enterprise-university chairs is more critical when the opinion of students is taken into account, what may reflect that their established communication lines with students are not working properly or that their actual offers for students do not attract their attention.

Even though the impact of more punctual activities, such as master classes by invited experts, visits to enterprises and factories, attendance to congresses or study trips, receive lower punctuations, their related "success / implementation time" and "success / implementation cost" ratios (see Fig. 3) may provide additional interesting results. For instance visits to enterprises and factories are very effective (in fact we have noticed that a one-morning visit to a manufacturing enterprise helps students to grasp more firmly the concepts of a whole semester manufacturing subject) and easy to implement. The same happens with master classes by invited experts from enterprises, they are very easy to implement, provide very useful information on concrete aspects of a subject and, even though their overall impact in not so high, the related success ratios, when considering time and cost, are remarkable indeed.

Surprisingly the very positive aspects of educational trips are perceived more clearly by teachers than by students, who are also even more critical with the implementation time and costs involved. According to these results, probably a couple of visits to enterprises or factories, together with some talks by invited experts, may have more impact on the teaching learning process, than a whole-week educational trip visiting several dependencies. Attending to congresses and industrial fairs seems to be also too expensive and time-involving for conventional subjects and study plans, and it is surely more adequate for researchers pursuing their PhD and for teachers themselves. Future studies should also consider the opinions of PhD students and research personnel, so as to obtain a broader discussion and more widespread conclusions.

The information provided by the Kano diagrams from Fig. 4 is also noteworthy, as there seems to be no straightforward dependence between the success of a programmed activity and its related implementation time or related cost. From teachers' opinions very mild positive dependencies can be perceived, although according to students' opinions such dependencies can be even roughly negative. In other words very expensive activities, such as organizing a trip or an industrial meeting, do not provide the expectable teaching-learning outcomes; while other actuations, easier to implement, prove to be also very effective.

Regarding the promotion of employability, both teachers and students remark the positive effects of organizing industrial meetings. In the case of our Industrial Engineering School at Universidad Politécnica de Madrid we have to mention the remarkable impact of "Induforum", our industrial fair organized annually for promoting student employability. In this fair, during a week, more than 500 students handle their curricula to more than 25 multinationals searching for talent. Surely the very positive effects obtained year by year during the last decade of "Induforum" have influenced this particular result and our students' perception.

4. Conclusions and future proposals

Present study has focused on assessing the success, implementation time and cost of the most common teaching-learning activities carried out in collaboration between academia and industry, as well as of those aimed at a greater connection between studies and "real" industrial world, considering both the opinions of teachers and students. Final aim was to analyze such opinions, together with the "success/implementation cost" and "success/implementation time" ratios for the different activities, so as to improve our understanding on the most efficient ones and reinforce our subjects trying to prioritize these collaborative actuations. We wanted also to provide a complement, centred on teaching-learning processes and outcomes, to several available studies on collaboration between industry and university mainly focused on enhancing research and innovation results.

Main results have shown again the beneficial effects of project-based learning activities and of students' taking part in real projects for developing their final degree theses. In addition several actuations easy to implement, such as visits to enterprises or invited talks, have resulted to provide more remarkable teaching-learning outcomes, than other expensive and more complicated activities including educational trips.

In the particular case of our Industrial Engineering School at Universidad Politécnica de Madrid, the annual organization of an industrial fair for promoting employability has remarkable effects. However we believe additional efforts should be put forward for promoting the impact of professional associations on students' life and learning process, what is probably also linked to national structural problems of the working market and a lack of tradition, together with perceiving "corporatism" only in a negative sense.

We hope future analyses will help us to propose strategies for the detected current limitations, as well as to validate the effectiveness of reinforcement activities carried out following the advices derived from present study. We also truly expect that the assessment presented here may be of help for teachers wishing to improve the connections of their subjects (or even plans of study) with the industrial world and provide some advice about the more successful and efficient actuations to implement.

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