PROJECT-BASED LEARNING IMPLEMENTATION. COLLABORATION BETWEEN UNIVERSITY AND INDUSTRY

Carmen Jaca, Marta Ormazabal

University of Navarra, Tecnun, Industrial Management Department, San Sebastian, Spain

Mikel Arizmendi

University of Navarra, Tecnun, Department of Mechanical Engineering and Materials, San Sebastian, Spain

Carmen Blanco

University of Navarra, Tecnun, Department of Biomedical Engineering and Sciences, San Sebastian, Spain

ABSTRACT

This paper presents two experiences of collaboration between university and industry through the implementation of the Project-based Learning (PBL) model in the University of Navarra. One of them has been developed by third year students of the Industrial Management Engineering Degree, and the participation is voluntary. The other one is carried out by students of the Master of Industrial Engineering, and it is mandatory. In both cases, the students visit a company, and it is the enterprise that poses them a challenge to solve or a project to be developed. After working in groups for several weeks, students present their project to the company managers. The main objective of this paper is to examine the benefits of developing PBL in a company context. It also aims to analyze the development of students' skills, motivation and commitment in comparison with other similar activities where the problem to be solved is defined by the teachers. It pretends as well to know the opinion of the enterprises regarding the university-industry collaboration and the work done by the students. The students value this experience, in both cases, positively, as it allows them to work on a real case, in which they test their knowledge and capabilities. The companies also appreciate this experience, as it is valuable for them. Apart from all the advantages that active learning methods entail for students, developing it in the context of university-industry collaboration leads to many other benefits. We have verified that when the project consists of solving a real problem proposed by a company, the engagement and motivation of students increases. Moreover, this experience provides a rich learning environment, closer to what their professional life will be.

KEYWORDS

Project-based learning, university-industry collaboration, Standards: 2, 3, 7, 8, 9

INTRODUCTION

Nowadays the job market is in a continuous change. This demands to the future professionals the capacity of developing a continuous learning and adaptation to the new requirements. Higher education must promote deep content knowledge but also professional and personal skills that allow students to face professional life. Wager (2008) enumerates what he calls "the seven survival skills": critical thinking and problem solving, collaboration and teamwork, agility and adaptability, initiative and entrepreneurship, effective oral and written communication, curiosity and imagination. Other attitudes like honesty, social responsibility and professional ethics must be promoted as well. In the context of Engineering Education, The CDIO Syllabus, in addition to learning outcomes for technical disciplinary knowledge, specifies learning outcomes as personal and interpersonal skills, and product, process, and system building (CDIO, standard 2). Crawley et al (2011) point out the Syllabus which can be described as an adaptation of the UNESCO framework (Delors et al, 1996) to the context of engineering education. Engineering accreditation bodies like EUR-ACE (2008) and ABET (2018) identify as well the need of reinforce transversal competences.

Higher education is incorporating new methodologies that facilitate students developing professional skills at the same time that acquire deep content knowledge (Smith et al, 2005) "Active learning methods engage students directly in thinking and problem-solving activities. There is less emphasis on passive transmission of information, and more on engaging students in manipulating, applying, analyzing, and evaluating ideas." (CDIO, standard 8).

Project-based learning (PBL) is one of the pedagogical approaches that can be particularly useful in the CDIO design-implement courses (Edström & Kolmos, 2012). In this method, students develop a project or investigate solutions for a problem. It gives students the opportunity to do something closer to what is done in real professional life, facilitates students to apply their knowledge, helps them to connect key concepts and develop creativity and critical thinking, often in a collaborative and interdisciplinary context (CDIO, standard 7).

Collaboration between university and industry is beneficial for the teaching-learning process in higher education, especially for technical degrees, as their graduates probably will end up working in industries. The creation of opportunities for students to interact with industrial companies is a way to contribute for the development of the students' competences (Mazini et al., 2018). Different kind of activities such as visits to enterprises and factories, invited talks or master classes by industrial experts, internships in companies, development of final degree or master theses in enterprises, etc. can be organized to approach the students to the "real wold". Diaz et al. (2013) assessed the efficiency of the most common teaching-learning activities in collaboration between academia and industry in terms of success vs. implementation cost and success vs. implementation time and concluded the beneficial effects of PBL activities and of students' taking part in real projects for developing their final degree theses. This methodology allows students to apply what they have learned in classrooms to real challenges instead of problems proposed by teachers. It is very enriching for students to experience the limitations of theories learned in class, the necessity of adapting models to real situations and requirements, etc. Moreover, these kinds of activities are not only beneficial for the teaching-learning process, but also for the company as the students can contribute to the enterprise innovation (Buser, 2013).

This paper describes and analyzes two experiences of collaboration between university and industry through the implementation of the PBL model, in undergraduate and master's students.

In both cases, the students visit a company, and it is the enterprise that poses them a challenge to solve or a project to be developed. The objectives of this work are:
1) To explore students' perception of their skill development, motivation and engagement using PBL activities in the context of a company compared to other similar activities where the problem to be solved is defined by the teachers.
2) To know the opinion of the enterprises regarding the university-industry collaboration and the work done by the students.

In the methodology section, we describe the experiences' development, their phases and surveys conducted by the students and enterprises. We summarize the main results obtained from the surveys in the results section and finally, we point out the most relevant conclusions that are derived from the study.

RESEARCH METHOD

This research has been carried out with the students from the University of Navarra, particularly with the Engineering School (Tecnun) students. The degree and master's curriculums are designed in such a way that the practical part of the subjects is obtained through laboratory practices, work designed by the professor himself, visits to companies, teaching by guest professors from companies, etc. However, in an internal and external analysis carried out in 2018, a weakness that came to light in this curriculum was "the scarce contact of students with real companies".

In project-based learning, students work in groups to solve challenging problems that are authentic, curriculum-based and often interdisciplinary (Solomon, 2003). Getting students to work on real business projects also allows students to connect what they learn in class with real business experience (Biedermann et al., 2017). Therefore, if we can get the students to work on a real project facilitated by the company, the students will be able to better assimilate the knowledge taught in class.

In order to implement this project, it has been decided to have one experience in a degree not linked directly to any specific subject and another in a master program directly linked to a specific subject.

Degree Project

This project has been carried out in a machine tool company. This company delivers value-driven engineered solutions for their customers' manufacturing needs, becoming their partners for advanced productivity systems.

As mentioned above, the work is not directly related to any subject. Participation is voluntary and the objective of the activity is to perform a team project that solves a challenge proposed by the company. Students visit the company and have the opportunity to learn about its activity, processes, products and markets. During this visit, one of the managers presents them a challenge that has to be solved in 6-8 weeks. The challenge can be related to different topics: quality, production, people management, sales, etc. To better understand the challenge, students receive information and data. After working in groups for several weeks, students present their project to the company managers, who decide which is the best proposal. The students that have developed the selected proposal receive a diploma and a cash prize.

Master Project

On the other hand, the project that is carried out among the students of the Master of Industrial Engineering is developed within the subject "Automated Manufacturing Systems and Industrial Robotics ". In this case, the company proposing the project is part of one of the largest machine tool groups in Spain and they are world leaders in blade grinding machines used on aircraft engine rotors.

The project consists of the design of a machine for the manufacturing of an industrial component, such as a railway axle or a tubular connection for the oil and gas industry. In order to reinforce students' understanding of the machine design process, students visit the company and specific sessions related to precision engineering and manufacturing automation are given by engineers of the company. This gives students opportunities to learn how the industry faces real-life problems and to realize the connection between the technical content they are learning at the university and the real work. Finally, students make an oral presentation of the developed projects to the company's engineers.

Surveys

In order to respond to the objectives proposed in the Introduction, the questionnaire proposed by Biedermann et al. (Biedermann et al., 2017) has been adapted to the context of these projects. Those questions that referred to a specific activity have been modified (e.g., "The company has been able to provide the key aspects to be applied to the design of the brand" has been changed to "The company has been able to provide the key aspects to develop the project"). The first questionnaire designed for the students aims to collect a comparison between this project that they have carried out with a company and other projects that they have carried out throughout their studies at the university. In this way, not only can we see that the PBL is a good option for improving the skills of our students, but it is also better than traditional projects.

On the other hand, with a second survey, we have asked those responsible for projects in companies about their satisfaction with these projects. The respondents were asked to indicate the extent to which they agreed or disagreed with these statements.

In both surveys, a five-point Likert scale was used (1 represented "strongly disagree" and 5 represented "strongly agree").

Table 1 shows the items in the questionnaire, related to the competences acquired during the project (C*), the content of the activity carried out (A*), the collaboration provided by the company (B*) and the motivation they have experienced when carrying out the work (M*). In addition, the students were asked about the reasons that motivated them to participate in the challenge, in the case of the Degree project, which participation is voluntary, and about the positive aspects of the project in the case of the master project, within the subject Automated Manufacturing Systems and Industrial Robotics.

Table 1. Questionnaire items (students)

Competencies	
C1	Capacity for analysis and synthesis.
C2	To develop my social skills, leadership and communication skills
C3	To increase my responsibility at work with the group
C4	Ability to manage information
C5	Ability to apply knowledge to practice
C6	Decisions making
C7	To increase my capacity to generate creative and innovative ideas.
C8	To increase my ability of creative thinking
C9	To increase my ability to work in team
C10	To increase my ability to solve problems
C11	To acquire basic skills for my profession
Activity	
A1	The activity has served to meet the needs of the company(ies)
A2	The activity has helped me develop my personal and professional skills
Collaboration	
B1	The company has been able to provide the key aspects to be applied to the project
B2	This type of activity helps me to show potential business needs
B3	This type of activity is a good way for bringing companies closer and gives the possibility to cooperate with them
Motivations	
M1	The possibility that my project is implemented in the company
M2	The fact that my project competes against others
M3	To experience similar to professional life situations
M4	The possibility to include a real project to my CV
M5	Dealing with a real problem
M6	I am encouraged to consider the possibility of starting my own business in the future
M7	To take part of an active learning process.

On the other hand, with a second survey, we have asked those managers responsible for projects in companies about their satisfaction with these projects. Table 2 shows the items for this survey to company managers.

Table 2. Questionnaire items (managers)

Competencies	
C1	Capacity for analysis and synthesis.
C4	Ability to manage information
C5	Ability to apply knowledge to practice
C6	Decisions making
C11	To acquire basic skills for their profession
C12	To concern about the quality
Activity	
A3	The activity is an added value for the training of the students
A4	The activity has brought value to the company
A5	I would like the approach of this activity to be repeated in other subjects

A6	This type of activity helps to show students potential business needs
A7	This type of activity is a good way of bringing companies and university closer and make them both to cooperate
Collaboration	
B4	Students have been able to make the appropriate questions to extract key information to develop the project
B5	Students have been able to interpret the key issues to be applied to the project
B6	Students have contacted us to solve their doubts
B7	I would have liked to have more meetings with students

RESULTS

In the case of the degree project, a total of 37 students had participated over two last academic years (2018 and 2019). A total of 16 students responded to the survey, that is a response rate of 43 percent. This is considered acceptable given the response rate of similar studies. As can be seen in table 3, all items score higher in the case of the in-company project than in the case of traditional projects, in subjects, except for item M6 (I am encouraged to consider the possibility of starting my own business in the future). This could be explained by the fact that students in this degree have specific projects related to entrepreneurship, within some of the subjects of the degree. Those difference are statistically significant for most of the items (paired t-test, $p < 0.05$). The small sample size (16 responses) may explain that not all the items are statistically significant. Furthermore, all the items score above 3.5, which indicates that the project developed in the company is highly valued both in relation to the competencies acquired, to the activity itself and to the collaboration with the company and to the motivation they have in general to carry out the project.

In the case of the master project, a total of 54 students participated in the last academic year (2019). A total of 42 students responded to the survey, that is a response rate of 78 percent. As can be seen in Table 3, all items score higher in the case of the in-company project than in the case of traditional projects. Furthermore, all the items score above 3.5 except for item M6, which indicates that the project developed in the company is highly valued in relation to the competencies, the activity, the collaboration with the company and the motivation. The smallest differences in the scores correspond to items C4 (Ability to manage information) and M6 (I am encouraged to consider the possibility of starting my own business in the future). Those differences are also statistically significant for most of the items (paired t-test, $p < 0.05$).

When the students were asked about the aspects that they would highlight from the challenge, their answers were very similar in both degree and master students. The answers were related to the fact of being a different activity, working with a real case of a company and seeing its application. Moreover, the students remarked positively the idea of exposing their solution to the company, receiving feedback from managers and competing against their mates. The students also consider that this type of projects is very useful for preparing them for their future job, in which the problems of the companies arise in very different ways and are not easy to solve. In the case of the master students, they also pointed out working in a multidisciplinary project applying theoretical knowledge to practice.

Table 3. Paired t test of assessment of attributes between traditional and company project

	Degree (n=16)			**Master (n=42)**		
	Traditional project mean (SD)	**Company project mean (SD)**	**p-value**	**Traditional project mean (SD)**	**Company project mean (SD)**	**p-value**
C1	3.500 (0.894)	3.688 (0.946)	0.485	3.452 (0.593)	4.071 (0.513)	0.000**
C2	3.500 (1.095)	4.000 (0.966)	0.040*	3.524 (0.740)	4.143 (0.718)	0.000**
C3	3.813 (0.981)	3.938 (0.929)	0.652	3.619 (0.731)	4.095 (0.692)	0.000**
C4	3.563 (0.727)	3.563 (1.263)	1.000	3.524 (0.671)	3.881 (0.739)	0.017*
C5	2.875 (0.885)	3.938 (1.181)	0.012*	3.524 (0.740)	4.524 (0.634)	0.000**
C6	3.688 (1.014)	4.125 (0.957)	0.048*	3.500 (0.707)	4.214 (0.645)	0.000**
C7	3.313 (1.078)	4.250 (0.856)	0.003**	3.214 (0.898)	4.357 (0.821)	0.000**
C8	3.188 (0.911)	4.188 (0.981)	0.000**	3.310 (0.950)	4.143 (0.751)	0.000**
C9	4.000 (0.966)	4.313 (0.946)	0.206	3.929 (0.894)	4.119 (0.772)	0.103
C10	3.313 (1.014)	3.750 (1.000)	0.089	3.643 (0.759)	4.048 (0.795)	0.000**
C11	3.750 (0.856)	3.875 (1.088)	0.633	3.524 (0.804)	4.071 (0.745)	0.000**
A1	2.500 (0.816)	4.313 (0.873)	0.000**	2.976 (0.841)	4.262 (0.734)	0.000**
A2	3.500 (0.966)	4.000 (0.966)	0.056	2.500 (1.042)	4.452 (0.803)	0.000**
B2	2.875 (0.885)	4.375 (0.806)	0.000**	2.595 (1.106)	3.976 (0.869)	0.000**
B3	3.000 (1.033)	4.563 (0.629)	0.000**	3.595 (0.857)	4,119 (0.803)	0.000**
M1	2.313 (1.078)	4.063 (1.181)	0.000**	2.452 (1.087)	4.000 (1.059)	0.000**
M2	3.375 (1.088)	4.188 (0.981)	0.005**	3.286 (1.111)	4.143 (0.843)	0.000**
M3	2.875 (0.719)	4.313 (0.793)	0.000**	3.190 (0.917)	4.381 (0.764)	0.000**
M4	2.563 (1.504)	3.500 (1.506)	0.030*	2.333 (1.097)	3.333 (1.337)	0.000**
M5	2.813 (0.911)	4.063 (1.124)	0.194	3.071 (0.973)	4.190 (0.773)	0.000**
M6	2.563 (1.209)	2.500 (1.414)	0.827	2.548 (1.064)	2.881 (1.194)	0.029*
M7	3.500 (0.894)	3.688 (1.250)	0.509	3.476 (0.804)	3.952 (0.795)	0.000**

* p<0.05
** p<0.01

The results of the survey to the managers were quite high, in most cases above 3.5. In both companies, two managers answered the survey. Table 4 shows the mean value for each company.

The results obtained in the two companies are similar except for items A5 and B7. In the case of item A5, we ask about the possibility of repeating this experience in other subjects. A possible reason for the low value in the case of the master may be that the project is designed to solve a specific problem to a particular subject, so it would not make sense to repeat this experience in other subjects. In the case of B7, managers were asked about having more meetings with the students throughout the project. In the case of the degree, they consider that the students were self-sufficient enough to develop the project in a satisfactory manner without the company managers.

Table 4. Response of projects' managers

	Mean (Degree)	**Mean (Master)**
C1	4	4.5
C4	3.5	3.5
C5	4	4.5
C6	4	4.5
C11	4	4
C12	3	3.5
A3	4.5	4.5
A4	4	4.5
A5	4	2
A6	5	3.5
A7	4.5	4.5
B4	5	3
B5	4	3.5
B6	3.5	4.5
B7	2	4.5

CONCLUSIONS

The two experiences carried out with undergraduates and masters' students have allowed us to analyze how students perceive that PBL helps to improve their skills. In addition, students positively value the fact that the project is developed in a company's environment, knowing its challenges and working on real projects.

It is also worth noting the difference between this type of project and those proposed by teachers in traditional projects. In all cases, the score has been higher in the challenges posed by the company with the exception of the item related to entrepreneurship in the case of students of engineering degree in industrial organization. As mentioned above, these students have taken courses and developed projects directly related to entrepreneurship.

Finally, it should be noted that the students have felt positive towards the approach and that these experiences have brought value to the companies (item A4).

These results encourage us to continue promoting collaboration between the university and the company in our degrees and masters that favors the stakeholders involved: university, students and companies.

REFERENCES

ABET (2018) Criteria for accrediting engineering programs: effective for reviews during 2019-2020 Accreditation Cycle. ABET https://www.abet.org/wp-content/uploads/2018/11/E001-19-20-EAC-Criteria-11-24-18.pdf.

Biedermann, A., Muñoz López, N. & Serrano Tierz, A. (2017). Developing students' skills through real projects and service learning methodology. In: Eynard B., Nigrelli V., Oliveri S., Peris-Fajarnes G., Rizzuti S. (eds). *Advances on Mechanics, Design Engineering and Manufacturing, Lecture Notes in Mechanical Engineering*. (951-960). Springer Cham. DOI:https://doi.org/10.1007/978-3-319-45781-9_95

Buser, M. (2013). Engineering Students as Innovation Facilitators for Enterprises. *The International Journal of Engineering Education*, 29(5), 1080-1087.

Crawley,E. F., Malmqvist, J., Lucas, W.A. & Brodeur, D.R. (2011). CDIO Syllabus v2.0. An Updated Statement of Goals for Engineering Education. *Proceedings of the 7th International CDIO Conference, Technical University of Denmark, Copenhagen.* http://cdio.org/files/project/file/cdio_syllabus_v2.pdf

Delors, J., et al. (1996) Learning – the Treasure Within: Report to UNESCO of the International Commission on Education for the Twenty-First Century. UNESCO Publishing, Paris, France. https://unesdoc.unesco.org/ark:/48223/pf0000109590

Díaz, A., Lafont, P., Munoz-Guijosa, J.M., Muñoz, J.L., Echavarri, J., Muñoz, J., Chacón, E. & De la Guerra, E. (2013). Study of Collaboration Activities between Academia and Industry for Improving the Teaching-Learning Process. *The International Journal of Engineering Education*, 29(5), 1059-1067.

Edström, K., Kolmos, A., (2012) Comparing two approaches for Engineering Education Development: PBL and CDIO. *Proceedings of the 8th International CDIO Conference. Queensland University of Technology, Austria.*

EU-ACE (2008) EUR-ACE Framework standards and guidelines. www.enaee.eu

Mazini, S.R., Pontes, W., P. Rodrigues, P. & Scarpin, L. (2018). The improvement of faculty competence and collaboration between academia and industry: a case study in the engineering courses of a Brazilian university center. *Proceedings of the 14th International CDIO Conference. Japan*

Norman, G.& Schmidt, H. (2000). Effectiveness of problem-based learning curricula: theory, practice and paper darts, *Medical Education*, 34, 721-728. DOI: 10.1046/j.1365-2923.2000.00749.x

Smith, K.A., Sheppard, S.D., Johnson, D.W. & Johnson, R.T. (2005). Pedagogies of Engagement: Classroom-Base Practices, *Journal of Engineering Education*, 94(1), 87-101. DOI: 10.1002/j.2168-9830.2005.tb00831.x

Solomon, G. (2003). Project-based learning: A primer. *Technology and learning Dayton*, 23(6), 20.

Wagner, T. (2008). *The global achievement gap: why even our best schools don't teach the new survival skills our children need—and what we can do about it*. New York: Basic Books. http://www.hosa.org/emag/articles/advisors_corner_oct08_pg2_5.pdf

BIOGRAPHICAL INFORMATION

Carmen Jaca is currently teaching several courses on Strategy Management and Operation Management at Engineering School of the University of Navarra (Tecnun), Spain. Her research area is focused on Circular Economy, sustainability and continuous improvement within industrial companies.

Marta Ormazabal is an Associate Professor of Industrial Management at Tecnun, University of Navarra (Spain). She is currently teaching "Economics and Business" and "Business Administration" and she holds sessions about environmental management. Her research area is focused on sustainability within industrial companies and more specifically on the implementation of Circular Economy in SMEs.

Mikel Arizmendi is an Associate Professor of Mechanical Engineering at Tecnun, University of Navarra (Spain). He is currently teaching "Manufacturing Tecnology" and "Automated Manufacturing Systems and Industrial Robotics". His research is focused on advanced manufacturing and precision engineering.

Carmen Blanco is an Associate Professor of Mathematics, Engineering School of the University of Navarra (Tecnun), Spain. Currently, her research is focused on the analysis, development and application of the new technologies and methodologies for the improvement of the learning process.

Corresponding author

Marta Ormazabal
Tecnun-University of Navarra
P/Manuel Lardizabal 13
20018 San Sebastian (Gipuzkoa), Spain
mormazabal@tecnun.es