Interdisciplinary coordination and Problem-Based Learning: evidence from Higher Education

Coordinación interdisciplinar y Aprendizaje basado en problemas: Educación Superior

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Abstract

The aspect of the European Higher Education Area is the need to educate students using a multidisciplinary approach. The undergraduates should also acquire competencies that will be essential in their future profession. The interdisciplinary approach provides many benefits that develop into much needed lifelong, learning

skills that are essential to the student's future learning. The aim of this work is to apply interdisciplinary coordination of two subjects of Degree for the achievement of the competencies and the skills of students. In this context, this work describes an educational constructivist, innovation consisting of interdisciplinary coordination between two subjects from the Bachelor's Degree in Business Administration and Management: Production Management and Business Statistics, using Problem-based learning (PBL). As secondary objectives we set out, to intend, to encourage the participation and implication of students through the proposals of real problems and motivators; to ensure that students have a global and integrating vision of the production and operations function and the possibilities of statistical techniques; to Improved communication between students and teachers, promoting teamwork and work together with some of the necessary skills in the degree. We ran the educational innovation project over three consecutive academic years, the results demonstrate that acquiring knowledge via interdisciplinary coordination is highly valued by students and also allows them to acquire competencies that will be essential in their future careers. It highlights the need for a policy maker to evaluate an interdisciplinary curriculum.

Keywords: Business education; interdisciplinary education; problem-based learning; coordination

Resumen

El objetivo del Espacio Europeo de Educación Superior es la necesidad de educar a los estudiantes utilizando un enfoque multidisciplinario. Los estudiantes de grado también deben adquirir competencias que serán esenciales en su futura profesión. El enfoque interdisciplinar proporciona muchos beneficios que se convierten en habilidades de aprendizaje para toda la vida y que son esenciales para el aprendizaje futuro del estudiante. El objetivo de este trabajo es aplicar la coordinación interdisciplinaria de dos asignaturas de grado para el logro de las competencias y habilidades de los alumnos. En este contexto, este trabajo describe una innovación educativa constructivista, que consiste en la coordinación interdisciplinaria entre dos asignaturas de la Licenciatura en Administración y Dirección de Empresas: Gestión de la Producción y Estadística Empresarial, utilizando el aprendizaje basado en problemas (PBL). Como objetivos secundarios nos propusimos fomentar la participación e implicación de los estudiantes a través de propuestas de problemas reales y motivadores; asegurar que los estudiantes tengan una visión global e integradora de la función de producción y técnicas estadísticas; mejorar la comunicación entre alumnos y docentes, promoviendo el trabajo en equipo y el trabajo conjunto. Ejecutamos el proyecto de innovación educativa durante tres años académicos consecutivos, los resultados demuestran que la adquisición de conocimiento a través de la coordinación interdisciplinar, que resulta muy valorada

por los estudiantes y también les permite adquirir competencias que serán esenciales en sus futuras carreras profesionales. Destaca la necesidad de que un responsable de políticas educativas evalúe un plan de estudios interdisciplinar.

Palabras clave: Empresariales; educación interdisciplinar; aprendizaje basado en problemas; coordinación

Introduction

The introduction of Bachelor Degrees, adapted to the European Higher Education Area (EHEA), has involved significant changes in the teaching-learning model: the main actors –students and lecturers/professors – have had to change their roles. The lecturer has become a guide in the teaching process. The student has become a highly active part of this process because "learning to learn" conditions the methodologies, evaluation and results. The contents, resources and strategies of teaching-learning should be designed to place the students in what is going to be their future professional context (Huber, 2008). This implies a need for coordination and cooperation between different departments. This scenario corresponds to constructivist learning (O'Donnell, 1997).

The subject matters making up degree of course cannot be considered in isolation either in their contents or methodologies. Course designers need to take a multidisciplinary approach and exploit the synergy effect. If the students have to work on projects spanning different disciplines, they will be better prepared to face real-life situations characterised by interdisciplinary. Undergraduates must acquire not only a knowledge but also the competencies that prepare them for their profession. In their future working, lives they will be exposed to the complex situations defined by interrelated variables and requiring a multidisciplinary approach to be tackled successfully.

The aim of this work is to apply interdisciplinary coordination Production Management and Business Statistics taught in the second year of Degree in Business Administration and Management at Rey Juan Carlos University (Spain). The project ran for two consecutive academic years (2014-2015 and 2015-2016) experimentally with volunteers. Then, in the academic year 2016-2017 two units are taught in the same semester and are highly complementary. To carry out this educational innovation, we chose the Problem-based learning (PBL) methodology. The intention is to encourage the participation and implication of students through the proposals of real problems and motivators, to ensure that students have a global and integrating vision of the production

and operations function and the possibilities of statistical techniques, improved communication between students and teachers, promoting teamwork and work together with some of the necessary skills in the degree.

This work makes three of several contributions. First, we offer a methodological innovation in tertiary-level education that allows students to develop a competencies that will be essential in their future profession. Second, we encourage both active learning and teamwork processes among students by establishing a structure that allows educators to coordinate their educational activities across the subjects. Third, our work aims to contribute to the advancement of the PBL, situating interdisciplinary coordination as a key in the alternative to traditional assessment and evaluation methods in the methodological strategy for inductive learning. As recommended, policy makers should encourage interdisciplinary curricula. The Europe 2020 strategy puts the quality and relevance of education and training systems at the heart of EU efforts to improve competitiveness and achieve smart, sustainable and inclusive growth.

The work is structured as follows. First, the antecedents and the theoretical review are introduced. Then the educational innovation project is described. Third, the methodology described by defining the units of analysis, participants, the data collection and the results. Finally, the conclusions are included.

Theoretical review. Antecedents

Constructivism is a learning theory which explains how people might acquire knowledge and learn. The theory suggests that humans construct knowledge and meaning from their experiences. Piaget's theory of Constructivist learning has had wide ranging impact on learning theories and teaching methods in education and is an underlying theme of many education reform movements. There are different strategies and approaches which can be implemented by teachers when planning a constructivist classroom.

The structure of EHEA-adapted syllabuses focuses on the acquisition of competencies. In the face of the new challenges posed by the EHEA, teaching coordination should become one of the fundamental pillars in the development of the professional competencies the students need to acquire (Golding, 2009). The interdisciplinary approach synthesizes more than one discipline and creates teams of teachers and students that enrich the overall educational experience (Jones, 2009).

Over recent decades, authors have proposed many different ways of using interdisciplinary to improve its efficacy in the lecture hall. Follari (1980) stresses two basic forms of interdisciplinary: one focusing on the creation of a new theoretical object between two distinct sciences, and a second focusing on applying theoretical elements from different disciplines to a single practical object.

Interdisciplinary learning allows the student to gain a more comprehensive knowledge than when they study a subject in isolation. This method may prove less effective than traditional learning with respect to in-depth knowledge about a single subject, but it stresses higher-level knowledge (analysis, application, critical thinking, etc.) because the student seeks out meaningful connections between two or more disciplines (Ivanitskaya et al., 2002, Monreal-Gimeno and Terrón-Cano, 2011; Engström, 2015).

Problem-based learning is an alternative to traditional teaching methods, and a methodological strategy for inductive learning. Under Constructivism Teaching Theory, PBL can be thought of as a combination of cognitive and social constructivist theories, as developed by Piaget and Vygotsky. Concepts as student autonomy, personal motivation, prior knowledge and questioning are in Cognitive Constructivism (Piaget, 1972), authentic problems, team study and group processing, social dialogue and multiple viewpoints, base Social Constructivism (Vygotsky, 1978).

A classroom committed to constructivist practices would not promote solely sequential, linear-based, didactic assignments or techniques. (Niederhauser and Fields, 1999). The PBL methodology encourages students to learn in-depth and independently. The students – working in small groups and guided by a tutor – use the solving of the problem as the basis for achieving learning goals and developing competencies that are transferable to professional practice (Hung, 2009). The methodology also potentially improves student motivation, because teaching and learning take place through problems that are meaningful to the students and because a stronger relation exists with future working practices (Duch et al., 2001). Brown and Brown (1997) describe how the use of problem-based learning strategies effectively incorporate real-world problems, an interdisciplinary environment that models the workplace (especially teamwork), and desired pedagogical techniques such as active learning and collaborative learning. The integration of real-life business problems in academic education configures a context in which creativity and entrepreneurial behaviour can be nurtured and developed (Rossano, et al., 2016). The first experiments testing PBL appeared in the

health sciences (Barrows and Tamblyn 1980). Researchers then experimented with this methodology in other disciplines.─In the field of Business Administration, numerous business schools use PBL. Authors such as Gijselaers (1995), Milter and Stinson (1995), and Savery and Duffy (1995) demonstrate its usefulness in this discipline. For example, the University of Ohio has a full programme based on PBL for its MBA course.

In the specific case of Production/Operations Management, Kanet and Barut (2003) stand out. This work describes the use of PBL in the teaching of Production/Operations Management at Clemson University. Its results show that using this methodology helps students to develop the professional qualities demanded in the real world. The students' expectations were satisfied because they had to solve real problems and could see an obvious connection between theory and practice. PBL can be advantageous over the conventional learning strategies in taking multiple perspectives, generating greater understanding of science concepts, and making connections across science disciplines, thereby fostering interdisciplinary learning (Hung, 2009; Betsy et al., 2011). Experiments similar to the one we present here that use PBL to achieve interdisciplinary coordination have been conducted in other degrees (Stentoft, 2017), such as Materials Engineering (Sanchez et al. 2013), in introductory courses in engineering technology (Wood and Mack, 2001), in a food biotechnology course (Betsy et al., 2011), and in other subjects such as Leadership (Sternberg, 2008).

Materials and methods

Unit of analysis

We carried out our educational innovation experimentally by volunteers during the academic years 2014-2015 and 2015-2016, and then in the academic year 2016-2017 we launched the full study using four complete groups of students (245 students), at Rey Juan Carlos University, in Madrid, Spain. Our aim was to carry out a project in interdisciplinary coordination based on PBL. The two units involved are taught in the second year of the Degree in Business Administration and Management at that university, namely Production Management and Business Statistics. Five lecturers took part in the project. The Production Management unit teaches about the Production/Operations area in the firm, the production function with a strategic focus, and the decision-making linked to product, process, capacity, localisation and quality. The unit is strongly theoretical-practical in character. Hence, the need to design active-learning methodologies that help the students

better understand operations management concepts and their strategic importance for the firm and that is adapted to the needs of the curriculum and meet the firms' requirements (Fish, 2008). Business Statistics is an instrumental subject matter, and teaches statistical techniques, specific descriptive and inferential analysis. The subject is a very useful complement to other subjects with an empirical content, offering the ability to analyse exploratory and confirmatory data.

These two units have always been taught independently at the university. Nevertheless, interrelations between the two were obvious. Many of the problems that need to be solved in the production area require statistical techniques to analyse the data, and the results of these analyses then support the decision-making. Making these interrelations clear to the students is obviously very positive and enriching, because it offers them an integrating vision of the areas of knowledge to help them understand the multidisciplinary nature of the subjects and the problems they have to solve. We analysed the syllabuses of the two units to identify the points where coordination based on the design of the PBL methodology was possible. The common generic competencies to work on in coordination between the two units were as follows:

GC1. *Ability to analyse and summarise*: be able to analyse, summarise, evaluate and take decisions on the basis of relevant information about the situation and the conceivable evolution of the firm.

GC3. *Oral and written communication* in native language: be able to understand and communicate correctly, in different scenarios, in Spanish. Be able to make yourself understood by managers and subordinates clearly and concisely, and to write up consultation reports and business management projects (global or by functional area).

GC6. *Ability to seek, distinguish and analyse information coming from diverse sources*: be able to identify sources of relevant economic information, select and obtain relevant information unrecognisable for non-professionals.

GC8. *Ability to solve problems: efficiency and flexibility to provide solutions to problems identified (evaluating the problems, managing the problems, decision-making, resolving the problem, examining the results).*

GC10. *Ability to apply to the analysis of problems professional criteria based on the use of technical tools*.

GC18. *Ability to do critical reasoning: mental behavior that questions things and is interested in the foundations to reassess claims accepted as true on the basis of new theoretical or empirical information and reach a reasonable and justified intellectual position on an issue.*

GC21. *Independent learning: ability to think, act and pursue their own studies or research autonomously, without the same levels of support you receive from a teacher*.

GC28. *Ability to apply knowledge to practice: use of knowledge acquired to perform a task that is novel for the individual, in particular, apply knowledge acquired academically to problems and real life situations.*

Participants and procedure

In the experimental stage, we selected 25 students to participate in the project in each academic year. Participation in the project was entirely voluntary. In the academic year 2016-2017 a total of 245 students participated obligatorily. In order to develop the PBL, we designed a case involving a real firm whose main activity is to provide physical and electronic communication and parcel delivery services in the Spanish market: Correos, the national postal service in Spain. In the design process, we ensured that the following characteristics were met: relevance and interest for students, clear definition of objectives, a certain level of complexity and interdisciplinary nature.

We used the 4x4 PBL model, which is particularly appropriate with large groups of students (Prieto et al., 2006). The stages in which the work is organised according to this model are: Activation-Analysis, Research, Resolution, and Evaluation.

PBL is structured into different sessions some of which require students to be present and some not. The sessions take place in the lesson periods, inside the classroom. Students are divided into groups of 4 components. The grouping is done randomly looking for diversity rather than uniformity or affinity. We have the necessary resources to develop this methodology properly, such as a classroom, facilitating group work, since the mobility of seats and tables is allowed. The duration of each session is sufficiently broad to allow the development of scheduled tasks correctly. Normally, the duration is from two to two and a half hours.

In the first session, the students learned about the project and the plan for the following sessions. The participants were divided into groups, with the students themselves choose which group to join. They were also handed a form in which to note down the activities of each group member over time, the sources of information consulted and how long each activity took. In the second session, the students were given the first part of the case study. The students worked on and analysed the environment in which Correos operates. They received information about the evolution of the firm in the past 10 years, the structure of the market and the competition. The case focuses on the production and operations functional areas in the aspects localisation, capacity, layout, process, and automation, as well as on data analysis via descriptive statistics. As they debated the case the group gradually gained a clearer idea about the unknown aspects of the problem. The Activation-Analysis stage of PBL takes place in this session.

In the third session, the students visited the Automated Handling Centre at Madrid-Vallecas. This is one of the 17 such centres Correos has – located at strategic points – to receive and send on post around the country. This visit became a key source of information for the students. Apart from showing them the installations and how the processes worked, the students met the manager of the Centre and had the chance to ask questions and clear up their doubts. The Research stage of PBL takes place in this session. In the fourth session, the students organised all the information found by the group members to respond to the questions posed. The students discussed and presented their results to the other groups. The students were then given the second part of the case study and they discussed the new environment. This part of the case focused on the quality management system at Correos. Here, the students work on the Analysis and Resolution of the case.

In the fifth session, the students were taught how to draw quality-control graphs. The groups reorganised all the information worked on during the case to solve the problems posed and came to some final conclusions. Each group presented its results to the other groups and debated the results. In the final session, the students interpreted the index numbers calculated for different variables. They discussed and modelled situations involving defects and stoppages in the classification machinery. They then calculated the confidence intervals for the difference of means of the operating time of the machinery and tested hypotheses for the difference of means in relation to two correspondence classification machines. In this session the fourth stage of PBL – Evaluation – takes place.

Data collection

In the experimental stage of the educational innovation, we collected information from the students via questionnaires at two points: at the beginning and at the end. For the design of these questionnaires we consulted Gómez Esquer et al. (2009) and adapted their questionnaires to meet the requirements of our project. For each questionnaire, we carried out a pre-test, requesting the cooperation of lecturers who taught these units and students.

The first questionnaire consisted of 12 questions, each measured in 5-point Likert scales. It asked the students for their opinion about some aspects to do with the activities carried out in the units, the methodologies and the coordination between the two units, and about their expectations for the experiment. The final questionnaire aimed to evaluate elements of the sessions of the project (contents, planning, teamwork, Problem-based learning, presentations, independent learning, and students' perception that it is a real problem), as well as the acquisition of competencies (on a scale of 1 to 10). The students were also asked about the usefulness of the experiment, interdisciplinary activities, the theoretical-practical focus, independent learning, the complementary contents and coordination (on a scale of 1 to 5). In the application stage students were only given the final questionnaire.

Results

Before starting with the implementation of the project, the profile and opinions of the participating students are analyzed. It is intended to know what has motivated their participation, what methodology they consider most appropriate for their learning and what expectations they expect from the experience. Having prior knowledge on these issues allows the teacher to guide the dynamics of the sessions towards the achievement of the pre-established objectives with interdisciplinary coordination. In the first place, according to the motivation for which they access this project, the motivation called "innovative activity" is the one that presents the highest percentage followed by the clearly practical consideration and close to the business reality in which they will have to develop their professional future. On the contrary, complementary theoretical aspects are considered residual.

The results are similar in both academic courses, which invites us to think, on the one hand, that they have not regularly experienced this type of methodologies when considering it as a novel activity and on the other, that

we must make great efforts to guarantee the levels of high motivation (see Table 1).

Table 1. Motivation for participation (only experimental stage)

Main motivation for participating in experiment	Year 2014-2015		Year 2015-2016	
	Frequency	%	Frequency	%
Innovative	11	44	12	48
Practical	4	16	4	16
Close to reality	5	20	6	24
Useful for general education	4	16	5	20
Complementary contents	1	4	0	
Total	25	100	25	100

Regarding previous opinions and ideas about the possibilities and advantages of certain methodologies, it is evident that teamwork, debate and discussion provide useful in teaching, according to the vision of the students participating in the experience (they want this type of "methodology"). However, as usual, oral exposure in public generates some rejection, perhaps, because at this early stage in their degree course they lack experience of speaking in public.

Both in the experimental and the application stages the data obtained in the final questionnaire produced some interesting results (see Table 2).

Table 2. Methodologies (only experimental stage)

	Statistics	Teamwork	Discussion & debate	Oral presentation
Year 14-15	Mean	4.17	3.88	3.17
	SD	0.64	0.85	1.01
Year 15-16	Mean	4.17	3.88	3.17
	SD	0.64	0.85	1.01

The information obtained in the initial questionnaire led us to make great efforts to try to maintain the expected levels of motivation and to meet their demands in the most appropriate way possible.

After the experience of educational innovation, we provided a final questionnaire that allowed us to jointly assess the methodology under study.

The first analysis compares the students' opinions (5-point Likert scale) about the methodologies they receive in general, in these units and in others, and the methods used in these sessions (see Table 3).

Table 3. Comparison of opinions at project start/end

Year	Statistics	Usefulness in understanding the two units	Independent learning	Coordination between units	Coordination between theory & practice	Inter-disciplinary activities	Statistics complements Production
14-15	Mean	3.75 / 3.67	3.33 / 3.63	**2.42 / 3.21**	3.00 / 3.42	2.92 / 3.38	2.75 / 2.96
	SD	0.68 / 0.70	0.92 / 0.71	1.06 / 0.88	0.98 / 0.50	0.97 / 0.82	0.99 / 1.04
15-16	Mean	3.86/ 3.91	3.35 / 3.68	**3.00 / 4.3**	2.94 / 3.56	3.00 / 4.14	2.95 / 3.83
	SD	0.88 / 0.69	0.72 / 0.61	0.86 / 0.75	1.08 / 1.50	0.74 / 0.91	0.83 / 1.11
16-17	Mean	3.02/ 3.70	3.06 / 3.76	**2.08 / 3.92**	2.17 / 3.98	2.31 / 4.11	2.32 / 4.08
	SD	1.20 / 0.93	1.19 / 0.92	0.75 / 0.94	0.72 / 0.91	0.83 / 0.88	0.77 / 0.86

Regarding the methodologies received, the clear improvements or advantages achieved in coordination between units, interdisciplinary activities and theory-practice coordination stand out. If we analyze the results of each academic year, we verify that the academic year 16-17, in which the experience is developed, the average values improve in all the items considered. This indicates the need to establish activities that address problems globally: several thematic optics (several subjects), several approaches to complex problems (interdisciplinary activities), and approaches with application associated with reality (theory-practice coordination).

In the experimental stage what the students value the most – with a score of over 9 out of 10 – is the "visit to the installations" of the firm. This indicates the need to seek an immediate connection with reality (different from the usual teaching). It also highlights the activity "case discussion" and the activity "quality study", closely related to the consideration of the importance of debate and teamwork for learning.

Opposite, in the first moment in which the experience is developed, what has less acceptance is the mathematical content associated with the activity "data analysis". However, in the following courses, the average value of this item rises considerably. We justify this ascent, by the time available and previous knowledge. In the first course, the students had little time for their development and some of the aspects to be assessed had not yet been taught

in class, in the second, they had more time to develop this last activity and all the concepts had previously been discussed in the theoretical classes.

This shows that the activities are clearly improving after the experience gained in the previous two years, but the visit, remains the most popular activity. Regarding the methodology and the motivation achieved, what is most valued is the "teamwork" methodology. This data corroborates what is stated in the initial questionnaire, what they are looking for is the exchange of experiences and ideas as a preferred way of working.

It also highlights the "close to reality" as a necessary stimulus in the teaching activity, thereby achieving one of the objectives set out with this experience: encourage the participation and involvement of students through the approach of real and motivating problems. It should be noted that "independent learning" is the one with the least acceptance. They do not feel able to work independently, they need the figure of the tutor to guide and guide them. We consider it necessary to develop work dynamics, enabling the students to work independently (with minimum educator intervention), with group tutorials for solving doubts, management of activities and supervision of progress (Prieto et al. 2006).

Table 4 reports what the students think about the specific contents of the project and reports the main statistics concerning the students' opinions about the methodologies.

Table 4. Project contents and Methodologies

Year	Statistics	Project global contents	Project planning	Activity: Case	Activity: Visit	Activity: Quality	Activity: Data	Methodologies: Teamwork	Problem-based learning	Oral presentation	Independent learning	Close to reality
14-15	Mean	7.21	7.54	8.08	**9.04**	8.25	5.83	**8.08**	7.25	7.33	6.54	**7.54**
	SD	1.14	1.41	1.32	1.08	1.03	2.14	1.25	1.70	1.52	1.77	2.04
15-16	Mean	7.54	8.1	8.25	**9.1**	8.33	7.03	**8.18**	7.35	7.30	6.82	**7.60**
	SD	0.96	0.88	1.16	0.98	0.93	1.84	1.3	1.60	1.45	1.37	1.4
16-17	Mean	7.90	8.09	8.23	**8.74**	8.52	7.13	**8.20**	7.92	7.20	6.60	**8.11**
	SD	1.33	1.24	0.85	0.85	0.92	2.12	1.26	1.38	1.41	1.13	1.25

Regarding the acquisition of competencies, it is intended to assess (scale from 1 to 10) the level of certain competencies developed during these activities (see Table 5).

Table 5. Acquisition of competences

	Statistics	Analyse & summarise	Oral & written communication	Seek & analyse information	Solve problems	Apply professional criteria	Critical reasoning	Independent learning	Apply knowledge to practice
Year 14-15	Mean	6.79	**7.50**	**7.33**	6.42	6.38	**7.33**	6.96	**7.25**
	SD	1.35	1.59	1.63	1.86	1.84	1.76	1.33	1.73
Year 15-16	Mean	6.65	**7.60**	**7.45**	6.63	6.45	**7.41**	**7.01**	**7.53**
	SD	1.25	1.76	1.35	1.65	1.58	1.65	1.52	1.16
Year 16-17	Mean	7.68	**7.80**	**7.91**	7.58	7.08	**7.32**	**7.17**	**8.29**
	SD	1.45	1.33	1.22	1.42	1.78	2.02	1.76	0.82

In the experimental stage the students consider that the competencies they have acquired the most solidly during the project (mean scores of over 7 out of 10) are: "Oral and written communication", "Seek and analyse information", "Critical reasoning", and "Apply knowledge to practice". The competency that the students have acquired the least solidly is "Apply professional criteria".

In 16-17, we see a general improvement in the acquisition of competencies, since scores are up on the previous two years for practically all the items.

These results are similar to those of some previous work, such as Gomez Esquer et al. (2009). They show that we have fulfilled another of the objectives of this experiment: for the students to acquire the competencies shared by the two units.

In the 2016-17 academic year the acquisition of competencies was also assessed objectively. With PBL this means progress testing to establish the individual's knowledge and testing for competency rather than for isolated factual knowledge (Montgomery, 2001, Prieto et al., 2006). It is very important to choose the right methodologies for the acquisition of competencies.

In our project, the activities carried out in each session enable the evaluation of the competencies (see Table 6).

For each activity capable of being evaluated we drew up evaluation tables using scales of 1 to 5. We evaluated oral presentation, debates and discussion groups, proposed solution, written report, search for and summarising of information.

Table 6. Assessment of competences

Competence	Assessment
Analyse & summarise	• Written report of solution of case • Search for and summarising of information • Debates and discussion groups
Oral & written communication	• Written report of solution of case • Debates and discussion groups • Oral presentation
Seek & analyse information	• Search for and summarising of information
Solve problems	• Proposed solutions • Debates and discussion groups
Apply professional criteria	• Final conclusions
Critical reasoning	• Written report of solution of case • Proposed solutions • Debates and discussion groups
Independent learning	• Search for and summarising of information • Proposed solutions
Apply knowledge to practice	• Written report of solution of case • Proposed solutions • Debates and discussion groups

The results from the objective evaluation coincide with the results from the students' perception (self-evaluation). The competencies with the highest scores are "Oral and written communication", "Seek and analyse information", "Critical reasoning", and "Apply knowledge to practice".

In the experimental stage, the students give the project a mean global evaluation of over 7.5 out of 10. Comparing this project of educational innovation to other actions carried out in the same degree course at this university, this score is very high, since the mean score of the other actions is 6.7.

In the academic year 2016-2017, when the full project was running, the students obtained a mark of 7.3, on average, in Operations Management, and 6.6 in Business Statistics, which represent improvements of 14% (before mark of 6.4) and 11% (before mark of 5.95), respectively, in the year 2015-2016.

Although this work is based on the opinions of students gathered on questionnaires, objective improvement in ratings seems to support the

methodology. In addition, the teachers involved also perceived improvements in the learning process. We can therefore say that with this project we have improved both students' marks and their acquisition of competencies. These results are consistent with other previous Works such as Jones (2009).

In short, based on the results we can establish the following:

1) We have achieved that students have a global and integrative vision of the production and operations function and the possibilities of statistical techniques.
2) Thanks to the experience, communication between students and teachers has been improved, encouraging teamwork.
3) We have tried to encourage the participation and involvement of students through the presentation of real and motivating problems, fulfilling one of the objectives foreseen with this experience.
4) We have fulfilled another objective of this experience by working together with some of the necessary skills in the degree.

Conclusions

The development of the new bachelor degrees adapted to the European Higher Education Area has led to important changes in the teaching-learning model. The main actors – students and academics – have been forced to change their roles. The future graduates need to acquire knowledge, but also competencies and skills in preparation for their profession. When they are working in their profession they will be exposed to new and complex situations defined by interrelated variables. They would need a multidisciplinary approach to tackle problems. This leads us to propose the following question: Is the student being educated using a multidisciplinary approach? And: does he or she know how to find solutions to real problems using the competencies they have acquired? It is necessary that the curricula is designed to answer these questions.

Applying Problem-based learning (PBL) to various units in the same "problem" is easier than applying the methodology to just one unit. A novelty of our work is our use of PBL with an interdisciplinary character to teach the Production Management and Business Statistics units. Using PBL, the students have achieved a deep understanding of the topics, have interrelated the two disciplines, and in particular, have developed the capacity to use the knowledge they have acquired to analyse and solve new problems associated with an environment-context that is close to reality. It has built a constructivist learning environment in the classroom. Our work contributes to the theory of

Constructivist learning, applying interdisciplinary coordination by PBL, to make the students discover by themselves how they need to solve a structured problem, reaching necessary competencies and skills.

The current paper has cleared implications for both academics and practitioners. The experiment facilitates the coordination between subjects, allowing for an integrated learning by carrying out that activities involve aspects from different units in the same year. It encourages the students to coordinate and optimise their work. And we have developed methodologies of active learning, offering a clear example for their use in other units. Our project becomes a previous step to the students' final project, which calls for an interrelation between disciplines.

Different studies highlight the benefits of cooperating with companies to enrich education (Forsyth et al., 2009), curriculum design (Plewa et al., 2014) and students' employability skills (Baaken et al., 2015). While including the interdisciplinary in the curricula implies a greater workload for the professor, that additional work will lead to positive results in the acquisition of skills, and a low graduates to better face the workplace.

Policy makers should encourage interdisciplinary curricula. The Europe 2020 strategy puts the quality and relevance of education and training systems at the heart of EU efforts to improve competitiveness and achieve smart, sustainable and inclusive growth. The development of partnerships between Higher Education Institutions and employers is seen as a critical factor in identifying learning requirements, improving the relevance of education and facilitating access to education and learning. Graduates in programs that foster relevant work experiences, foster student talent and alert companies about what they can expect from these graduates (Allen et al., 2011). In this context, interdisciplinary becomes a key aspect of this strategy.

Our recommendation on how this should be done can be summarized in the following points:

- Analyzing the conceptual relationships between different materials that make up a curricula.
- Developing of integrated curricula. It would be desirable to consider the needs of the professional environment, where students will face multidisciplinary and complex problems. Integrated curricula can be seen as the intentional and coordinated overlap/interdependence in courses at the programme level and the requirement of teacher to

collaborate with each other to ensure alignment of integrated programme components (Bowers, 2006, Hardman, 2009, Carlsson et al., 2010).

- Providing students with a better understanding of complex problems: more personal construction of knowledge, emphasis on coping with difficult tasks and the search for multiple solutions, focusing on the evolving connections among ideas, and interpretation and application of knowledge across several contexts.
- Using active teaching methodologies and constructivist work environments. Shifting the programmatic focus from memorization of facts to focus in a central theme, application of knowledge relative to this theme, and reflection on the thinking process. Convert problem-based learning into a pedagogical practice, favors student learning in all disciplines (Stentof, 2017).

As future research that enables the advance of the integration of subjects in degrees in business, the implementation of the combination of other subjects would be appropriate, as well as the implementation in different universities.

Despite these implications, our work has some limitations. The main limitation is the small sample size. But this stage has proved fundamental for us to be able to replicate this project using students from an entire year's intake to give us a larger number of participating students. Another initial limitation is that the data are obtained on the basis of student perceptions. Finally, we believe that official curricula should include and stress the importance of interdisciplinary, that academics should consider the specific meaning of this concept and how to define and implement it. Nevertheless, if interdisciplinary is to become a reality in the curriculum, the teaching staff must be willing to apply it in the lecture hall.

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References

Allen, J., Coenen, J., Humburg, M., Pavlin, S., Robert, P., Svetlik, I., and van der Velden, R. K. (2011). *Competencies and early labour market careers of higher education graduates in Europe*. Ljubljana, Slovenia: Faculty of Social Sciences.

Baaken, T., Kiel, B., and Kliewe, T. (2015). Real World Projects with Companies Supporting Competence Development in Higher Education. *International Journal of Higher Education*, *4*(3), 129-139.

Barrows, H.S., and R.M. Tamblyn. (1980). *Problem-Based Learning: An Approach to Medical Education*. New York: Springer Publishing Company.

Betsy L.L., Kueh, C.Y., and Yin. K.H. (2011). Students' Perception of Interdisciplinary, Problem-Based Learning in a Food Biotechnology Course. *Journal of Food Science Educatio*n *10* (1), 4-8.

Bowers, H.F. (2006). Designing Quality Course Management Systems that Foster IntraProfessional Education". *Nurse Education Today, 26*(8), 726-731.

Brown, B. F., and Brown, B. F. (1997). Problem-based education (PROBE): learning for a lifetime of change. In *Proceedings of the 1997 ASEE Annual Conference and Exposition* (pp. 15-18).

Carlsson, S. A., Hedman, J., and Steen, O. (2010). Integrated curriculum for a bachelor of science in business information systems design (BISD 2010). *Communications of the Association for Information Systems*, *26*(1), 24.

Duch, B. J., Groh, S.E., and Allen, D.E. (2001). *The power of problem-based learning: A practical "how to" for teaching undergraduate courses in any discipline.* Sterling Virginia US: Stylus Publishing.

Duffy, T. M. and Cunningham, D.J. (1996). Constructivism: Implications for the design and delivery of instruction. *DJ Jonassen (Ed.,) Handbook of Research for Educational Communications and Technology*, 170-198.

Engström, H. (2015). A model for conducting and assessing interdisciplinary undergraduate dissertations. *Assessment and Evaluation in Higher Education*, *40* (5), 725-739.

Fish, L. A. (2008). Graduate student project: employer operations management analysis. *Journal of Education for Business*, *84* (1), 18-30.

Follari, R. (1980). Interdisciplinaridad, espacio ideológico. In *Simposio sobre Alternativas Universitarias, UAM-Azcapotzalco, México*.

Forsyth, D. (2009). *Group Dynamics*. Wadsworth: Cengage Learning.

Gijselaers, W. (1995). Perspectives on problem-based learning. In Gijselaers, W., Tempelaar, D., Keizer, P., Blommaert, J., Bernard, E., and Kasper, H. (Eds.). (1995). *Educational innovation in economics and business administration: The case of problem-based learning*. Boston, MA: Kluwer Academic Publishers.

Golding, C. (2009). *Integrating the disciplines: Successful interdisciplinary subjects*. Centre for the Study of Higher Education, University of Melbourne.

Gómez Esquer, F., Rivas Martínez, I., Mercado Romero, F., and Barjola Valero, P. (2009). Aplicación interdisciplinar del aprendizaje basado en problemas (ABP) en ciencias de la salud: una herramienta útil para el desarrollo de competencias profesionales. *Revista de Docencia Universitaria*, *7*(4).

Hardman, M. L. (2009). Redesigning the Preparation of all Teachers within the Framework of an Integrated Program Model. *Teaching and Teacher Education, 25*(4), 583-587.

Huber G. L. (2008). Aprendizaje activo y metodologías educativas. *Revista de Educación* número extraordinario: 59-81.

Hung, W. (2009). The 9 steps problem design process for problem-based learning: Application of the 3C3R model, *Educational Research Review, 4* (2), 118-141.

Ivanitskaya, L., D. Clark, G. Montgomery, and R. Primeau. (2002). Interdisciplinary Learning: Process and Outcomes, *Innovative Higher Education, 27* (2), 95-111.

Jones, C. (2010). Interdisciplinary approach-advantages, disadvantages, and the future benefits of interdisciplinary studies. *Essai*, *7*(1), 26.

Kanet, J.J., and Barut, M. (2003). Problem-Based Learning for Production and Operations Management. *Decision Sciences Journal of Innovative Education, 1* (1), 99-118.

Milter, R. G. and Stinson, J.E. (1995). Educating leaders for the new competitive environment. In Gijselaers, W., Tempelaar, D., Keizer, P., Blommaert, J., Bernard, E., and Kasper, H. (Eds.). (1995). *Educational innovation in economics and business administration: The case of problem-based learning*. Boston, MA: Kluwer Academic Publishers.

Monreal-Gimeno, M.C., and Terrón-Caro, M.T. (2011). Una experiencia interdisciplinar y evaluación de competencias en la doble titulación de trabajo social y educación social. *UPO Innova* 1*:* 350-360.

Montgomery, K. (2001). *Authentic Assessment: A Guide for Elementary Teachers*. New York: Longman.

Niderhauser, D., Salem, D.J., and Fields, M. (1999). Exploring teaching, learning, and instructional reform in an introductory technology course. *Journal of Technology and Teacher Education, 7(*2), 153-172.

O'Donnell, A. M. (1997). Constructivism by design and in practice: a review. *Issues in Education*, *3* (2), 285-294.

Olmedo Peralta, E. (2012). La interdisciplinariedad en el aprendizaje basado en problemas en las enseñanzas jurídicas: la necesidad de coordinación entre materias. In *Coordinación y planificación en los estudios de Derecho [Recurso electrónico]: 15 al 16 de septiembre 2012: Universidad de Valladolid* (pp. 328-353). Universidad de Valladolid.

Piaget, J. (1972). *Insights and illusions of philosophy*. New York: Routledge and Kegan Paul.

Plewa, C., Galán-Muros, V. and T. Davey, T. (2014). Engaging business in curriculum design and delivery: a higher education institution perspective. *Higher Education, 70* (1), 35-53.

Prieto, A., J. Barbarroja, E. Reyes, J. Montserrat, D., Díaz, M., Villarroel, M., and Alvarez-Mon, M. (2006). Un nuevo modelo de aprendizaje basado en problemas, el ABP 4x4, es eficaz para desarrollar competencias profesionales valiosas en asignaturas con más de 100 alumnos. *Aula Abierta,* (87), 171-194.

Rossano, S., Meerman, A., Kesting, T., and Baaken, T. (2016). The Relevance of Problem-based Learning for Policy Development in University-Business Cooperation. *European Journal of Education, 51*(1), 40–55.

Savery, J. and Duffy, T. (1995). Problem based learning: An instructional model and its constructivist framework. *Educational Technology, 32* (5), 31–38.

Stentoft, D. (2017). From saying to doing interdisciplinary learning: Is problem-based learning the answer?. *Active Learning in Higher Education*, *18*(1), 51-61.

Sternberg, R.J. (2008). Interdisciplinary Problem-Based Learning: An alternative to traditional majors and minors". *Liberal Education, 94* (1).

Striegel, A., and Rover, D. T. (2002). Problem-based learning in an introductory computer engineering course. In *32nd Annual Frontiers in Education* (Vol. 2, F1G-F1G). IEEE.

Vygotsky, L. S. (1980). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Wilder, S. (2015). Impact of problem-based learning on academic achievement in high school: a systematic review. *Educational Review*, *67*(4), 414-435.

Wood, J. C., and Mack, L. G. (2001). Problem-based learning and interdisciplinary instruction. *Age*, *6*, 1.