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Student Long-Term Perception of Project-Based Learning in Civil Engineering Education: An 18-Year Ex-Post Assessment

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Abstract: In 1998, the Universidad de Castilla-La Mancha (UCLM) began to offer a 5-year civil engineering degree that, in the Spanish context, contained an innovative teaching model, which was characterized by a reduced number of students and project-based learning (PjBL) included in the curriculum. Now, 15 years after the graduation of the first civil engineers from the UCLM, graduates were given a questionnaire to evaluate the extent by which the advantages described in the PjBL literature were perceived as such by these graduates. As a result of chain-referrals and in order to cross-reference the results, a parallel questionnaire was given to their work colleagues. The survey revealed how the development of PjBL-related abilities and skills were appreciated by UCLM graduates, such as the ability to work in groups, communication/debate skills, and leadership. The engineers were generally satisfied with their theoretical and practical learning due to the high demands required of engineering undergraduates in Spanish universities. Those that had worked with PjBL, in addition to developing the skills and abilities indicated above, also considered their learning to be more effective and with a better result-to-effort ratio.

Keywords: project-based learning; civil engineering; evaluation; learning methodology; student-centered learning; curriculum change

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1. Introduction

Over the last 25 years, project-based learning (PjBL) has become one of the most widely employed innovative teaching methods in engineering courses, particularly in civil engineering [1]. Due to the characteristics of engineering education, PjBL adapts well to many of the contents that future engineers have to learn, and develops the abilities and skills required on exercising their profession during the course of which civil engineers undertake diverse projects such as new construction work, renovations, maintenance, or improvement of existing works, network optimization, management, planning, etc.

There are numerous testimonials of the experiences of professors and lecturers in practically all areas of civil engineering, at all levels of teaching (undergraduate, Master), and in geographical locations. These experiences reveal the successful use of different forms of PjBL methodology in specific subjects [2–4] or even outside the curriculum [5]. The movement beyond individual subjects and the global introduction of a different methodology on the curriculum to that of lecture-based learning, as sought out by PjBL, is a complicated task as it is necessary to overcome a series of hurdles, such as adaptation to the new teaching method by the majority of the academic staff, the allocation of specific areas where the students can carry out the projects, and the provision of a certain amount of infrastructure such as cartography, software, copiers, computers, etc. Although PjBL methodology has started to be introduced in certain European countries over the last few years [6] as a result of adapting to the Bologna framework [7], there are still only a few university centers where PjBL has been fully integrated into the curriculum of civil engineering studies [8]. Because the experience of these are relatively recent, it is not yet possible to make a long-term evaluation.

In 1974, in a pioneering venture in Europe, the Aalborg University introduced this method across the board in all its degree programs and, from this time on, has become the point of reference for many other universities. In a similar manner, the Faculty of Civil and Environmental Engineering at the Norwegian University of Science and Technology (NTNU) in Trondheim introduced PjBL in 1997, following a review of the curriculum and extended the study period from 4.5 to 5 years. These two universities served as points of reference for the Universidad de Castilla-La Mancha (UCLM), which introduced a new 5-year civil engineering degree (equivalent to a Master of Civil Engineering Degree). The UCLM was the first university in Spain to use PjBL in an integral manner in civil engineering studies. This degree course was in place until the 2016 academic year, when it terminated as result of adaptation to the European Higher Education Area (EHEA), which replaced engineering degrees of over 5 years by the Bachelor-Master model (4 + 2). Over these years, a total of 545 graduates from 12 course admissions left their classrooms and entered the workplace with a high regard for the quality and value of their university studies.

In this context, the direction of the UCLM Civil Engineering School decided to evaluate how its civil engineering graduates perceived the teaching methodology and the learning environment employed in their education as a means of facing workplace challenges. In order to do so, it was first established that the survey should be conducted using a variation of the respondent driven sample technique in order to obtain a chain-referral from each participant, which in this case was formed by the work colleagues of UCLM graduates.

The present article is structured as follows: following on from this introduction, we shall explain the characteristics and advantages of the PjBL method described in the bibliography, before outlining the PjBL-based curriculum defined by the UCLM for 1998. We shall then proceed to indicate the assessment method employed for the survey of the graduates and their work colleagues, before revealing the results of the survey, which show that the use of PjBL met the expectancies of UCLM graduates.

2. PjBL in Civil Engineering

2.1. Key Aspects of PjBL Methodology

PjBL is defined as a learning environment in which students learn key aspects of their education by solving complex and realistic projects in a professional manner, while generally working in teams under the guidance of their teacher over long periods of time [9,10]. These projects evidently have more than one solution, and this is obtained by applying knowledge of different subjects (multidisciplinary), tools, and techniques of a professional nature, such as software programs, together with a certain degree of constructive research in order to gain the necessary knowledge to resolve these problems. PjBL projects must be flexible and allow different approaches. The final solution should be found through discussion, alternative testing, failure/success, improvement, and correction of previous solutions, instead of finding solutions in a unique way. Workplace civil engineering projects fit well into this methodology [11]. Once a solution has been defined and the project has been solved, each group of students is responsible for presenting the same by graphic and written communication tools and, very frequently, by oral and often public presentations. The result of the project has to be presented to the client in the same way as it would be in professional life.

As such, PjBL teaching methodology, by its very nature, encourages student-centered learning outcomes on the basis of teamwork, negotiation, debate/discussion among fellow students, leadership, and all communication skills (i.e., oral, graphic, and written) derived from the presentation of results [12]. PjBL also helps develop research skills to obtain the necessary baseline information such as cartography, data/reports, and the use of computer programs and engineering techniques. With the PjBL approach, learning becomes student-centered, not teacher-centered. Students must also change their roles, from a passive listener to an active problem-solver, involved in a process where they are responsible for success. As students find their "own" solutions, they are more passionate in defending their positions and ideas. In addition, they develop their creativity [13]. The change of the students' role favors the teacher–student relationship, making it more intimate than the traditional method where the teacher is more of a partner and a facilitator rather than a judge dictating the theoretical and practical knowledge of the student.

With this learning methodology, the need for knowledge is evident (i.e., needed to solve the project), and students subsequently know why they learn the things they learn. This serves to motivate students and learning becomes more effective. As the Chinese proverb says [14], "Tell me and I will forget, show me and I will remember, involve me and I will understand, step back and I will act". The quality of the acquired new knowledge is better than in the traditional method, as each new concept is related to a personal experience and is easily recalled later for solving new problems.

2.2. Implementation of PjBL in Civil Engineering Education

There are many experiences of the use of PjBL in engineering education. However, these generally tend to be restricted to experiences in isolated subjects within the curriculum in practically all areas of civil engineering, i.e., structures [1], transportation [2,3], sustainable construction [4], geotechnical engineering [5], etc. In some cases, PjBL is employed in all the subjects related to a particular area of knowledge within a program [6] or even as co-curricular courses in collaboration with other professionals [7].

These experiences have generally been evaluated by interviews and/or surveys with participating students who tend to be asked to compare PjBL with the more traditional form of lecture-based teaching [5,8–13]. However, and as already indicated, experiences of the integral use of PjBL on the civil engineering curriculum are few and far between.

The universities of Aalborg and NTNU are two of the most representative examples of the application of this methodology across the board in their engineering curricula. Aalborg University appears to have the most effective educational system of all Danish engineering educational institutions (about 80% of students pass their examinations in the prescribed time). Their students take subjects given under the PjBL method (project work) in all courses, which over the first years takes on a more professional focus, while over the latter this is more oriented towards innovation and research [14–16]. In a similar approach, the NTNU introduced this methodology in its engineering programs to include different activities. The first five PjBL activities are organized on a project progress process, from the planning phase through the building phase and to the organizational phase (i.e., physical planning and the environment; environmental and resource engineering; building materials, design of buildings, and infrastructure; and organization and economy in building and construction projects). The latter two PjBL activities are organized in a specialization environment. The first is referred to as "Experts in Team", where students work in teams with professionals from other disciplines. The second is called the "Specialization Project", which is related to one of several specialization fields that are offered at NTNU [17].

However, with regards to the quality and educational level ex-post analyses of these experiences, these are much less prevalent in the literature and only some key points are obtained from the Aalborg University results, which were audited by the Danish State Parliament. There are generally no differences between the graduates from this university and those from more traditional educational institutions, but the former were better at problem solving, communication, cooperation, and general technical knowledge, while the latter were stronger in specialist knowledge and technical methodology [14].

With regard to the case of the UCLM, while there are a whole host of different university rankings, there are no breakdowns by degree course and it is difficult to measure the quality of the graduates. In Spain, the only comparative assessment to date with regard to degree courses is in relation to employability as developed in the QEDU study (i.e., what and where to study at University) by the Ministry of Education, Culture, and Sport [18]. This cross-referenced the numbers of graduates in each degree course at each university for the 2009–2010 academic year with the number of social security (national insurance) registrations four years later (2014). The study did not include graduates who worked abroad or those who became part of the civil service prior to 2011 and, as such, were not registered with social security and not always unemployed. This study made it possible to ascertain the percentage of graduates in employment and the number of those that held jobs matching their level of education.

This survey by the Ministry of Education, Culture, and Sport revealed (Figure 1) that the highest proportion of graduates (94%) holding jobs in accordance with their level of education were graduates from the UCLM. This follows a trend that has been exceeded by the graduate employability ranking of the University of Alicante (74% as opposed to the 68% of the UCLM). The University of Alicante has probably moved away from this general tendency as this university offers degree courses to many intermediate-level engineers (ITOPS or public works technicians) as higher engineers, and it is very probable that these were already in employment prior to their graduation as Civil Engineers and hence their greater employment rate, though with jobs less suited to their qualifications.

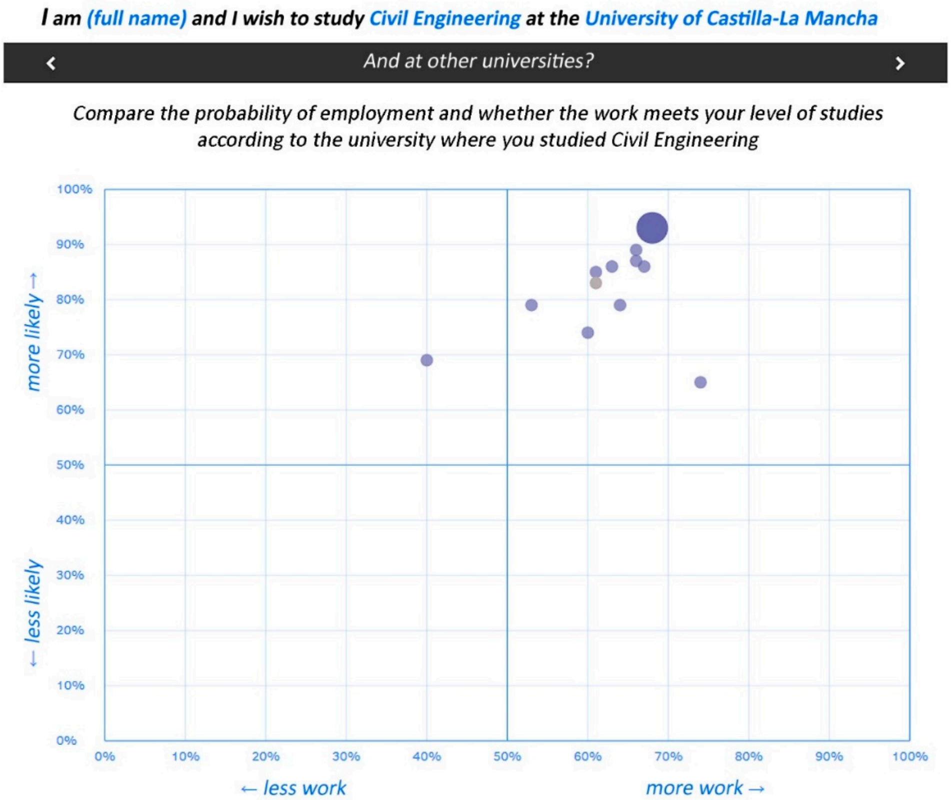

Figure 1. Universidad de Castilla-La Mancha (UCLM) civil engineering graduates (largest dot) vs. the rest of Spanish universities. *Y* axis: percentage of graduates working in jobs that meet their level of education; *X* axis: percentage of graduates in employment and registered with social security four years after completing their studies. Captured and translated from the web [18].

The results of this report reveal the higher quality of UCLM graduates due to their greater employability and the fact that they hold jobs more suited to their qualifications. However, the question that arises is whether this greater quality is related to the innovative learning method employed (PjBL). In order to assess in detail all aspects of the method, its results, and, particularly, the perception of the same held by graduates, a specific survey was given to graduates from the center.

3. PjBL Curriculum in Civil Engineering in UCLM

The new School of Civil Engineering at the UCLM was created in June 1998 [19]; academic activities started in September 1998. At that time, there were seven universities in Spain where civil engineering could be studied at the postgraduate level, all of which were located in major Spanish cities. The challenge for the new school was considerable for two main reasons: firstly, Ciudad Real is a small city (60,000 inhabitants at the time) with relatively recent university experience (the UCLM was founded in 1985); and secondly, because the Spanish Professional Institute of Civil Engineering (Colegio de Ingenieros de Caminos, Canales y Puertos) was opposed to the creation of new schools because of rising unemployment. As a result, it was decided that the new school would strive to be a high-quality academic institution with different teaching and specialization approaches from existing schools. These characteristics [19] were as follows: (1) a small number of students (50 new students admitted each year); (2) an intense student progress monitoring (student/faculty ratio of 6.5); (3) a school specializing in those subjects considered relevant for the future, such as environmental and spatial aspects of civil engineering, conservation, rehabilitation and quality management, and information technologies; and finally (4) a project-based learning approach that focused on group learning, communication, and innovation.

There were four additional specific reasons for the adoption of PjBL in the Civil Engineering curriculum at UCLM in 1998 [19,20]:

- To introduce students to an active learning environment. Spanish engineering graduates had good abstract knowledge but they were passive and had poor entrepreneurial capabilities, which could be related to the traditional learning environment in which they had developed their studies.
- To introduce students to team activity. In Spain, most learning activities were individual. Students received many lectures (more than 25 h per week), went home, and studied what the professor explained with little contact with their classmates and making scarce use of the university facilities and libraries. In professional work, the majority of the activities are carried out in teams, making extensive use of the materials and facilities available.
- To get students in early contact with engineering-related topics. In Spain, most civil engineering curricula devote the first two years to basic sciences (e.g., mathematics, physics, chemistry, drawing, materials science, fluid mechanics). PjBL activities allow students early contact with quasi-real engineering activities [21].
- To introduce students to an evaluation framework in which the response to questions are not sectorial, unique, or exact. In Spain, the evaluation of engineering courses was mainly done through written exams with subject-specific questions requiring single and exact answers. In engineering, there are no categorical, single, and exact solutions; on the contrary, there are always several options, with different advantages and disadvantages for each multidisciplinary problem.

Adopting PjBL was not an easy task, as in Spain all university degrees are nationally regulated by minimum subject requirements. The 5-year civil engineering degree was regulated in 1991 by the Real Decreto 1425/91, with a minimum total load of 300 credits (1 credit equals ten teaching hours), out of which 10% were elective courses and 192 credits specifically defined by law [20]. As such, the universities' freedom to define their own civil engineering curricula was limited to around 25% of the total credits.

Accordingly, the 5-year civil engineering curriculum adopted at the UCLM only included PjBL activities, workshops called "trabajos proyectuales", which were included in both semesters during the 2nd, 3rd, and 4th years. These workshops took between 25% and 32% of the student semester workload (see Table 1). By the end of their studies, every student had worked on six group-projects plus the individual final project.

Second-year projects were basically oriented to developing concepts on drawing and cartography, some of them learnt during the first year. The first semester project also had an introductory role as, for many students, it was the first time in their lives that they had dealt with these project-based learning activities. As the technical background of second year students is quite reduced, the engineering project was the design of a greenway for cyclists and pedestrians [22]. The latter second-year project concerned the design of a riverbank recreational area and introduced students to environmental science and hydraulics.

The following four group projects focused on main civil engineering themes: planning, transportation, structures, and hydraulics. This thematic approach of each semester in the third and fourth years was adopted in order to dedicate a period of time to each engineering subject similar to that dedicated to these subjects in other schools. The planning project usually dealt with the design of a city expansion area close to a transportation infrastructure such as a railway station or highway interchange [23]. The transportation project dealt with the design of a ringroad around a city; the hydraulics project was oriented towards the hydrological planning of a river, while the structures project usually dealt with the design of a bridge or building structure [24].

Table 1. Project-based learning (PjBL) distribution in civil engineering at UCLM [25].

Year	Compulsory Courses	Optional Courses	Number of Projects	PjBL % of Student Time	Project Theme	
					1st Semester	2nd Semester
1st	10	0	0	0	—	—
2nd	8	0	2	25	Road related environment	Water-related environment
3rd	6	1	2	32	Land-use urban planning	Transportation
4th	6	1	2	32	Structures	Hydraulic infrastructure
5th	4	5	1	17	Final Project (individual)	

PjBL workshops were developed with students working in groups of three to five students with the support of three faculty members, using specific spaces for the PjBL activity (Figure 2), with assigned areas for each group and computer facilities. These spaces were accessible to students 24 h a day, seven days a week.

Figure 2. Students in PjBL classrooms working in groups during the 2002 academic year.

The reduced size of the school and class groups also ensured a closer relationship between students and the teaching staff. Many students benefited from an Erasmus scholarship. Furthermore, the UCLM decided to change the distribution of the semester periods, so that students could take all their exams before their summer vacations (end of June), thereby eliminating the re-sitting exams in September. In this way, 60% of third and fourth year students could spend an important part of their summer holidays as interns in building or consultancy companies. This new scheduling has since spread to other UCLM degrees and many Spanish universities are now using similar schedules.

Finally, it is important to highlight that all these projects in the UCLM civil engineering curriculum served as a link between the different departments and faculty members, as they are multidisciplinary and students must develop and integrate knowledge acquired in different courses and from different sources [25]. Furthermore, some more traditional courses, such as physics, have also introduced this methodology to some extent.

The civil engineering curriculum remained stable during the 18 years of PjBL methodology use, although there was a slight evolution as the experience of the faculty grew and some adjustments were made to coordinate with conventional courses. However, the essential characteristics of the students' experience can be considered fairly similar for all of them.

The new curricula created after the Bologna framework also maintained this methodology [26–29] but it was necessary to introduce the learning outcomes and descriptors required by the National Quality Assessment Agency (ANECA). This adaptation was a challenge as the previous courses had to be assigned to the degree or the master level and some of them had to be readapted in contents and length. However, the school kept the extensive use of PjBL, which were a key aspect in the EUR-ACE certification of the actual degrees.

4. Evaluation of Graduate Perception of PjBL Methodology

An evaluation was made of the curriculum perception of UCLM civil engineer graduates to establish whether the expectations placed in PjBL in 1998 had been met and to compare this with other centers where PjBL had not been applied (essentially, the remainder of the Spanish universities).

4.1. Evaluation Method

Between 2003 and 2016, when the course was finally removed in order to adapt to the Bologna Framework, the University "produced" 545 graduates over 12 course admissions, 62% of which were male and 38% female. The graduates were approached via e-mail and by groups of former students via LinkedIn (177 members) or Facebook (345 members) to make an electronic survey divided into four parts: (1) advantages of PjBL; (2) characteristics of the learning environment; (3) characteristics of the engineering projects tackled by the students; and (4) general aspects of their education. Each of these factors was assessed in accordance with a satisfaction scale from 1 to 5, in response to questions ranging from "strongly disagree" to "strongly agree" [9,30]. The design of these four blocks and the questions included in each of them was based on a review of the available literature about PjBL and in some of the assumptions made by the UCLM in 1998 when the implementation of this methodology was decided. The characteristics of the PjBL method described in the literature include, among other things, the ability of teamwork, the development of communication skills, and the creativity in problem-solving. Therefore, the questionnaire introduced specific questions in relation to each of these issues.

The survey also gathered a series of general information about the students, such as age on completing studies, receipt of an Erasmus grant while at university, means of obtaining first employment, professional area in which they were employed, country, and location, etc.

Following the filtering of incoherent replies (e.g., using the same satisfaction scale for all answers), 52 valid responses were obtained from a total of 545 engineers that had graduated from UCLM between 1998 and 2016, which made up 9.5% of the total population and was considered to be a suitable sample size for an error of 11% and a confidence level of 90%.

The respondent-driven sampling technique (RDS) [31] was employed to compare the replies. Each graduate was asked to select a work colleague as similar to them as possible (position, experience, etc.) but who had not studied at the same University, and to ask them to complete the survey. In this way, a "mirror" population was obtained whose answers could serve as a reference for comparison with the answers given by UCLM graduates. Moreover, each UCLM graduate must have a mirror colleague answering the questionnaire to be accepted as a valid response, so both samples are the same size. The answers of this "mirror" population were unrepresentative in themselves in absolute terms due to the limitations of the sample size and the limitations of the RDS sampling technique (RDS) [32,33], but were still useful as a qualitative reference and in order to assess in relative terms the answers to the different questions of the survey.

4.2. Results

With regards to the general data of the population, the mirror population was more heterogeneous than that of the UCLM, as was expected. Moreover, 24% were graduates from the Universidad Politécnica de Madrid (UPM), 14% from the Universitat Politècnica de València (UPV), 14% studied at universities abroad, and 12% were graduates from UCLM, but on other engineering courses. Further, 46% were civil engineers that had graduated at Spanish universities, while 14% were civil engineers that had graduated from international universities. Lastly, 10% were public works technical engineers and the remainder were graduates from different engineering and architectural degree courses.

While 33% of the UCLM population were female (38% of all graduates), the female proportion of the reference population was 18%. Further, 38.5% of all UCLM graduates obtained an ERASMUS grant as opposed to 27% of their work colleagues; this was a high percentage, indicating that similar mirrors should be sought in this respect. The average age on completing studies was 24.4 for UCLM graduates and 25.5 for their colleagues.

With regards to the method of gaining first employment, it is interesting to note that UCLM graduates obtained a greater percentage of employment through placements/internships (24% vs. 12%) performed during their degrees and which, as we have already indicated, was considered as an additional strength of the university due to its reduced size, or gained through personal contacts, on many occasions made during Erasmus study programs in the case of those graduates who worked abroad. By way of comparison, their work colleagues tended to gain employment through more traditional methods, such as job offers from the professional association of engineers (8% vs. 2%), or regulated job-seeking procedures organized by universities (e.g., recruitment fairs, job events, etc.)

The values of our mirror sample are only representative of an average of the graduates working together with our graduates of similar characteristics: age, education, responsibility, etc., and are thus useful as a reference. However, the size of the sample was insufficient to individually appraise other universities or colleges.

We then examined the replies of both populations to the four sections of the survey. For ease of understanding, the average answers of each populations are shown in the table below. In all events, the analysis was based on the results of variations and modes, which are included in Table 2, and which make it possible to measure the degree of unanimity of the answers and the most frequent values for each population.

It should be noted that the responses of our students always had higher values, which was logical. On the one hand, the survey asked about aspects related to PjBL methodology and, on the other hand, UCLM students are more unanimous (see Table 2). In all events, the results of the mirror population can be useful both in relative terms and as a reference.

Table 2. Answers of UCLM graduates and their work colleagues: averages, modes, and mode frequencies.

	QUESTION	UCLM	Other Univ	Difference	VAR UCLM	VAR Others	DIFERENCE VAROthers-UCLM	Mode UCLM	% Mode Freq. UCLM	Mode others	% Mode Freq. Others
METHOD	The teaching methods used in my university studies helped me to develop my ability of . . .										
	. . . teamwork	4.69	3.45	1.24	0.275	1.256	0.980	5	75%	3	33%
	. . . oral communication (speaking in public	4.58	2.79	1.80	0.364	1.985	1.621	5	60%	1	27%
	. . . graphic communication (presentations, panels, posters, etc.)	4.50	3.06	1.44	0.543	1.609	1.066	5	58%	3	33%
	. . . written communication (documents, reports, records, etc.)	4.06	3.45	0.60	0.797	1.693	0.896	4	44%	4	41%
	. . . defending ideas, negotiating, debating (discussion)	4.11	2.97	1.14	0.730	1.530	0.800	5	40%	2	29%
	. . . resolving problems creatively	4.42	3.58	0.84	0.421	1.502	1.080	5	50%	4	37%
	. . . team leadership	4.19	3.15	1.04	0.504	1.695	1.191	4	54%	3	45%
ENVIRONMENT	The learning environment used in my university studies favored . . .										
	. . . my participatory attitude and initiative with regards to problem solving	4.43	3.67	0.76	0.487	1.292	0.804	5	52%	4	43%
	. . . collaboration with course companions (learning through collaboration with others, and not just alone).	4.58	3.45	1.13	0.364	1.506	1.141	5	60%	4	39%
	. . . my motivation and involvement in my education	4.11	3.67	0.44	0.787	0.917	0.129	4	46%	4	45%
	. . . teacher–student interaction and intimate learning.	4.44	2.79	1.66	0.425	1.985	1.559	5	56%	2	31%
	. . . use of engineering techniques and tools (software)	3.89	2.85	1.04	0.959	1.195	0.236	4	42%	3	33%
	. . . my capacity to seek information, cartography, data, etc.	4.39	3.45	0.93	0.587	1.256	0.668	5	48%	4	47%
PROJECT	During my studies, I frequently faced the resolution of problems/practices/projects . . .										
	. . . complex and open solution (not one solution)	4.64	3.66	0.98	0.352	1.394	1.043	5	67%	4	39%
	. . . requiring the reaching of different, and often contradictory, objectives	4.22	3.42	0.80	0.692	1.064	0.372	5	42%	4	37%
	. . . enabling the practical application of theoretical knowledge	4.47	3.76	0.71	0.599	1.002	0.403	5	56%	4	43%
	. . . that included a multidisciplinary focus (with content from various subjects)	4.33	3.50	0.83	0.514	1.613	1.099	5	46%	4	43%
	. . . of real and professional nature	4.36	3.61	0.76	0.466	1.059	0.593	4	42%	4	45%
	. . . in specific places and situations that could be visited, studied and understood in-situ, etc.	4.61	2.97	1.64	0.473	1.218	0.745	5	62%	4	33%
	. . . that helped me understand the need for continuous learning throughout my professional life	4.36	3.55	0.82	0.637	1.443	0.806	5	48%	3	31%

Table 2. *Cont.*

	QUESTION	UCLM	Other Univ	Difference	VAR UCLM	VAR Others	DIFERENCE VAROthers-UCLM	Mode UCLM	% Mode Freq. UCLM	Mode others	% Mode Freq. Others
GENERAL	In general, I consider . . .										
	. . . adequate number of field trips and/or educational visits	4.06	2.36	1.69	0.797	1.114	0.317	4	42%	2	31%
	. . . adequate placements or internships in companies/civil service/university	3.28	2.55	0.73	1.806	1.631	−0.176	4	25%	1	31%
	. . . reasonability of workload during my studies	3.14	2.82	0.32	1.380	1.466	0.086	2	35%	2	33%
	. . . adequate result to effort ratio	3.86	3.13	0.74	0.809	1.145	0.336	4	42%	3	31%
	. . . the theoretical knowledge acquired has been useful in my professional life	3.78	3.61	0.17	1.092	0.996	−0.096	4	44%	4	43%
	. . . the skills acquired have been useful in my professional life (capacity to do something with theoretical knowledge)	4.31	3.85	0.46	0.675	0.945	0.270	4	50%	4	43%
	Evaluate your university studies in general from 1 to 5	4.43	3.41	1.02	0.311	0.830	0.519	4	52%	4	45%

4.2.1. Personal Skills

The first section of the survey (Figure 3) was related to the personal skills developed during the studies. The below graph shows the average values of the replies of both populations. From the analysis of the results, it is possible to establish the following key points:

- The most highly valued aspect of UCLM graduates, not just in relation to this section but in terms of the entire survey, was the capacity to work on a team (4.69), which demonstrates the use of PjBL to develop this capacity, as all the project work was developed in teams of between 3 and 5 students and, furthermore, this methodology was extended to other subjects. This appraisal was backed up by the second answer in the following section in which the respondents were asked about collaborative learning. For their part, the reference population also awarded a relative high appraisal (3.45; mode 3) though with a greater spread, which shows that they performed group activities, such as projects, works, etc., and, at the very least, studying and resolving problems in groups with colleagues.
- With regards to oral communication skills, the fact that each project work included a final oral defense, in addition to various partial defenses, meant that UCLM were capable of developing these skills and this was duly acknowledged in the survey (4.58). The difference with respect to the reference population was broadened here as the latter group gave this a lower ranking that did not even reach a pass (2.79), and where mode 1 appeared with a frequency of 27%. In fact, this was the only answer to have mode 1 other than that concerning company internships, which goes to demonstrate the serious learning weaknesses with respect to oral communication of Spanish universities at that time, due to the predominance of traditional lecture-based methods.
- Two questions related to oral communication and group work, such as the capacity to defend ideas, negotiate, and debate, as well as that regarding group leadership, also revealed large differences between the UCLM students (4.11 and 4.19) and their mirror group (2.97 and 2.15), though the average values of the UCLM graduates were somewhat lower than in the previous answers, as there was a greater diversity of answers. This would seem to indicate that while PjBL encourages the development of these skills (which was recognized as such by the students), it is not equally effective

for everyone. This, in our experience, comes down to personal differences in character at the outset. When there is one student in the group with greater leadership skills and/or higher intelligence, this can restrict the development of these skills within the rest of the group, who let themselves be led by the leader, and similarly reduces debate and discussion among the group.

- With regards to graphic communication skills, the difference was also high (4.5 opposed to 3.06), as all the project work conducted throughout all the courses required the preparation of diagrams, sketches, plans, and panels to resolve the project. To the contrary, in the traditional focus of the engineering colleges, drawing, and draughtsmanship is only given in the first years and their content tends to be abandoned or even forgotten before ending the studies. However, the difference remained small in terms of written communication skills (4.06 as opposed to 3.45), as these skills were more common under traditional teaching methods.

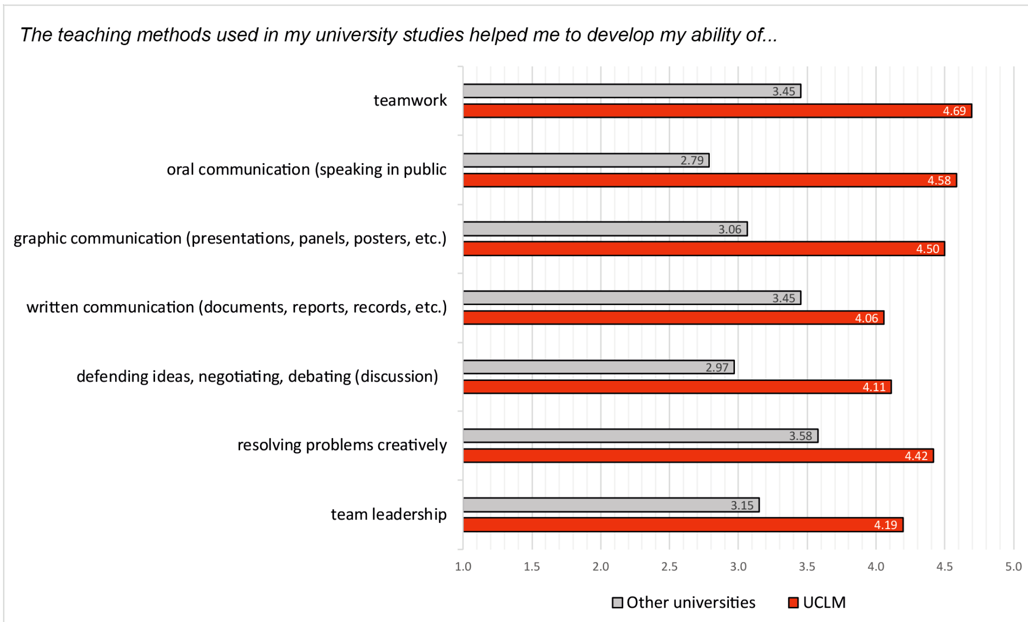

Figure 3. Answers related with personal skills developed during the studies. Average values for the UCLM and mirror populations.

4.2.2. Learning Environment

The second block of the survey focused on the learning environment (Figure 4) because PjBL methodology transforms this by modifying the roles of the student, who takes a more proactive role both inside and outside the group, and that of the lecturer, who has to tutor and guide the work of the students. In this respect, the survey produced the following key results:

- The largest difference between both populations, as was expected, was the teacher–student relationship (4.44 vs. 2.79). The response revealed the huge gap between the UCLM Civil Engineering college, with reduced groups and PjBL, and the rest of the Spanish universities, where groups may reach up to 200–300 students and where PjBL is barely used.
- However, with regards to the motivation and involvement of the student, the differences narrowed (4.11 vs. 3.67), as the difficulty of engineering degrees means that students, regardless of teaching method, always have a high level of motivation and involvement. This positive attitude of the students was confirmed by the question related to their participatory attitude and initiative to resolve problems and where the

very high values of UCLM students (4.43) were almost matched by the value of the reference population (3.67).

- The aspect most highly appraised by UCLM students was that of collaborative learning or learning from others (4.58 vs. 3.45), and this, as we have already forwarded, is one of the most positive aspects of PjBL and one that is readily confirmed by the survey.
- While there was a large difference between the responses of the two populations in terms of learning environment, both gave their lowest scores to the use of engineering software (3.89 vs. 2.85), which demonstrates the difficulty universities have in equipping themselves and keeping updated in this respect, regardless of the teaching methodology employed.

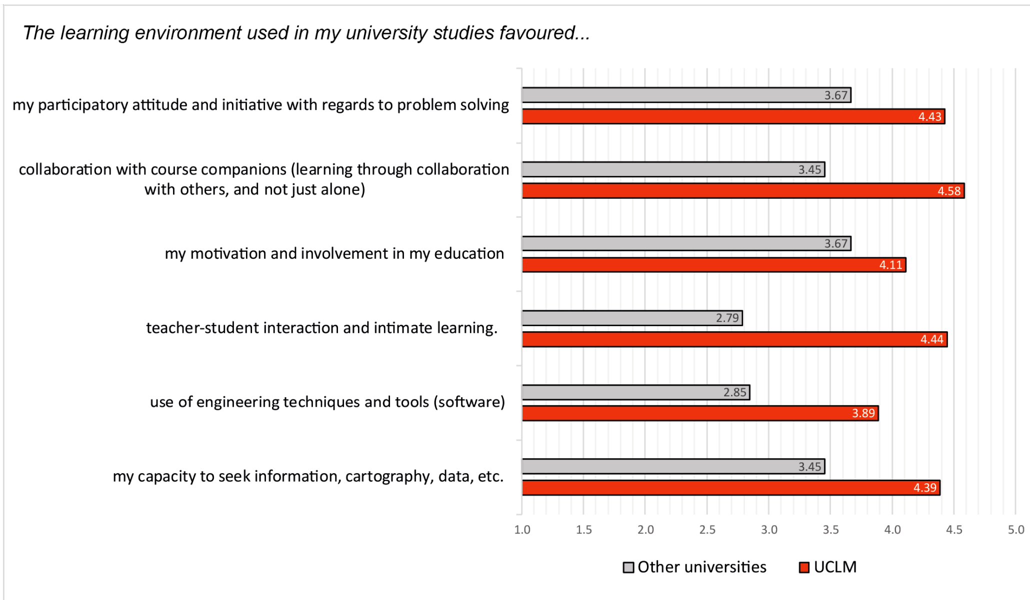

Figure 4. Answers related with the learning environment. Average values for the UCLM and mirror populations.

4.2.3. Types of Projects Resolved

There is always a large practical component in the training of civil engineers, as could not be otherwise. The third block of the survey considered the characteristics of the projects resolved at UCLM (Figure 5), in comparison with the practical exercises carried out at other centers:

- UCLM graduates clearly identified that the projects they had resolved were complex and did not have a single solution and gave this aspect one of the highest scores of all the questions (4.64), only exceeded by that regarding the capacity to work in groups. The difference between UCLM graduates and the reference population was nigh on one point in this respect (3.66).
- The largest difference between both populations was with respect to the possibility of visiting project sites (4.61 vs. 2.97). One of the characteristics of project work at UCLM is the incorporation of site visits, among other aspects. However, at Spanish universities in general, and with the large groups involved, it is difficult and fairly uncommon to make field trips and site visits and it is normal that this is a failing that was recognized by this student population.
- To the contrary, the gaps between both populations narrowed with respect to the practical application of theory (4.47 vs. 3.76) and the real and professional nature of projects and training (4.36 vs. 3.61), which would appear logical as the teaching of engineering is practical and applied by definition, regardless of the teaching method employed. For this reason, both populations considered the need for continuous learning throughout their professional lives (4.36 vs. 3.55).

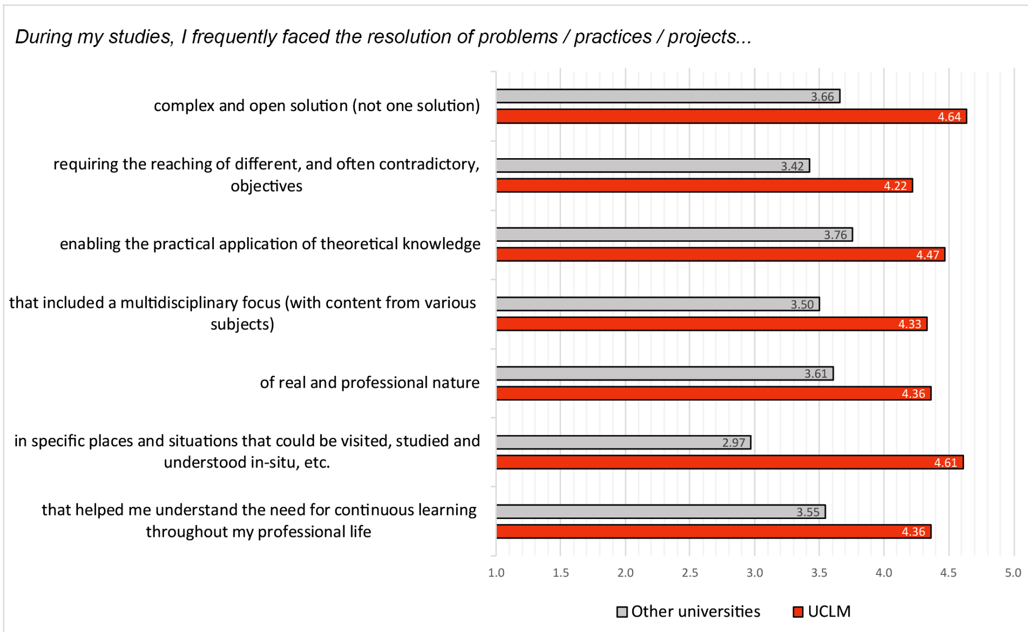

Figure 5. Answers related with the types of projects resolved. Average values for the UCLM and mirror populations.

4.2.4. General Aspects

The survey concluded with questions on general aspects of the studies (Figure 6), supplementary activities such as trips or training, workload, and satisfaction with the degree. The answers in this section largely served to confirm the previous answers. This section established that:

- Both populations were equally satisfied with the theoretical knowledge acquired and its use (3.78 and 3.61), which shows that the time employed in practical work by PjBL was not perceived by graduates as a loss of theoretical knowledge. With regards to practical skills, the ability to apply theoretical knowledge was positively appraised by both populations (4.31 vs. 3.85) though the difference in favor of UCLM grew slightly.
- The greatest difference in favor of UCLM in this section of the survey were with respect to the adequate number of field trips (4.06 vs. 2.36), which as commented earlier was one of the strong points of UCLM and one of the weak points of Spanish universities.
- The differences were also large, though to a somewhat lesser extent, with regard to company placements or internships (3.28 vs. 2.55). At the time the UCLM had a non-compulsory extracurricular internship program in place, and in many cases it was up to the student to do training or not. For this reason, the spread in the response was easily the largest (variation of 1.8). In all events, the merit of internships/placements was demonstrated in the answers of both populations because many of the UCLM graduates found their first employment through the same, as indicated in the previous section. It is of note that the current degree and master programs in civil engineering at the UCLM includes curricular placements.
- The responses given with respect to the reasonability of the workload were found to be low for both populations (3.13 vs. 2.82), which demonstrates the high demands on engineering undergraduates in Spain. However, while the effort required is high for everyone, UCLM graduates were far more appreciative of the result to effort ratio than the reference population who were more negative in this regard (3.86 vs. 2.82). This demonstrates that PjBL helps to make the efforts of the student more effective and allows them to develop skills that are positively appraised in the workplace, as shown by the survey.

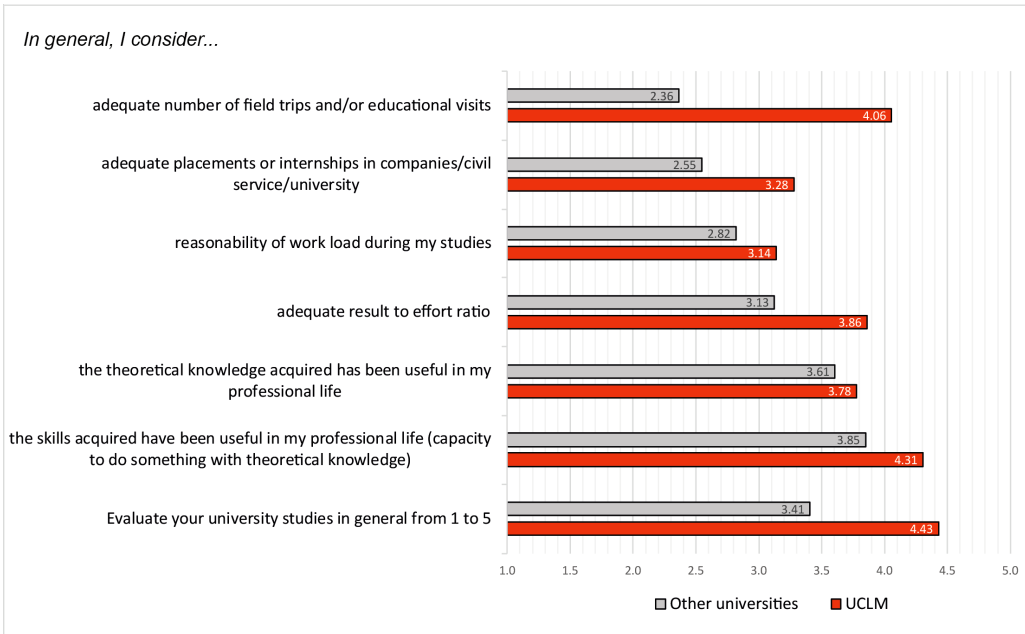

Figure 6. Answers related with general aspects of the studies. Average values for the UCLM and mirror populations.

In this latter aspect, the effectiveness of PjBL is reflected by the very high general satisfaction of the former students from UCLM with their university studies (4.43 vs. 3.41), and where the most important characteristic was the integral use of PjBL on the civil engineering curriculum.

5. Conclusions

PjBL is a teaching–learning method that has been shown to be effective for engineering studies in general and civil engineering in particular. While there are many experiences of the use of this methodology throughout the world, in the majority of cases this has concerned isolated experiences led by teachers who wished to incorporate the method into their courses. However, there are very few civil engineering colleges that have introduced this methodology in an integral manner throughout the curriculum. This was the case of the civil engineering program given at the UCLM between 1998 and 2016, which was evaluated by a survey aimed at a population of 545 graduates and their work colleagues in order to gain a reference population that could serve for comparative evaluation.

The survey showed that the development of skills associated with PjBL was appreciated by UCLM graduates, such as the capacity to work in groups, oral and graphic expression, debating and leadership skills. PjBL methodology changes the roles of the teacher and student, encouraging a more fluid relationship between both. In the same way, course colleagues were seen as partners in the learning process.

The engineers were largely satisfied with their theoretical and practical training in view of the high demands of engineering qualifications at Spanish universities, but those working with PjBL, in addition to the development of the skills indicated above, also found their education to be more effective in terms of results to effort.

Although the survey was useful for determining former students' perception of the PjBL methodology implemented in the UCLM civil engineering school, we are aware that their perception may be partial, as they may perceive this assessment of the methodology as an evaluation of themselves to some extent. Therefore, this analysis will be complemented in the future with a survey to their employers to assess if they identify in their employees these capabilities and skills acquired during the university studies.

The use of PjBL as an integral teaching method across the entire curriculum with relatively small groups of 50 students, together with the high number of field trips and the possibility of placements/internships, are key to the education given to the civil engineering graduates by the UCLM Civil Engineering college. The quality of this education has been acknowledged by the graduates featured in this survey and, even more importantly, has been confirmed in a survey on employability conducted by the Spanish Ministry of Education, Culture, and Sport. However, the effectiveness of the PjBL methodology was amplified by the school's following characteristics: a reduced number of students whose access grades were above the average; the qualification and motivation of the faculty facing the challenge of introducing the methodology; and the solid support of the University of Castilla-La Mancha to provide all of the required teaching infrastructure (buildings, laboratories, computers, etc.).

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