Project Based Engineering School: Evaluation of its implementation. Students' Perception

Adrian Gallego-Ceide+, Mª José Terrón-López, Paloma J.Velasco-Quintana and Mª José García-García *

School of Engineering, Universidad Europea de Madrid, 28670- Villaviciosa de Odón, Spain

Email: +21201387@live.uem.es, * m_jose.terron@uem.es, pjulia.velasco@uem.es, mariajose.garcia@uem.es

Abstract

The School of Engineering at Universidad Europea de Madrid (UEM) implemented, starting at the 2012-2013 period, a unified academic model based on project-based learning (PBL) as the methodology used throughout the entire School. This model expects that every year, in each grade, all the students should participate in a capstone project integrating the contents and competencies of several courses. This paper presents an evaluation of its implantation from the students point of view. The results are encouraging as students are more motivated and the initial set objectives were accomplished.

Keywords: project based learning; student's motivation; learning process.

1   Introduction

The high level of abstraction and the large theoretical workload inherent to engineering degrees using lecture based teaching has been connected with low student motivation and high rates of student dropout (Devadoss and Foltz 1996). Under the EHEA (European Higher Education Area) approach proposed by the Bologna Declaration, faculty members of the Engineering degrees of the Universidad Europea de Madrid decided to implement in their classrooms some new active teaching and learning methods and strategies (Terrón López and García García 2010, Fernández Santander, et al. 2012, Terrón López, García García y Blanco Archilla 2009). Teaching methods were therefore centred in the students.

Spencer and Spencer (2008) stand that 'the better the fit between the requirements of a job and the competences of a person, the higher the person's job performance and job satisfaction will be'. Recent surveys to employers (Association of American Colleges & Universities, 2013) say that they seek for students prepared for success as workers and citizens in the 21st century. This means that they have to develop personal and professional skills including sustainability, problem solving and decision-making as well as technical competences, teamwork, leadership and communication. In particular some of the accreditation approaches for engineering programs such as , the European Accreditation of Engineering Programs (EUR-ACE®), as well as the Accreditation Board of Engineering and Technology (ABET) stand that they have to demonstrate that their graduates acquire the industry desired skills and qualities in the future. This demand for engineering professionals is characterised by requirements of deep and solid interdisciplinary technical competences and communication and management skills (Chandrasekaran, Stojcevski, Littlefair, & Joordens, 2012). Changing Engineering programmes to meet these requirements can be addressed by different active learning methodologies centred in the students such as problem-based or project-based learning (Mills & Treagust, 2003). To integrate into the curricula projects to provide a specific solution to a problem allows students to apply and integrate knowledge from several subjects while developing competences such as teamwork, communication skills and time management (Land & Zembal-Saul, 2003; Dopplet, 2003). Using projects as engineers do in their profession, students learn to make interdisciplinary connections between what they have learnt and the application of this knowledge. That is why several institutions of higher education have been addressing project approaches to engineering education. Using PBL students apply knowledge and techniques of different subjects to a project making interdisciplinary connections between them and developing, in parallel, engineers competences (Helle, Tynjälä, Olkinuora, & Lonka, 2007; Lima, Carvalho, Flores, & Van Hattum-Janssen, 2007; Hilnoven & Ovaska, 2010).

As a consequence, in 2012 to apply a Project Based Learning methodology was decided in the Polytechnic School of the Universidad Europea de Madrid (UEM). Starting at the 2012-2013 period to build a Project Based

Engineering School (PBES) applying this methodology throughout the entire School was decided (Gaya López, et al., 2014). Some good experiences that helped the implementation of our Project Based Engineering School (PBES) can be found in the literature: Aalborg University, Monash University, Central Queensland Universitu are some examples among others.

1.1 Context

To implement a Project Based Engineer School was the aim of the School of Engineering of the Universidad Europea de Madrid in the 2012-13 academic year (Gaya López, et al., 2014). The objectives of this *Project-Based Engineering School (PBES)* were to:

- Increase motivation and pride of belonging of students and teachers.
- Obtain a deeper learning.
- Develop and promote key skills.
- Bring the classroom close to the profession.
- Focus on social, economic and environmental sustainability.
- Encourage entrepreneurship, technological innovation and internationality.

During the projects development, teachers must guide their students in order to ensure deep learning, generating a greater satisfaction with their studies. Additionally, the participation of real companies should increase the motivation in our students to lifelong learning. This will help to achieve higher levels of employability, since the companies are participating in the training of future employees Additional consequences of the implementation of this model are the greater involvement of students in university life, the support of the university through mentors in developing emotional intelligence of its students, and the increase in the students of an interest in innovation. All this process can be seen in figure 1.

Figure 1: Academic Model of the Project Based Engineering School (PBES)

The School of Engineering at the Universidad Europea de Madrid (UEM) offers degrees in four fields of study: Information and Communications Technology (ICT), Industrial, Aerospace and Civil Engineering. The strategy is to offer every student at least one engineering capstone project per year in which the knowledge developed through various courses converges and it is used for the design and development of one integrating project. Although not all subjects are directly involved in the projects, the rest is replacing traditional blackboard classes using active learning strategies instead, i.e. flipped classroom, collaborative work, etc. (Velasco Quintana & Castilla Cebrián, 2013; Terrón López & García García, 2010).

After its first year of implementation we detected as one of the biggest benefits to increase the relationship of the UEM with local companies (Terrón López et al., 2015). The integration between companies and the university means that professionals in those companies are aware of the solid training received by our students. This connection may result in an increase in the employability of our students.

During the 2013-2014 academic year the scope of engineering degrees and schedules remained but, as we can see in figure 2, the number of projects was increased by 10, thereby having more courses (101) and teachers involved (66) in the PBES. Also the number of capstone projects that were done in or for a company was increased substantially. During 2014-15 the data are very similar to the previous year.

Comparative PBES 2012-2013, 2013-2014 & 2014-15

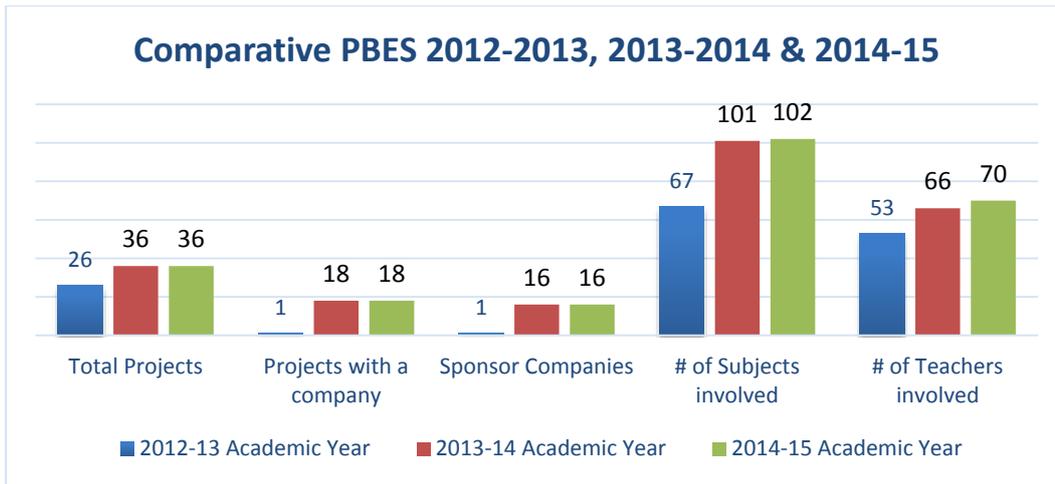|	Total Projects	Projects with a company	Sponsor Companies	# of Subjects involved	# of Teachers involved
2012-13 Academic Year	26	1	1	67	53
2013-14 Academic Year	36	18	16	101	66
2014-15 Academic Year	36	18	16	102	70

Figure 2. Comparison of the results of PBES implementation between academic years

As this paper is written by one of the students participating in the PBES as a student and as a researcher, the objectives of this paper are to evaluate the current state of implementation of the PBES from the students' point of view, to promote particular actions of improvement.

2   Methodology

At the end of each academic year, data were collected through an online survey for the students and teachers that took part in the projects. This survey finished with three open ended questions: what was the best in this methodology?, what was the worst?, how will you improve it?. Likewise, semi-structured interviews (Kvale, 2014) with an academic supervisor and several students were conducted on the following dimensions: deeper learning experiences; skills development; student motivation; sustainability; strengths and limitations of the PBES implementation; doubts and difficulties and ways of overcoming them; suggestions of improvement. The purpose was to measure the accomplishment of the objectives.

Overall, 228 students responded to the survey during 2012-13 and 2013-14 academic years, representing a 58% return rate. A representative group of each degree was invited to participate in a semistructure interview (we don't still have data from the 2014-15 academic year). The general topics covered by the interviews were the objectives of the PBES, although some other topics emerged during them.

The resultant data from both sources was analysed using a mixed qualitative-quantitative methodology. The quantitative data were processed by performing a statistical study and had been presented elsewhere (Terrón López, García García, Gaya López, Velasco Quintana, & Escribano Otero, 2015). The qualitative data was analysed by content through coding and interpretative analysis techniques, generating different categories of description in relation to the objectives of the project. We present in this paper the results of the qualitative analysis because of its richness (Berg, 2004) to explore the extent to which students are comfortable with this 'learning by doing' methodology.

3   Students' perception

We present here the students perceptions from the categories emerged from the qualitative analysis of the open ended questions and the semistructure interviews. The final category structure corresponds to a system based on the global objectives sought to design and implement the PBES. Once these main categories identified, we proceeded to its division into several subcategories. This division was varied throughout the analysis. References were added and the structure of the categories was reviewed. Therefore the main categories that emerged were: Motivation and pride of belonging; Deeper learning; Key skills development; Closeness to the profession; Sustainability; Encourage technological innovation; Other perceptions.

As subcategories we looked for positive, neutral or negative references. As we will see, in general, students' perceptions regarding to the implementation of the project based engineering school are positive.

3.1 Motivation and pride of belonging

To learn using projects emerged in the interviews as a factor that increased the students' motivation as well as their pride of belonging to the Universidad Europea de Madrid. A 70% of the coded references were positive, 21 % negatives and 9% neutral. Students compare their motivation when there was not this methodology implemented in the School with the actual year:

'Compared to the previous year, I would say yes, my motivation is greater because in addition to learning in a different way, due to the constant practice, you develop healthy competition when you see others can manage to do it and you don't. Therefore, you try to study every day on your own and you want to go to classes. You ask about doubts you have and that enhances your motivation. It is much more stressing at the end but you are motivated and you do want to come to classes to keep learning and to say, "Ah, I want to do it as that group has done it." It is much more motivating than without it.'

They also compare this type of projects with other smaller ones that they have done previously, linking motivation to both learning and struggling with solving a bigger problem:

'To me, personally, a bigger project motivates me much more than a small thing like a button that does a little thing. It is a real thing that has a beginning, a purpose and a functionality. You feel overwhelmed at the beginning and say "Oh, what a big thing I have to do!" but little by little going to class that is where we set out the project, at home where we have to progress and see how to do. Little by little thanks to classes, classmates, or even by self-initiative you start to see the light, finding the way and so... That seems to be a very, very positive aspect to me... The thing is that it is really cool!, to see how you start to get the project off the ground and little by little you are learning and so.'

3.2 Deeper learning

Students referred they have achieved a deeper learning with the PBL methodology, being a 95% of the coded references positive and a 5% negatives. They see the project as something which challenges them to learn rather than to just merely study:

'Yes I have learnt more, much more. I have gone from studying in order to pass, to study in order to learn, that the mark will eventually follow. It is very important, not only because I have improved my marks but because the concept has changed; it is not the same when you study to pass an exam than when what matters to you is to learn in order to get the project off the ground. When you finish, then you, inside, know much more and that for the future is the most important, in my opinion.'

In addition, they consider that they do not only learn more but in fact they retain that knowledge better:

'Learning without a clear example it is easier for you to forget what you are learning, whereas if you are doing it yourself in a real project then you retain more.'

'The project is the way in which you learn best. You truly have a linearity, each day you learn a bit more. With an exam you learn in one go at the end and then you forget it. With the project since you have to apply what you are learning, you learn much more.'

3.3 Key skills development

Students also highlighted that they have learned other competences important to their future profession such as how to communicate (using project writing and presenting their own work to others), to manage a team and planning among others. 71% of the coded references about this category were positive while 29% were negatives. Teamwork, autonomous learning and responsibility were the key skills mainly coded.

Teamwork was the one with more references. Students compare the project with other practical exercises done in groups stating that within a big project teamwork is better developed:

'You have to distinguish between practical exercises and the project. In practical exercises you divide the tasks and each member of the group is in charge of his/her part and then you unite. In fact you do not learn to work in a team. In a larger group you have to plan because if not the project will fail. You have to know which tasks each member can do, and everyone has to be in the know because if not there are people that cannot continue with the project. When there is someone that doesn't follow, you have to help him/her and it gets complicated. In this sense you develop it more in the

project; in practical exercises you don't get to plan neither to work as much as a team, you only divide tasks and distribute them.'

On the other hand, the students complained about the main problems that emerged within their teams. The principal conflict that appeared in many cases was regarding the individual team members that didn't work:

'You have to coordinate from the beginning. You have to help your mates and be very careful so that what happened to […] doesn't happen to you. It also happened to me, you think that everybody is going to do his/her work and at the end you find yourself the last day having to do it all by your own because if not you will fail too. You have to anticipate and be alert for those things. If in two weeks you already see that the team doesn't respond, you have to take decisions: help them or warn them.'

In addition to teamwork, many students also highlighted the development of autonomous learning:

'Concerning self-learning: the project implies knowing things that, although you don't study them to have a 10 in the exam, things do come out, problems start to set out that then will appear later. For example, when we started this project, at the beginning we didn't have a clue about how to do a web application, but classmates with experience tell you things, you start looking,... and then when the time comes to do the design you have to learn things that you will re-learn or go in depth later on.'

Responsibility was the third skill with more references, especially in the positive sense:

'I think the project helps a lot with responsibility. Since you are working always on the same thing, you must be up-to-date or at least you shouldn't be too delayed, whereas when you work with many different activities, if you do not do one of them, you will do the next one, it won't matter.'

3.4 Closeness to the profession

Another important aspect that students have pointed out is the relationship that exists between the projects they have made and their future professional careers. Concerning this, a distinction is made between those references linking the content of the project to the profession, in which a 90% of the references were positive, 2% negatives and 8% neutral; and those references about the collaboration of companies in the projects, in which 79% of the references were positive and 21% negative.

With respect to the references linking the content of the project to the profession, the students believe that the project has helped them to be better prepared for their future:

'It has been a really interesting experience to live through. Knowing what we are going to deal with in the near future is a very good way to prepare ourselves for what is to come. We have faced real-life situations which will allow us to perform our jobs better and that is extra experience when entering the world of work.'

'I think it's that, that it introduces you directly into that world... into what you are going to do in that subject. Because it is not the same that someone explains to you: ok, a road has to be X km long; than that you really start to design a road with the regulation in your hands, which is what you will find when you come out of university. To me, that is the most important aspect.'

The students also enjoyed performing a real-life-based project:

'Yes because I prefer to do a project about how I think the aircraft of 2040 will be, why and how it would be, than doing a presentation about topic 4 of propulsion, which are the typical presentations and projects that are done; presentations about something from the subject of materials, for example we did a presentation about thermoplastics […] it doesn't have as much to do as the design of the aircraft of 2040 which can interest you more because I think it is more real than a presentation about that.'

Regarding the collaboration of external companies, some students thought that problems about intellectual property and other legal aspects could arise, but generally they believe it was a positive experience:

– Academic supervisor: 'In one of the first interviews with [the company] the resentment came out that, if the project finally had the enough quality, [the company] could "take advantage" of the work done by the students. How do you feel with respect to this problem?'

– Student: 'If finally [the company] got benefit from the project, I would try to see it as the best letter of introduction in the future when the time comes to entering the professional world: "I have done this, and this company, which is real, is

profiting with it". If part of that benefit corresponds to us by right or not, are legal issues which I do not have much knowledge about and, as a student, it wouldn't matter much to me.'

Moreover, the students whose project didn't involve an external company see it as a great opportunity:

'In addition they come and they tell you the first day, this company, a man comes to you and tells you, "we want this, this and this" and if besides that if they tell you maybe we are going to give to the best one a pen-drive or a pin or whatever, then you go like more motivated. And if moreover you think for yourself, that if I stand out I may be able to go in. Although they don't tell you, the thing is that it works that way. Or even if you cannot go in, the thing is that then you are going to have an internship interview and you can say, look, I have participated in this…'

3.5 Sustainability

In general, students have reflect about economic, social and/or environmental sustainability while developing their projects (60% of the coded references said so), but we find that 24% of the references stay that they haven't done (while in 16% of the references we find they don't know). We should stress than some of them think that thanks to these projects they have been concerned about issues regarding sustainability:

'This project helps you consider issues that wouldn't be developed in any other way.'

'[…] as the subject goes by and they explain you things, you start to see why something would be like this and not in another way, and you include it in the project […] so they explain you things and you say "ok, I have to take this into account when…".'

3.6 Encourage technological innovation

With respect to technological innovation, all the references state that the projects have mainly encouraged the students to develop new ideas for their future:

'Yes, that it has a purpose not clearly academic in the sense that you present that, but instead you have an idea that then can be good, it can help you with the rest of your career and even your future.'

3.7 Other perceptions

Apart from the perceptions based on the global objectives sought to design and implement the PBES, the students also noted other interesting aspects, some of which were frequently mentioned. Between the positive additional perceptions, the students highly valued feeling useful and being capable of making things while doing the project:

'By the time the quarter ends, and you are not stressed out anymore you end up liking it and you say, "Look, I did that and the window that opens my code" When you manage to make it work, you are proud of yourself and you say, "Do you want me to show you the project I did at the university? In the end, it is something good indeed and it holds the course together. It does not feel like a dead end. It brings the quarter to a continuum.'

They also appreciated the support received from some of the teachers involved in the projects:

'[…] for example in the part of thermodynamics we had like small weekly deliveries and after presenting it we had a feedback, so we always knew where to head and then of course that could be seen in the final result.'

An interesting point to mention was that students felt more aware of their degree thanks to the project:

'It is very important to be aware of the knowledge you are acquiring and to see which functions you can perform in the future. During the freshman and sophomore years in any major program, you study things you usually do not find useful. That is why most students are stuck in the first years. […] There are times when students don't know exactly what is it they are studying but until their third year in college. Now, by having this kind of graphic interface project during our first year, things become real. If you do not find that motivating, then that means you may be studying the wrong major.'

In addition, the projects provided a global vision of the different subjects to the students:

'Moreover you can relate some subjects with others; you don't just centre in what can be done in one subject. You say, look, with this I have learnt this, but in addition I can associate it with this subject, and with this one and this one.'

Yet, not all perceptions were positive, and several negative aspects from the project arose. The most repeated complaint was regarding the distribution of the workload:

'It should be better distributed. There is too much workload of PBL and too much of exam, being insufficient the time available for the students to develop both, being prejudicial to the latter.'

'What I liked the least is the stress at the end of the project. The project has to be better organized in order to give it continuity instead of being "do it in the last two weeks and let's see what you can manage to do".'

Linked to this, the students also mentioned the negative effect of the coincidence of the project's deadline with the exam dates:

'The deadline of the projects should be better selected so that it doesn't overlap with the exams, due to the weight that such projects tend to have, both in the sense of weight in the final grade as well as theory to present.'

Another highly repeated negative aspect, was regarding the bad organization of the projects:

'The desperation for spending hours, hours and hours without obtaining any result until you became aware. This is also due to the bad management of the topics explained in the subject itself, since most of the things that had to be applied were explained weeks later in class.'

Moreover, the students said they didn't have enough information about the project, about what had to be done, and this impacted negatively on their motivation:

'In one of the subjects they didn't explain us anything about what we had to do and that puts us off attending to class due to not knowing how to perform the work, and to work by my own I prefer to work at home.'

Apart from the lack of information, some of them attract attention to the lack of knowledge required to do the projects:

'I understand that it is important to develop these competencies, but we are at the university, what no one can think is that with simple notes we will be capable of performing projects of such magnitude.'

4   Results and conclusions

After processing the student's perception data from the 2012-2013 and 2013-14 academic year we have noticed that most of the students agree that doing the project has motivated them. It has helped the students understand and know the contents of the subjects better. Students have perceived that they have acquired more skills they will need in their profession. This, together with the closeness to the professional world, has influenced positively in their motivation.

In general, students' perceptions regarding to the implementation of the project based engineering school are positive. They have also perceived an improvement in their academic performance and as a result their satisfaction with the academy has risen.

However, the bad organization and distribution of the workload, as well as problems with the teams for the projects are issues that have impacted negatively on their motivation. It seems that if the time of making the project is too busy or too short, it can decrease students' motivation instead of increasing it.

From these results next year project will be designed considering some aspects as:

- Trying to make a better coordination between teachers providing them some coordination tools.
- To get an active participation of all the faculty even if their subjects are not involved in an integrating project.
- Increase industry participation and terms of this participation.
- Review workload related to each project making projects charts.

5   References

Association of American Colleges & Universities. (2013). It Takes More than a Major: Employer Priorities for College Learning and Student Success: Overview and Key Findings. Retrieved December 2014, from http://www.aacu.org/sites/default/files/files/LEAP/KeyFindingsfrom2013SurveyofEmployers.pdf

Berg, B. L. (2004). Qualitative research methods for the social sciences. New York: Pearson Education.

Chandrasekaran, S., Stojcevski, A., Littlefair, G., & Joordens, M. (2012). Learning through Projects in Engineering Education. SEFI 40th annual conference. Thessaloniki (Greece).

Devadoss, S., & Foltz, J. (1996). Evaluation of factors influencing student class attendance and performance. American Journal of Agriculture Economics, 78(3), 499 - 507.

Dopplet, Y. (2003). Implementation and Assesment of Project-Based Learning in a Flexible Environment. International Journal of Technology and Design Education, 13(3), 255 - 272.

Fernández Santander, A., García García, M. J., Saez Pizarro, B., & Terrón López, M. J. (2012, March). Development and Assessment of Key Skills in Undergraduate Students: An action-research experience. Higher Learning Research Communications, 2(1), 32-49.

Gaya López, M., García García, M., Martínez Lucci, J., Vigil Montaño, M., Velasco Quintana, P. J., Terrón López, M. J., & Escribano Otero, J. J. (2014). PBES. Una experiencia de aplicación PBL con resultados muy prometedores. VIII Congreso Internacional de Docencia Universitaria e Innovación (CIDUI). Tarragona.

Helle, L., Tynjälä, P., Olkinuora, E., & Lonka, K. (2007). 'Ain't nothin' like the real thing'. Motivation and study processes on a work-based project course in information systems design. British Journal of Educational Psychology, 77(2), 397-411.

Hilnoven, J., & Ovaska, P. (2010). Student Motivation in Project-Based Learning. Recuperado el January de 2015, de http://icep.ie/wp-content/uploads/2011/02/Student-Motivation-in-Project-Based-Learning.pdf

Kvale, S. (2014). InterViews: An Introduction to Qualitative Research Interviewing. SAGE Publications.

Land, S. M., & Zembal-Saul, C. (2003). Scaffolding reflection and articulation of scientific explanations in a data-rich, project-based learning environment: An investigation of progress portfolio. Educational Technology Research and Development, 51(4), 65 - 84.

Lima, R. M., Carvalho, D., Flores, M. A., & Van Hattum-Janssen, N. (2007). A case study on project led education in engineering: students' and teachers' perceptions. European Journal of Engineering Education, 32(3), 337-347.

Mills, J., & Treagust, D. (2003). Engineering Education – Is Problem-based or Project-based Learning the Answer? Retrieved january 16, 2015, from http://www.aaee.com.au/journal/2003/mills_treagust03.pdf

Spencer, L. M., & Spencer, S. M. (2008). Competence at work: models for superior performance. New York: Wiley.

Terrón López, M. J., & García García, M. J. (2010). Key skills development through students learning activities. International Technology, Education and Development Conference (INTED). Valencia.

Terrón López, M. J., García García, M. J., & Blanco Archilla, Y. (2009). Integrating key skills in information and communication technology degrees. Its assessment in the students. International Conference of Education, Research and Innovation (ICERI). Madrid.

Terrón López, M. J., García García, M. J., Gaya López, M. C., Velasco Quintana, P. J., & Escribano Otero, J. J. (2015). Project Based Engineering School (PBES): An implementation experience with very promising results. Proceedings of the IEEE Global Engineering Education Conference (EDUCON2015). Taillin: IEEE.

Velasco Quintana, P. J., & Castilla Cebrián, G. (2013). Aula UE: un canal abierto al aprendizaje. X Jornadas Internacionales de Innovación Universitaria. Villaviciosa de Odón: Universidad Europea de Madrid.